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Do Education Human Capital and Environmental Regulation Drive the Growth Efficiency of the Green Economy in China?

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Abstract: The question of how to gradually transform the economic growth mode from extensive growth to intensive economic growth, and steadily improve the efficiency of green economic growth (GEGE), has become the focus of society and scholars. The present study uses the SBM-DDF directional distance function to measure GEGE from 2008 to 2021 in China, and then selects the bootstrap regression method to test the influencing factors of China's GEGE. The following conclusions are obtained: (1) the GEGE level is still low, and its average value in the fourteen-year period from 2008 to 2021 is 0.484; areas with low levels of GEGE account for approximately 66.7% of the country, and those with relatively high levels account for approximately 20% of the country; high-level green development areas account for 13.3% of the country; (2) environmental regulation's impact on GEGE has a U-shaped relationship, which means that when the regulation intensity increases, GEGE will first decrease and then increase, and once it crosses the inflection point, the effect of improving GEGE becomes obvious; the elasticity coefficient of educational human capital is significantly negative, which has a hindering effect on GEGE; (3) FDI is significantly negatively correlated with GEGE; there is a U-shaped relationship between GEGE and urbanization, and the industrial structure has a negative effect on GEGE, while trade dependence has the same effect.

Keywords: human capital in education; environmental regulation; growth efficiency of green economy; sustainable development; economic growth

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1. Introduction

The green economy is a form of market economy that realizes environmental rationality and economic efficiency, and it is a sustainable economy that pursues the unification of economic reproduction and ecological reproduction and maximizes economic, ecological and social benefits [1,2]. In 2012, the OECD, World Bank described green growth as the promotion of economic growth while ensuring the sustainability of natural resources in terms of the resources and environmental services on which human beings depend, i.e., the process of economic growth to ensure efficient resource use [3]. In contrast, the United Nations Environment Programme (UNEP) argues that green growth aims to improve the welfare of the population and promote social equality, while reducing environmental risks and ecological scarcity, and this view affirms that green growth needs to consider social equality as a social well-being issue.

Recently, China has gradually entered the green transformation stage, focusing on transitioning "from quantity to quality", guiding traditional industries toward clean production and promoting enterprises to "reduce energy consumption, reduce pollution, increase efficiency" in order to achieve green development. According to the BP World Energy Statistics Yearbook, China's energy consumption was expected to reach 5.24 billion tons of standard coal in 2021, an increase of 5.2% over the previous year. Coal consumption was expected to increase by 4.6%, crude oil consumption by 4.1%, natural gas consumption by 12.5% and electricity consumption by 10.3%, but China's economy will account for 15.6%

of the global economy in the same period, showing that China's economic growth is still more dependent on energy consumption. In 2020, China put forward the "3060" carbon target, and, for the first time, "doing a good job of carbon peaking and carbon neutral work" was written into the government work report; the "14th Five-Year Plan", with the theme of promoting high-quality development, will accelerate the promotion of green low-carbon development, and the development of the green economy will be a long-term priority task. The question of how to promote the development of the green economy in a sustainable and stable manner is an important issue at present [4,5].

The endogenous growth theory posits that human capital can induce economic growth. Human capital can promote clean production, thus improving GEGE [6,7]. In 2017, China began to optimize its development model and develop new driving forces for economic growth. The focus on quality should be boosted by human capital for economic and social development. In order to achieve economic transformation, the low-carbon development model needs to comprehensively strengthen personnel training and strengthen the country through talent, accelerate the construction of innovative systems and promote scientific and technological progress. The level of human capital is the carrier of technological progress, the link among technological innovation and GEE and the source of power to achieve green development [8]. Therefore, human capital will play a pivotal role in China's growth towards a green economy.

Meanwhile, environmental pollution is an important factor restricting green growth. Pollution has not only brought serious losses to the Chinese economy, but also poses a huge threat to the healthy lives of residents [9]. Appropriate use of environmental regulatory tools is conducive to achieving green economic growth. Specifically, economic green development includes two dimensions of environmental sustainability and social equality. From the perspective of environmental sustainability, environmental regulation is conducive to pollution reduction and provides high efficiency of economic green development, thereby promoting green economic development [10,11]; From the perspective of social equality, environmental pollution affects residents' health and changes the employment structure, thereby affecting social well-being, while environmental regulation is conducive to improving social inequality and improving social well-being. Therefore, the question of how to improve GEGE through environmental regulation is an important issue for scholars and policy makers [12,13].

Therefore, in the face of the ongoing epidemic and the need for green economic recovery, the focus of the current research is to explore the impact on China's green economic growth by organically combining educational human capital, environmental regulation and GEGE, following the concept of sustainable development. In this regard, in this paper, we measure GEGE in China by taking 30 Chinese cities as examples, and, on this basis, we verify the influence of educational human capital and environmental regulation on GEGE, in order to provide a reference for the formulation of policies related to environmental regulation and green development.

Section 1 provides the introduction to the paper, which highlights the background, significance and motivation of the study. Section 2 is the literature review, which mainly discusses the research contributions of domestic and foreign scholars in this field and highlights the research value of this paper through comparison. Section 3 presents the methodology of the research, explaining the main methods used and discussing the applicability of the methods. Section 4 contains the research results of the study and analyzes the results of the empirical analysis. Finally, the conclusions and recommendations related to the study are presented, and corresponding policy recommendations are proposed regarding the results of the empirical analysis.

The main contributions of this paper are as follows. (1) The efficiency of green economic growth is the only means by which to achieve the high-quality development of the global economy, which reflects the requirements of the development of the present era. Research in the field of green economic growth efficiency is a useful supplement and improvement to the existing research. (2) Analyzing the GEGE in different regions will help different regions to understand the regional status quo and provide a theoretical reference for policy implementation. (3) Although most studies have analyzed the role of human capital in promoting economic growth, they pay less attention to the relationship between human capital and green economic growth efficiency. This study can fill the gaps in this field and is an expansion of existing research.

2. Literature Review

2.1. Green Economic Growth Efficiency

The research on GEGE started late in the academic field, mainly considering two aspects: measurement methods and influencing factors. According to the research purpose and direction of this work, the study focuses on research on the meaning and measurement of GEGE.

2.1.1. Meaning of GEGE

The term "green economy" has a long history. It was first proposed by British economist David Pierce in the Blue Book of Green Economy in 1989. Subsequently, as a new economic development model, green economic growth has gradually become a research hotspot in the field of environmental economics and sustainable development. Important international research institutions have also given relevant explanations. For example, the United Nations proposed, in the Green Growth Seoul Initiative in 2005, that green growth is an environmentally sustainable economic growth mode. In the 2011 report Towards Green Growth, OECD proposed that green growth should not only promote economic growth and development but also ensure that natural assets can continue to provide resources and environmental services indispensable to human well-being, and it must promote investment and innovation that can support sustainable growth and generate economic opportunities [14]. We believe that the core of green economic growth is to be green and to facilitate development. It is a development form that realizes the sustainable use of natural resources, the sustainable improvement of the ecological environment, the continuous improvement of citizens' living quality and the sustainable development of the economy and society within the scope of ecological environment capacity and resource carrying capacity.

