A Study of The Climate Mitigation Potential of The Implementation of Green GDP Indicators

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Abstract. GDP is the main indicator to measure economic health, but it fails to comprehensively measure the sustainability of economic and environmental conditions. Therefore, a comprehensive GGDP accounting system is established. This article chooses the direct market method and the productivity method to account for environment and resource value. Specifically, the model divides the accounting of GGDP into two levels of indicators including seven secondary indexes. After setting up the GGDP accounting system,a multiple regression model was developed to study the impact of GGDP adoption on global climate.

Keywords: Multiple regression, clustering model, Green GDP, grey correlation analysis.

1. Introduction

For more than half a century, the most widely accepted measure of a country's economic development has been a change in its gross domestic product (GDP). Since its creation, the economists involved have always stressed that GDP is a measure of economic activity, rather than a measure of economic well-being. GDP ignores the changes in natural, social, and human resources in community capital on which its continued survival and well-being depend. Thus, GDP does not only measure the key aspects of quality of life; but also it encourages activities that are not good in the long term in sustainability field. Since the 1960s, global environmental pollution and ecological destruction have become a major obstacle to sustainable urban development. Since then, it has been found that natural capital must be valued and incorporated into the system of economic accounting [1].

The emergence of green GDP evaluates the inadequacy of traditional GDP in considering the economic costs of natural resource consumption and pollution damage that affect human and planetary well-being. The main purpose of green GDP accounting is to provide a more accurate measure of welfare and to examine the sustainability of the economy. In recent years, green GDP accounting has become an important basis for all countries in the world to formulate and implement sustainable development strategies [2].

In 1993, SEEA 1993 proposed the concept of green GDP [3], which refers to the adjustment of resource depletion, environmental degradation and environmental protection expenditure of the total economy as green GDP accounting [4]. No country has yet published green GDP data in the name of government internationally, and only a few countries have conducted case, stage, and local studies [5]. As of 2012, we have the SEEA - Central Framework, the first international statistical standard for environmental economic accounting, which became a versatile conceptual framework for understanding the interactions between the economy and the environment, as well as for describing environmental asset stocks and stock changes (Abdul Rahim and Noraida, 2015). The shadow economy is another important aspect to consider when measuring GDP [6].

To establish the model of calculating GGDP and evaluate the global impact of the GGDP model, We select appropriate GGDP comprehensive accounting system and calculation formulas of each part, and assign weights to secondary indexes in the accounting system. Then, 42 representative countries are selected for cluster analysis and divided into two categories. And the col-linearity test of the four main factors affecting climate is carried out. The feasibility models of multiple linear regression and multiple ridge regression are established by using SPSS software.

2. Glossary & Symbols

2.1. Glossary

GGE —— Greenhouse Gas Emission.
WDC—— the cost of water resource waste.
MC ——the cost of mineral resource consumption.
AC —— the cost of air pollution
DECS—— developing and energy-consuming countries
DES——developed and energy-saving countries

2.2. Common symbols(Infrequently used symbols are indicated when used)

Table 1 Common symbols

Symbols	*Definition*	*Units*
θ_{ik}	The value of the i index in the k country	$
α	The change in the resource vector	/
ρ	The coefficient vector of the regression equation	/
A,β_0	An error term which obeys normal distribution	/
r_{oi}	Constant term	/
ε_t	Relevancy	/

Common symbols are shown in table 1.

