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The Impact of GGDP on the Global Climate

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Abstract: *Green GDP (GGDP) incorporates environmental and sustainability considerations alongside traditional GDP, thereby fostering policies and initiatives that prioritize the well-being of our planet's ecosystem. This study investigates the global impact of GGDP on climate, population, and other factors by gathering data on GGDP determinants, climate, and population from various countries and developing relevant machine learning models. Subsequently, the study examined sustainable human development and the relationship between population, economic, and environmental changes in the United States. A linear correlation between GDP and CO2 emissions, as well as GGDP and CO2, was established using the least squares method to analyse GGDP's environmental optimization with respect to CO2 emissions. Lastly, a model was devised to evaluate the connection between economic development, the capacity to support future generations (linked to education and healthcare expenditures), and gross national income in China, based on data from earlier inquiries.*

Keywords: *GDP, GGDP, Carbon dioxide emissions*

1. Introduction

Gross Domestic Product (GDP) quantifies the aggregate value of goods and services produced by resident units within a country or region over a specific period, using market prices. GDP can be conceptualized through three perspectives: value, income, and product. In terms of value, it reflects the net added value, representing the difference between the total value of goods and services produced and the value of non-fixed asset goods and services invested during a given period. From an income standpoint, GDP embodies the cumulative initial income generated and distributed by both resident and non-resident units within a specific timeframe. Regarding product, GDP signifies the difference between the value of goods and services created for final use by resident units and the value of imported goods and services. GDP is calculated using three methodologies: production, income, and expenditure, each of which highlights different facets of GDP and its components, with identical theoretical results.

Nevertheless, conventional GDP computations neglect environmental quality. Should governments abolish all environmental regulations, businesses might generate goods and services without considering pollution. Although this may lead to increased GDP, overall welfare could decline as deteriorating air and water quality would counteract the welfare gains of augmented production. Furthermore, GDP overlooks the adverse effects of economic development on resources and the environment, which frequently entails the consumption of land, water, forest, and mineral resources and results in pollution.

To rectify these limitations, we propose an alternative GDP calculation method incorporating environmental factors, dubbed "Green" GDP (GGDP). GGDP represents the residual GDP after subtracting the depletion value of ecological resources, encompassing resource consumption and environmental pollution, from traditional GDP. This novel approach amalgamates various environmental consequences within an economic framework.

This paper will scrutinize global climate, population, and other variables influenced by GGDP by collecting data on GGDP-related determinants, climate, and population from diverse countries and developing pertinent machine learning models. Moreover, the paper will explore sustainable human development and assess the relationships among population, economic, and environmental transformations. A model will be devised to account for economic development levels, the ability to support future generations through education and healthcare expenditures, and the association between economic development and gross national income, in order to reflect GGDP's environmental optimization. Conclusions will be drawn based on these analyses.

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2. Literature Review

The concept of Green GDP (GGDP) emerged in the early 1990s as a response to the limitations of traditional GDP measures in accounting for specific environmental economic costs that affect human well-being. Pollution costs and energy consumption are two crucial factors in GGDP calculations[1-3] Xu Linyu et al. [4] selected Wuyishan, a typical natural resource-based city in China, as their study subject, finding that energy consumption significantly impacts the urban ecosystem's functioning. Moreover, Shanzhong Qi et al. [5] investigated GGDP computation in China's Zhejiang Province and the implications of using GGDP as a GNP calculation tool compared to GDP on environmental resources.

Most countries have not yet adopted GGDP as a replacement for GDP. Hoff et al. [6] analyzed the hesitancy of policymakers in accepting GGDP from political science and public governance perspectives, highlighting the challenges in assessing non-market environmental services. Stjepanović et al. [7] argued that natural resource depletion or pollution increases should be incorporated into traditional GDP measures, but most developing and underdeveloped countries face difficulties in accounting for environmental costs, thus limiting GGDP's applicability. Tomic [8] examined the utility of GGDP in growth models, finding that green GDP growth models produce results consistent with standard economic growth models' general characteristics. The relationship between economic openness and green growth is both ambiguous and plausible, but there is insufficient international evidence regarding the impact of openness on economic growth.

In this paper, we will analyze the global influence of GGDP on climate, population, and other factors by developing relevant machine learning models. Additionally, this paper builds upon previous research by considering sustainable human development and comparing the relationships among demographic, economic, and environmental changes.

