GGDP: A Better Measure of a Country's Economic Health

Linlin Zhao, Yaqi Yang*

School of Data Science and Media Intelligence, Communication University of China, Beijing, China, 100024

* Corresponding author: yaqiyang@cuc.edu.cn

Abstract. According to a report by the United Nations Environment Programme (UNEP), half of the world's GDP is dependent on nature, and Green GDP (GGDP), which takes into account all types of natural resource depletion, may be a better indicator of economic health. To determine whether GGDP can be a better measure than GDP, this paper firstly determines the accounting method of GGDP based on the SEEA accounting system and the research of scholars in the field, then constructs the Climate Benefit Index (CBI) to measure the global climate quality, and finally proposes a three-stage projection model to collect relevant data of the top 20 countries in terms of GDP from 2010 to 2021. The analysis found that the global climate quality improved significantly after GGDP replaced GDP as the accounting indicator. This suggests that GGDP is a better indicator of economic health.

Keywords: GGDP, Climate Benefit Index, Distributed Lag Model, Grey Prediction.

1. Introduction

The UNEP report Becoming Generation Restoration found that half of the world's GDP depends on nature and that every dollar invested in ecological restoration creates an economic benefit of up to $30. According to research, the majority of countries in the world are experiencing resource depletion and environmental degradation [1]. and foreign researchers have tested the sustainability of economic development in more than 20 countries and found that most countries' development is unsustainable after considering the value of resource and environmental depletion [2]. The frequent occurrence of natural disasters, extreme weather and severe land desertification are reminders to mankind that the pursuit of GDP growth is not desirable and that greater attention needs to be paid to environmental degradation. This is why the United Nations has proposed a standard that can truly measure the economic health of a country, GGDP, which can effectively promote the environmental health of the planet while assessing the level of a country's economy.

Based on the System of Integrated Environmental and Economic Accounting (SEEA) proposed by the UN and the research of other scholars [3], this paper identifies a more refined way of accounting for GGDP in the hope of correctly revealing the relationship between socio-economic development and ecological systems. The main contributions made in this paper are:

(1) Based on existing GGDP accounting methods and in conjunction with the SEEA system proposed by the United Nations, this paper proposes a GGDP accounting method that is considered reasonable and achievable to specifically measure climate mitigation.

(2) The Climate Benefit Index (CBI) is proposed to evaluate the overall global climate situation.

(3) A three-stage projection model is constructed to predict the impact of GGDP on global climate when it replaces GDP, where the change in global climate is quantified using the CBI and the model is validated using data from the top 20 countries in terms of GDP.

2. GGDP Accounting System Created Based on SEEA

The way GGDP is accounted for consists of three factors-GDP, resource depletion costs and environmental pollution breakage costs, and this sub-section provides a brief overview of how the three factors are quantified.

2.1. Indicators Needed to Account for the GGDP

2.1.1. GDP Accounting

There are many accounting formulas for GDP, such as the production method, income method and expenditure method [4]. On the basis of previous studies, integrating operability, economy, long-term measurement and accuracy, this paper calculates national GDP based on the expenditure method, calculated as:

$$GDP = C + I + G + NX \tag{1}$$

Where C represents the amount of final consumption expenditure by residents; I represents fixed asset investment, including residential and non-residential investment, etc. G is total government consumption and expenditure. NX represents the value of total exports minus the value of total imports.

2.1.2. The Cost of Resource Consumption

The resource depletion factor is not taken into account in the GDP accounting as it is an exogenous variable. However, with the increase in environmental degradation, it is necessary to include it in the GGDP accounting. As renewable resources can be used sustainably by regulating the usage rate, this paper mainly considers non-renewable resources and defines the resource depletion cost (REC) as:

$$REC = C_e + C_m \tag{2}$$

$$C = Q \times P \tag{3}$$

Where C_e denotes the cost of energy consumption, including coal, electricity and metal consumption. C_m denotes the cost of mineral resource consumption, including oil, gas and nuclear energy consumption. Q is the quantity of energy or mineral consumed and P is the price per unit quantity of different resources.