3. The Model of GGDP

3.1. The Basic GGDP Accounting Model

In this section, we finalize the green GDP accounting method based on the SEEA accounting system by finding a large amount of literature related to the accounting of GGDP[7-8]. The calculation of green GDP can be described simply as:

$$GGDP = GDP – NC \tag{1}$$

$$NC = EP+RD \tag{2}$$

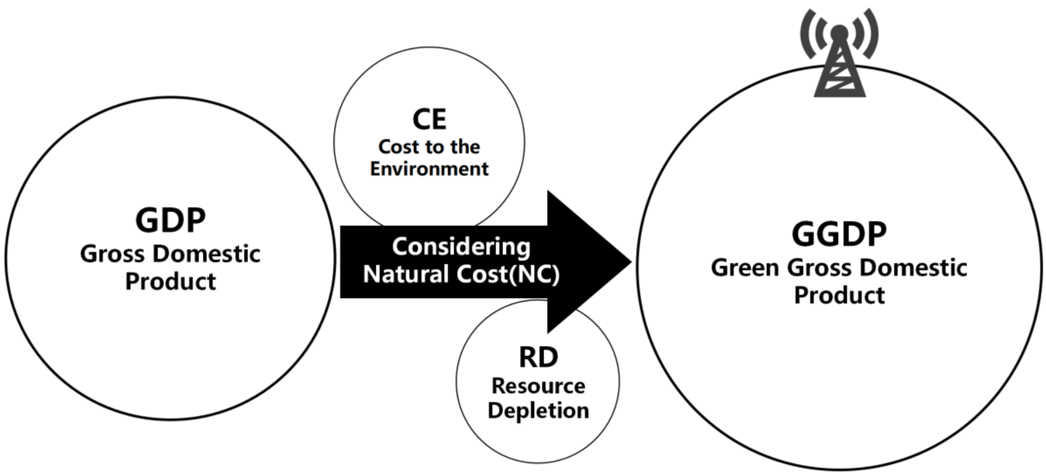

Fig 1. GDP and Green GDP

GDP and Green GDP are shown in figure 1.Further, we divide the environmental cost part into three parts: water pollution cost, air pollution cost, and solid waste pollution cost. The resource depletion is divided into three parts: water depletion value quantity, land resource depletion value quantity [9], mineral resource depletion value quantity and forest resource depletion value quantity, which are used as the secondary indicators for calculating green GDP. In the following, we will introduce how to convert the amount of environmental resources into the amount of value.

3.2. Natural Cost Accounting

3.2.1 Accounting of environmental pollutants

The cost caused by environmental pollution is estimated by direct market method.

The formula is as follows:

$$P_t = \sum_{j=1}^{m} K_j \sum_{i=1}^{n}(M_{ij} - M_{ij}^0) + \sum_{i=1}^{n} M_{ij} \,(K_j - K_j^0) \tag{3}$$

Among them：

$\boldsymbol{P_t}$ ——The loss value caused by environmental pollution to production;

$\boldsymbol{M_{ij}}$ —— Production of j products affected by i pollution;

$\boldsymbol{M_{ij}^0}$ —— Production rate of products not affected by pollution;

$\boldsymbol{K_j}$ —— Market price of product j under the influence of pollution;

$\boldsymbol{K_j^0}$ ——Market price of j product not affected by pollution;

i ——Pollution types (water pollution, air pollution, etc.);

j ——Types of products affected by the contamination.

3.2.2 Accounting of resource depletion

In this section, we use the net price method approach to calculate the economic value of the environment.

The net price approach is modeled as

$$N = \frac{A_t - B_t - D_t}{Q_t} \sum Q_t \tag{4}$$

N ——Value of resource assets；

$\mathbf{A_t}$——Revenue from sales of resource assets during period t；

$\mathbf{B_t}$——The cost of producing a resource asset in period t；

$\mathbf{D_t}$——Normal profit and risk return on invested capital of the resource asset in period t；

$\mathbf{Q_t}$——The cost of production of resource assets in period t the amount of resource utilization in period.Comprehensive Green GDP Accounting System is shown in figure 2.

