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Design of GGDP accounting system based on multiple regression model

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Abstract: *In order to analyze the impact of the implementation of green GDP on climate and natural resources, this paper first selects a suitable GGDP accounting formula. Secondly, this paper chooses seven indicators to measure the value of natural resource loss in various countries, and uses multiple regression model to analyze carbon emissions. Again, the reduction of energy consumption will cause some economic losses in the short term and compared with the positive impact of GGDP on mitigating global warming. Finally, taking China as the analysis object, the mathematical model of natural resource consumption and green GDP is established by adding ecological protection effect to the original GGDP formula. Comprehensive analysis shows that the use of GGDP will help China reduce the consumption of natural resources. Compared with traditional GDP, the reduction of natural resource consumption will cause short-term economic losses, but will bring more long-term economic growth.*

Keywords: *GGDP Index; Carbon emission; Multiple Regression Model*

1. Introduction

Gross domestic product (GDP) is one of the most famous and commonly used measures of the health of a country's economy. GDP measures the monetary value of the final goods and services produced by a country over a given period of time: it calculates all the output generated within a country. This calculation is so important and often cited as to benefit today's production, but is not considered to save resources for tomorrow. For example, a country with rich mineral resources could increase its current GDP by exploiting large quantities of minerals and selling them. Despite the excessive loss of resources and other negative environmental consequences, the country can still do so without punishment. Similarly, a country can now increase GDP with few renewable resources without causing irreversible damage to non-renewable resources.

In 1993, the United Nations System of Environmental-Economic Accounting (SEEA) [1] formally proposed the concept of "green GDP," which is the "gross domestic product adjusted for environmental factors." Green GDP refers to the ultimate economic output of a country or region that takes into account the impact of natural resources (primarily including land, forests, minerals, water, and oceans) and environmental factors (including ecological, natural, and human environments) on economic activity. This involves subtracting the costs of resource depletion and environmental degradation incurred in economic activity from the GDP.

Because GDP does not focus on and praise natural resources, perhaps it is not a very good measure of a country's true economic health. If countries change the way they assess and compare their economies, governments may change their behavior, promote policies and programs more conducive to the health of the planet's environment. Therefore, green GDP may be a better measure than the current traditional GDP.

2. Materials and Methods

2.1 Data Sources and Analysis

This paper analyzes and studies the GGDP accounting method in the 2023 Interdisciplinary Contest in Modeling (https://www. comap. com/undergraduate/contests/mcm/login. php). The calculation formula of GGDP is determined, and it is found that compared with traditional GDP, the reduction of natural resource consumption will cause short-term economic losses, but will bring longer-term economic growth. At the same time, the use of GGDP will also help China reduce the consumption of natural resources.

2.2 Method introduction

2.2.1 Analysis of three GGDP measurement methods

Green GDP accounting mainly includes natural resources accounting, ecological resources accounting and environmental pollution accounting. In the specific calculation, some calculate from the perspective of production, from the perspective of income, and from the perspective of the final use of the product, but they all have something in common, that is, the calculation of green GDP is the increase of resource cost, environmental cost and social comprehensive cost on the basis of the original calculation of GDP. We will show three commonly used green GDP accounting methods.

(1) Method 1

Based on the analysis framework of SEEA, the accounting of green GDP usually includes three aspects: resource consumption value, environmental governance investment and ecological protection benefits. [2] The specific calculation formula is as follows.

$$\text{GGDP} = \text{Traditional GDP} - \text{Value of Natural Resource Depletion and Environmental Degradation} - \text{Environmental Management Expenditures} + \text{Ecological Conservation Benefits} \quad (1)$$

Under this formula, the indicators are easy to measure, and the consumption of natural resources is closely related to environmental governance and ecological protection and the national climate change, which is a better accounting method to measure GGDP.

