Green GDP: the Goal of the Future Economic Health

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Abstract. At present, the most widely used composite index for measuring economic growth in the world is GDP and its growth rate, but this composite index does not fully emphasize the importance of climate and environment, while green GDP focuses on economic development while also paying attention to the protection of the natural environment. In order to establish a green GDP accounting system and test whether the green GDP system can alleviate climate change, this paper considers the impact of natural resource depletion and environmental pollution, selecting data from 23 countries, using EWM and CVM for calculation, and obtaining The resource and environment index RNI finally determines the accounting system of green GDP. In order to study the relationship between the green GDP system and climate change, this paper develops a GGDP-climate change coupling model, and the chi-square independent test is used for the correlation between GGDP and climate change. Pearson's contingency coefficient (C) is used for to determine how close the correlation is, the Spearman correlation coefficient is used to determine the direction of the correlation. The study found that GGDP has the effect of slowing down the deterioration of global climate.

Keywords: REC model, GGDP-Climate a Change Coupling Model, Natural resource depletion, Environmental pollution.

1. Introduction

Traditional GDP does not reflect these negative impacts of economic development on resources and the environment [1] and it ignores social costs, environmental consequences, income inequality and ecological concerns [2].

The United Nations Bureau of Statistics and the World Bank have jointly developed a systematic comprehensive environmental and economic accounting account, which incorporates resources and pollution costs into the national economic accounting system, thus introducing the concept of green GDP. [3] Later, Muhammad et al. considered the value of natural resources and ecosystem services when establishing GGDP, so this paper considers more comprehensively when establishing GGDP [4]. In addition, Qi jie Yang proposed that the promotion of green GDP can focus on economic development while also paying attention to the protection of the natural environment, making up for the shortcomings of GDP that only focuses on economic growth [5]. Rounaghi et al. pointed out that green GDP can be used in policy formulation and evaluation, which can help to raise the awareness of national governments/policy makers on sustainability issues [6].

All countries are advocating sustainable development, building a global development community. If green GDP is adopted, significant progress will be made in alleviating the climate crisis and ecological crisis, which will help all mankind to develop better.

In this paper, considering the impact of natural resource depletion and environmental pollution, a REC model is developed to measure GGDP, and a GGDP-climate a Change coupling model is established to explore the relationship between GGDP and climate change. Detailed work is showed in Figure 1:

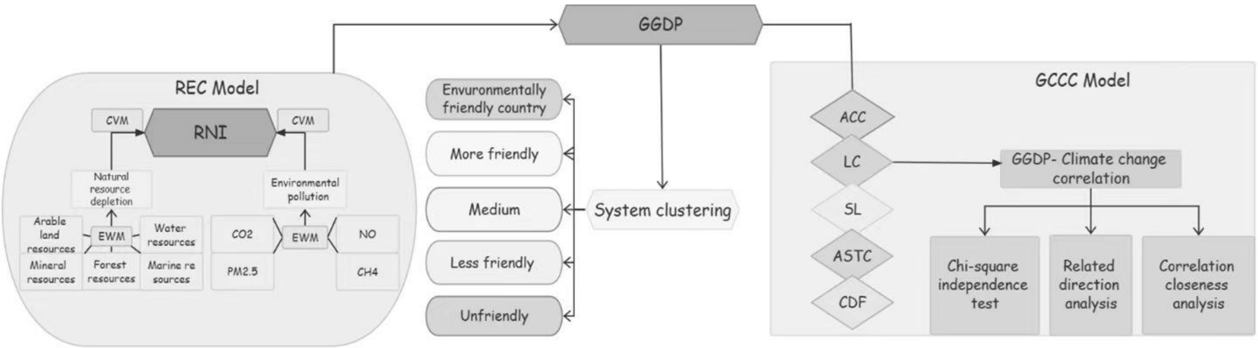

Figure 1. Flow chart of our work

2. Resource environment index EWM and CVM

2.1. Index selection

According to the calculation method of green GDP in Green GDP and Sustainable Development in Malaysia: Green GDP= Gross Domestic Product - Natural Resources Depletion - Pollution Damage [7]. This paper considers the depletion of natural resources and environmental pollution, and conducts a comprehensive analysis of five aspects of natural resources and four types of polluting gases produced during waste treatment.