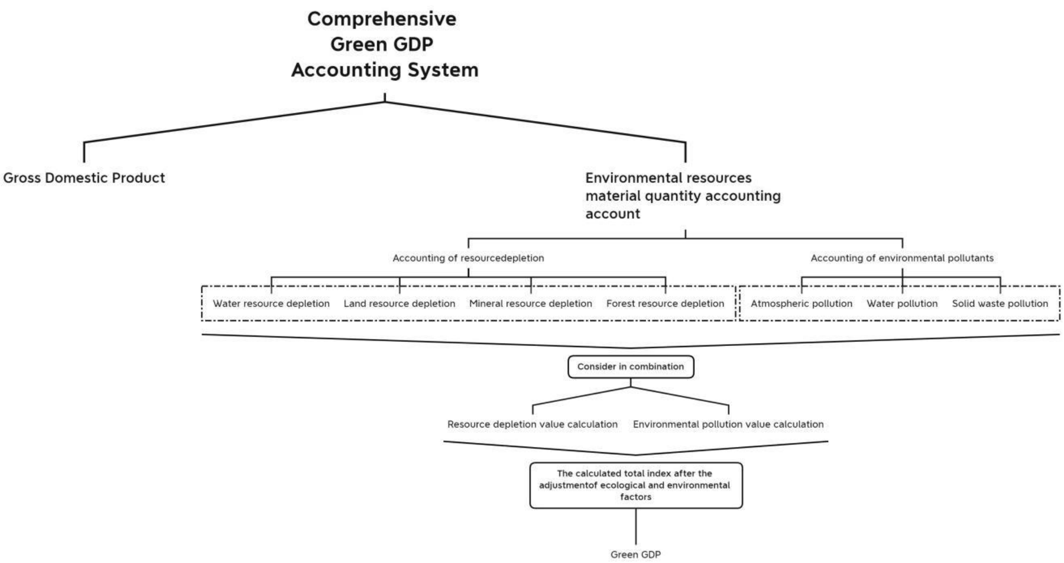

Fig 2. Comprehensive Green GDP Accounting System

By searching the literature on environmental resource indicators and considering the data availability, we selected the value of water depletion, the value of air pollution, and the value of mineral resource depletion as three representative indicators, and used them in the following discussion as well as in the calculation.

3.3. Evaluation Model of GGDP Impact on Climate Change

GGDP is the total quality of material wealth obtained after considering the cost of environmental damage and resource loss based on the index of national economic condition measured by GDP. Compared with the traditional GGDP, it can more comprehensively reflect the real level of human social economy and welfare development. The use of GGDP will also have a profound impact on the environment and sustainable development. That is, if the GGDP is adopted as the main measure, governments will pay more attention to the environment and sustainable development issues and promote policies and projects that are more beneficial to the Earth's environment and climate.

We select 42 countries for representative analysis based on the GGDP and economic position of different countries towards climate change. There are many measures of climate impact, such as greenhouse gas emissions, rising land and sea temperatures, sea level rise, melting glaciers and the frequency of extreme weather. Here we use greenhouse gas emissions as the main factor to measure climate change. For different countries, the implementation of GGDP has different impacts. In order to more accurately explore the impact of GGDP on climate, we cluster these 42 countries according to the constructed secondary index.

We firstly collected relevant data from IMF and other official data websites, then we standardized the data, and adopted the systematic clustering method to conduct K-means clustering for 42 countries.

3.3.1 Classification and Selection of Countries

According to their economic situation, wasting of water and mineral consumption and air pollution damage, we divide the world into two categories.

Developing and Energy - consuming countries (DECS): the class state of resource consumption and environmental pollution is stronger, and the low level of per capital GDP, such as China, Argentina, Russia and so on.

Developed and Energy - saving countries (DES): the class state for resource depletion and environment pollution are relatively weaker and the level of GDP per capital is higher, such as Britain, the United States, the Netherlands and so on.

According to the data of the World Bank and the National Bureau of Statistics, the amount of water loss, the amount of mineral resource loss, the amount of air pollution and Gross Domestic Product in each country are obtained. And according to formula (3) and formula (4), the value of resource loss, mineral resource loss and air pollution of selected countries were calculated.