2.1.2. Measurements of GEGE

The research on green economic growth in academia started relatively late, mainly considering the two aspects of measurement methods and influencing factors. According to the research purpose and direction of this work, we focus on identifying the research on the measurement of GEGE. Due to the lack of direct data, it must be measured with the help of mathematical programming methods. The academic community has not yet formed a generally accepted accounting system for GEGE. Most scholars generally believe that the key lies in the coordination and unity of economy and ecology—that is, on the basis of ensuring steady economic growth—to achieve the efficient use of resources and environmental improvement [15–17]. Meanwhile, an important criterion for measuring and evaluating green economic growth is energy and environmental performance—that is, the question of how to create the greatest economic benefits with the least resource utilization and the least environmental damage [18]. The existing measurement includes energy and environmental performance. There are three categories: single-factor indicators, full-factor indicators and comprehensive evaluation indicators [19].

The commonly used measurement methods of GEGE include stochastic frontier analysis (SFA), data envelopment analysis (DEA) and index analysis based on DEA theory. Among them, SFA is based on the production function or cost function. Wang [20] and Jiang [21] calculated the inter-provincial GEGE based on this stochastic frontier model. DEA is used to evaluate the relative efficiency of multiple homogeneous units based on multiple inputs and multiple outputs. Yang and Hu [22] and Qian and Liu [23] used the classic DEA and SBM model to measure GEGE in China. Index analysis is the combination of DEA theory and the Malmquist index. The most commonly used model is the DEA-Malmquist model, which is different from SFA and DEA. The measurement result of the DEA-Malmquist model is the growth rate of GEGE.

2.2. Educational Human Capital Impact on GEGE

2.2.1. Direct Impact of Educational Human Capital on GEGE

The direct impact of educational human capital is dominated by the labor output effect, which is manifested in the fact that the human capital of education is attached to the labor force participating in production, and the output is increased with higher labor productivity. A number of researchers have empirically tested its direct impact. Gemmell [24] conducted a study with a sample of OECD countries and found that human capital can promote economic growth. Mankiw et al. [25] also obtained the same result. Du and Zhao [26] also found that educational human capital can directly act on the output as "factor accumulation" and promote economic growth.

2.2.2. Indirect Effects of Educational Human Capital on GEGE

Educational human capital indirectly affects total factor productivity. Nelson and Phelps [27] established a theoretical model by correlating technological progress with the production level, and they clarified the indirect mechanism through total factor productivity. Scholars such as Benhabib and Spiegel [28] and Islam [29] suggested that educational human capital can promote total factor productivity. Pablo-Romero and Sánchez-Braza [30] studied OECD, NAFTA, BRIC, Eastern Europe and East Asia by estimating the total transformed production function of human and physical capital and production energy as production factors, focusing on the strength of the link between energy and economic growth in 15 EU countries, proving that human capital is a powerful substitute for energy and has important implications for sustaining economic growth. Cole et al. [31] selected 15 industries in China to study factors affecting industrial carbon emissions. The results found that areas with higher human capital, as measured by training and experience, were more likely to comply with environmental regulations.

According to this, this paper puts forward hypothesis 1: human capital has a significant role in promoting the efficiency of green economic growth.

2.3. Environmental Regulation Impact on GEGE

There are three representative views in the existing literature on the relationship between environmental regulation and economic growth.

2.3.1. The "Compliance Cost Theory" of the Impact of Environmental Regulation

There are three representative views in the existing literature. One is the "follow the cost theory", which holds that the implementation of environmental regulations would increase production costs, reduce production efficiency and lead to a competitiveness decline [32–35]. Among the authors mentioned, Yuan and Liu [36] performed a study from the perspective of economic regulation classification, and they believed that cost-based environmental regulation had no relationship with economic growth, while investment-based environmental regulation had significant effects.

2.3.2. The "Innovative Compensation Theory" of Environmental Regulation Impact

The second is the "innovation compensation theory", which holds that appropriate environmental regulation can produce technology diffusion and structural upgrading effects [37,38]. Among the mentioned authors, Isern et al. believed that environmental regulation had a positive incentive effect to increase the total factor productivity of oil companies. Zhang et al. [39] found that environmental regulation can aid in enhancing the confidence and future expectations of enterprises to promote competitiveness.

2.3.3. The "Uncertainty Theory" of Environmental Regulation Impact

The third is the "uncertainty theory", which holds that the impact is uncertain [40,41]. Qian and Liu [42] suggested that the environmental regulation impact on GEGE has nonlinear characteristics. Song et al. [43] confirmed the "inverted U" shape between them. However, these works did not measure and analyze the threshold value of environmental regulation intensity, and they did not accurately describe the dynamic process of environmental regulation's impact on GEGE.

Based on this, this paper proposes hypothesis 2: the relationship between environmental regulation and green economic growth efficiency is uncertain.

From the above, it can be seen that although existing studies have described some useful explorations of the driving role of human capital on economic growth and the interactive correlation effects, there are still two shortcomings, which are as follows. First, although most studies have analyzed the driving role of human capital on economic growth, they have paid less attention to the green development effect of human capital. Unlike the traditional total factor productivity, green economic growth efficiency more strongly emphasizes the impact of economic growth on the environment. Second, although the existing literature has conducted some fruitful studies on environmental regulation's impact on GEGE, it has neglected the joint effect of human capital, which is closely related to the effect of human capital on GEGE. To address the shortcomings of existing studies, this paper adopts a non-radial directional distance function approach with global reference in the framework of DEA to measure the GEGE in China, and we construct a panel data model based on this approach to analyze the effects of environmental regulation and educational human capital on GEGE. This paper aims to provide useful insights for the promotion of regional economic quality development and to fill the existing research gaps.

3. Method

The existing research on measuring GEGE mainly adopts the stochastic frontier analysis (SFA) model, the DEA model without considering the unexpected output and the DEA model with consideration of the unexpected output. Among them, the SFA model is easily affected by the form of production function and is only applicable to the problem of multiple inputs per unit output. Although the DEA model without considering the unexpected output solves the problem of multiple inputs and multiple outputs, it regards environmental factors as input factors and cannot meet the analysis requirements of expected output maximization under environmental constraints. After considering the negative externalities of pollution emissions, the unexpected DEA model defines environmental factors as "unexpected" outputs, which meet the internal needs of actual production. However, it can only measure the static efficiency and has no overall and dynamic characteristics. Tone [44] proposed a non-radial, non-oriented SBM model based on slack variables, and the problem of the overestimation of production efficiency was solved. Since then, Fukuyama and Weber [45] have further combined this approach with the directional distance function to form a non-radial, non-oriented directional distance function based on the relaxation measure SBM-DDF, which can take into account both inputs and outputs. In order to scientifically and rationally measure the growth efficiency of China's green economy dynamically, this study selects the SBM directional distance function (SBM-DDF) to measure the GEGE of 30 Chinese cities. The SBM-DDF does not need to set a specific function form, and it avoids the inaccuracy of the calculated efficiency results. Therefore, the SBM-DDF method has become the mainstream method for measuring GEGE in recent years.