2.1.1. Natural resource depletion

Detailed natural resource depletion indexes are showed in Table 1:

Table 1. Natural resource depletion index

Water resources	$WCV = WP \times WCR$	WCV	water consumption value
		WP	water price
		WCR	water consumption reduction
Arable land resources	$AL = ALC \times PCL$ $PCL = GAP \div AC$	AL	depletion value of arable land resources
		ALC	area of agricultural land change
		PCL	price of arable land resources per unit area
		GAP	Gross agricultural production value of the region
		AC	agricultural land in the region in the current year
Forest resources	$FRV = TWC \times ULP +$ $FCA \times UFP$	FRV	value of forest resource depletion
		TWC	total stock of live standing wood consumption
		ULP	unit area live standing wood resource price
		FCA	forest land resource change area
		UFP	unit area forest land resource price
Mineral resources	$MRV = MP \times \mu \times \eta$	MRV	mineral resource depletion value
		MP	mineral resource price
		μ	scale adjustment coefficient
		η	taste adjustment coefficient
Marine resources	$VM = L \times S \times P$ $V_e = R_d + F_j + C_r + E_p + P_p$ $E_P = \sum(\frac{B_t - C_t}{(1+r)^t} - P_h)$ $MLV = VM + V_e + E_P$	VM	Value of marine living resource depletion
		L	amount of species loss
		S	survival rate of species
		P	average unit price of species
		V_e	value of marine mineral resource depletion
		R_d	resource extraction rights
		F_j	resource discovery rights
		C_r	compensation for resource depletion
		E_c	ecological compensation of mineral resources
		P_p	compensation for exploration
		E_P	estimated net value of wind energy assets
		B_t	sales price in period
		C_t	production cost in period
		P_h	initial investment

2.1.2. Environmental pollution

The treatment methods of solid waste mainly include landfill and incineration. Both treatments produce gas. Therefore, in this section, the annual average exposure to PM2.5, carbon dioxide emissions, methane emissions, and nitric oxide emissions are analyzed. Detailed environmental pollution indexes are showed in Table 2:

Table 2. Environmental pollution index

Formula	Indicators I	Indicators II	Indicators III
GGDP=GDP×RNI	RNI	Pollution Damage	PM2.5
			CO2
			CH4
			NO
		Natural Resources Depletion	Arable land resources
			Water resources
			Mineral resources
			Marine resources
			Forest resources

2.2. Model building

2.2.1. Entropy weight method and Coefficient of variation method

In this section, according to the evaluation indicators defined above, we further determine the weights of these nine indicators, thus forming a combination of main indicators.

According to the concepts of self-information and entropy in information theory, the information entropy of each evaluation index can be calculated. Based on the information entropy, we will further calculate the weight of each evaluation index we defined before. Finally, we can get the weight of natural resource depletion and environmental pollution.

$$\begin{cases} NRD_i = w_1 y_{1j} + w_2 y_{2j} + w_3 y_{3j} + w_4 y_{4j} + w_5 y_{5j} \\ NP_i = w_6 y_{6j} + w_7 y_{7j} + w_8 y_{8j} + w_9 y_{9j} \end{cases} \tag{1}$$

After expressing the nine indicators as two comprehensive variables, the two indicators are integrated into one comprehensive indicator, which is used to evaluate GGDP considering the impact of environmental resources. We can calculate the weights of two Composite Indicators by Coefficient of variation method:

$$W_i = \frac{C\dot{V}_i}{\sum_{i=1}^{n} C\dot{V}} \quad \text{i=1,2} \tag{2}$$

2.2.2. Relative to GGDP

We synthesize the existing literature and first calculate the resource environment index RNI:

$$RNI_i = \frac{S_i}{\max(S_i) - \min(S_i)} \times 0.4 + 0.6 \tag{3}$$

Among them, S_i is the resource environment score of *i* country, max(S_i) is the maximum value of the resource environment score of all countries, and min(S_i) is the minimum value of the resource environment score of all countries.

GGDP can then be calculated with the formula:

$$GGDP_i = GDP_i \times RNI_i \tag{4}$$

2.2.3. Result analysis

According to the above model, we get the weight of each indicator in Table 3:

Table 3. Indicators' weights

Indicators I	Weights (%)	Indicators II	Weights (%)
Natural resource depletion	51.083	Arable land resources	13.936
		Water resources	19.751
		Mineral resources	12.901
		Marine resources	11.216
		Forest resources	5.767
Environmental pollution	48.917	PM2.5	5.634
		CO2	12.614
		CH4	8.959
		NO	9.221