(2) Method 2

The fuzzy evaluation model can not only comprehensively consider multiple influencing factors but also convert qualitative factors into quantitative ones. When calculating green GDP, it is not necessary to deduct resource and environmental costs from the original GDP. Instead, the method of multiplying the original GDP accounting results by a green GDP coefficient can be adopted, that is, Green GDP = GDP × T. GDP refers to the current GDP, and T is a GDP adjustment coefficient derived based on comprehensive resource and environmental factors, temporarily referred to as the "Green GDP coefficient". This coefficient is the object calculated using the fuzzy evaluation model. [3]

Firstly, the evaluation index is determined, namely the factor and setting the factor: $X = \{x_1, x_2, x_3, \dots\dots, x_m\}$

Secondly, according to the data obtained by relevant departments and experts, the evaluation matrix is obtained according to the expert evaluation method: $R = [r_{ij}]$

Then, the weight: $A = \{A_1, A_2, A_3, \dots\dots, A_n\}$fuzzy operation, obtain the comprehensive evaluation index matrix: $B = \{B_1, B_2, B_3, \dots\dots, B_m\}$

Finally, quantified according to the grade, which is the green GDP coefficient.

However, this method determines the weight for accounting through expert evaluation and scoring, which has strong subjectivity, so it is not used as an appropriate calculation formula to measure GGDP.

(3) Method 3

Social welfare measurement method. On the basis of welfare economics, we believe that the national welfare can be defined as broad green GDP, external economy is external damage cost theory, external economy is economic behavior to external welfare spillover, and puts forward the theoretical model of national welfare accounting, the external economy relative to the whole GDP is very small, thus can save external economic factors, which can ignore the last item. [4] The total formula is as follows.

$$\text{Total national welfare value (GNW)} = \text{gross domestic product (GDP)} - \text{external damage cost} + \text{external welfare spillover} \quad (2)$$

2.2.2 Selection results

Based on the above three methods and comparative analysis, we judge and related analysis from two perspectives, and think that the first method is more reasonable and easy to implement.

As for method 1, the consumption value of natural resources is closely related to the cost of environmental governance and climate factors, the calculation system is relatively complete, so we adopt method 1.

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As for method 2, the resource cost and environmental governance cost are large, which is easy to cause the disadvantages of low GGDP to complete the national GDP accounting target. Moreover, the expert evaluation of the comprehensive weight of indicators has strong subjectivity, so method 2 is not used.

As for method 3, in the accounting method of gross national welfare, the analysis of climate factors is less and difficult to measure, and the data is not easy to collect and analyze, so method 3 is not used.

3. Establishment and solution of the model

3.1 The Calculation of GGDP and GGDP Index

3.1.1 Calculation of GGDP Index

In order to calculate the GDP, we evaluate it according to the formula selected by the first question. We need data on the depletion value of natural resources, the investment of environmental governance costs and the income of ecological benefits. For the reduction of natural resource consumption, we select three indicators: net reduction of forest area, energy consumption and water resource reduction; For the cost of environmental treatment, we select four indicators: sulfur dioxide emissions, wastewater emissions, solid waste emissions and particulate matter emissions; As for the ecological benefit income, we temporarily assume that the income brought by it in the early stage is very small and negligible.

According to relevant literature [5], the estimation formula of resource depletion value is obtained as follows.

$$Resource\ \text{depletion value} = \text{Resource consumption reduction} \times \text{Resource price} \quad (3)$$

At present, we have collected indicators that can represent its consumption and reduction. Next, we need to determine the corresponding prices of various resource parameters. According to the data collected in literature, we can obtain the parameter prices shown in Table 1.

Table 1: Parameter Price Description

Specific Indicator	Parameter	Parameter Price
Forest Resource Depletion Value	Unit Area Soil and Water Conservation Compensation Fee	1.5 RMB/m^2
Water Resource Depletion Value	Unit Volume Water Resource Price	1.12 RMB/m^3
Energy Resource Depletion Value	Unit Standard Coal Price	741.87 RMB / t
Industrial Waste Gas Treatment Investment	Unit SO2 Treatment Cost	778 RMB / t
Agricultural Solid Waste Treatment Investment	Unit Plastic Film Recycling Cost	5.85 RMB / kg
Industrial Wastewater Treatment Investment	Unit Wastewater Treatment Cost	2.31 RMB / t
Municipal Solid Waste Treatment Investment	Unit Municipal Solid Waste Treatment Cost	243 RMB / t

