Study on the Impact of Green GDP Accounting System on Climate —— Based on Global Climate Mitigation Index Model

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Abstract. GDP index can't measure the level of a country's sustainable economic development because it only pays attention to economic development but not to climate protection.Green GDP is the core index of the comprehensive environmental-economic accounting system, which incorporates resources and environmental factors into the current GDP to better reflect a country's real economic health. This paper develops a GGDP accounting model based on SEEA, which is closely related to GDP, and analyzes the relationship between green GDP accounting system and climate mitigation. In order to study the impact of GGDP on climate, this paper divides the global countries into four categories, selects 30 representative countries, establishes a global climate mitigation index model based on GCAM model and EWM, and calculates the impact of GGDP system on climate. The results show that the growth of GGDP has a positive impact on climate mitigation. This study puts forward a new accounting system of economic development level, which is of great significance to alleviate climate change.

Keywords: Green GDP; SEEA; GCAM model; Global climate change.

1. Introduction

GDP is the core index of national economic accounting, and it is also an important index to compare economic situation and development level among countries[1]. In the past few decades, many countries have taken GDP growth as their goal for the coming year at the beginning of the year. However, because natural resources are not considered in GDP accounting, countries can use natural resources without being punished. Therefore, if we only rely on GDP to measure national strength, we must not consider sustainable development, which means that at some point in the future, the earth will no longer be suitable for human habitation. In this case, it is imperative to add green and environmental protection measures through the revision of GDP[2].

Green GDP is the core index in the comprehensive environmental-economic accounting system. It can better reflect a country's real economic health by integrating resources and environmental factors on the basis of current GDP. If GGDP is used as a new measure, countries may change their behavior and make our global village develop in a greener, healthier and more sustainable direction.

At present, many researchers have shown many methods or models for accounting GGDP, but the research results of GGDP are relatively slow due to technical difficulties, imperfect systems, backward concepts and other factors.

To sum up, GGDP accounting methods can be roughly divided into the following four types: SEEA accounting system, SERIEE accounting system, NAMEA accounting system, ENRAP accounting system and similar GDP accounting methods[3].

The SEEA accounting system was put forward by the United Nations in 1993 through the SEEA manual, and it was tried out on the topic of the environment that has more influence on the economic activities of various countries. The SERIEE accounting system was put forward by Eurostat in 1994, which only calculates environmental protection expenditure and does not calculate all kinds of pollution damage. The NAMEA accounting system was put forward by the Director of Statistics Netherlands. Except for national income, the rest are all physical accounts expressed in quantitative units. The ENRAP accounting system was put forward by economist Menry Paskin in 1989, which calculates the deductions that are harmful to the environment and those that are beneficial to the environment, but some contents are still controversial at present. Accounting methods similar to GDP are divided into direct calculation method and brief calculation method[4]. Direct calculation method includes production method and expenditure method, and indirect calculation method includes external influence factor calculation method, social welfare calculation method and balance calculation method based on SEEA.

Various methods in literature review all adopt different accounting ideas, framework structure, index system and functional application, but the existing highly recognized GGDP accounting methods lack methods to verify that using GGDP as the main measure of a country's economic health does have an impact on global climate change[5]. In this paper, we establish the accounting model of GGDP which is closely related to GDP based on SEEA. On this basis, we establish the global climate mitigation index model (GCMI), and select 30 representative countries to analyze the relationship between this model and climate mitigation.

2. Model building

2.1. GGDP accounting model

The accounting model of GGDP based on SEEA released by the United Nations from the perspective of economic and environmental balance is more authoritative than other methods. SEEA has built an evaluation system that is fair to all countries and hopefully caters to the international situation. Judging from the number of related studies, more scholars have conducted GGDP accounting in different regions based on SEEA, which shows that SEEA is more widely accepted in academic circles, with less calculation resistance, lower research difficulty or more perfect accounting methods. In addition, SEEA puts forward the concept of maintenance cost, which refers to the cost paid to avoid or reduce the actual environmental damage during the accounting period. This concept internalizes the cost of environmental pollution and can achieve the purpose of slowing down global climate change after GGDP is popularized.

To put it simply, the specific calculation method is to deduct the cost of resource depletion and environmental degradation paid in economic activities from GDP, that is, GGDP=GDP- resource depletion cost-environmental degradation cost =GDP- value of resource depletion-value of environmental pollution control loss-value of environmental pollution degradation loss[6].

