The Standard for the Health of Economics: GGDP or GDP?

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Abstract. With the development of society and technology, the earth's environment is getting worse. To ease the burden on the earth, this paper refer to SEEA accounting system and establish GGA System Model to evaluate the relationship between economic development and ecological environment. Based on this, the paper calculate GGDP and its related indicators, and use Spearman's correlation coefficient to analyze the relationship between GGDP and climate. In addition, the K-Means clustering algorithm is used to divide 59 countries into five categories according to GGDP and related indicators. At the end, this paper states that the growth of GGDP will have a positive impact on the climate, whereas in some cases GGDP is negatively correlated with economic development indicators.

Keywords: GGA System Model; Correlation Analysis; Clustering Model; GGDP.

1. Introduction

Gross Domestic Product (GDP) is well-known as an effective method to measure the state of a nation's economy and the level of development and the result of the production activities of all permanent units in a country (or region) within a period. However, the higher production also brings more resource consumption and pollution, resulting in harmful influence on the economy health in the long term[1]. It's important to formulate a new standard to measure the health of a nation's economy by adding "Green" into the GDP system. Therefore, a balance between the economy and the environment is found.

17 types of data are selected to build the GGDP accounting Model based on the SEEA system. Excepted from the GDP of countries, the collected data includes the indicators from: depletion of natural resources(energy, field, water and forest consumption), damage of environmental pollution(loss of environmental degradation: depreciation for fixed assets, natural disaster, physical health; cost of pollution treatment: virtual liquid waste, virtual flue gas and virtual solid waste treatment and actual treatment) and environmental improvement benefit(ecological value of green plants: absorption of urban dust, carbon fixation and oxygen release, air purification and climate regulation; life extension). The data describes the natural resources of 260 countries and regions and the time span from 2010 to 2021.

1.1. Notation

The main mathematical notations used in the paper are shown in table.1.

Table.1. The main Notations

Symbol	Description	Symbol	Description
V_x	The value of x	S_x	The total area of x
N_x	The amount of x	C_x	The cost of x
P_x	The unit price of x	L_x	The loss of x
ΔS_x	The area change of x	ΔC_x	The unit of x

2. The GGAS Model Based on SEES and Its Climate Impact

2.1. The building of Green GDP Accounting System

Indicators used to calculate GGDP are selected and shown in Table 2.

Table.2. GGDP Indicators（Updated）

GGDP	Primary Indicators	Secondary Indicators	Indicators
GGDP	Depletion of Natural Resources		Energy Consumption Field Consumption Water Consumption Forest Consumption
	Damage of Environmental Pollution	Loss of Environmental Degradation	Depreciation for Fixed Assets Natural Disaster Physical Health
		Cost of Pollution Treatment	Virtual Liquid Waste Virtual Flue Gas Virtual Solid Waste Treatment Actual Treatment
	Environmental Improvement Benefit	Environmental Improvement Benefit	Absorption of Urban Dust Carbon Fixation and Oxygen Release Air Purification Climate Regulation
		Life Extension	Life Extension

The formulas used in calculating GGDP are classified into three classes and listed in Table.3, Table.4, Table. 5.

Table.3. Accounting Methods for Indicators（Depletion of Natural Resources）

Indicators	Formulas
Energy Consumption	$V_{Energy}=\sum_{i=1}^{3} N_{i,Energy}\cdot P_{i,Energy}$
Field Consumption	$V_{Field}=\Delta S_{Field}\cdot P_{Field}$ $P_{Field}=\frac{Gross\ Energy\ Production}{S_{Field}}$
Water Consumption	$V_{Water}=N_{Water}\cdot P_{j,Water}$ $P_{j,Water}=\frac{F_j}{Q_j}\cdot\alpha_j$ $\alpha_j=\begin{cases}3\% & R_i\in[0,500]\\ 3\% - \frac{1}{1250}(R_j-500)\% & R_i\in[500,3000]\\ 1\% & R_i\in[3000,\infty]\end{cases}$
Forest Consumption	$V_{Forest}=\Delta S_{Forest}\cdot P_{Forest}$