2.1.3. Cost of Environmental Damage

The cost of environmental pollution damage consists of two main aspects, one is the cost of treatment consumed for environmental pollution caused by natural disasters and the other is the cost of virtual treatment of existing environmental pollution. In this sub-section, both aspects are described in detail.

(1) Natural economical loss

Natural disasters not only endanger human life and health and normal production and life, hinder economic development and weaken human sustainable development capacity. Therefore, this paper includes the economic losses caused by eight natural disasters, such as wildfires, floods, earthquakes, droughts and storms, in the scope of GGDP accounting [5], defining them as:

$$NDL = LC + EL \tag{4}$$

$$EL = \mathrm{LP} + \mathrm{LS} + \mathrm{FR} \tag{5}$$

Where LC and EL are the casualty losses and economic losses caused by natural disasters, respectively, while economic losses are calculated from primary disaster losses (LP), secondary disaster losses (LS) and post-disaster reconstruction funds (FR).

(2) Virtual treatment costs for environmental pollution

Environmental value assessment methods include the direct market value method, revealed preference method, benefit transfer method and stated preference method [6], and this paper chooses to use the virtual cost of governance method in the revealed preference method to conduct environmental value assessment. Environmental pollution mainly includes air pollution, water pollution and solid waste pollution. By the availability of data and specific information analysis, the cost of air pollution treatment mainly includes the treatment cost of NO, CO_2, CH_4 and other gases

and particulate dust. Water pollution costs are measured by the cost of industrial wastewater purification. Solid waste costs are characterised using the economic losses caused by the recovery and use of resources from solid waste.

$$EDC = EDCa + EDCw + EDCs \tag{6}$$

$$D = E \times C \times \gamma \tag{7}$$

$$\gamma = \alpha \times \tau \times \omega \tag{8}$$

Where $EDCa$ is the cost of air pollution treatment, $EDCw$ is the cost of water pollution purification, and $EDCs$ is the cost of solid waste recycling and utilization. Eq.7 is the pollution cost calculation formula, where D is the amount of environmental pollution damage. E is the amount of pollutants discharged. C is the unit cost of treatment of pollutants, and the unit price of treatment of specific pollution was determined after consulting Table 1 [7].

Table.1. Cost of pollution control

Pollution types	Unit price of governance
Toxic Gas	116.70
Dust	63.30
Waste water	0.34
Solid waste	36.45

2.2. GGDP Accounting

The concept of GGDP was first formally introduced in 1993 in the Handbook on Integrated Environmental-Economic Accounting published by the United Nations Statistical Office, and is defined as:

$$\begin{aligned}\text{GGDP} = \text{GDP} - &Depreciation\ of\ fixed\ assets \\ &- Resource\ and\ environmental\ costs\end{aligned} \tag{7}$$

However, the system does not take into account the impact of environmental improvements [8]. After continuous refinement by scholars [9][10], green GDP has been defined as:

$$\begin{aligned}GGDP = GDP &- Resource\ depletion\ costs - Environmental\ pollution\ loss \\ &- Public\ environmental\ protection\ input\end{aligned} \tag{8}$$

Based on this accounting method, this paper additionally considers the economic losses caused by disasters and natural disasters due to human failure to protect the environment, and constructs virtual governance indicators for environmental pollution to be attributed to environmental pollution losses in order to explore the economic costs of environmental governance. The finalised GGDP accounting formula is:

$$GGDP = GDP - REC - EDL \tag{9}$$

Where REC is the resource depletion cost and EDL is the environmental pollution loss. This accounting approach allows for measurable impacts on climate mitigation to be assessed alongside GDP, with a system for constructing specific indicators as shown in Table 2.

Table.2. GGDP Accounting Indicators

Primary index	Secondary index	Three-level index
REC	C_e	Coal
		Power
		Metals (cobalt, lithium, rare earth metals, etc.)
	C_m	Petroleum
		Natural Gas
		Nuclear Power
EDL	NDL	LC
		LP
		LS
		FR
	EDC	$EDCa$
		$EDCw$
		$EDCs$

3. Climate Benefit Index Construction

Using GGDP to measure the economic health of countries takes into account more ecological benefits than GDP. We build on the previous section to develop a climate evaluation model to explore the mitigation effects of GGDP on global climate. Climate change and human social activities such as temperature and precipitation are added as first-order indicators.

