Research On the Evaluation of Green Gdp System Based on Comprehensive Evaluation Method

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Abstract. In order to adjust traditional GDP to achieve a comprehensive measure of the sustainability of national economies and to optimize national policy-making, this paper constructs an assessment system of 11 indicators to measure GGDP in 3 dimensions: economic development, resource use and environmental pollution, and selects 24 countries as samples. Based on Coupled EWM-PCA, we construct Green Adjustment Coefficient (GAC) to adjust GDP to GGDP. Impact measurement based on Spearman Correlation. Results show that GGDP has the greatest correlation(-0.9) to suppress global CO_2 emissions, followed by global temperature (-0.7) and global ocean temperature (-0.6).

Keywords: EWM-PCA, GGDP, Spearman Correlation.

1. Introduction

Gross Domestic Product (GDP) is the most widely adopted indicator of a country's economic development, determining its international purchasing power and the availability of external debt, as well as being a major reference point and core objective for future policy formulation in the country[1,2].However, as discussions and cooperation around the climate crisis and sustainable human development have developed and intensified, the issue of updating the corresponding global institutional framework system has gradually emerged [3]. Among them, the discussion of constructing a new indicator Green GDP (GGDP) to evaluate the level of economic development is particularly crucial in order to more comprehensively measure the sustainability of each country's economy and use it for future decision-making. This is because it can provide an objective factual basis for subsequent international conversations and cooperation among countries.

Therefore, we have constructed a reasonable GGDP indicator system to complement and replace the original GDP, and to assess its possible effects on climate issues and the transformation and benefits brought by its replacement of the original GDP measure, with a view to increasing the future acceptability of the indicator, enhancing the sustainable decision-making and contributing to the future sustainable development of the human world. Exactly this paper establishes a global GGDP system and analyze the measurable impact of the established GGDP on climate.

2. Construction of an Index System to Measure GGDP

2.1 Chosen Indicators

Combining our understanding of the intrinsic relationship between GGDP and GDP [4], as shown in Fig.1, where R represents the promotion of growth by implementing policies, i.e., strengthening the cycle; the opposite can also contain and balance growth (B); the following system of GGDP measures is attempted.

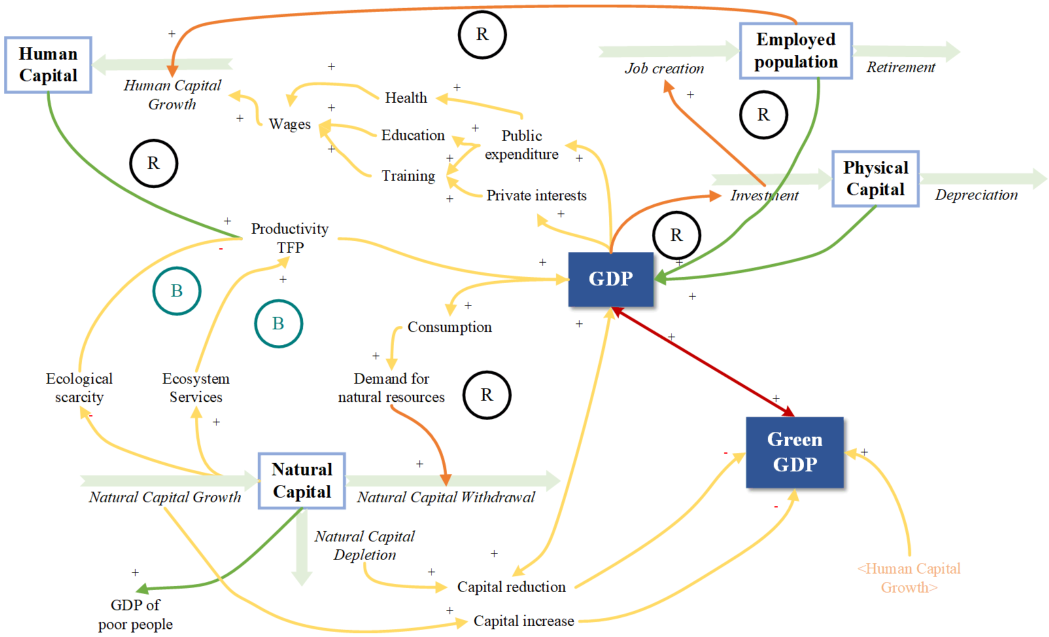

Figure 1: Inner Relationship between GGDP and GDP

(1) Objective Economic Development

Objective Economic Development Indicators are shown in table 1.