$N_{i,Energy}$ is the consumption reduction of the each category of energy, $P_{i,Energy}$ is the real-time unit price of the each category of energy. Here only consider the Depletion Value of three fossil energy sources – Oil, Coal, and Natural Gas. ΔS_{Field} is the change area of field resources, P_{Field} is the real-time unit price of field resources. S_{Field} is the total area of field. Considering the availability of the data, the gross energy product is replaced by traditional GDP. N_{Water} is the consumption and reduction of water resources, P_{Water} is the real-time unit price of water resources. In the estimation of water resource price, the empirical method that is easy to operate and internationally used is used for estimation[1]. $P_{j,Water}$ is the unit price of water resources in the country j; F_j is the total value created by water industry producers in country j, which traditional GDP is used to approximately replace; Q_j is the water consumption of country j; α_j is the coefficient of consumer willingness to pay in country j[3]. R_j is the per capita water resources of country j without distinguishing the water industry. ΔS_{Forest} is the change area of forest resources, P_{Forest} is the average unit price of various forest resources.

Table.4. Accounting Methods for Indicators（Damage of Environmental Pollution）

Indicators	Formulas
Depreciation for Fixed Assets	$L_{DFA}=W_{Industry}\cdot 5.5\% \cdot 5.2\%$
Natural Disaster	$L_{Natural\ Disaster}=L_{Earthquake}+L_{Geology}+L_{Flood}+L_{Drought}+L_{Ocean}+L_{Fire}$
Physical Health	$HL_{j,k}=HC_{j,k}\cdot \Delta HL_{j,k}$ $\Delta HL_{j,k}=\Delta NP_j\cdot \eta_k \cdot [1-1/\exp(\beta_k\cdot \Delta m)]$ $HC_{j,k}(t)=HC(2015)\cdot(1+\%\Delta GDP+\%\Delta CPI)^u$ $\%\Delta GDP=\frac{GDP\ Per\ Capita\ in\ year\ t-GDP\ Per\ Capita\ in\ 2015}{GDP\ Per\ Capita\ of\ Beijing\ in\ 2015}\cdot 100\%$ $\%\Delta CPI=\frac{National\ CPI\ in\ year\ t-National\ CPI\ in\ 2015}{National\ CPI\ of\ Beijing\ in\ 2015}\cdot 100\%$
Virtual Liquid Waste Virtual Flue Gas Virtual Solid Waste Treatment	$C_{Virtual}=\sum_{i=1}^{3} N_{i,Pollution}\cdot C_{i,Pollution}$
Actual Treatment	Direct Access to Yearbook

L_{DFA} is the Loss of Depreciation for Fixed Assets. The depreciation rate of fixed assets caused by environmental pollution is difficult to obtain, so the method proposed by Xu Heng and Li Jihong[4] is used. $W_{Industry}$ is the total industrial output value of the country, which is replaced by GDP. $L_{Natural\ Disaster}$ is the Loss of Nature Disaster. According to the data of the global disaster data platform, Earthquake, Geological Disaster, Flood, Drought, Ocean, Forest, and Grassland Fire are selected. $L_{Physical\ Health}$ is the Loss of Physical Health. The Exposure-Response Function[6] is used to measure the relationship between the change of PM2.5 concentration and human health, so that the Loss of Physical Health can be evaluated quantitatively[5]. Human health problems such as death or illness caused by PM2.5 are defined as Health Terminal[6]. $\Delta HL_{j,k}$ is the unit quantity of Health Terminal k in country j caused by PM2.5 pollutants; Δm is the difference between the median value of the assessed PM2.5 pollution grade concentration range and the reference value of the PM2.5 pollutant concentration; ΔNP_j is the population of country j; η_k is the incidence rate of k Health Terminal β_k is the exposure - corresponding coefficient of k Health Terminal.

The reference value of PM2.5 pollutant concentration is based on the World Health Organization's daily average PM2.5 concentration guideline（$10\mu g/m^3$）, For η_k and β_k, we refer to previous research to take the value[5].$HC_{j,k}$ is the unit economic loss of each Health Terminal. $HC_{j,k}(t)$ is the unit economic loss of k Health Terminal in country j caused by PM2.5 pollutant in year t; $HC_{Bejing}(2015)$ is the benchmark data selected, namely the economic loss of Health Terminal units in Beijing in 2015; u is the Income Elasticity, and the value is 0.8[8]; $\%\Delta GDP$ and $\%\Delta CPI$ are the Proportion Coefficients related to GDP Per Capita (Gross National Product) and National CPI (Consumer Price Index) respectively. $N_{i,Pollution}$ is the emission of pollutant I, $C_{i,Pollution}$ is the unit treatment cost of item i pollutant. The Maintenance Cost Pricing Method is used to estimate[1] the $C_{Virtual}$ and choose Liquid Waste, Flue Gas and Solid Waste to calculate the cost of virtual pollution treatment. Referring to the existing research[9].