The State of the Global Climate 2021 report published by the World Meteorological Organisation (WMO) in 2022 states that climate is an integrated description of temperature, humidity, air pressure, wind, precipitation, atmospheric composition and numerous other meteorological elements, based on statistical data over a long period of time or a specific region. This question constructs climate evaluation indicators from this to calculate the CBI.

3.1. Indicators Needed to Account for the CBI

(1) Temperature

Since entering the 21st century, global warming has become an inescapable practical problem, and the common greenhouse gases mainly include carbon dioxide, methane and nitrous oxide. This paper obtains the emissions of various greenhouse gases from various countries in recent years to portray the global temperature, and the higher the temperature, the more severe the global climate situation is [11].

(2) Precipitation

The Earth's ecological balance cannot be achieved without water systems, and precipitation is one of the key links in the water system cycle. Changes in climate lead to changes in the structure of precipitation, making arid places drier and wet places more prone to flooding. So the dynamics of global precipitation conditions can effectively reflect climate mitigation [12].

(3) Illumination

Light is also an important factor in assessing climate conditions, and light is usually measured using total solar radiation and average hours of light, with higher total solar radiation and longer average hours of light both contributing to higher temperatures and thus affecting climate.

(4) Extreme Weather Quantity

Extreme weather is an important factor in reflecting climate conditions, and the IPCC climate change assessment report states that the 21st century will see more heat and rain events and increased drought levels in some parts of the world, threatening countries' food and energy security. The number

of extreme weather events is therefore included in the model in this question to reflect the stability of the climate [13].

(5) Social Activity

The activities of human society play a controlling role in climate change. Humans contribute to climate change by releasing excess atmospheric constituents into the atmosphere, which in turn affects the energy conversion of the Earth's circulatory system. Social activities mainly include land exploitation and the use of chemical fertilisers. Land exploitation refers to people cutting down forests to increase the area of cultivated land for production and livelihood, which increases the concentration of CO_2 in the atmosphere [14]. Chemical fertilisers such as nitrogen and corrosive fertilisers affect the radiative climate in some parts of the world, increasing surface temperatures and thus influencing climate conditions.

3.2. CBI Accounting

Based on the above analysis, the evaluation index system of the Climate Benefit Index (CBI) constructed in this paper is shown in Table 3, containing a total of 5 primary indicators and 10 secondary indicators. In the empirical study, the climate benefit index (hereinafter referred to as CBI) will be calculated using the hierarchical analysis method (AHP) and CRITIC method.

Table.3. Climate Benefit Index Evaluation System

Primary index	Secondary index	Three-level index
Temperature	Carbon dioxide concentration	
	Methane concentration	
	Nitric Oxide Concentration	
	PM2.5 Index	
Precipitation	Annual average Precipitation	
Illumination	Total annual solar radiation for Each country	
	Average annual sunshine hours by Country	
Extreme Weather Quantity	Number of Extreme weather	
Social Activity	Degree of Land Development	Deforestation Area
		Land area under Cultivation
	Chemical fertilizer Use	Nitrogen fertilizer Use
		Corrosion of fertilizer Volume

4. Three Phase Projection Model: GGDP-Climate Projection Model

In order to further analyse the impact on the global environment of the replacement of GDP by GGDP as a measure of countries' development status, this paper further presents a three-stage forecasting model, the main work of which is described in detail in this sub-section. A specific demonstration of the analysis is presented in the empirical analysis in Section 5.

4.1. Step 1: Distributed Lag Model

In regression analysis involving time series data, it takes time for the explanatory variables to fully act on the dependent variable for various reasons, and the current changes in the dependent variable are influenced by their own past values. That is, the model contains not only the current values of the explanatory variables but also their past values, and such a model is called a distributional lag model.