Table 1 Objective Economic Development Indicators

Tier 1 Indicators	Variables	Variable Meaning	Detailed description
Level of Economic Development	y_1	GDP per Capita	shows a country's GDP divided by its total population
	y_2	GDP Growth Rate	be defined as the increase or improvement in the inflation-adjusted market value of the goods and services produced by an economy
	y_3	CPIA Structual Policies Cluster Average	It ranges from 1(= low) to 6(= high).
Economic Growth Drivers	y_4	Number of R&D Researchers	measure the number of R&D reseachers per million people
	y_5	Proportion of Fixed Capital Formation	It is an important driver of growth in real gross domestic expenditure and a major contributor to growth in real GDP.
Industrial Structure Transformation	y_6	Proportion of Trade in Services	records the value of services (including transport, travel, communications services etc.)
	y_7	High-tech Export	capture technology intensity of exports
Urbanization&Social Security	y_8	Proportion of Urban Population	refers to the proportion of people living in cities
	y_9	International Murder Crime Rate	describes the number of crimes committed during a period of time in a society

(2) Sustainability

Sustainability Indicators are shown in table 2.

Table 2 Sustainability Indicators

Tier 1 Indicators	Variables	Variable Meaning	Detailed description
Ecological Health	y_{10}	Renewable Inland Water	measuring the internal renewaable resources in a country.
	y_{11}	PM2.5 Concentration	determines the clearness level of air.
Pollution and Greenhouse gas Control	y_{12}	Nitric Oxicide Emissions	measure the pollution level of NO_X.
	y_{13}	CO_2 Emissions	desicive indicator of climate issue
	y_{14}	Methane Emissions	a vital factor of the climate change.
Low Carbon Development	y_{15}	Natural Gas Rent	measures the contribution of natural resources to economic output
	y_{16}	Coal Rent	measures the contribution of natural resources to economic output
	y_{17}	Proportion of Renewable Energy	indicates the development and usage situation of renewable energy of a country.
Resource Saving	y_{18}	Urban & Rural Power Consumption	shows the amount of energy used per unit time
	y_{19}	Energy Consumption per Capita	refers to a country's total energy consumption per capita,

(3) Green Development Motivation

Green Development Motivation Indicators are shown in table 3.

Table 3 Green Development Motivation Indicators

Tier 1 Indicators	Variables	Variable Meaning	Detailed description
Infrastructure	y_{20}	Total Railway Kilometers	analyzing the development of the infrastructure of a country.
	y_{21}	Mobile Data Subscriptions	measure the information development level of a country
Resource and Environment Management	y_{22}	CPIA Quality of Public Administration Rating	civilian central government staff is structured to design and implement policy and deliver services effectively.
A. Endogenous Growth Booster	y_{23}	Number of Resident Patent Applications can be used to	indicate the innovation level of a country.
	y_{24}	Number of Science and Technology Journal Articles	showing the innovative potential in the comming future.

GGDP indicator system can be described by **Fig.2**.