3.1. Global SBM Directional Distance Function

3.1.1. Global Production Possibility Set

This paper first regards a region as a decision-making unit, DMUk, and then assumes that DMUk has N inputs $x_k^t = \left(x_{k1}^t, \cdots, x_{kN}^t\right) \in R_+^N$ and obtains M expected outputs $y_k^t = \left(y_{k1}^t, \cdots, y_{kM}^t\right) \in R_+^M$, accompanied by I types of undesired outputs $b_k^t = \left(b_{k1}^t, \cdots, x_{kI}^t\right) \in$

R_+^I. Then, the input and output of DMUK in period t are expressed as $\left(x_k^t, y_k^t, b_k^t\right)$, and the production possibility set $P^t(x)$ in the current period is expressed as

$$P^t = \left(x_k^t, y_k^t, b_k^t\right) \in R_+^{N+M+I} \tag{1}$$

$$\begin{cases} \sum_{j=1}^K \lambda_j^t x_{jn}^t \leq x_{kn}^t & \forall n \\ \sum_{j=1}^K \lambda_j^t y_{jm}^t \leq y_{km}^t & \forall m \\ \sum_{j=1}^K \lambda_j^t b_{ji}^t \leq b_{ki}^t & \forall i \\ \sum_{j=1}^K \lambda_j^t = 1; \lambda_j^t \geq 0 & \forall j \end{cases} \tag{2}$$

Among them, λ_j^t is the weight used by the DMU in the reference set to construct the effective production frontier. If $\sum_{j=1}^K \lambda_j^t = 1; \lambda_j^t \geq 0 \; \forall \, j$, then it represents the constraint under variable returns to scale (VRS). However, in the case of $P^t(x)$, technological regression may occur, and the efficiency measures of different periods are not directly comparable. Therefore, Ho and Oh [46] set $P^G(x)$, which emphasizes the consistency of the production front and the comparability of the efficiency measures, as follows:

$$P^G = \left(x_k^t, y_k^t, b_k^t\right) \in R_+^{N+M+I} \tag{3}$$

$$\begin{cases} \sum_{t=1}^T \sum_{j=1}^K \lambda_j^t x_{jn}^t \leq x_{kn}^t & \forall n \\ \sum_{t=1}^T \sum_{j=1}^K \lambda_j^t y_{jm}^t \leq y_{km}^t & \forall m \\ \sum_{t=1}^T \sum_{j=1}^K \lambda_j^t b_{ji}^t \leq b_{ki}^t & \forall i \\ \sum_{t=1}^T \sum_{j=1}^K \lambda_j^t = 1; \lambda_j^t \geq 0 & \forall j \, \forall t \end{cases} \tag{4}$$

3.1.2. SBM-DDF Model

The study draws on the SBM-DDF, proposed by Liu and Xin [47]:

$$\begin{cases} \vec{D}^t\left(x_k^t, y_k^t, b_k^t; g_x, g_y, g_b\right) = max \dfrac{\frac{1}{N}\sum_{n=1}^N \frac{S_n^x}{g_n^x} + \frac{1}{M+I}\left(\sum_{m=1}^M \frac{S_m^y}{g_m^y} + \sum_{i=1}^I \frac{S_i^b}{g_i^b}\right)}{2} \\ \text{s.t.} \; \sum_{j=1}^K \lambda_j^t x_{jn}^t + S_n^x \leq x_{kn}^t \quad \forall n \\ \sum_{j=1}^K \lambda_j^t y_{jm}^t - g_m^y \leq y_{km}^t \quad \forall m \\ \sum_{j=1}^K \lambda_j^t b_{ji}^t + S_i^b \leq b_{ki}^t \quad \forall i \\ \sum_{j=1}^K \lambda_j^t = 1; \lambda_j^t \geq 0 \quad \forall j; \; S_n^x \geq 0, \forall n; S_m^y \geq 0, \forall m; g_i^b \geq 0, \forall i \end{cases} \tag{5}$$

Among them, (g^x, g^y, g^b) is the direction vector, representing the direction of input reduction, expected output increase and undesired output reduction, respectively. (s^x, s^y, s^b) is a slack variable, representing the amount of redundant input, insufficient expected and excessive undesired output, respectively. The global SBM-DDF can be expressed as follows:

$$\begin{cases} \vec{D}^t\left(x_k^t, y_k^t, b_k^t; g_x, g_y, g_b\right) = max \dfrac{\frac{1}{N}\sum_{n=1}^N \frac{S_n^x}{g_n^x} + \frac{1}{M+I}\left(\sum_{m=1}^M \frac{S_m^y}{g_m^y} + \sum_{i=1}^I \frac{S_i^b}{g_i^b}\right)}{2} \\ \text{s.t.} \; \sum_{t=1}^T \sum_{j=1}^K \lambda_j^t x_{jn}^t + S_n^x \leq x_{kn}^t \quad \forall n \\ \sum_{t=1}^T \sum_{j=1}^K \lambda_j^t y_{jm}^t - S_m^y \leq y_{km}^t \quad \forall m \\ \sum_{t=1}^T \sum_{j=1}^K \lambda_j^t b_{ji}^t + S_i^b \leq b_{ki}^t \quad \forall i \\ \sum_{t=1}^T \sum_{j=1}^K \lambda_j^t = 1; \lambda_j^t \geq 0 \quad \forall j \, \forall t \\ \sum_{t=1}^T \sum_{j=1}^K \lambda_j^t = 1; \lambda_j^t \geq 0 \quad \forall j \, \forall t; \; S_n^x \geq 0, \forall n; S_m^y \geq 0, \forall m; g_i^b \geq 0, \forall i \end{cases} \tag{6}$$

3.1.3. Variable Selection

(1) Input indicators

Capital stock: At present, there is a lack of raw data on capital stock, so the data on the gross fixed capital formation from 2008 to 2021 are used, and we use the perpetual inventory method [48]. The formula is as follows:

$$K_{it} = K_{it} - 1(1 - \delta) + I_{it}, K_0 = I_0/(g + \delta) \quad (7)$$

Among them, K_{it} and K_{it-1} are the capital stock of region i in year t and t−1, respectively; I_{it} denotes the actual gross fixed capital formation of region i in year t. δ is the depreciation rate; in line with many similar works, in this study, we let δ = 10.96%. In this paper, the capital stock K is represented by the real gross fixed capital formation at a constant price in 2008 as the base year. I_0 is the total investment in the base year, and g is the average annual growth rate of actual investment.

Energy: Total energy consumption refers to the total amount of various types of energy consumed by a region. Due to the heterogeneity of various types of energy consumption, the study converts the energy input (including coal, oil, natural gas, hydropower, etc.) into the energy consumption of 10,000 tons standard coal.

Labor force: For the measurement of labor force, we use the sum of employees in units and private individuals published in the statistical yearbooks of each province.

Technology: Technology introduction can directly introduce foreign advanced technology, avoiding the opportunity costs that may be caused by independent research and development technology. However, the introduction of technology will form path dependence, which is constrained by the technology exporter. Moreover, the general technology exporter will only export some advanced technologies of the low-end production chain, and they will retain the core technology of the high-end production chain for themselves. Therefore, if a region wishes to promote sustainable and stable economic growth, it can only rely on its own innovation drive. Therefore, it is believed that the independent research and development of advanced technology is the leading factor in promoting technological progress. Talent accumulates human capital, and one can reserve outstanding R&D personnel to indirectly promote technological progress. Therefore, the level of technological progress is measured by the ratio of the sum of scientific and educational expenditures to GDP.

(2) Output indicators

Expected output indicator: Taking GDP as an indicator of desirable output, we use the GDP deflator to calculate the actual GDP from 2008 to 2021; the data are taken from the "China Statistics Yearbook" for each year.