The GGDP accounting system we constructed earlier takes into account the costs of resource damage and pollutant management. However, the impact of humans on nature is far-reaching, and

the impact of damaged environmental barriers on climate change will slowly become apparent in the future. So climate change will be influenced not only by the environmental conditions of the current year, but also by those of the past. We will use a distributional lag model to explore the relationship between GGDP and climate indices that can encompass both current climate change and past changes. Therefore, in the first stage, we use a distributional lag model with GGDP as the explanatory variable and CBI as the dependent variable to investigate the relationship between CBI and GGDP.

4.2. Step 2: Grey Prediction Model

The Gray Forecast Model is a method of building a mathematical model and making forecasts from a small amount of incomplete information. Due to the difficulty of obtaining data, in most cases in the empirical analysis only 10-20 years of more accurate GGDP data can be calculated. Therefore, in the second stage, the grey forecast model is used to forecast the future value of GGDP.

4.3. Step 3: CBI Prediction

In the third stage, the GGDP projections obtained in the second stage are brought back to the CBI-GGDP relationship obtained in the first stage to obtain future climate projections. The value of the environmental benefits of replacing GDP as a measure of development for each country can be demonstrated by plotting the trends between CBI and GGDP and between years.

5. Empirical Analysis

In this section, data on each indicator for the top 20 GDP rankings from 2010 to 2021 are obtained for empirical analysis, and are sourced from publicly available data networks such as the World Bank (https://data.worldbank.org.cn/), the Global Platform for Disaster Data (https://www.gddat.cn/), the Food and Agriculture Organisation of the United Nations (https://www.fao.org/home/zh), CEIC database (https://www.ceicdata.com/zh-hans), etc.

5.1. CBI Acounting

To facilitate comparison, the indicator data for the different characteristics are first normalised in this paper in the following way:

(1) Extremely large indicators:

$$\tilde{x}_{ij} = \frac{x_{ij} - min\{x_i\}}{max\{x_i\} - min\{x_i\}} \tag{10}$$

(2) Very small indicators:

$$\tilde{x}_{ij} = \frac{\max\{x_i\} - x_{ij}}{\max\{x_i\} - \min\{x_i\}} \tag{11}$$

After that, this paper uses the AHP-CRITIC method to calculate the weights of each indicator, and the results obtained are shown in Table 4.

Table.4. Index weighting

Temperature		Illumination		Social Activity	
CO_2 concentration	0.2951	Total annual solar radiation for Each country	0.5673	Degree of Land Development	0.3428
CH_4concentration	0.2422				
NO concentration	0.3257	Average annual sunshine hours by Country	0.4327	Chemical fertilizer Use	0.6572
PM2.5 Index	0.1370				

5.2. Three Phase Projection Model

5.2.1. Step 1: Distributed Lag model

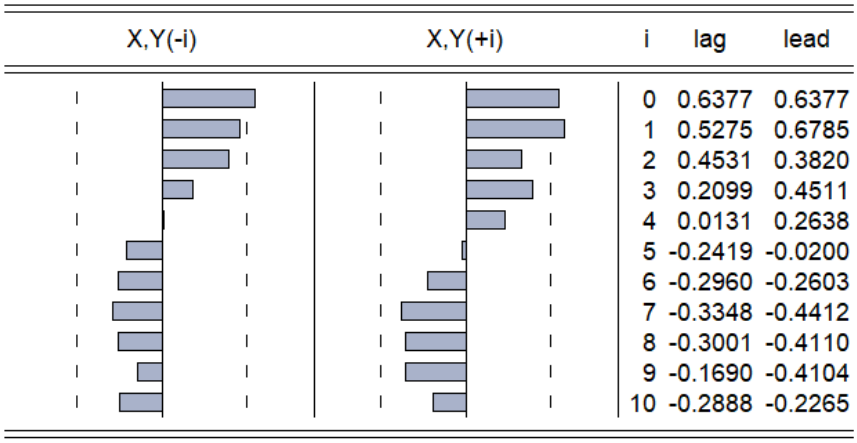

Fig.1. Intercorrelation analysis graph for GGDP and CBI

Figure 1 shows the correlation analysis plotted for GGDP and CBI, where the first column is a histogram of the correlation coefficients for the lags, from which it can be seen that the Climate Benefit Index has some correlation with GGDP for the current year and the previous 1 to 3 years, we have compared the lags 1, 2, 3 and 4 in turn as shown in Table 5.