By K-means calculates the distance between each data object and the initial clustering center, classifies the data object into the cluster class that is closest to the center, constantly adjusts the new class and calculates the clustering result of the new class center, as shown in the figure below.

The Euclidean distance between the data object and the cluster center in space is calculated as:

$$d(x, C_i) = \sqrt{\sum_{j=1}^{m}(x_j - C_{ij})^2} \tag{5}$$

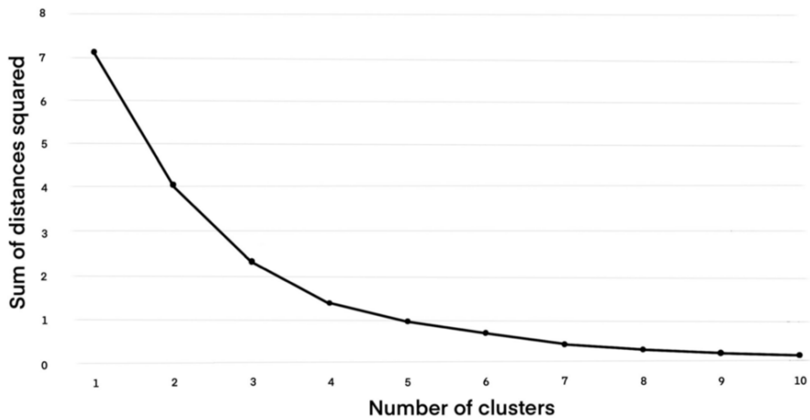

Fig 3. Liner Relation between Cluster and Coefficients

In the figure 3, the abscissa is the cluster ordinate for the coefficients, and the image is abrupt when the cluster is equal to two. Therefore, the above 42 countries are divided into two categories.

3.3.2 Construction of Evaluation Model

The main factors affecting the climate include Water Resources Consumption Value Accounting (WDC), Air Pollution Damage Value Accounting(AC),Mineral Consumption Value Accounting (MC) and Gross Domestic Product(GDP) [10]. Therefore, a defendable evaluation model of GGDP impact on climate change as shown in equation (2) can be constructed.

$$y = \beta_0 + \beta_1 x_{t1} + \beta_2 x_{t2} + \cdots + \beta_k x_{tk} + \varepsilon_t \tag{6}$$

Use the least squares method to obtain the solution of $\boldsymbol{\beta}$ (The goal of solving the above regression problem using least squares is to minimize the equation as follows):

$$y = \sum_{j=1}^{p} \beta_j\, x_j + \beta_0 \hat{\beta}\, argmin_{\beta}\ \sum_{i=1}^{N} (y_i - \beta_0 - \sum_{j=1}^{p} \beta_j\, x_i)^2 \tag{7}$$

Calculation of slope b:

$$u(b) = \sqrt{\frac{S_{yy} - bS_{xy}}{(n-2)S_{xx}}} = \sqrt{\frac{\frac{S_{yy}}{S_{xx}} - b^2}{(n-2)}} \tag{8}$$

Calculation of intercept a:

$$u(a) = u(b)\sqrt{\frac{\sum x_i^2}{n}} \tag{9}$$

4. Results

4.1. Results For DES

Firstly, we use SPSS to test the correlation between independent variables. The test results are shown in Table2.

Table 2 ANOVA and Model Summary

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig*
Rregression	431.030	4	107.758	33.016	.001b
Residual	16.319	5	3.264		
Total	447.349	9			
R	.982a		***Adjusted R Square***		.934
R Square	.964		***Std.Error of the Estimate***		1.80659

It can be seen from Table that F=33.016 and Sig are less than 0.05, so the linear relationship between Dependent Variable and Predictors is significant, and a linear equation can be established. The value of the correlation coefficient R is 0.982. The fitting degree of the equation is very high, and 98.2% of the sample value can be interpreted by the regression equation, so the fitting effect is good.Linear regression analysis results table is shown in table 3.