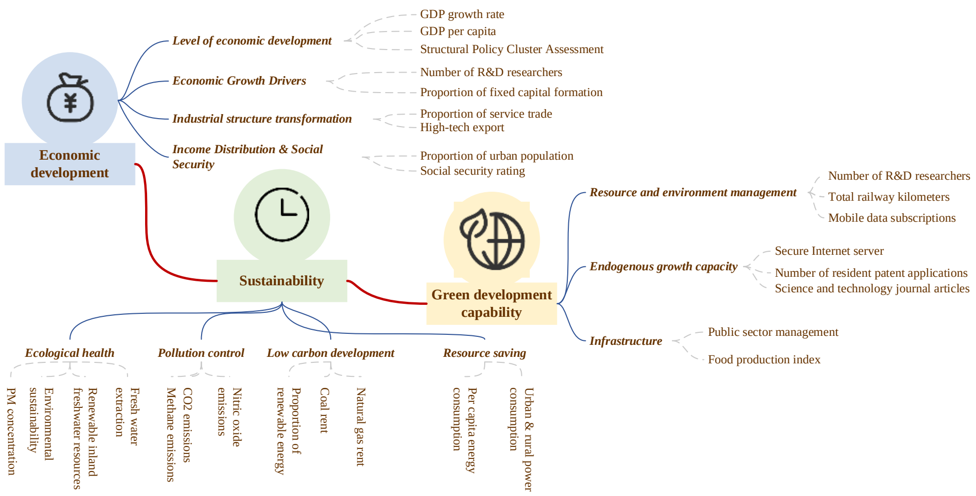

Figure 2: Schematic of the Original Indicator System

2.1.1 Weight Calculation and Green Adjusted Coeffient (GAC)

On the basis of preprocessing, entropy weighting method (EWM) was used to assign weights to the screened 11 indicators and coupled principal component analysis (PCA) method was used to calculate the composite score on the basis of the assigned weights. Finally, we transformed the composite score obtained on the basis of this mechanism into a mathematically equivalent space to obtain a series of values between 0 and 1, which we defined as green adjustment coefficient (GAC).

(1) Data pre-processing

We selected 11 core indicators common to 44 countries as the final indicators to be included in the model, and at the same time ensured the richness of the dimensions encompassed by these 11 indicators, as shown in Fig. 3 and Fig. 4.