Table.5. AIC and SC tests

	1	2	3	4
AIC	1.6422	1.3861	0.8462	0.9719
SC	1.7632	1.4738	0.8859	0.9410

The Table 5 shows that the values of AIC and SC are the lowest for a lag order of 3, indicating that 3 is the optimal lag order. The distribution lag model can be set as follows:

$$Y = a + b_0 X_t + b_1 X_{t-1} + b_2 X_{t-2} \tag{12}$$

The final coefficients of the model using the Almon transform are shown in Table 6.

Table.6. Distributional lag model coefficients

Variable	Coefficient	Std. Error	t-Statistic
C	-0.2500	0.3133	0.1784
0	-0.1530	0.1369	0.9506
1	0.0489	0.2384	0.9426
2	0.3557	0.1532	2.3449

Based on the results in the Table 6, the lagged model of the distribution of CBI and GGDP can be obtained as:

$$Y = -0.2500 - 0.1530 X_t + 0.0489 X_{t-1} + 0.3557 X_{t-2} + 0.7674 X_{t-3} \tag{13}$$

Cumulating the current and lagged GGDP coefficients gives [15]:

$$Y = 1.019 X \tag{14}$$

This indicates that the elasticity coefficient of the effect of GGDP on CBI is 1.019. The model is then tested and the results are presented in Table 7.

Table.7. Model test results

R^2	F	significance	D-W
0.6921	7.8806	0.0773	2.4481

The R^2 of the model is close to 0.7 and the adjusted R^2 is greater than 0.7, indicating that the model fits well. the significance in the F-test is less than 0.1, indicating that the effect of GGDP on the climate index is significant. the D-W test has a D-W value close to 2, indicating that the model has no autocorrelation and the model works well.

5.2.2. Step 2: Grey Prediction

In the second stage, the paper obtains the global average GGDP values from 2022 to 2026 through grey forecasting.

Table.8. Gray prediction results

year	2022	2023	2024	2025	2026
GGDP(Billion dollars）	9.288	9.5302	9.7787	10.0337	10.2953

Based on the results in Table 8, this paper argues that when GGDP is adopted as a measure instead of the original GDP, countries will increase their focus on GGDP, develop new policies for GGDP and achieve climate mitigation to some extent.

5.2.3. Step 3: CBI Prediction

The GGDP results obtained from the grey projections (Table 8) were brought back to eq.13 to estimate the global CBI values for the future years 2022 to 2023, and the results are shown in Table 9.

Table.9. Results of CBI prediction

year	2022	2023	2024	2025	2026
CBI	1.7392	2.0605	2.0236	2.0829	2.1437

The results in Table 9 show that the values of the CBI generally show an upward trend from year to year, suggesting that the use of GGDP instead of conventional GDP will lead to a certain degree of future global climate mitigation.

5.3. Additional analysis

The paper then sets the distance between GGDP and GDP to "GGDP-GDP", calculated as GDP minus GGDP, and plots the change in fluctuation between "GGDP-GDP" and CBI from 2010-2021 as shown in Figure 2.