3. Method

GDP: Gross Domestic Product

GGDP: Green Gross Domestic Product

Cost of environmental degradation:

Cost of environmental degradation is mainly aimed at mining, energy, forestry and freshwater affected by climate change fluctuations. Loss of other factors caused by time, mainly include changes in Loss of forest ecosystem destruction (EcDCf),Loss of grassland ecosystem destruction (EcDCg),Loss of wetland ecosystem destruction(EcDCw),Loss of agricultural ecosystem destruction (EcDCa)and so on.

Cost of ecological damage:

Among the costs of direct climate influencing factors, we consider different regions of the world on five continents, and believe that climate change will directly affect Air pollution environmental degradation costs (EnDCa), Water pollution environmental degradation costs (EnDCw) ,Soil pollution environmental degradation costs (EnDCs).

Data processing:

(1) The data for sulfur dioxide emissions, nitrogen oxide emissions, energy consumption, mineral resource consumption, and total industrial and domestic wastewater in the United States from 1991 to 2019 were collected, along with the corresponding unit prices for their treatment and consumption. The total cost of environmental damage was then calculated using relevant algorithms based on the collected data.

(2) In the model1, consider economic status, status and future ability to provide for future generations. Taking China as an example, we analyse its impact on the change of green GDP in depth, reconstruct the green GDP model. Next, find data on gross national income, health expenditure, and education expenditure from 2003 to 2020 from the official website of the National Bureau of Statistics. The coefficient of variation method is used to find β_1 ,β_2 and β_3 respectively.

Assumptions:

(1) This study relies on several assumptions, including the constant value of GDP over a year, and the consideration of only a limited number of environmental pollution factors, including sulfur dioxide,

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nitrogen oxide, energy consumption, mineral consumption, and water pollution. Moreover, it is assumed that the unit prices for the treatment of sulfur dioxide, nitrogen oxide, industrial and domestic wastewater, as well as the prices of energy consumption versus mineral resource consumption, remain constant in the United States between 1991 and 2019.

(2) Do not consider other environmental pollution factors except sulfur dioxide, nitrogen oxide, energy consumption, mineral consumption, and water pollution. Social factors other than per capita income, age and educational attainment are ignored to affect economic status, and the ability to provide for future generations. β_1 and β_2 are constant at 0.1735 and 0.1023, respectively.

4. Model and Analysis

Model 1: Impact of GGDP on global climate mitigation and environmental improvement

Developing a simple model to assess the impact of Gross Global Domestic Product (GGDP) as the primary indicator of a country's economic health on climate mitigation and global environmental improvement. The proposed model aims to evaluate the extent to which the adoption of GGDP as an economic measure would influence the ability of countries to mitigate the impacts of climate change and promote environmental sustainability worldwide.

Here, the amount of CO2 emissions will be used as a replacement for climate mitigation and improvement of the environment.

GGDP = GDP - cost of environmental degradation - cost of ecological damage

Since other factors such as environmental resources, climate conditions and population are different in different countries, we need to give corresponding weight coefficients in the GDP model to distinguish different indicators in different countries.

$$\boldsymbol{GGDP = GDP - \alpha_1 \times \textbf{cost of environmental degradation} - \alpha_2 \times \textbf{cost of ecological damage}}$$

Then use the coefficient of variation method to find the specific weight of each one, and finally take the average.

Because of the large number of countries around the world, in order to estimate the expected global impact on climate mitigation, we selected a representative country from each of the five continents to consider the global impact.

Table 1: The coefficient of four countries by CV method

Country	Method	DMRC	DCEC	DFRC	DAFW	InDNOE	InDPD	InDER
China	CV	0.005	0.355	0.334	0.000	0.053	0.190	0.064
Germany	CV	0.006	0.134	0.269	0.000	0.318	0.258	0.014
South Africa	CV	0.006	0.432	0.242	0.000	0.167	0.034	0.119
Australia	CV	0.003	0.259	0.152	0.312	0.169	0.022	0.082

By introducing the weighted coefficient obtained by CV method in the above table 1 into the model equation, the trends of GDP and GGDP of different countries in the line chart below can be obtained.

Figure 1: The trends of GDP and GGDP in China, Germany, Australia and South Africa.