Unexpected output indicators: Some studies only consider one pollutant as an undesired output and this is not comprehensive. Considering that the "three industrial wastes" are pollutants that mainly damage the ecological balance and natural resources, the total amounts of industrial wastewater discharge, industrial sulfur dioxide discharge and industrial smoke dust emissions are used as a measure of undesired output.

The data of each input–output indicator involved in the above are derived from the regional "Statistical Yearbook", "China Energy Statistical Yearbook", "China Environmental Statistical Yearbook" and various prefecture-level cities. For the statistical yearbooks and other official statistical data, the missing data in some years are obtained by an interpolation method. The descriptive statistics are shown in Table 1.

3.2. Bootstrap Truncated Regression Model

For the choice of regression methods, different scholars currently use different methods, and the conclusions reached also have some variability, but the more commonly used methods are Bootstrap truncated regression model, fixed effects model (FEM), random effects models (REM), generalized method of moments (GMM) and pooled mean group (PMG) methods, each method has its advantages and disadvantages, this study will choose Bootstrap truncated regression model for regression and we will try to use other methods to study in the subsequent research.

Table 1. Descriptive statistics of input and output variables.

Indicator	Secondary Indicators	Unit	Mean	Standard Deviation	Minimum	Maximum
Input indicator	Capital stock	million	2773.0261	1892.883	298.0932	7983.7622
	Labor force	10,000 people	2777.921	4309.911	98.082	44,982.231
	Energy	10,000 kWh	567,342.674	768,522.556	3987.444	4,905,331.884
	Technology	/	0.134	0.123	0.005	0.346
Expected output	Real GDP	billion	9,984,322.775	568,234.033	333,458.032	99,457,785.195
Unexpected output	Industrial waste water discharge	tons	2134.422	2567.032	98.532	22,345.886
	Industrial soot emissions	tons	346,791.992	187,542.674	478.096	2,245,781.863
	Industrial SO2 Emissions	tons	43,571.563	112,569.993	789.143	3,345,671.564

3.2.1. Model Building

The least squares method is the most commonly used method for the estimation of regression coefficients in a wide range of scientific fields. The least squares method requires the error term to satisfy the Gauss–Markov assumption, but, in practice, many problems do not satisfy this assumption, making it challenging to produce non-parametric estimation methods, such as the Brown–Mood method and Theil method. While the Brown–Mood method is not easily affected by outliers, compared with other methods, it will lose a large amount of information about the sample data, making the coefficient difficult to obtain. Therefore, it is necessary to adjust and improve this non-parametric coefficient estimation method.

The non-parametric bootstrap method can effectively solve the problem of an insufficient sample size and improve the validity of the parameter estimation. Therefore, the non-parametric bootstrap method is used to adjust and improve the Brown–Mood regression coefficient estimation method, which can appropriately compensate for the shortcomings of the original Brown–Mood method. Moreover, since the authors are more familiar with the method, we choose it for the analysis.

To conduct research on the influencing factors of green economic growth efficiency, most scholars choose the Tobit regression model, but, due to the existence of unknown and complex serial correlation, the regression results may be invalid. Therefore, more and more scholars have begun to choose the bootstrap truncated regression model for analysis [49], and this method is also used in this paper. The bootstrap method and its basic idea were proposed by Efron [50] to approximate the distribution of complex statistic estimates.

Let $X = (x_1, x_2, \cdots, x_n)$, where X is an independent sample from the population *F(x, θ)*, and θ is the population parameter, where X can be a sample sequence of various forms. The empirical distribution function $\mathrm{F}_n(x, \hat{\theta})$ based on the sample X converges to *F(x,θ)* in a certain probability sense—that is, the empirical process $\sqrt{n}\left[\mathrm{F}_n(x, \hat{\theta}) - \mathrm{F}(x, \theta)\right] - \infty < x < \infty$ converges weakly to U(F), where U is a Brown bridge on [0, 1], i.e., a Gaussian random process with mean 0, indicating that when $n \rightarrow \infty$, $\sqrt{n}\left[\mathrm{F}_n(x, \hat{\theta}) - \mathrm{F}(x, \theta)\right]$ converges to 0 with probability. The self-help experience process is also constructed by the bootstrap method.

$\sqrt{m}\left[\mathrm{F}_m(x, \hat{\theta}^*) - \mathrm{F}(x, \hat{\theta})\right] - \infty < x < \infty$ for almost all sample sequences $\mathrm{X} = (x_1, x_2, \cdots, x_n)$, and when m and n tend to ∞y, $\sqrt{m}\left[\mathrm{F}_m(x, \hat{\theta}^*) - \mathrm{F}(x, \hat{\theta})\right]$ also weakly converges to U(F), i.e., $\sqrt{m}\left[\mathrm{F}_m(x, \hat{\theta}^*) - \mathrm{F}(x, \hat{\theta})\right]$ has the same limit as $\sqrt{n}\left[\mathrm{F}_n(x, \hat{\theta}) - \mathrm{F}(x, \theta)\right]$. In this way, the bootstrap method, estimated by distribution parameters, replaces the true distribution *F(x,θ)* with the empirical distribution $\mathrm{F}_n(x, \hat{\theta})$ based on the sample X and uses the independent sample $X^* = (x_1^*, x_2^*, \cdots x_n^*)$ to replace $\mathrm{X} = (x_1, x_2, \cdots, x_n)$, which constitutes the experience of a new random variable R* under $\mathrm{F}_n(x, \hat{\theta})$. It can replace the real distribution of random variable R to perform hypothesis testing and parameter estimation, so as to solve the problem of the statistical accuracy of reliability for feature quantities in the case of small samples or an unclear distribution of error terms.

3.2.2. Variable Selection

(1) Explained variable

GEGE: GEGE is an evaluation system for green economic development, guided by the current concept of ecological civilization construction. Compared with the traditional economic growth efficiency, environmental pollution is also included in the evaluation index. The higher the value, the higher the comprehensive efficiency of green economic development. This paper uses the SBM directional distance function measurement results as the explained variables.

(2) Explanatory variables

Educational human capital (EDU): This is expressed by the number of employed persons and the average years of education [51]. The average educational level refers to Yang and Zhao [52]. The data used are from the "China Population and Employment Statistical Yearbook" for each year. Human capital has economic value based on workers and is a reflection of the workers' quality. Among them, educational level and health status are important factors that affect the formation of human capital. Talent is the main driving force and decisive factor for GEGE. R&D activities, the application of technological innovation achievements and the whole process of industrialization are inseparable from the strong support of high-level human capital. By attracting high-quality talent and encouraging them to engage in scientific research activities, the efficiency of green economic growth will be improved.

Environmental regulation (ER): Judging from the current status of environmental regulation in China, there is no fixed form of government intervention, and no special pollution tax is levied [53]. At present, when scholars measure environmental regulation, there is no unified indicator. To summarize, there are three main categories: one is measured by environmental laws and policies; the second is measured by the income of sewage charges; the third is measured by pollution control investment to the output value or cost ratio. Based on the relative rationality of the indicators, in this paper, we consider that the ratio of industrial pollution control investment completion to the regional industrial output value can better reflect the government's attention to the current environmental governance, reflects the level of pollution control efforts in various regions and can indirectly reflect the intensity of environmental regulation [54]. This indicator is measured by the ratio of the investment in industrial pollution control to the GDP of each region. This paper adds the quadratic form of environmental regulation (ER^2) to the regression.