For the convenience of calculation, natural resources are divided into water resources, energy resources, cultivated land resources, forest resources and fishery resources, and environmental losses are divided into environmental pollution control losses and environmental pollution degradation losses[7]. The classification table 1 of natural resources is as follows.

Table 1: Classification table of natural resources

Natural resource	Environmental pollution control loss	Environmental pollution degradation loss
Water resource	Total amount of funds invested in environmental pollution control in various regions	Accelerated depreciation loss of fixed assets
Energy resources		
Cultivated land resources		Human health loss
Forest resources		
Fishery resources		Natural disaster loss

(1) Water resources

Water resource depletion value = water resource price × water resource depletion amount

$$W_{dv} = P_{wi} \times W_d \tag{1}$$

According to the international common empirical method of water resources prices, we get:

$$P_{wi} = \frac{F_{wi}}{Q_{wi}} \times a_i \tag{2}$$

Considering the availability of data, where P_{wi} represents the price of water resources in region i ; F_{wi} is actually the total output value created by producers in the water-using industry in region i, but this data is not easily available[8], so we use the approximation of the GDP of region i instead; Q_{wi} is the regional per capita water consumption (Q, m3/person); a_i is the regional consumer willingness to pay coefficient, regarding a_i, some scholars have given the formula as follows.
When

$$Q \leq 500, a = 0.03$$

$$500 < Q < 3000, a = 0.03 - \left(\frac{Q - 500}{125000}\right) \tag{3}$$

$$Q \geq 3000, a = 0.01$$

(2) Energy resources

Energy resource depletion value = energy resource price × energy resource depletion

Considering data availability, the data of the average crude oil of the three major markets are used here for approximation instead, yielding:

$$E_{dv} = P_{ei} \times E_d \tag{4}$$

It is worth noting here that the price estimation of energy resources uses the average crude oil price (USD/barrel) of the three major markets for the year, corrected by the energy price index, and then estimates the relationship between barrels and kilograms, multiplied by the energy use.

(3) Arable land resources

Depletion value of cropland resources = price per unit area of cropland resources × area of change in cropland resources:

$$L_{dv} = P_{li} \times L_{vi} \tag{5}$$

P_{li} denotes the price per unit area of cultivated land resources in region i, and L_{vi} denotes the area of change of cultivated land resources in region i.

Where, the price per unit area of cultivated land resource = agricultural GDP of region i in that year / area of cultivated land in region i in that year

$$P_{li} = RPV_i \div S_{li} \tag{6}$$

(4) Forest resources

Depletion value of forest resources = depletion of the total stock of vital wood resources × price of live wood resources per unit area + area of forest land resources change × price of forest land resources per unit area

$$R_{dv} = TADW_i \times PSR_i + FLRC_i \times PRL_i \tag{7}$$

(5) Fishery resources

Depletion value of fishery resources = total value of marine fishing + total value of freshwater fishing

$$F_{dv} = TVM_i + TVF_i \tag{8}$$

Step2: Value of environmental damage

(1) Environmental pollution control losses

This item includes two aspects, the first one is the total amount of money invested in environmental pollution treatment in each region, C_1, which can be directly obtained from the relevant data; the second aspect is to examine the virtual treatment cost C_2 that has not yet been put into treatment.

Therefore,

$$VEPC = C_1 + C_2 \quad (9)$$

(2) Environmental pollution degradation losses

①Accelerated depreciation losses on fixed assets

Environmental pollution may lead to accelerated depreciation of fixed assets, but this depreciation rate is difficult to obtain. We use the maintenance cost method to calculate. This method holds that 5.5% of the total industrial output value is used for the total maintenance expenses of fixed assets and equipment, while the accelerated depreciation expenses of fixed assets caused by environmental pollution degradation account for 5.2% of the maintenance expenses.

Therefore,

$$FA = W_I \times 5.5\% \times 5.2\% \quad (10)$$

Where FA denotes the value of accelerated depreciation loss of fixed assets and W_I denotes the total industrial output value.