2.3. System clustering

We use the method of systematic cluster analysis to classify 23 countries according to GGDP. When classifying, it is necessary to estimate the direct distance of different samples to measure the similarity between sample points. We use the Euclidean distance to measure. Classified results are showed in Table 4:

Table 4. classified results

Type	Country
Environmentally friendly country	United States
More environmentally friendly countries	China Mexico Canada Australia Brazil Germany Russia Italy England France
Medium environment country	Japan
Less environmentally friendly countries	Syria Poland Somalia Egypt Nigeria Cuba Jamaica Haiti Sudan Kenya
Environmentally unfriendly country	India

3. GGDP-Climate Change Coupling Model (GCCC)

3.1. Climatic variation index

Detailed climatic variation indexes are showed in Table 5:

Table 5. climatic variation index

Indicators	Explain
ASTC	mean surface temperature change during the period 2000-2021
ACC	yearly Atmospheric Carbon Dioxide Concentrations in different parts per million
SL	yearly change in sea level
LC	climate altering land cover index (Select the value year of 2015 as 100)
CDF	climate-related disasters frequency (Include drought, flood, storm, wildfire, land slide, extreme temperature)

3.2. GGDP- Climate change correlation

In order to confirm the correlation between GGDP and climate change, we take green GDP and climate change as two-dimensional attributes.

Therefore, this page uses the chi-square independence test to test the relationship between green GDP and climate change on a global scale. One country is selected from each of the five categories of results in 3.2 as the case country. The final selected countries are the United States, France, Japan, Egypt and India, and the climate change data of each country in 2021 are used for specific analysis.

3.2.1. Chi-square independence test

Step 1: Hypothesis

H_0: Green GDP and climate change are independent of each other

H_1: Green GDP and climate change are interrelated

Step 2: Chi-square independence test

$$F_0 = \begin{pmatrix} f_{011} & f_{012} & \cdots & f_{01j} \\ f_{021} & f_{022} & \cdots & f_{02j} \\ \vdots & \vdots & \ddots & \vdots \\ f_{0i1} & f_{0i2} & \cdots & f_{oij} \end{pmatrix} \tag{5}$$

$$f_{ri} = \sum_{j=1}^{5} m_{ij} \tag{6}$$

$$f_{cj} = \sum_{i=1}^{5} m_{ij} \tag{7}$$

$$F_e = \begin{pmatrix} f_{e11} & f_{e12} & \cdots & f_{e1j} \\ f_{e21} & f_{e22} & \cdots & f_{e2j} \\ \vdots & \vdots & \ddots & \vdots \\ f_{ei1} & f_{ei2} & \cdots & f_{eij} \end{pmatrix} \tag{8}$$

$$f_{eij} = \frac{f_{ri} f_{cj}}{\sum_{i=1, j=1}^{5} f_{oij}} \tag{9}$$

According to the selected data, we construct the matrix F_0, and the F_0 matrix represents the observed value. Where f_{0ij} represents i case countries corresponding to j data reflecting climate change. f_{ri} and f_{ci} represent the sum of data in the i-th row and the sum of the data in the j-th column, respectively. The expected matrix F_e is calculated by the calculation formula of f_{eij}.

Then, we can calculate the chi-square value:

$$\chi^2 = \sum \frac{(f_{0ij} - f_{eij})}{f_{eij}} \tag{10}$$

$$df = (i-1)(\mathrm{j}-1) \tag{11}$$

Finally, we get χ^2=80.07878. Determine the significance level α=0.05 and degrees of freedom df. Looking up the table shows that the chi-square critical value is 26.296. The chi-square value is much greater than the chi-square critical value, so the hypothesis H_0 is rejected. There is a relationship between GGDP and climate change on a global scale.

3.2.2. Correlation Closeness Analysis

$$C = \sqrt{\frac{\chi^2}{\chi^2 + \sum_{i=1, j=1}^{5} f_{oij}}} \tag{12}$$

Bringing in relevant data, we finally determine that there is a correlation between green GDP and climate change. The C_0 calculated = 0.381042 of the matrix F_0 proves that there is a certain influence between green GDP and climate change. And calculate the Pearson's contingency coefficient of the case country separately, and the results are shown in Table 6:

Table 6. results

Type	Environmentally friendly country	More friendly countries	Medium countries	Less friendly countries	Unfriendly country	overall level
Value of C	0.457641508	0.17691853	0.33579513	0.358955793	0.03453069	0.381042
Deviation from the general level	20.1028%	53.5698%	11.8744%	5.7962%	90.9378%	
Rank	1	4	3	2	5	

In general, there is a certain correlation between green GDP and global climate change. Among them, the green GDP of the environmentally friendly countries has the closest correlation to climate change, followed by the less environmentally friendly countries. The degree of closeness of green GDP to climate change is close between less environmentally friendly countries and moderately environmentally friendly countries. There is a smaller correlation between green GDP and climate change in environmentally unfriendly countries.