Table 3 Linear regression analysis results table

<table>
<tr><th colspan="10">Linear regression analysis results(n=10)</th></tr>
<tr><th rowspan="2">DES</th><th colspan="2">Nonstandardized coefficient</th><th>Standardized coefficient</th><th rowspan="2">t</th><th rowspan="2">P</th><th rowspan="2">VIF</th><th rowspan="2">R²</th><th rowspan="2">adjust R²</th><th rowspan="2">F</th></tr>
<tr><th>B</th><th>Standard error</th><th>Beta</th></tr>
<tr><td>constant</td><td>-338.73</td><td>94.273</td><td>-</td><td>-3.593</td><td>0.016**</td><td>-</td><td rowspan="5">0.964</td><td rowspan="5">0.934</td><td rowspan="5">F=33.016 P=0.001***</td></tr>
<tr><td>WR</td><td>0.054</td><td>0.019</td><td>0.671</td><td>2.85</td><td>0.036**</td><td>7.592</td></tr>
<tr><td>AP</td><td>0.489</td><td>0.263</td><td>0.211</td><td>1.859</td><td>0.122</td><td>1.771</td></tr>
<tr><td>MC</td><td>22.517</td><td>5.214</td><td>1.106</td><td>4.318</td><td>0.008***</td><td>8.999</td></tr>
<tr><td>GDP</td><td>1.772</td><td>0.821</td><td>0.529</td><td>2.159</td><td>0.083*</td><td>8.241</td></tr>
</table>

According to the result analysis of F test, the significance P value is 0.001***, showing significance at the level, rejecting the original hypothesis that the regression coefficient is 0, so the model basically meets the requirements. VIF is all less than 10, so there is no multidisciplinary problem in the model, and the model is well constructed.

Thus, for DES countries, the relationship between their greenhouse gas emissions and the indicators is

$$\boldsymbol{GGE = -338.73 + 0.489AP + 22.517WR + 0.054MC + 1.772GDP} \tag{10}$$

According to the standardized coefficient (after eliminating the correlation between the data), AP, WR, MC, GDP and the dependent variable greenhouse gas emissions are all positively correlated. Among these factors, WR has the greatest impact on GGE, while AP has the least impact on GGE.The relationship between secondary indicators and greenhouse gas emissions for DES countries is shown in figure 4.

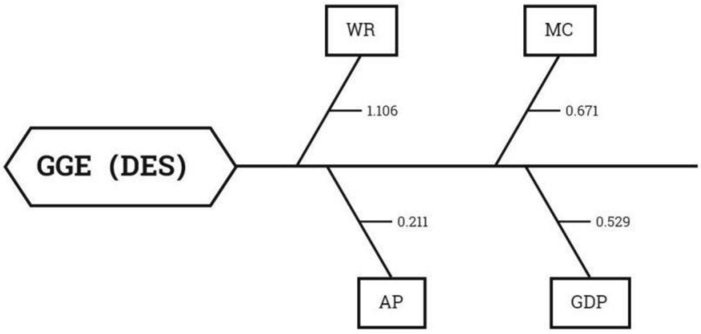

Fig 4. The relationship between secondary indicators and greenhouse gas emissions for DES countries

According to the multiple regression equation established by us (sensitivity analysis is carried out). The standard amount we added to each indicator for each country is

$$\boldsymbol{\beta}=[20,1,20,1], \quad \boldsymbol{\rho}=[\boldsymbol{\alpha_1}, \boldsymbol{\alpha_2}, \boldsymbol{\alpha_3}, \boldsymbol{\alpha_4}]^{\boldsymbol{T}}$$

$$\Delta GGE = \beta \times \rho \tag{11}$$

Where:ΔGGE representing the change of greenhouse gas emission.