②Human health loss

The premature death of population will affect production. The loss here can be understood as the value that people who die prematurely can still create if they live. We use per capita GDP to replace everyone's value and get the following formula.

$$C_H = N_{pi} \times GDP_{0i} \quad (11)$$

Where C_H represents the value of human health loss, N_p represents the number of premature deaths due to environmental pollution in region i. Considering the availability of data, we use "the number of deaths caused by household and ambient air pollution" to approximate N_p, GDP_{0i} represents the GDP per capita in region i .

③Natural disaster losses

The economic losses caused by the destruction of resources and ecological environment caused by human activities, various disasters caused by the degradation of environmental quality[9], and disasters caused by natural variation should be deducted from GDP. In this paper, forest fires, geological disasters, earthquake disasters, drought disasters and marine disasters are mainly accounted for.

$$C_N = C_F + C_G + C_E + C_D + C_O \quad (12)$$

where C_N is the value of natural disaster loss, C_F is the value of forest fire loss, C_G is the value of geological disaster loss, C_E is the value of earthquake disaster loss, C_D is the value of earthquake disaster loss, and C_O is the value of ocean disaster loss.

Step3: Derive the model for calculating GGDP

$$GGDP = GDP - W_{dv} - E_{dv} - L_{dv} - P_{li} - F_{dv} - R_{dv} - VEPC - FA - C_H - C_N \quad (13)$$

Step4: Impact of GGDP on climate mitigation

According to the climate indicators published on the official website of the World Meteorological Organization, we can know that global climate indicators are a set of parameters that describe climate change, including: temperature and energy, atmospheric composition, ocean and water, and cryosphere[10]. This means that if another indicator pays attention to all or part of temperature, energy, atmospheric composition, ocean, water and cryosphere, it means that this indicator is related to climate. Therefore, the calculation method we choose makes GGDP related to climate.

2.2. Verification of GGDP's Impact on Global Climate Change

(1) Data Processing

Get data from the World Bank website

Data Standardization

Data normalization

Calculation of index weights

(2) The Foundation of Model

We first divided the countries in the world into four categories according to their population density and selected 30 representative countries: Mongolia, Australia, USA, South Africa, Egypt, France, UK, Sri Lanka, etc. Then according to the method of calculating GGDP in the first task, we calculated the GGDP of 30 countries in the past 20 years and classified them into two categories based on GGDP, and selected a typical country from each of these two categories, the United States and India. Then we used the simplified GCAM method to calculate the climate change index (GCMI) by referring to the GCAM model to select appropriate climate indicators, and used EWM to assign weights to these climate indicators. Finally regressed with GCMI as the dependent variable and GGDP as the independent variable using data from the United States and India, respectively.

2.2.2 Model Establishment

Step1: GGDP developed countries and GGDP underdeveloped countries

We calculated the GGDP of 30 countries for the past 20 years and classified them into two categories based on GGDP, GGDP developed countries and GGDP underdeveloped countries. In the figure, the darker the color represents the more developed GGDP, and the white areas are the countries we did not select due to various reasons such as missing data. GGDP distribution is shown in Figure 1.

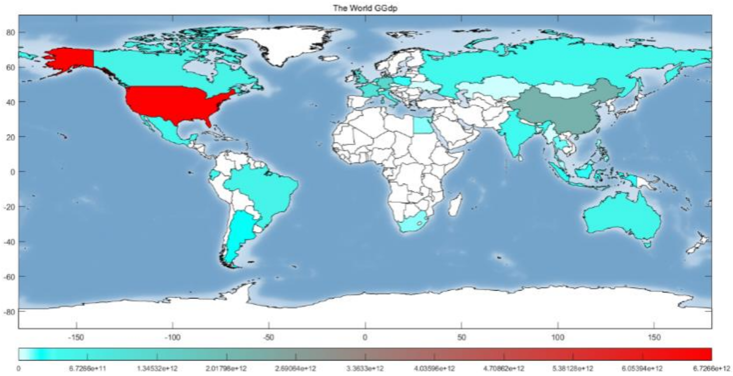

Figure1. GGDP Distribution

Using K-means algorithm for clustering, K-means clustering is to randomly select K data objects as the initial clustering center, by calculating the distance of other objects to these K initial clustering centers to divide the category, so as to continuously adjust the clustering center, the final results converge or reach the number of iterations to stop the cycle, the clustering results are as follow Figure2.