(3) Control variables

Urbanization (UR): Urbanization is the optimal allocation and agglomeration of population and industries in space [55,56]. This paper believes that this is an important factor affecting GEGE. In order to fully reflect the impact of the urbanization index, the study measures urbanization from three dimensions: population urbanization, spatial urbanization and economic structure urbanization. Specifically, the population urbanization index is expressed as "the proportion of urban non-agricultural population to the total population", and the spatial urbanization index is expressed as "the proportion of the built-up area of urban municipal districts to the total area of municipal districts" to express the urbanization of the economic structure. The indicator is expressed as "the proportion of urban non-agricultural economic output to urban GDP". The overall urbanization indicator is weighted by three urbanization indicators, each with a weight of 1/3.

Foreign direct investment (FDI). The fact that "foreign investment-led", as a typical feature of China's trade growth, has profoundly influenced the scale and quality of regional economic development, as well as the fact that China's economic development at the early stage of the expansion of the economic scale, and the active development of international markets have led to a rapid increase in the amount of foreign investment in China. However, the looser environmental regulations and lower environmental protection costs compared to those of developed countries at this time caused foreign investors to invest in resource-rich regions and labor-intensive industries, resulting in the unfavorable situation of high resource consumption and high pollution emissions in China [57]. Although the entry of foreign investors has, to some extent, bridged the capital gap and improved the hard and soft environment, it has also brought about problems such as market monopoly, environmental pollution and industrial structure dualization [58]. Therefore, there may be positive or negative effects of FDI on green economic growth, and further verification is needed. The present study uses the proportion of FDI to GDP to measure the degree of foreign capital entry. Since the technological spillover effect and product structure impact the effect of FDI on GEGE, the characterization of GEGE depends on two effects.

Industrial structure (ES). As a necessary requirement of economic and social development, the "structural dividend" brought by industrial structure upgrading is proof of the great achievements of economic construction in the reform and opening up [59], and the rationalization and advanced industrial structure not only help to improve the regional ecological environment but also inject vitality into urbanization and become the backbone of green development [60]. The industrial structure, dominated by primary and secondary industries, can no longer meet the needs of urban development, and industrial structure upgrading is a new requirement of regional green development nowadays. The study selects the industrial added value proportion of the GDP to measure the adjustment and optimization of the industrial structure.

Trade Dependency (FT). At present, the dependence of China's economy on foreign trade exceeds 30%, and most foreign trade enterprises are industry leaders in the manufacturing industry, with long industrial chains and extensive supply chains, which are the "key minority" to achieve green and low-carbon development [61]. In this paper, the proportion of total regional import and export to GDP (%) is used, where total imports and exports expressed in US dollars are converted into RMB according to the RMB exchange rate of the year. The specific selection and descriptive statistics of each variable are shown in Tables 2 and 3.

Table 2. Variable selection.

Variables	Symbol	Variable Meaning
Green Economic Growth Efficiency	GTFP	SBM directional distance function measure
Environmental Regulation	ER	The ratio of industrial pollution control investment completion to regional industrial output value
Education Human Capital	EDU	The product of employment and average years of education
Industrial Structure	ES	The proportion of industrial value added to GDP
Foreign Direct Investment	FDI	Ratio of foreign direct investment to regional GDP
Trade Dependence	FT	Total regional imports and exports as a percentage of GDP
Urbanization	UR	Population, spatial and economic urbanization

Table 3. Descriptive statistics of variables.

Variables	Number of Samples	Mean	Standard Deviation	Minimum	Maximum
GEGE	420	0.484	0.441	0.216	1.111
ER	420	0.633	0.129	0.213	0.987
EDU	420	0.479	0.424	0.273	0.914
ES	420	0.346	0.188	0.111	0.923
FDI	420	0.362	0.372	0.123	0.432
FT	420	0.034	0.098	0.002	0.612
UR	420	0.214	0.2394	0.037	0.342

4. Results

4.1. Calculation Results of GEGE

Based on the data selected, the econometric analysis software Frontier 4.1 was used to analyze the GEGE of each region in China from 2008 to 2021, and we obtained the GEGE of each region in China, as shown in Table 4 below.

Table 4. Results of GEGE.

	Region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean
Eastern	Beijing	0.689	0.683	0.734	0.762	0.834	0.802	0.829	0.831	0.963	0.968	1.092	1.096	1.108	1.111	0.893
	Tianjin	0.564	0.561	0.574	0.582	0.633	0.686	0.615	0.626	0.729	0.728	0.812	0.822	0.829	0.901	0.69
	Hebei	0.411	0.413	0.439	0.438	0.569	0.505	0.616	0.619	0.723	0.749	0.801	0.811	0.814	0.815	0.623
	Liaoning	0.322	0.324	0.327	0.328	0.341	0.347	0.446	0.407	0.535	0.548	0.571	0.582	0.587	0.612	0.448
	Shanghai	0.579	0.566	0.614	0.612	0.736	0.738	0.739	0.741	0.766	0.723	0.893	0.912	0.917	1.023	0.754
	Jiangsu	0.502	0.512	0.513	0.514	0.631	0.645	0.789	0.862	0.916	0.928	1.017	1.032	1.056	1.072	0.785
	Zhejiang	0.522	0.525	0.535	0.534	0.767	0.711	0.736	0.815	0.935	0.952	0.975	1.011	1.038	1.082	0.796
	Fujian	0.411	0.41	0.423	0.422	0.547	0.559	0.565	0.566	0.668	0.761	0.772	0.785	0.81	0.811	0.608
	Shandong	0.415	0.417	0.422	0.431	0.579	0.583	0.526	0.521	0.618	0.625	0.701	0.705	0.719	0.721	0.57
	Guangdong	0.419	0.42	0.422	0.421	0.508	0.521	0.528	0.531	0.624	0.636	0.711	0.716	0.753	0.869	0.577
	Hainan	0.315	0.318	0.323	0.325	0.416	0.417	0.418	0.425	0.531	0.585	0.627	0.634	0.665	0.671	0.476
Central	Shanxi	0.347	0.348	0.334	0.336	0.342	0.35	0.355	0.36	0.465	0.516	0.528	0.576	0.536	0.612	0.429
	Jilin	0.337	0.334	0.333	0.336	0.345	0.348	0.35	0.365	0.414	0.585	0.589	0.618	0.632	0.648	0.445
	Heilongjiang	0.338	0.339	0.334	0.338	0.371	0.373	0.375	0.412	0.512	0.514	0.527	0.565	0.577	0.69	0.448
	Anhui	0.431	0.433	0.435	0.44	0.439	0.531	0.542	0.554	0.667	0.672	0.688	0.723	0.733	0.742	0.574
	Jiangxi	0.314	0.315	0.316	0.321	0.406	0.411	0.413	0.414	0.484	0.487	0.501	0.515	0.624	0.639	0.44
	Henan	0.303	0.307	0.308	0.312	0.416	0.427	0.42	0.421	0.532	0.541	0.543	0.548	0.55	0.555	0.442
	Hubei	0.303	0.305	0.31	0.314	0.317	0.328	0.338	0.634	0.548	0.539	0.545	0.554	0.556	0.564	0.44
	Hunan	0.321	0.323	0.324	0.321	0.328	0.339	0.441	0.449	0.553	0.557	0.558	0.559	0.561	0.562	0.443
Western	Neimenggu	0.321	0.323	0.301	0.302	0.315	0.317	0.323	0.324	0.426	0.437	0.444	0.445	0.451	0.462	0.371
	Guangxi	0.331	0.333	0.326	0.337	0.402	0.406	0.41	0.411	0.422	0.427	0.432	0.435	0.437	0.456	0.398
	Chongqing	0.323	0.328	0.334	0.332	0.342	0.353	0.359	0.371	0.429	0.43	0.435	0.442	0.454	0.515	0.389
	Sichuan	0.313	0.316	0.314	0.311	0.364	0.365	0.379	0.386	0.495	0.496	0.503	0.511	0.519	0.527	0.414
	Guizhou	0.268	0.265	0.268	0.264	0.311	0.328	0.338	0.342	0.347	0.358	0.354	0.355	0.358	0.41	0.326
	Yunnan	0.226	0.231	0.223	0.231	0.237	0.242	0.335	0.378	0.416	0.413	0.428	0.431	0.439	0.443	0.334
	Shaanxi	0.218	0.218	0.219	0.216	0.235	0.239	0.247	0.258	0.359	0.363	0.364	0.37	0.432	0.347	0.292
	Gansu	0.196	0.195	0.197	0.188	0.322	0.267	0.273	0.317	0.326	0.332	0.337	0.339	0.345	0.347	0.284
	Qinghai	0.282	0.183	0.184	0.181	0.287	0.214	0.222	0.23	0.241	0.245	0.257	0.259	0.285	0.323	0.242
	Ningxia	0.219	0.219	0.223	0.221	0.254	0.256	0.258	0.268	0.273	0.276	0.284	0.372	0.373	0.39	0.278
	Xinjiang	0.216	0.222	0.225	0.226	0.286	0.295	0.293	0.297	0.311	0.356	0.303	0.42	0.411	0.412	0.305
National mean		0.359	0.356	0.361	0.363	0.429	0.43	0.449	0.471	0.541	0.558	0.586	0.605	0.619	0.644	0.484