Table.5. Accounting Methods for Indicators（Environmental Improvement Benefit）

Indicators	Formulas
Absorption of Urban Dust	$V_{AUD}=\Delta S_{Forest}\cdot 10.9\cdot \Delta C_{AUD}$
Carbon Fixation and Oxygen Release	$V_{CFOR}=\Delta S_{Forest}\cdot 328.5\cdot 40.94\cdot 12\cdot 400$
Air Purification	$V_{AP}=\Delta S_{Forest}\cdot 0.296\cdot \Delta C_{AP}$
Climate Regulation	$V_{CR}=\Delta S_{Forest}\cdot 0.9\cdot 24\cdot 189\cdot \Delta C_{E}$
Life Extension	$V_{Life\ Extension}=Y_{Extension}\cdot \Delta E\cdot CP$

V_{AUD} is the value of Absorption of Urban Dust, ΔS_{Forest} is the area of forest change; ΔC_{AUD} is the unit dust absorption cost，V_{CFOR} is the value of Carbon Fixation and Oxygen Release, V_{AP} is the value of Air Purification, ΔC_{AP} is the unit purification cost，V_{CR} is the value of Climate Regulation, ΔC_{E} is the unit electricity price.

2.2. The Spearman's Rank Correlation Analysis

Spearman rank correlation coefficient is a nonparametric measure of the monotonic association to investigate the linear relations between two variables**[10]**. To prove that replacing GDP with GGDP will has a good effect on the climate, Spearman's Rank Correlation is used to further analyze the correlation between the GGDP and climate. For sample size of n, the data are converted into grade data, and the correlation coefficient ρ between variables X and Y is defined as

$$\rho = 1-\frac{6\sum d_i^2}{n(n^2-1)} \tag{1}$$

In which the $d_i=x_i-y_i$.

2.3. Global Impact of GGDP on Climate Mitigation based on three standards.

The GGDP is closely connected to the climate mitigation and it's a more reasonable indicator of the heath of a country compared to GDP. Now analyze its impact on different countries around the world. To better find the impact of environment, three indicators are used here: they are **the GGDP**, **the GGDP index** and **GGDP per capita**.

The three indicators can exhibit the GGDP in different dimensions, the GDP result. Since the GGDP might be seriously decided on a countries' economic strength and population base. In comparison section, it can't successfully show the impact of national source. Here set a new indicator GGDP index. For country j, the GGDP index I_j is represented as:

$$I_j=\frac{GGDP_j}{GDP_j} \tag{2}$$

Dividing the GGDP by GDP of country j, we weaken the influence of economic aggregate and use a better presentation to strengthen the impact of natural sources on GGDP. Another per capita use the population of a country to cut down the impact of cardinal population number in the country. The formula GGDP per capita is built:

$$B_j = \frac{GGDP_j}{CP_j} \tag{3}$$

2.4. K-means Clustering of GGDP

To show the impact of GGDP on different countries, K-means is used here to cluster the GGDP indicator. An appropriate number of clusters is required to get a good clustering result. The idea of the Elbow method is to measure the distance between the data and the center of the cluster and show the trend of the sum of squared errors (SSE)[11]. Based on certain range they are classified and SEEs are calculated and visualized. The bend node of the visualized line is the best number of clusters.

$$W_k = \sum_{r=1}^{k} \frac{1}{n_r} D_r \tag{4}$$

where k is the number of clusters, nr is a data point in the cluster r, and Dr is a sum of the distance between data points in the cluster[11]. Here use the elbow method and the best number of clusters is 4. However, considering the hierarchy of countries, 5 is chosen here as our number of clusters eventually.

Using u_k to represent the mean vector of clustering k, x_i to represent the i^{th} sample in dataset $X = \{x_1, x_2, ..., x_3\}$, The objective function of K-means model is:

$$J = \sum_{i=1}^{N} \sum_{k=1}^{K} r_{ik} \, ||x_i - u_k||^2 \tag{5}$$

r_{ik} equals to 1 when the sample x_i is clustered to the k clustering, else it is 0.

$$r_{ik} = \begin{cases} 1, & x_i \in k \\ 0, & x_i \notin k \end{cases} \tag{6}$$

50 is set here as the number of iterations and it can have a good clustering result.