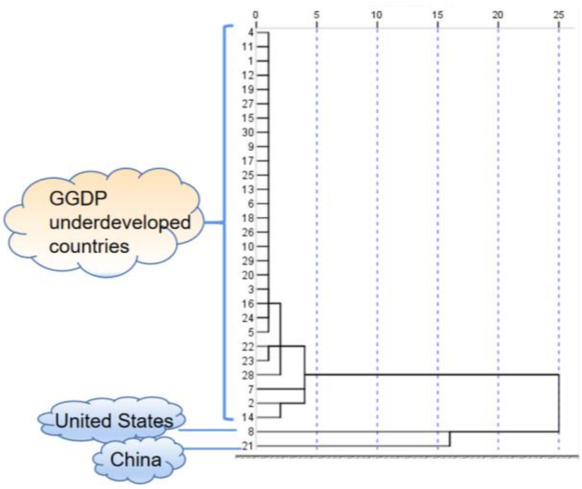

Figure 2. GGDP Clustering Results

Among them, India is classified as GGDP developed countries and other countries are GGDP underdeveloped countries. The United States is selected as a representative among GGDP underdeveloped countries and India is selected for discussion among GGDP developed countries, which will make our discussion in this question more representative.

Step2: S-GCAM

To calculate the Global Climate Change Index (GCMI), we refer to GCAM (Global Change Analysis Model) to build a simple model that makes it easy to estimate the expected global climate change impacts when GGDP is used as the primary measure of a country's economic health.

GCAM is a global model that links the world's energy, agriculture and land use systems to climate models[5]. Designed to assess various climate change policies and technology strategies globally over time, the model tracks emissions and atmospheric concentrations of greenhouse gases, carbonaceous aerosols, sulfur dioxide, and reactive gases, and provides estimates of associated climate impacts, and the model has been widely used to explore the costs of technologies and policies for climate change mitigation. Figure 3 shows GCAM model core.

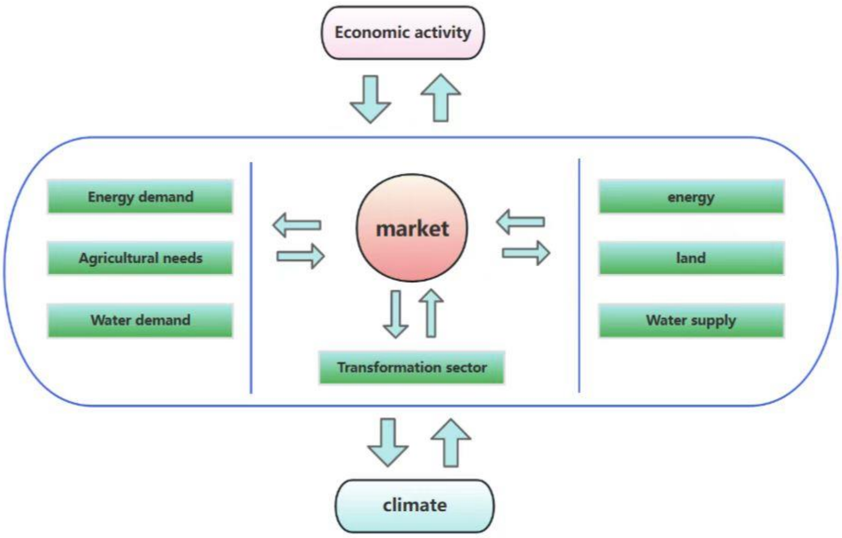

Figure 3. GCAM model core

However, due to its wide coverage and large indicator system, this paper selects some of these indicators for GCMI calculation: forest area (FC), annual precipitation (AP), greenhouse gas emissions (GG), energy use (EU), and arable land area (CL). Since the SEEA accounting system was proposed by the United Nations Statistical Office in 1993 and the SEEA handbook was amended in 2001, this paper selects relevant data from 2001 to the year in which the latest data can be found, which is 2021 for analysis.

Step3:

The entropy weighting method (EWM) is based on the basic principles of information theory. For a certain indicator to determine its dispersion through the entropy value, the greater the dispersion indicates that the greater the weight, if the value of an indicator has no variation, the indicator weight is 0. Therefore, the entropy method is very suitable as an objective weighting method to provide a basis for the comprehensive evaluation of multiple indicators, the specific steps are as follows.