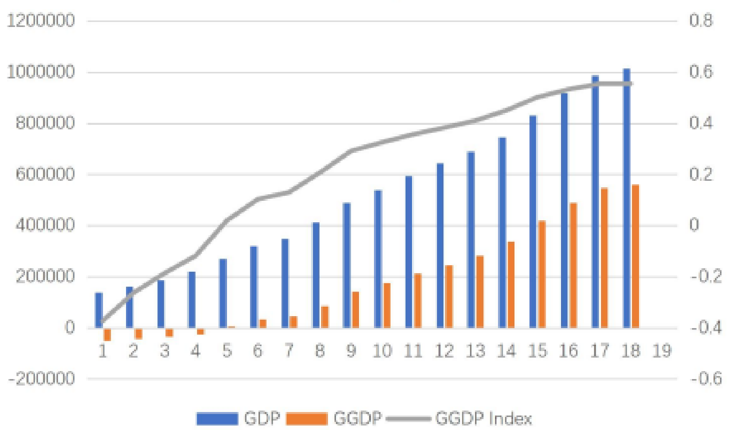

Figure 1: China's green GDP and GDP index

According to the prices in the Table 1, combined with the data of China's GDP and the above seven indicators from 2003 to 2020, we can get the calculated value of GDP and the GDP index. As shown in the Figure 1.

It can be seen that China's GDP index has been stable at around 0. 6 from a negative number, indicating that China's green development has been fruitful.

3.2 The Establishment and Solution of Model

By collecting data, due to the differences in national conditions of different countries, and ensuring the rigor and accessibility of data collection, we found that for different countries, carbon dioxide emissions or carbon emissions can be taken as relevant indicators to measure climate mitigation.

Therefore, the indicators of climate mitigation, namely carbon dioxide emissions or carbon emissions, are taken as the dependent variable y, and the indicators of energy consumption and other indicators are taken as the independent variable x.

Through the relevant scatter diagram, we found that the linear relationship is presented, so the linear regression equation is established. As shown in the Figure 2.

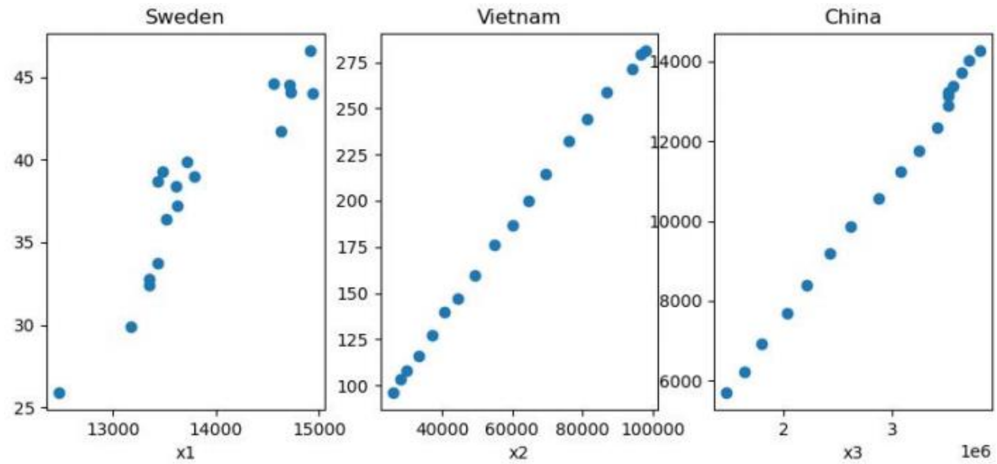

Figure 2: Scatter chart of energy consumption and carbon emissions

3.2.1 Selection of Variables

As the emission of sulfur dioxide decreases with the increase of carbon emissions, we can think that the emission of sulfur dioxide is abnormal, which may be caused by the policy changes at that time.

We take the above seven indicators as independent variables and carbon emissions as dependent variables, and conduct principal component analysis to select the three most important indicators for different countries for multiple linear regression analysis.