3.2.3. Related direction analysis

From the above analysis, we can see that there is a correlation between GGDP and factors affecting climate change. The magnitude gap between GGDP and the factor data affecting climate change is too large, and the climate change data is not linear. We use the Spearman correlation coefficient method to calculate the correlation between GGDP and climate change and the correlation between climate change indicators.

The Spearman correlation coefficient is solved by using the sorting position of the original data, which can well overcome the limitation of the Pearson correlation coefficient. The Spearman calculation formula is as follows, where $\overline{X}$ is the sample mean for X_i sample.

$$r = 1 - \frac{6\sum d_i^2}{n\left(n^2 - 1\right)} \tag{13}$$

After calculating the correlation coefficient, the relationship between GGDP and climate change can be presented in Figure 2 by drawing a heat map.

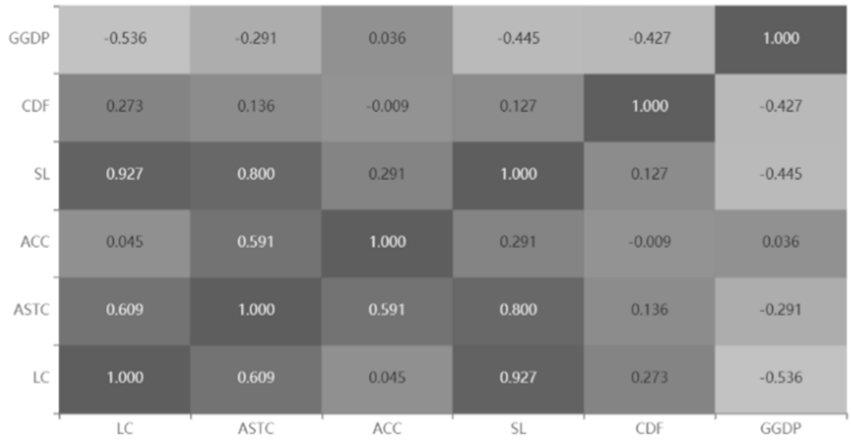

Figure 2. Diagram of correlation

Analyzing the relationship between GGDP and these five climate change indicators, it can be concluded that GGDP has a strong negative correlation with Climate Altering Land Cover Index, climate-related disasters frequency and Sea Levels. There is a weak negative correlation between GGDP and Annual surface temperature change. The positive correlation between GGDP and Atmospheric carbon dioxide concentrations is weak.

Climate change intensifies when the Climate Altering Land Cover Index and climate-related disasters frequency increase, sea levels rise and annual surface temperature change increases. Since there is a negative correlation between GGDP and Climate Altering Land Cover Index, climate-related disasters frequency, Sea Levels, and Annual surface temperature change, with the increase of GGDP, global climate change can be slowed down.

In addition, we can also conclude that there is a strong correlation between the various factors affecting climate change. A change in one is likely to cause changes in the others.

4. Conclusion

The formula $GGDP_i = GDP_i \times RNI_i$ shows that the larger the value of RNI, the larger the proportion of GGDP in GDP, that is, the smaller the environmental cost in economic development, which is more conducive to the coordinated and sustainable development of the national economy. Conversely, the smaller the GGDP value, the smaller the proportion of GGDP in GDP, that is, the greater the environmental cost in economic development, which is more unfavorable to the coordinated and sustainable development of the national economy. This paper uses the Spearman correlation coefficient method to find that there is a strong correlation between the indicators of climate change. Through the Chi-square independence test, it is found that there is a certain correlation between green GDP and global climate change. Among them, the green GDP of environmentally friendly countries has the closest correlation with climate change, decreasing in order, and there is a small correlation between green GDP and climate change of environmentally unfriendly countries, so we get that the adoption of GGDP can alleviate climate deterioration. In order to maximize returns, investors will often buy and sell volatile assets, and each transaction usually requires a certain commission. The time, frequency and quantity of the purchase and sale will have a key impact on the investor's return rate. This paper establishes a prediction and decision-making model based on data from all past trading days for us, and provides investment advice for investors in order to maximize returns.

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