Overall, China's GEGE level is lower. The average value during the fourteen years from 2008 to 2021 is 0.484. Among them, the average value for four consecutive years from 2008 to 2011 is lower than 0.4, fluctuating around 0.360. In other years, it was higher than 0.4. Since 2016, the GEGE has exceeded the critical point of 0.5. This is mainly because the five new development concepts put forward in 2015 considered green development as the priority, and the ecological environment has been further elevated to a national strategy. Therefore, after 2015, although the economy entered a "new normal" and the growth rate has changed from high to medium and high speed, due to China's large economy, vast territory and complex national conditions, a considerable amount of time will be required to truly realize the rapid development of green growth from a low level to a high level.

Specifically, the 30 inter-provincial units in the country can be divided into three categories according to the average value of green economic growth efficiency.

First, for areas with low levels, the average value of green economic growth efficiency in these areas is lower than 0.450, including 20 provinces, namely Inner Mongolia, Qinghai, Ningxia, Gansu, Shanxi, Shaanxi, Xinjiang, Guizhou, Yunnan, Hainan, Chongqing, Guangxi, Jiangxi, Sichuan, Hubei, Hunan, Henan, Heilongjiang, Jilin and Liaoning. The improvement in citizens' livelihoods cannot be effectively taken into account. A considerable part of the region ignores the emission of pollutants and the improvement of citizens' livelihoods. To a certain extent, their economic growth is achieved at the cost of destroying the environment, so GEGE is still in its infancy.

Second, for areas with relatively high GEGE levels, the green economic growth efficiency value of this type of region is between 0.570 and 0.690, including Shandong, Anhui, Guangdong, Fujian, Hebei and Tianjin, accounting for 20% of the national proportion. While achieving economic growth, such regions attach importance to the restriction of polluting industries and the improvement of citizens' well-being, and they can actively cooperate with the national strategic goals and actively adjust their industrial policies and layout. Therefore, their growth mode is changing from the traditional extensive mode to an efficient and clean mode in the process of transformation. In terms of location, these are mainly eastern regions. These regions have superior geographical locations, complete infrastructure, a generally high degree of openness and efficient and complete systems, so they can quickly adapt to green development.

Third, for high-level areas of GEGE, the average value of green economic growth efficiency in such regions is higher than 0.754, including Beijing, Zhejiang, Jiangsu and Shanghai, accounting for 13.3% of the country. In fact, the green economic growth efficiency of these four regions is much higher than the national average in most years, which means that their green development has reached the peak level of efficiency and has reached a relatively effective level nationwide. Thanks to the large-scale agglomeration of tourism, finance and high-tech industries, such areas can eradicate highly polluting industries, eliminate outdated production capacity and effectively control pollutant emissions while achieving high-level economic growth. The development of the dimension is relatively complete, and its green economic efficiency can be used as a national development benchmark.

On the whole, GEGE does not show a normal distribution form of "less at both ends and high in the middle", but shows a skewed distribution in which the low level occupies the largest proportion and the medium and high levels are lacking. In addition, the distribution of GEGE shows obvious regional differentiation characteristics.

4.2. Analysis of Influence Results of Green Economy Growth Efficiency

4.2.1. Correlation Analysis and Multicollinearity Test of Variables

The correlation analysis method is used to test the correlation between the explained variable GEGE and explanatory variables such as environmental regulation ER, education human capital, industrial structure, FDI, foreign trade dependence and urbanization. The Pearson correlation coefficient indicates a strong correlation in the relationship. In the weak case, the results are as shown in Table 5.

Table 5. Correlation analysis and multicollinearity test.

	GEGE	ER	EDU	ES	FDI	FT	UR
GEGE	1.000						
ER	0.133 ***	1.000					
EDU	0.049 ***	0.023	1.000				
ES	0.044	−0.028	0.011	1.000			
FDI	0.102	0.223	0.112	0.013	1.000		
FT	0.112 ***	0.02	0.021	0.112 ***	0.121	1.000	
UR	0.029 ***	−0.034	0.212 ***	0.023	0.013 ***	0.025	1.000

Note: *** means $p < 0.01$.

According to the specific analysis presented in Table 5, it can be seen that the correlation coefficient between GEGE and environmental regulation is 0.133 ($p < 0.01$), which indicates a significant positive relationship between GEGE and environmental regulation. The correlation coefficient between GEGE and educational human capital is 0.049 ($p < 0.01$), which means that there is a positive correlation between GEGE and educational human capital; the correlation coefficient value between industrial structure and GEGE is 0.044 ($p > 0.01$), meaning that there is no correlation between GEGE and industrial structure.

The correlation coefficient value between GEGE and FDI is 0.102 ($p > 0.01$), also indicating no significant correlation between them. The correlation coefficient between GEGE and FT is 0.112 ($p < 0.01$), indicating a significant positive correlation between GEGE and FT. In addition, the maximum absolute value of the correlation coefficient in the above table is 0.223 and no values are greater than 0.4, which would indicate that the model has a multicollinearity problem. Therefore, it can be determined that the empirical model presented in this paper does not have a multicollinearity problem.