3.2.2 Data and transformation

The relevant data in are the results obtained after standardization, so we converted x to the relevant analysis. The normalization formula is as follows.

$$X_{nom} = \frac{X - X_{min}}{X_{max} - X_{min}} \tag{4}$$

The principal component analysis method is used to analyze seven indicators of China, and three important indicators are obtained, namely, energy consumption, sulfur dioxide emissions and solid waste emissions. Make these three indicators as independent variables and carbon emissions as dependent variables, and carry out multiple linear regression. The equation is as follows.

$$y_{CO_2} = -0.43 + 1.25x_1 + 0.45x_2 + 0.21x_3 \tag{5}$$

Where is energy consumption, sulfur dioxide emissions and solid waste emissions; The adjusted R square of the multiple linear regression equation is 0. 99, indicating that the model has a good fitting effect.

According to the same idea and mathematical method, the data and linear regression equation of

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Sweden, an environmentally friendly country, are obtained.

$$y_{CO_2} = 0.02 + 0.67x_1 + 0.23x_2 + 0.12x_3 \tag{6}$$

Where x2 represents energy consumption, x4 represents sulfur dioxide emissions, and x6 represents solid waste emissions; The adjusted R square of the multiple linear regression equation is 0. 99, indicating that the model has a good fitting effect.

The following are the relevant data of Sweden, an environmentally friendly country.

$$y_{CO_2} = 28.72 + 8.64x_1 + 6.45x_2 + 3.84x_3 \tag{7}$$

Where x2 represents energy consumption, x5 represents wastewater discharge, and x6 represents solid waste discharge; The adjusted R square of the multiple linear regression equation is 0. 92, indicating that the model has a good fitting effect.

3.3 The Robustness test of the model

In order to promote the popularization of the model and ensure the feasibility and rigor of the model, we further selected the sample size and obtained the following robustness analysis results. Through the analysis results, it can be learned that the model has passed the robustness test and has good characteristics. among Equation1 Represents the regression equation coefficient obtained by regression with all 18 values; Equation2 Represents the regression equation coefficient obtained by regression by removing the first value; Equation3 Represents the regression equation coefficient obtained by removing the middle value; For China, Vietnam, X1: Energy consumption X2: Sulfur dioxide emissions X3: solid waste emissions. For Sweden, X1: energy consumption X2: sulfur dioxide emissions X3: solid waste emissions. As shown in the Table 2.

Table 2: Robustness analysis

Sweden			
	Equation1	Equation2	Equation3
(Intercept)	28. 717	28. 699	28. 719
X1	8. 6352	8. 7472	8. 5941
X2	6. 4479	6. 2807	6. 2773
X3	3. 8391	3. 877	4. 1293
China			
	Equation1	Equation2	Equation3
(Intercept)	-0. 42508	-0. 35099	-0. 42772
X1	1. 2481	1. 218	1. 2479
X2	0. 44795	0. 38264	0. 45012
X3	0. 21275	0. 16945	0. 21566
Vietnam			
	Equation1	Equation2	Equation3
(Intercept)	0. 002339	0. 004155	0. 000602
X1	0. 66766	0. 66993	0. 67265
X2	0. 22644	0. 22537	0. 24209
X3	0. 1245	0. 12307	0. 10259

3.4 Further Analysis and Model Building

We have established a mathematical model based on the trends of natural resource growth and the rules of economic development. [6]

$$GGDP = f(L, K, H, N) - G(N) + S(N, t, k) \tag{8}$$

In this model, L, K, H, and N represent labor, economic capital, human capital, and natural resource consumption, respectively, while t and k represent the number of years f or implementing green GDP and the annual natural resource growth rate after implementing green GDP, respectively. f represents the annual GDP, g represents the annual value of environmental management and natural resource consumption, and S represents the annual increment of ecological protection benefits [7].

$$s = (X - N)(1 + t)^{k \times P} \tag{9}$$

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X represents the remaining domestic ecological capital in the current year, and P rep resents the ecological protection benefits brought by each unit of ecological capital. When GGDP replaces GDP, the country seeks to maximize GGDP.

$$\frac{\partial f}{\partial N} = \frac{\partial S}{\partial N} \quad (10)$$

At this point, the natural resource consumption can not only maximize the GGDP of the current year but also generate significant ecological protection benefits in the following years. The difference between the N consumed under the dominance of traditional GDP and N is the amount of natural resource consumption that the country has given up for the development of GGDP.