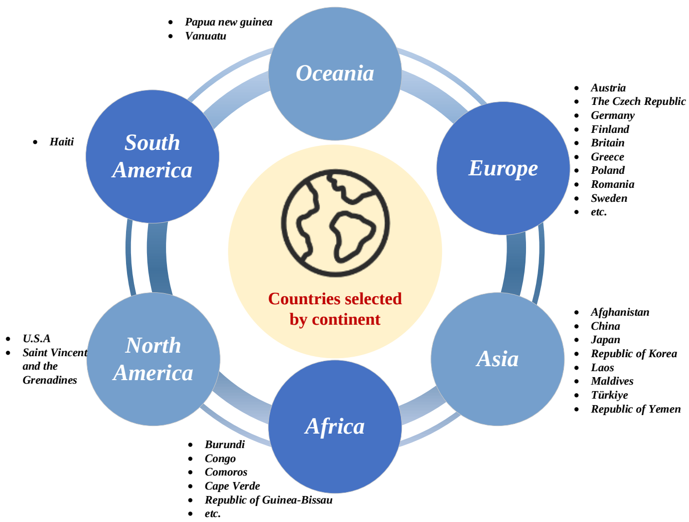

Figure 3: Continental Distribution of 44 Selected Countries

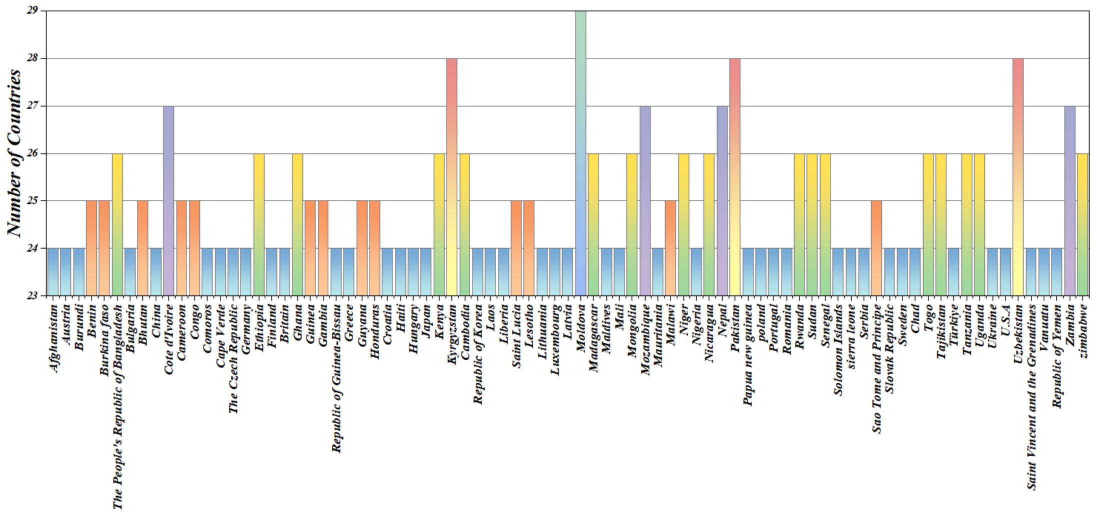

Figure 4: Analysis of the Number of Indicators Covered by Different Countries

Next, to make the raw data easier to identify and analyze, we need to pre-process and normalize the data.

$$r_{ij} = \frac{r'_{ij} - min\, i(r'_{ij})}{max\, i(r'_{ij}) - min\, i(r'_{ij})} \tag{1}$$

$$r_{ij} = \frac{max\, i(r'_{ij}) - r'_{ij}}{max\, i(r'_{ij}) - min\, i(r'_{ij})} \tag{2}$$

(2) EWM Method

Step 1. Calculate the entropy value for each indicator [5].

$$H_j = -k \sum_{i=1}^{m} f_{ij}.\ln f_{ij},\ j{=}1,...,11 \tag{3}$$

$$f_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}},\ \ k = \frac{1}{\ln \mathrm{m}} \tag{4}$$

i represents the year and takes the value of 2012-2017.

Step 2. Calculate the entropy weight of the j-th indicator.

$$w_j = \frac{1 - H_j}{n - \sum_{j=1}^{n} H_j} \tag{5}$$

Step 3. Calculate the combined weights of the indicators, and correct the weights obtained by the entropy weighting method.

$$\lambda_j = \frac{\lambda'_j w_j}{\sum_{j=1}^{n} \lambda'_j w_j} \tag{6}$$

Finally, we get the weights of different indicator factors. As the results in Fig.5 show, the weight of urban population(y_8)share is 2.98%, the weight of GDP per capita(y_1)is 15.784%, the weight of scientific and technical journal articles(y_{24})s 36.943%, the weight of renewable inland freshwater resources(y_{10})is 32.961%, the weight of renewable energy share of total energy(y_{17})is 7.521%, the weight of GDP per capita growth rate(y_2)is 0.244%, PM2.5 concentration(y_{11})with a weight of 1.337%, natural gas rent (y_{15})with a weight of 0.242%, carbon dioxide emissions per capita (metric tons per capita)(y_{13})with a weight of 0.918%, methane emissions(y_{14})with a weight of 0.562%, and nitric oxide emissions(y_{12})with a weight of 0.508%, where the maximum weight of indicators is scientific and technical journal articles(36.943%),and the minimum value is the indicator natural gas rent(0.242%).

Analysis of the Calculated Weights is shown in figure 5.