4.2.2. Stationarity Test of Variables

To avoid pseudo-regression and ensure the validity of the estimated results, Stata15.1 is used to test the stationarity of the data. According to the existence of the same root and different roots in the cross-section sequence in the panel data, the Hadri LM (HLM) test for the same root and the Fisher ADF (F-ADF) test for different roots were selected for the stationarity test; see Table 6. All variables reject the null hypothesis, indicating no unit root, so the regression can be performed directly.

Table 6. Unit root test results.

Variable	Differential Order	HLM Test		ADF Test	
		Statistic	*p*-Value	Statistic	*p*-Value
GEGE	0	3.23	0.000	223.452	0.000
ER	0	2.983	0.001	219.392	0.000
EDU	0	4.332	0.012	167.932	0.000
ES	0	5.32	0.003	159.327	0.000
FDI	0	6.324	0.000	127.334	0.000
FT	0	2.873	0.000	187.349	0.000
UR	0	5.445	0.000	178.235	0.000

4.2.3. Bootstrap Regression Results

Considering the above influencing factors, we select the bootstrap method to conduct the regression analysis. The results are as follows in Table 7.

Table 7. Bootstrap regression results.

Variable	Coefficient	*p*-Value
ER	−0.133	0.0012
ER^2	0.094	0.0000
EDU	−0.213	0.0021
ES	−0.227	0.0003
FDI	−0.043	0.0000
FT	−0.071	0.0001
UR	−0.004	0.0000
UR^2	0.123	0.0001
R^2	0.9902	
Log likelihood	25.68	

Environmental regulation. Environmental regulation and GEGE have a U-shaped relationship, which means that when the regulation intensity increases, green economic growth efficiency first decreases and then increases. Therefore, Hypothesis 2 of this study has been confirmed, and many scholars have also concluded that there is a nonlinear relationship between the two. For example, the impact of environmental regulation on green economic efficiency, as noted by scholar [62], shows not only a "time-delay", but is also "nonlinear". The reason behind this nonlinear relationship is as follows: at the beginning, enterprises responded to the regulatory policies issued by the government and increased their pollution prevention and control efforts to meet the required intensity level, which increased their investment in pollution control. This has suppressed the investment of enterprises in green research and development, which will inhibit GEGE improvement in the short term. As the government increases its efforts to regulate the environment, the benefits of enterprises in green innovation can cover their pollution control costs. New technologies bring a larger market to enterprises. The profits of new products are sufficient to offset the pollution control investment of enterprises. This can achieve long-term and stable development in the market. Therefore, in the long run, enterprises will take the initiative to give priority to the innovation of green technology, optimize green processes, reduce energy consumption, produce green products and control pollution emissions, to achieve a green transition. Some scholars have also conducted in-depth analysis on environmental regulation and divided it into different types for analysis. For example, Zhang et al. [63] assessed the impact of different types of environmental regulation, such as administrative, market and public participation, on the industrial green growth index, which is also the goal of further research in this work.

Educational human capital. The elasticity coefficient of educational human capital is significantly negative, which means that the human capital improvement level has a hindering effect on GEGE in space, which is inconsistent with the expectation of this study. It is inconsistent with Hypothesis 1. Moreover, in contrast to the conclusions drawn by a large number of scholars, the existing research mainly focuses on the impact of human capital on economic growth, so we can draw a positive relationship between them. For example, Bodman and Le [64] found that human capital can directly improve labor productivity and increase output as "factor accumulation", making a direct contribution to economic growth. This further shows that this research is a supplement to the existing research. Few scholars have studied the relationship between human capital and green economic growth efficiency, which is also one of the main innovations of this work. It is speculated that the possible reasons for this result are as follows. First, higher education does not pay sufficient attention to the cultivation of creative thinking and practical training in terms of innovation and entrepreneurship, which leads to a lack of innovative and practical abilities among individuals who receive higher education, and the accumulated knowledge and skills cannot be effectively used. Second, higher education does not lead to a strong awareness of environmental protection. The main purpose of technological innovation for higher education students is to improve labor productivity and promote economic growth. Insufficient attention has been paid to improving resource utilization and reducing pollutant emissions. The stimulation of economic growth via technological innovation causes producers to consume more energy and generate more pollution. The "rebound effect" induced by this technological innovation greatly inhibits innovative manpower, highlighting the role of capital in improving the efficiency of green economic growth. Third, the training of high-level talent is dislocated or decoupled from the market demand, and the investment of innovative human capital cannot fully meet the needs of green innovation development. On the one hand, the overall stock of the innovative human capital level is not high enough. On the other hand, due to the "siphon effect", there are both a "short supply" and "oversupply" of innovative human capital in the region, which widens the gap in innovation capability between regions.

FDI. FDI can significant inhibit GEGE. According to the theoretical analysis, FDI has both technology spillover effects and product structure effects. The impact on GEGE depends on the relative size of the two. The empirical test results show that the product structure effect of China's FDI is greater than the technology spillover effect. Green economic growth efficiency plays a negative role, supporting the "pollution paradise" hypothesis. This result is consistent with Yuan and Xie [65] and Wei [66]. Generally speaking, FDI can be divided into the export-oriented type and market-seeking type. The former aims mainly to exploit the comparative advantages of the investment country's resources and factors. Due to China's current weak environmental regulation level, this will have a strong impact on the production of polluting products. Therefore, FDI entry will show a strong product structure effect; the latter is intended for the purpose of developing a sales market in the host country, and when its market share reaches a certain level, it may adjust the product structure according to its comparative advantages. This will reflect the negative product structure effect. In addition, the fact that China uses GDP as the main performance evaluation indicator will cause local governments to lower the environmental threshold when attracting investment, and it will tend toward FDI with higher output value, further amplifying the effect of the product structure.

Urbanization. The coefficients of UR are all negative, and the coefficients of UR^2 are all positive, which shows that GEGE and the level of urbanization have an obvious U-shaped relationship; that is, GEGE shows a trend of first declining and then rising. This shows that in the early stage of urbanization, the rapid expansion of the population and the industrial space may have a significant negative impact on the local ecological environment. However, when the level of urbanization increases to a certain level, the urban agglomeration economy and radiation effects will gradually offset the negative impact and ultimately lead to an increase in GEGE.

Industrial structure. The industrial structure can inhibit GEGE significantly, and its coefficient is -0.227, indicating that every 1% increase in the industrial structure index reduces the green economy growth efficiency by 2.27%, which is also consistent with reality. China's secondary industry is dominated by industry, and most of it is energy-intensive, resulting in high environmental pollution intensity and energy consumption intensity, which seriously inhibits the improvement of GEGE.

Trade dependence. Trade dependence also has a reverse action on GEGE, as import and export trade cannot improve the GEGE. This shows that there are various deficiencies in the process of opening to the outside world: the export of labor-intensive products is still the mainstay, and such demand cannot stimulate investment in domestic independent research and development; in terms of imports, it is mainly based on the introduction of advanced machinery and equipment. To a certain extent, domestic independent research and development innovation has been inhibited. Therefore, only by changing the structure of import and export trade and changing the means of trade can we drive the transformation of technological progress in the provinces and reverse the current situation.