Considering China current economic development situation, although it depends heavily on the development of heavy industry, China current economic development is good, with per capita GDP at a high level. If GGDP is implemented at present, China domestic production will decrease in the short term, but the long-term economic benefits for future generations will far outweigh the short-term losses.

4. The potential advantages and disadvantages under the guidance of the green GDP measurement system

According to World Bank data, the energy consumption of China's GDP per unit is 0. 125 metric tons of standard coal, Vietnam's is 0. 121 metric tons of standard coal, and Sweden's is 0. 0775 metric tons of standard coal. The estimated reduction in GDP from giving up 10,000 metric tons of standard coal is compared with the reduction in carbon dioxide emissions from reducing one metric ton of standard coal. The carbon dioxide emissions are then converted into economic benefits to compare the advantages and disadvantages of the two. In the early stages, the advantage is not significant, but in the later stages, when using GGDP as the standard, this advantage becomes very apparent.

From another point of view, we choose China's GDP and GGDP growth rate from 2003 to 2021 to make a corresponding line chart. We will find that in the short term, the growth rate of GGDP is slightly slower than that of GDP, but under the guidance of national policies, the growth rate of GGDP increases rapidly. For example, in 2006, The State Council promulgated the Opinions on Strengthening Environmental Protection work, which clearly proposed to strengthen the accounting and release of green GDP. In 2007, China launched the green GDP pilot work, in 2013, the National Bureau of Statistics released China's first green development index report, a comprehensive assessment of the green development level of 31 provinces, in 2015, China held the first national green development index evaluation seminar, further promote the research and application of green GDP. In general, the development process of China's green GDP has gone through the process from proposing the concept to the trial calculation and pilot, and then to the publication of the index and evaluation. The application and development of this index in China have gradually paid attention, making a certain contribution to the sustainable development of China's economy and environmental protection. As shown in the Figure 3.

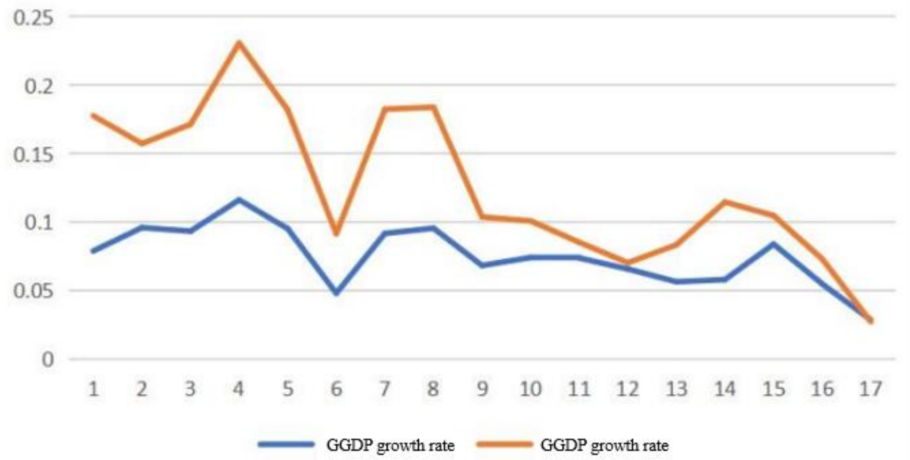

Figure 3: GGDP growth rate and GDP growth rate

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5. Conclusions

Through the analysis of the above problems, we will find that the GGDP accounting system is conducive to the real measurement and evaluation of the actual level of economic growth. Since green GDP reflects the natural resources consumed by human beings to promote economic growth and the degree of climate damage, it can pay attention to the protection and maintenance of resources when promoting people's economic development, so it can partially make up for the defects and deficiencies of traditional GDP.

Second, the green GDP is basically consistent with the traditional GDP analysis method. After the adjustment by SEEA, the traditional GDP data can be compared with the green GDP, ensuring the consistency of the national economic accounting system.

Third, SEEA is jointly developed by the United Nations and the World Bank, with a relatively complete compilation manual and operation instructions. At present, many countries and regions in the world are also trying to compile green GDP, which has strong operability and is also conducive to international comparison and promotion. In line with the development of internationalization and multilateral national security.

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