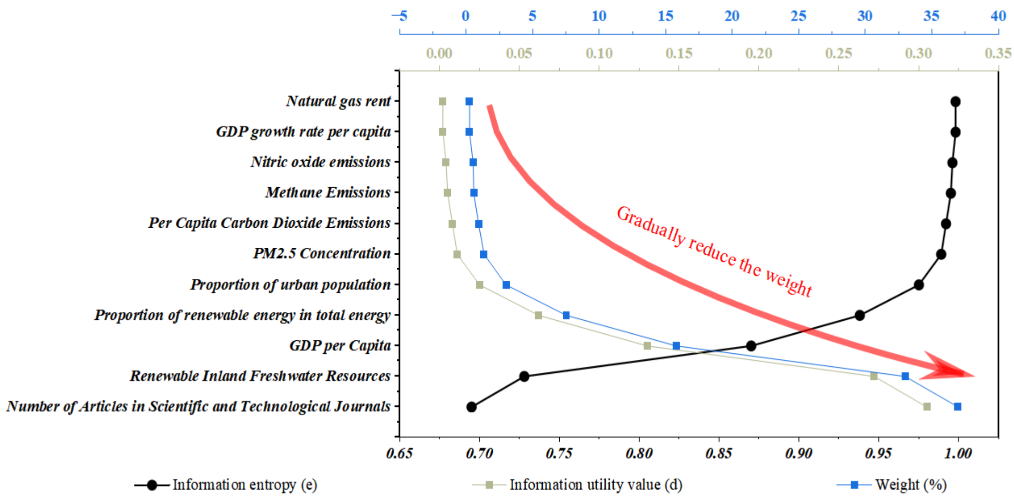

Figure 5: Analysis of the Calculated Weights

(3) PCA Method

We next use principal component analysis, perform further data dimensionality reduction, and calculate the composite score of principal components by combining the entropy weighting method. The steps are as follows [6].

Step 1. Standardization of raw data.

Step 2. Build the variable correlation coefficient matrix Rnxn(n=11);

Step 3. Find the characteristic roots of Rnxn $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_n > 0$, namely, the corresponding unit eigenvectors $\boldsymbol{E}_i$ ($i = 1,2,\ldots,$n);

Step 4. The cumulative contribution rate is obtained. Based on the obtained characteristic roots, the cumulative contribution rate is calculated:

$$E_k = \frac{\sum_{k=1}^{i} \lambda_k}{\sum_{k=1}^{n} \lambda_k}, \ \mathrm{k} \in (1,11) \tag{7}$$

Step 5. The principal components were derived. Based on the calculated cumulative contribution, the top p principal components with eigenvalues greater than 1 or cumulative contribution greater than 85% are selected, and then the principal components are written.

$$F_t = E_{1t}X_1 + E_{2t}X_2 + \ldots + E_{11t}X_{11}, t = 1,2,\ldots,6 \tag{8}$$

Step 6. Construct a comprehensive evaluation function. According to the steps of determining weights by the entropy weight method, the weights of each principal component are calculated, and a comprehensive evaluation function is constructed:

$$F = \omega_1 F_1 + \omega_2 F_2 + \ldots + \omega_n F_n \tag{9}$$

This process of calculating can be simplified as Fig.6:

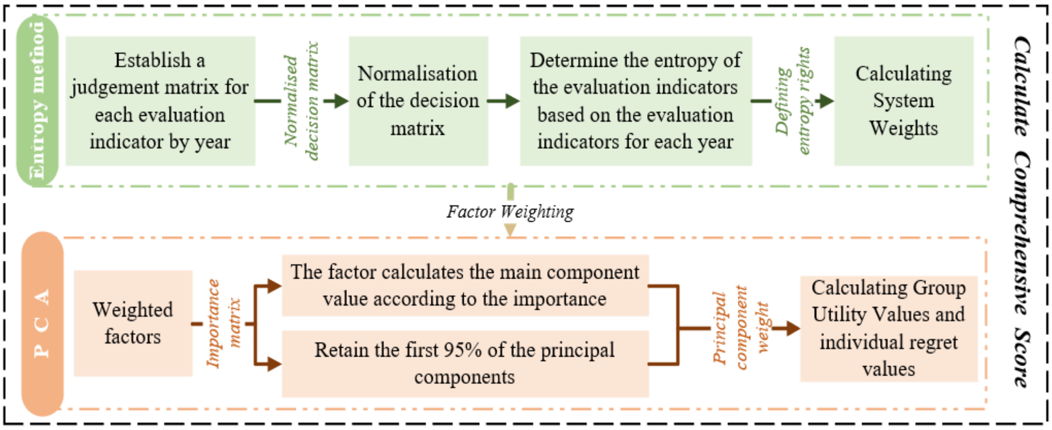

Figure 6: Process of Calculating Comprehensive Score

(4) Solution of Green Adjusted Coefficient(GAC)

We try to map the obtained composite score F between [0.8,1.0] by mathematical equivalence transformation to get our desired green coefficient.