Given the basic GGDP model build above, the K-means model is used to measure the impact on different countries using three types of standards. To visualize the results, we draw the diagrams and classify the countries into five classes based on their GGDP, GGDP index and GGDP per capita.

3. Results

3.1. The Result of GGDP

Concerning the availability and integrity of the data, about 60 countries are filtrated and their GGDP are calculated using the Green GDP accounting system built above. The world map shown in Figure 1 shows the state of GGDP in 59 countries. A high GGDP represent a good job the country is doing in balancing the natural sources and the economy.

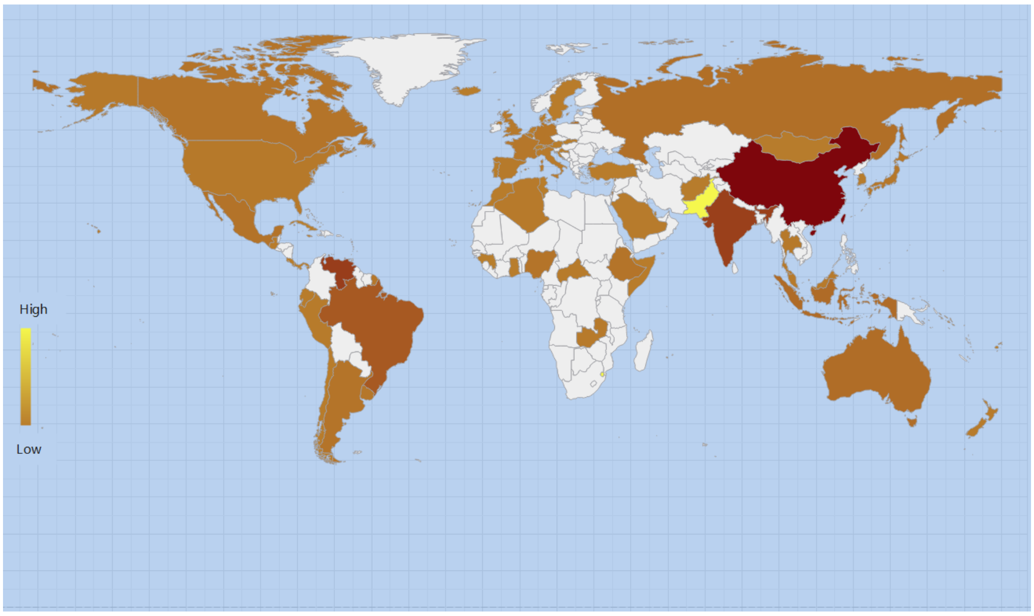

Figure 1. The GGDP Result in 59 countries from 2011 to 2017

Result gives a general conclusion about the GGDP around the world. The color of the country shows the condition of GGDP. General speaking, the countries in Europe and America did a better job in improving its GDP while protecting the environment at the same time.

3.2. The Spearman's rank Correlation Coefficient between GGDP and Climate indicators

Three relatively reliable indicators are selected to explore their correlations with the GGDP: the ocean annual heat content in 700m depth, the sea level and the concentration of CO2. The Spearman's rank correlation coefficient is set as the correlation coefficient in the analysis and acquire the result, as shown in Table 6.

Table.6. Comparison of power load forecasting of 403 line

Correlation coefficient	GGDP	Ocean heat content	Sea level	CO_2
GGDP	1			
Ocean heat content	-0.5357	1		
Sea level	-0.1786	0.7143	1	
CO_2	-0.2143	0.8928	0.8929	1

The result shows that the indicators have negative correlations with GGDP. When the GGDP increases, the heat connect of ocean will decrease, so does the sea level and the concentration of CO2. And the heat content will have a faster decrease.

3.3. GGDP, GGDP index and GGDP per Capita Rankings

Among the 60 typical countries, the GGDP rankings in the past decade is shown in Table 7. The table 8 list below show the 12 countries ranking of their GGDP index and GGDP per capita.