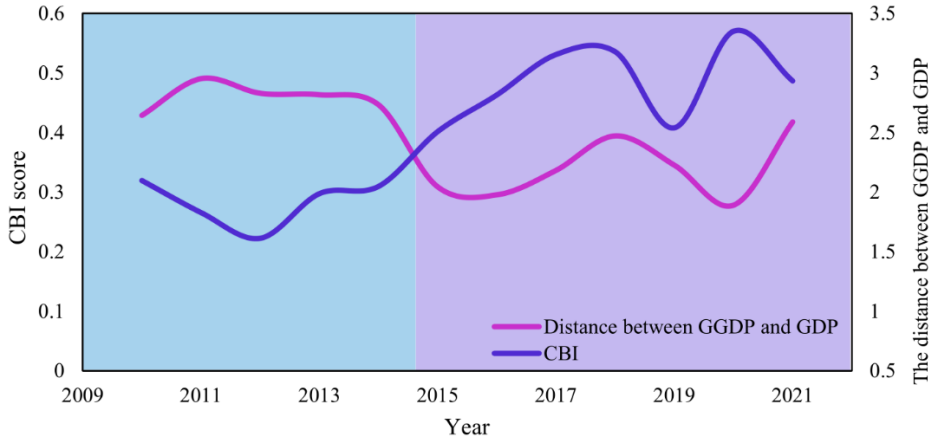

Fig.2. Fluctuation of $GGDP - GDP$ and CBI from 2010-2021

As can be seen from Figure 2, before 2015, the distance between GGDP and GDP was large, indicating that environmental pollution was more serious and the CBI score was lower. 2015 onwards the CBI value gradually picked up and in the same year the world climate was held in Paris countries faced up to the major problem of environmental pollution in time. It can be seen that human activities can have a positive impact on the climate environment.

6. Conclusions

After replacing GDP as the national economic development accounting indicator, GGDP can effectively control the global climate quality. This paper first identifies a feasible GGDP accounting method based on the SEEA accounting standard and research by scholars in the field, and proposes a quantitative global climate indicator (CBI) and a three-stage prediction model. Public data from the top 20 countries in terms of GDP are collected for empirical analysis, and the results show that GGDP has a significant improvement on climate quality after replacing GDP. It further demonstrates that GGDP is a better measure of a country's economic health.

References

[1] ASHEIM, G. Green national accounting: Why and how? [J]. Environment and Development Economics, 2000, 5(1), 25-48.

[2] Figueroa, E., Calfucura, E., & Nuñez, J. Green national accounting: The case of Chile's mining sector [J]. Environment and Development Economics, 2002, 7(2): 215-239.

[3] United Nations. Translation by the Division of National Accounts of the National Bureau of Statistics: System of National Accounts[M]. Beijing: China Statistics Press, 1995.

[4] Methodology for accounting for gross domestic product (GDP)[Z]. http://www.yinjiang.gov.cn/jgsz/zfbm/tjj/zcwj/202108/t20210806_69421797.html

[5] Global Platform for Disaster Data[Z]. https://www.gddat.cn/newGlobalWeb/#/PreviewNewDisaster

[6] Li Jinlei. Green Development Accounting in the Daihai Basin based on GGDP, GEP and GEEP [D]. Inner Mongolia University, 2021.

[7] Lei Huang, Xiwu Hu. SEEA-based green GDP measurement and evolutionary trends in Qinghai Province [J]. Environmental Ecology, 2022, 4(06):35-40.

[8] Jinnan Wang, Fang Yu, Dong Cao. China Green National Accounts Research Report 2004 [J]. China Population - Resources and Environment, 2006, (06): 11-17.

[9] Chao Dong. A Theoretical and Methodological Reconstruction of Green GDP Accounting [J]. Shanxi University of Finance and Economics, 2020.

[10] Likai Yang. Green GDP Accounting in Datong City Based on SEEA-2012 [C]. Proceedings of the Annual Scientific and Technical Conference of the Chinese Society of Environmental Sciences 2022 (I). 2022, 2022: 114-119.

[11] Brodie Jedediah F, Watson James E M. Human responses to climate change will likely determine the fate of biodiversity. [J]. Proceedings of the National Academy of Sciences of the United States of America, 2023, 120(8).

[12] Mikulčić Hrvoje, Wang Xuebin, Duić Neven, Dewil Raf. Climate crisis and recent developments in bio-based restoration of ecosystems [J]. Journal of Environmental Management, 2023, 332.

[13] Weather Science and Technology Update Half of extreme weather influenced by climate change Human influence on climate increases risk of extreme events [J]. Zhejiang Weather, 2013, 34(04): 11.

[14] Xinglin Qu. Human impact on climate [J]. Meteorological Technology, 1980, 1980(06): 36-37.

[15] Weili Huang. Estimation of profit elasticity of investment based on the Almonds distribution lag model [J]. Statistics and decision making, 2008, 2008(11): 19-20