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Then, the analysis of the impact of GGDP on CO2 emissions in different countries, select four countries from different continents, with GDP and seven other influencing factors as input variables and CO2 emissions as output variables, model training using a BP neural network. Based on Figure 1, the GGDP of four different countries are calculated separately and the weight coefficients are brought into the model for validation. Thus, the actual trend of CO2 change is analysed with the trend of CO2 change after replacing GDP with GGDP as shown in Figure 2.

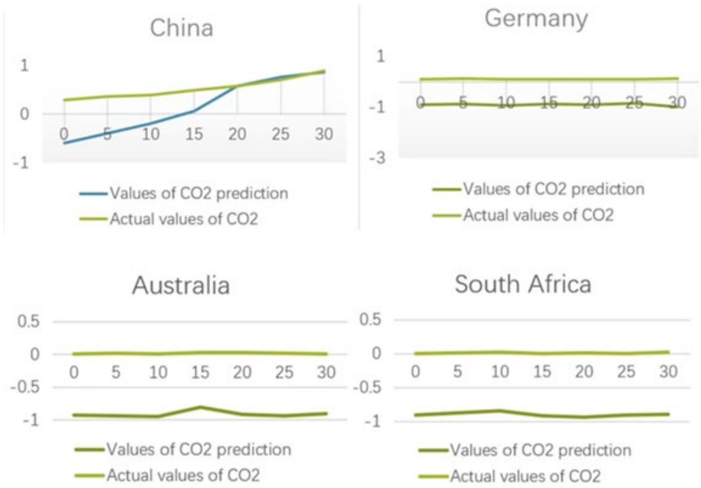

Figure 2: Predicted value and actual value of CO2 in China, Germany, Australia and South Africa.

In the next step, a prediction model was developed to predict CO2 emissions when GDP and GGDP grow by 10% at the same time (Figure 3 and Figure 4), respectively. We can clearly see the advantage of GGDP as an alternative to GDP is demonstrated by the difference between total CO2 emissions when GDP grows by 10% and total CO2 emissions when GGDP grows by 10% from Table 2.

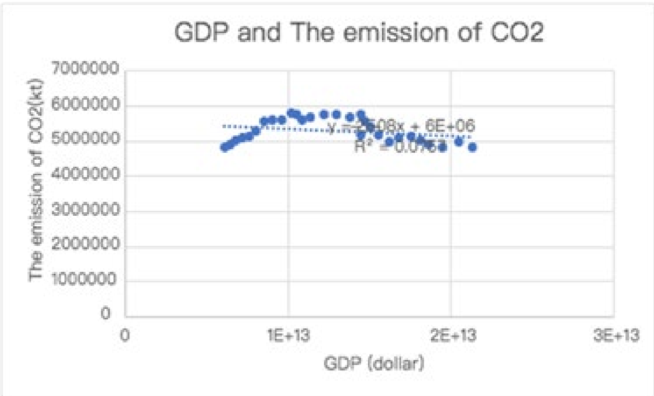

Figure 3: The linear relationship between GDP and CO2

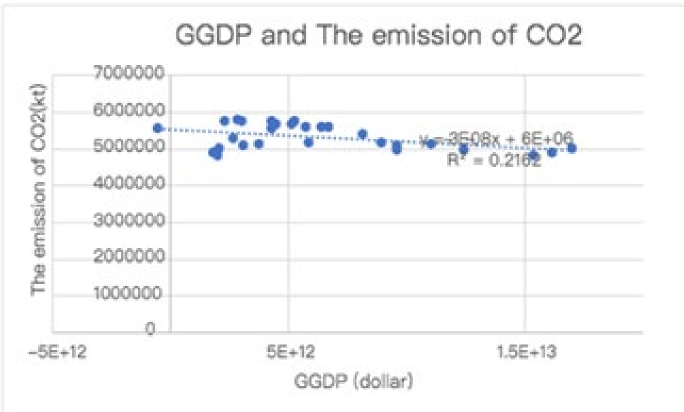

Figure 4: The linear relationship between GGDP and CO2

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Table 2: The emission of CO2 when GGDP and GDP rise 10 percent

	The Emission of CO2 (kt)
GDP up 10 percent from 2018	5069817.685
GGDP up 10 percent from 2018	5061566.649
Difference	8251.036464

Model 2: The impact of GGDP on national development

The Foundation of Model

$$\boldsymbol{GGDP = GDP - \alpha_1 \times \text{cost of environmental degradation} - \alpha_2 \times \text{cost of ecological damage} + \text{economic status} + \text{the ability to provide for future generations}}$$

Economic status and the ability to provide for future generations are mainly reflected in gross national income, health expenditure, and education expenditure.