The result is ΔGGE=35.149, so the conclusion is that every increase of a standard quantity X, the greenhouse gas emissions will increase 35.149 units. Based on the analysis of the GGDP accounting system, the final conclusion is that for DES countries, every increase of 40 units GGDP, the greenhouse gas emissions will decrease 35.149 units.

4.2. Results For DECS

Table 4 Linear regression analysis results

Linear regression analysis results(n=10)									
DECS	***Nonstandardized coefficient***		***Standardized coefficient***	***t***	***P***	***VIF***	***R^2***	***adjust R^2***	***F***
	B	***Standard error***	***Beta***						
constant	***-182.862***	***56.41***	***-***	***-3.242***	***0.023*****	***-***	***0.983***	***0.97***	***F=73.398 P=0.000******
WR	***12.665***	***2.643***	***0.282***	***4.792***	***0.005******	***1.035***			
AP	***0.073***	***0.031***	***1.227***	***2.381***	***0.063****	***79.288***			
MC	***0.002***	***0.002***	***0.107***	***1.04***	***0.346***	***3.183***			
GDP	***-0.424***	***1.268***	***-0.162***	***-0.334***	***0.752***	***70.211***			

Linear regression analysis results are shown in table 4.For the col-linearity of variables, the VIF value of the variable particle emission damage and total GDP was greater than 10, and there was a col-linear relationship, so we chose to carry out ridge regression to perform the regression again.

Ridge regression is to add a penalty term β^{bridge} to the minimization sub-goal.

$$\hat{\beta}^{bridge} = arg\ \mathrm{m}_{\beta}\{\sum_{i=1}^{N}(y_i - \beta_0 - \sum_{j=1}^{p}\beta_j\, x_i)^2 + \lambda\sum_{j=1}^{p}\beta_j^2\} \quad (12)$$

Ridge regression results show that: based on the significance of F test, P value is 0.001***, showing significance at the level, rejecting the null hypothesis, indicating that there is a regression relationship between the independent variable and the dependent variable. At the same time, the goodness of fit $R^2$of the model is 0.965, indicating that the model is relatively excellent.
The ridge regression equation obtained is

$$GGE = -125.015 + 0.026AP + 10.362WR - 0.001MC + 1.063GDP \quad (13)$$

By analyzing the standardized coefficients in the table, it can be seen that AP, WR, MC and the dependent variable greenhouse gas emissions are all positively correlated, while GDP is negatively correlated, but the coefficient of 0.07 is relatively small, so it can be ignored. Among these factors, WR has the greatest impact on GGE, while GDP has the least impact on GGE.

According to the equation of ridge regression, we conduct sensitivity analysis. For DECS countries, the result is ΔGGE=11.925, so the conclusion is that every increase of a standard quantity X, the greenhouse gas emissions will increase 11.925units. Based on the analysis of the GGDP accounting system, the conclusion is that for DECS countries, every increase of 40 units GGDP, the greenhouse gas emissions will decrease 11.925 units.

5. Conclusions

To establish the model of calculating GGDP , we select a feasible integrated accounting model for GGDP. Then we choose the direct market method and the productivity method to account for environment and resource value. The model divides the accounting of GGDP into two levels of indicators including seven secondary indexes: air pollution cost(AC), water pollution cost(WC), garbage pollution cost(GC),mineral depletion cost(MC), forest depletion cost(FC), water depletion cost(MDC), land depletion cost(LC). To evaluate the global impact of the GGDP model, A multiple regression model was developed to study the impact of GGDP adoption on global climate. We studied the status of GGDP in 42 countries around the world, using the three natural indicators AP, WR, MC and GDP as four indicators. Based on these indicators, we used the K-means algorithm to classify global countries into DECS and DES. We established the relationship between the greenhouse gas emissions of different types of countries and the indicators of the selected GGDP through multiple regression modeling to derive the impact of different countries' GGDP adoption on climate, and the results are shown by the global climate impact map.

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