5. Conclusions and Implications

In order to examine the impact of educational human capital and environmental regulation on GEGEG, this paper takes environmental regulation and educational human capital as explanatory variables and green economic growth efficiency as the explained variable, and incorporates the three into the same model. Based on empirical data, the SBM-DDF directional distance function is selected to measure GEGE, and we then use the bootstrap regression method to test the factors affecting GEGE in China. The conclusions are as follows.

(1) Overall, GEGE is still low. The average GEGE from 2008 to 2021 is 0.484. Among them, the average for four consecutive years from 2008 to 2011 is lower than 0.4, fluctuating at 0.36. In other years, it was higher than 0.4, and the GEGE in 2016 and 2017 exceeded the critical point of 0.5. After 2020, the green economy growth efficiency ushered in a period of growth opportunities.

From a regional perspective, for areas with low levels of GEGE, the average GEGE of such areas is lower than 0.45, including 20 provinces. Low-level areas account for approximately 66.7% of the country, so green development is still in its infancy. Second, areas with relatively higher GEGE values between 0.57 and 0.69 account for approximately 20% of the national proportion. While achieving economic growth, such regions attach importance to the restriction of polluting industries and the improvement of citizens' happiness, and they can actively cooperate with the national strategic intentions and actively adjust their industrial policies and layout. Therefore, their growth mode is changing from the traditional extensive mode to an efficient and clean mode in the process of transformation. A third, high-level area of GEGE with a value higher than 0.754 accounts for 13.3% of the national total. On the whole, GEGE does not show a normal distribution form of "less at both ends and high in the middle", but shows a skewed distribution in which the low level occupies a large proportion and the medium and high levels are lacking. In addition, the distribution of GEGE shows obvious regional differentiation characteristics.

(2) The influence of explanatory variables on GEGE

There is a U-shaped relationship between environmental regulation and GEGE, which means that GEGE first decreases and then increases, and once the intensity of environmental regulation crosses the inflection point, GEGE increases. Because the environmental regulation cost is higher than the benefit in the short term, this inhibits GEGE.

The elasticity coefficient of educational human capital is significantly negative. The result of this is that the improvement in the human capital level has a hindering effect on GEGE in space, which is not in line with the expectations of this study. The possible reasons are as follows. First, higher education does not pay sufficient attention to the cultivation of creative thinking and practical training in terms of innovation and entrepreneurship; second, a higher level of education does not result in a strong awareness of environmental protection; third, the investment of innovative human capital cannot fully meet the needs of the industry's structural upgrading, green innovation and development needs.

(3) The influence of control variables on GEGE

There is a significant negative correlation between FDI and GEGE. FDI has a negative effect on GEGE, supporting the "pollution paradise" hypothesis. GEGE and the level of urbanization show an obvious U-shaped relationship. There is a negative relationship between industrial structure and GEGE, which is also in line with reality. There is a negative correlation between trade dependence and GEGE, mainly in terms of exporting labor-intensive products, and such demand cannot stimulate domestic independent research and development investment; in terms of imports, it is mainly intended to introduce advanced machinery and equipment, as a result of which, to a certain extent, domestic independent research and development innovation has been inhibited.

5.1. Recommendations

(1) To improve the level of human capital and optimize the human capital structure. The impact of human capital in terms of improving the quality of China's economic development and realizing the transformation of the economic development mode is long-lasting. Education has been widely recognized as an important means to enhance the level and optimize the structure of human capital [27]. However, educational human capital has not yet played its proper role and is still at a low level overall. Therefore, in order to exploit the positive effect of educational human capital, in terms of policy formulation, we should strengthen the binding mechanism of the local government's investment in education and ensure the full amount of investment in education; while ensuring financial investment in education, we should pay more attention to the regional and urban–rural distribution of education expenditure, so as to reduce the unequal educational opportunities between regions and urban–rural areas caused by the uneven distribution of investment in education; and we should guide social organizations to participate in multi-level schooling. The government should guide social organizations to participate in multi-level education and create a favorable atmosphere for the development of education and human capital cultivation throughout the entirety of society; pay more attention to the quality of education at all levels; and improve the distinction between different levels of education, so as to promote the improvement of the overall level of human capital and the optimization of its internal structure [32].

(2) To formulate appropriate environmental regulation policies and provide corresponding government subsidies.

With the improvement in environmental regulation policies, the promotion effect of human capital investment on green technology innovation is being constantly weakened or may even exceed certain intensity [61]. Environmental regulation will seriously inhibit the contribution of human capital to green technology. Therefore, the government should adopt appropriate means and methods when formulating environmental policies, consider various influencing factors, determine the appropriate intensity of environmental regulation and select more flexible environmental regulation tools. In a short period of time, environmental regulation policies may inhibit the efficiency of green economic growth due to limited funds. Therefore, the government can provide certain policy subsidies to exploit the role of environmental regulation in promoting green technology innovation to provide a buffer [37].

(3) To be vigilant and prevent the negative effects of international trade on the green efficiency of China's economic growth.

In the long run, trade is indeed beneficial to improve China's technological level (including production technology and environmental protection technology) and promote GEGE, but, in the short term, international trade may have a negative impact on China's environmental pollution, thereby affecting GEGE, and also the real efficiency. If environmental factors are not considered, it may be easy to exaggerate the role of trade in promoting GEGE [67]. Therefore, it is very important to make full use of the positive effects of international trade and overcome its negative effects. Relevant guidance will encourage enterprises to enter industrial sectors with less environmental pollution and obvious technological spillover effects, so as to prevent China from becoming a "pollution paradise".

(4) To abandon the pursuit of GDP growth and focus on the transformation of the economic growth mode.

The degree of greening is not high, economic activities still show serious environmental unfriendliness, and the mode of extensive economic growth has not undergone a fundamental change. From the current point of view, the pollution situation is still very serious. Under the circumstances of an economic downturn, slowdown in growth rate and structural adjustment, on the one hand, a GDP-only performance evaluation system may cause local governments to adopt economic incentive policies and reverse the relationship between environment and economy, abandoning the principle of giving priority to the environment and ecology and continuing to adopt the economic development method at the expense of deteriorating the ecological environment; on the other hand, with the economic downturn, the decline in corporate efficiency leads to insufficient investment in environmental protection. However, in the face of severe forms of environmental governance, environmental governance cannot be delayed. To achieve this, on the one hand, we must abandon the pursuit of GDP growth and start to establish a green GDP accounting system, which reflects environmental benefits in economic accounting and realizes the integration of economic growth and the natural environment [14]. On the other hand, it is necessary to change the factor-driven economic growth mode of "high loss and high pollution", implement an innovation-driven policy, facilitate the progress of green and clean technology, focus on supporting high-tech green and clean industries and realize an improvement in green economic growth efficiency.

5.2. Shortcomings and Prospects

(1) Due to the existence of regional differences, there may be spatial effects between variables; while this paper is a study of spatial effects, it may ignore the impact of some of these effects and they should be analyzed in further research.
(2) Due to the complexity of macro-environmental policies, there are many factors that affect the green economy, and they are not limited to the variables proposed in this paper; thus, the research can be further enriched on this basis in the future.

(3) Due to our knowledge structure and research efforts, there is still a shortage of knowledge on the theoretical aspects of green economy development. In order to highlight the characteristics of the discipline, more useful attempts can be made to combine the relevant Marxist theories with the development of a green economy, so that the development of the green economy can be traced back to its roots at the same time, improving the development of the green economy in terms of the time span and theoretical level.

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