First, the higher the gross national income, the better the material conditions for future generations, which is directly proportional to the ability to provide for future generations. In addition, high health expenditure allows people to enjoy higher levels of health care and reduce mortality. At present, with the transformation and upgrading of the national economy, high-tech enterprises will become the main driving force for the economic development of cities and countries. As an indicator to measure the economic situation and development level of a country or region, GDP is closely related to high-tech industries. This requires people to have a higher level of education. Consequently, these three have a great impact on GGDP.

Therefore, we can get the following formula:

$$\boldsymbol{GGDP = GDP - \alpha_1 \times \text{cost of environmental degradation} - \alpha_2 \times \text{cost of ecological damage} + \beta_1 \text{gross national income} + \beta_2 \text{ health expenditure} + \beta_3 \text{education expenditure}}$$

Table 3: The amounts of GDP, education expenditure, medical expenditure, natural disaster losses and environmental pollution control respectively

	2010	2011	2012	2013	2014	2015	2016	2017
GDP (billion yuan)	410354.1	483392.8	537329	588141.2	644380.2	685571.2	742694.1	830945.7
Education expenditure (billion yuan)	19561.85	23869.29	28655.31	30364.72	32806.46	36129.19	38888.39	42562
Medical expenditure (billion yuan)	19980.39	24345.91	28119	31668.95	35312.4	40974.64	46344.88	52598.28
Natural disaster losses (billion yuan)	5339.9	3096.4	4185.5	5808.4	3373.8	2704.1	5032.9	3018.7
Environmental pollution control (billion yuan)	7612.19	7114.03	8253.46	9037.2	9575.5	8806.3	9219.8	9538.95

According to the coefficient of variation method based on the data in Table 3,

$$CV = \frac{standard\ deviation}{mean}$$

Therefore, we can get $\beta_1 = 0.2255,\ \beta_2 = 0.2422,\ \beta_3 = 0.3196.$

Next, we construct a relationship function between GDP and our new GGDP. According to Figure 5, it is concluded that the new GGDP has a strong positive correlation with GDP.

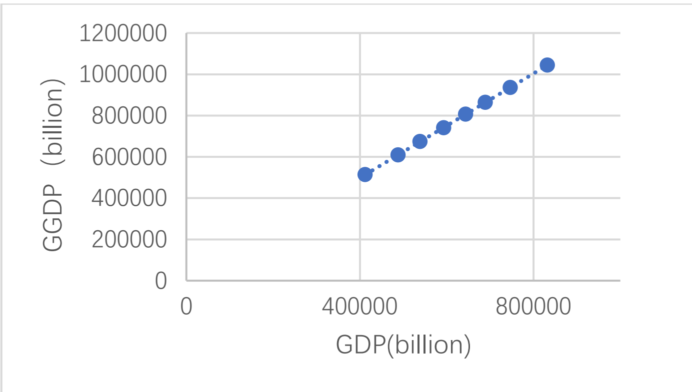

Figure 5: The linear relationship between GGDO and GDP

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5. Conclusions

The adoption of a new calculation method for measuring the final product of production activities of all resident units in a country, known as Gross Global Domestic Product (GGDP), instead of the traditional Gross Domestic Product (GDP) can be deemed beneficial. Our model 2 considers the economy, environment, and society, thereby providing a comprehensive evaluation of the sustainable development index system. Based on the findings presented in Figure 3 and Figure 4, it is observed that GGDP is more relevant to the emission of CO2, which represents a measure of the quality of the environment compared to GDP. Additionally, Table 2 reveals that the replacement of GDP with GGDP results in a deduction of 8251.036464 kt of CO2 emissions, indicating that the environment in the United States could be improved through the adoption of GGDP.

However, GGDP has some drawbacks. It can be challenging to calculate green GDP since GDP is typically measured using market transactions, and there is no standard method for estimating resource consumption in green GDP, including the price per unit of treatment of sulfur dioxide, nitrogen oxide, industrial and domestic wastewater, and the price of energy consumption versus mineral resource consumption.

Despite its limitations, the adoption of GGDP can foster the development of a green economy that incorporates ecological agriculture, circular industry, and continuous service structural systems. Such a development approach can contribute to the harmonious development of the economy and the environment.

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