Step 1. F_2 obtained by logarithmic transformation.

$$F_2 = \log(F - F_{min}) \tag{10}$$

Step 2. Normalization process gives F_3;

Step 3. Linear transformation gives GAC $\in$[0.8,1.0];

$$GAC = 0.8 + 0.2 * F_3 \tag{11}$$

2.1.2 Definition of GGDP

Multiplying the green adjustment factor by the corresponding real GDP, we end up with the GGDP under our definition:

$$GDP = GAC * GDP \tag{12}$$

2.2 Results Visualization and Global Climate Impacts

2.2.1 Results Visualization

Using the previous sections of the chapters, we calculated the 2012-2017 GGDP for the selected countries, and the results are shown in Fig. 7. The top countries in terms of average GGDP for 2012-2017 include the United States ($15,228 billion), China ($9,386 billion) Japan ($4,166 billion), and Germany ($1,181 billion). The bottom countries are Yemen ($29.68 billion) and Chad ($9.77 billion).

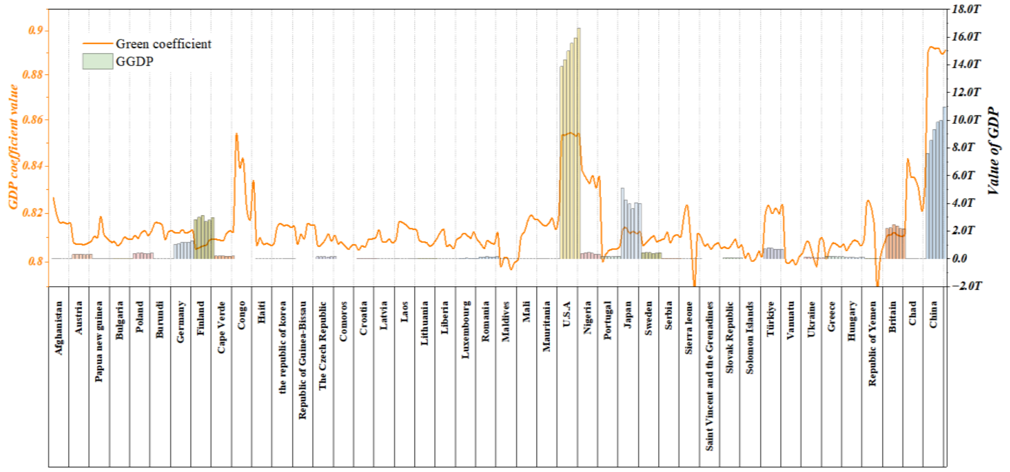

Figure 7: Results of GGDP of Different Countries

2.2.2 Global Climate Impacts

Next, in order to analyze the measurable impact of this GGDP on climate, we first obtained the global GGDP based on the calculated GGDP of each country, combined with the per capita weighting method, and then we selected the following climate factors shown in Fig.8: global temperature increase rate, global CO2 emission growth rate, global forest area change rate, Antarctic ice cover reduction rate, and global ocean temperature increase rate [7].

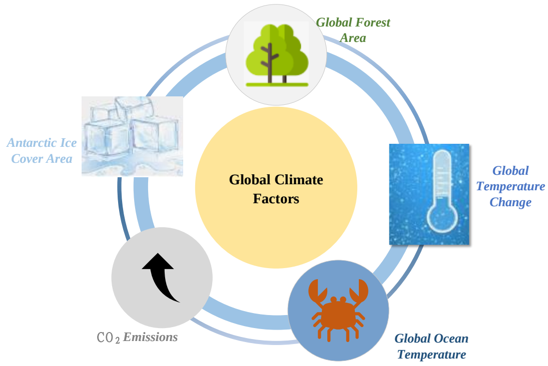

Figure 8: Global Climate Factors

Spearman correlation analysis was then used to explore the correlation between global GGDP and climate factors [8]. The calculated results are shown in Fig. 10. we found that the top three climate factors (negative) correlations with the constructed global GGDP are global CO2 growth rate (-0.9), global temperature growth rate (-0.7), and global ocean temperature rise rate (-0.6), which show a strong overall impact on climate. And the radar plot of the correlation coefficients of each climate factor shown in Figure 9 is obtained for visualization [9].