First of all, we need to forward the indicators, there are very large indicators and very small indicators, we use the maximum value of each indicator minus the value of the indicator to unify them into very large indicators.

$$max - x \tag{14}$$

Then we normalize the data by subtracting the minimum value from the value of the indicator and dividing it by the amplitude of the indicator.

$$\tilde{z}ij = \frac{xij - min\{x1j, x2j, \dots, xnj\}}{max\{x1j, x2j, \dots, xnj\} - min\{x1j, x2j, \dots, xnj\}} \tag{15}$$

Next, we normalize the data.

$$yij = \frac{zij}{\sum_{i=1}^{n} zij} \tag{16}$$

The third step is to calculate the information entropy of the indicator, i.e. the uncertainty of the occurrence of various possible events.

$$ej = k \sum_{i=1}^{n} yij \, ln \, y \, ij \tag{17}$$

$$dj = 1 - ej \tag{18}$$

Calculate the weighting coefficients of the indicators:

$$wj = \frac{dj}{\sum_{i=1}^{m} di} \tag{19}$$

Based on the above weights to calculate the GCMI, the GCMI for the U.S. and India from 2001 to 2020 is shown in the table below. GCAM model core is shown in Table 2.

Table 2. GCAM model core

	GCMI(US)	GCMI(US)		GCMI(US)	GCMI(US)
2001	0.669068948	0.59600362	2011	0.549124995	0.58149388
2002	0.612288908	0.597347123	2012	0.598538209	0.561345682
2003	0.479111727	0.577614259	2013	0.55107713	0.364557934
2004	0.401436441	0.569038687	2014	0.543286667	0.395248999
2005	0.366056849	0.561592105	2015	0.617097189	0.403804648
2006	0.390557648	0.525451304	2016	0.484876331	0.391380174
2007	0.315228732	0.495728106	2017	0.514268771	0.428219311
2008	0.404535717	0.493232378	2018	0.455151726	0.396770639
2009	0.598369183	0.480192926	2019	0.484404591	0.401889497
2010	0.475741432	0.443426285	2020	0.489778806	0.350863823

2.2.3 Results

Predicting Climate Change Mitigation Impacts through GGDP

The relationship between GGDP and GCMI is explored through a linear regression model. The default regression method in stata is least squares, and least squares is also the most common method for fitting regressions, which calculates the location of the regression line by minimizing the square of the distance between each sample data point and the regression line. Let the regression equation be as follows.

$$\mathrm{GCMI} = \alpha * \mathrm{GGDP} + \beta \tag{20}$$

The regression results are as follows Table 3.

Table 3: GCAM model regression results

Model	Var.	Coefficient		t	P
1		B	SE		
	Constants	0.481	0.011	42.251	0
	GGDP|India	-0.07	0.012	-5.961	0
2	Constants	0.500	0.022	23.154	0
	GGDP|US	0.001	0.022	0.028	0.978

From the regression results, it can be seen that the growth of GGDP brings a positive impact on GCMI for both GGDP developed countries and GGDP underdeveloped countries, and the impact on the improvement of climate mitigation index is more significant when the green GDP growth as GGDP underdeveloped countries, which means that the GCMI model can easily estimate the impact on global climate mitigation if GGDP is used as the main measure of a country's economic health.

2.2.4 Analysis of the Result

From the regression results, it can be seen that the growth of GGDP brings a positive impact on GCMI for both GGDP developed countries and GGDP underdeveloped countries, and the impact on the improvement of climate mitigation index is more significant when the green GDP growth as GGDP underdeveloped countries, which means that the GCMI model can easily estimate the impact on global climate mitigation if GGDP is used as the main measure of a country's economic health.

3. Conclusion

Based on the literature review required by the topic, this article developed a SEEA-based accounting model of GGDP that is closely related to GDP, and based on this, we analyzed the relationship between the model and climate mitigation.

To model the effect of GGDP on climate index, we divided global countries into four categories based on population density, selected 30 representative countries, and calculated GGDP of 30 countries in the same year based on the previous analysis. Based on the GCAM model and EWM, we built the Global Climate Mitigation Index Model (GCMI), mapped the developed GGDP based on GGDP clustering and GGDP underdeveloped countries based on GGDP clustering, and used the GCMI model to illustrate that GGDP growth positively affects climate mitigation regardless of GGDP developed or GGDP underdeveloped countries.

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