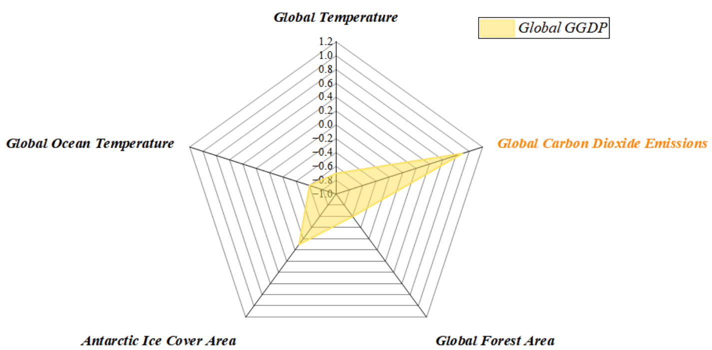

Figure 9: Correlation Effects of GGDP and Various Climate Factors

2.3 Model Validation

We conducted correlation analysis on 11 indicators in the three dimensions involved in the construction of GGDP, and the results are shown in Tab.4.

Table 4: Correlation Matrix of Standardized Data

	Nitric oxide emissions	Number of articles in scientific and technological	Natural gas rent	GDP per capita	Per capita carbon dioxide emissions	Proportion of renewable energy in total energy	GDP growth rate per capita	Methane emissions	Renewable inland fresh water resources	PM2.5 concentration	Proportion of urban population
Nitric oxide emissions	1.00	0.90	-0.03	0.08	0.30	-0.19	0.18	1.00	0.91	0.26	0.11
Number of articles in scientific and technological	0.90	1.00	-0.08	0.28	0.50	-0.30	0.14	0.91	0.94	0.03	0.28
Natural gas rent	-0.03	-0.08	1.00	-0.17	-0.22	0.25	-0.09	-0.01	-0.01	0.42	-0.12
GDP per capita	0.08	0.28	-0.17	1.00	0.82	-0.37	0.00	0.09	0.15	-0.46	0.67
Per capita carbon dioxide emissions	0.30	0.50	-0.22	0.82	1.00	-0.62	0.09	0.31	0.35	-0.39	0.747(
Proportion of renewable energy in total energy	-0.19	-0.30	0.25	-0.37	-0.62	1.00	-0.06	-0.18	-0.14	0.21	-0.51
GDP growth rate per capita	0.18	0.14	-0.09	0.00	0.09	-0.06	1.00	0.17	0.16	-0.13	0.07
Methane emissions	1.00	0.91	-0.01	0.09	0.31	-0.18	0.17	1.00	0.94	0.25	0.10
Renewable inland freshwater resources	0.91	0.94	-0.01	0.15	0.35	-0.14	0.16	0.94	1.00	0.11	0.10
PM2.5 concentration	0.26	0.03	0.42	-0.46	-0.39	0.21	-0.13	0.25	0.11	1.00	-0.39
Proportion of urban population	0.11	0.28	-0.12	0.67	0.75	-0.51	0.07	0.10	0.10	-0.39	1.00

It can be seen that most of the data correlation coefficients are close to 0, indicating that the correlation between the corresponding variables is low. This further verifies that our variables can be considered as independent indicators, indicating that our model meets the independence test and gives reliable and accurate results [10].

3. Conclusions

In order to adjust traditional GDP to achieve a comprehensive measure of the sustainability of national economies and to optimize national policymaking, we construct the Green GDP (GGDP) to analyze the potential impact of this economic accounting approach incorporating environmental factors on global climate and countries at different levels.

First, we construct an assessment system of 11 indicators to measure GGDP in 3 dimensions: economic development, resource use and environmental pollution, and selects 24 countries as samples. Based on Coupled EWM-PCA, we construct Green Adjustment Coefficient (GAC) to adjust GDP to GGDP. Impact measurement based on Spearman Correlation. Results show that GGDP has the greatest correlation (-0.9) to suppress global CO_2 emissions, followed by global temperature (-0.7) and global ocean temperature (-0.6).

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