Table.7. GGDP ranking of a few countries in the past decade

	Country	GGDP		Country	GGDP
1	The Solomon Islands	-121845935	7	Qatar	-96181016417
2	Equatorial Guinea	-18539531309	8	Panama	-1.68729E+11
3	Fiji	-20443461738	9	Costa Rica	-1.91754E+11
4	Iceland	-35478113094	10	Croatia	-2.1242E+11
5	Tunisia	-42160001691	11	Slovakia	-2.24651E+11
6	Jamaica	-52006438047	12	Switzerland	-2.56239E+11
			...	…	…

Table.8. GGDP index ranking and GGDP per Capita Ranking

Country	GGDP Index	Country	GGDP Index	Country	GGDP Per Capita	Country	GGDP Per Capita
The Solomon Islands	0.224	Italy	-0.094	The Solomon Islands	511	Fiji	-1900
US	-0.006	Turkey	-0.102	US	-331	Jamaica	-2777
Switzerland	-0.053	Netherlands	-0.107	Tunisia	-403	Italy	-3051
Japan	-0.082	Republic of Korea	-0.109	Türkiye	-1062	Japan	-3171
Qatar	-0.090	Tunisia ...	-0.113	Equatorial Guinea	-1627	India ...	-3407

3.4. The Result of K-Means Clustering

By using the K-means Clustering Algorithm, we cluster the GGDP, GGDP index and GGDP per capita of dozens of countries selected and get five categories of countries.

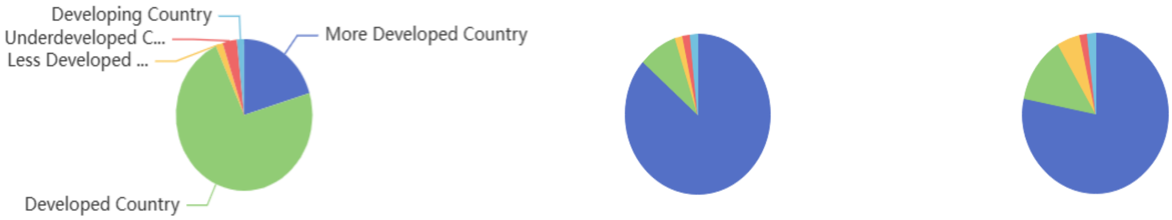

Figure.2. Country Classification Chart on GGDP, GGDP Index and GGDP Per Capita

The diagrams Figure 2 show the classified countries are relatively unbalanced though the developed countries and more developed countries take up the main portion.

3.5. Further Analysis of the Impact on Climate and Economy

Replacing GDP with GGDP will meet with some resistance, economics might give in to caring more for environment. To prove the feasibility of GGDP, for global GGDP and global GDP, correlation analysis is used to further study their relationship with Carbon Dioxide Concentration, Sea Level Height and Ocean Heat Content, as shown in Figure.3.

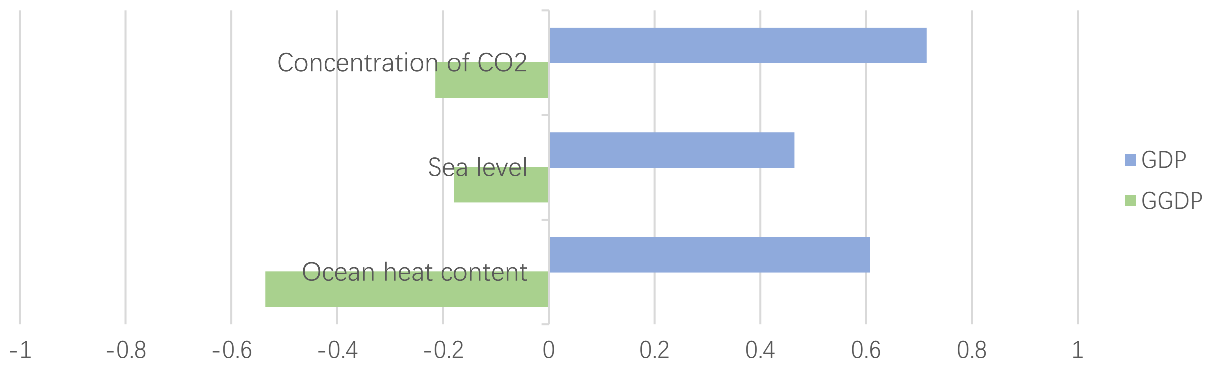

Figure.3. Correlation coefficient about the Climate Mitigation

It's found that GGDP and indicators are negatively correlated, and GDP and indicators are positively correlated. Combining with the corresponding calculation formula, from a certain point of view, it can be judged that the growth of GGDP will have a positive impact on the climate, and the growth of GDP will have a negative impact on the climate.

For the five categories of countries in the world, a typical country is selected from each category to analyze the impact of GDP on the annual inflation rate, non-performing loan rate of banks and GDP growth rate per capita of the country, as shown in Figure.4.

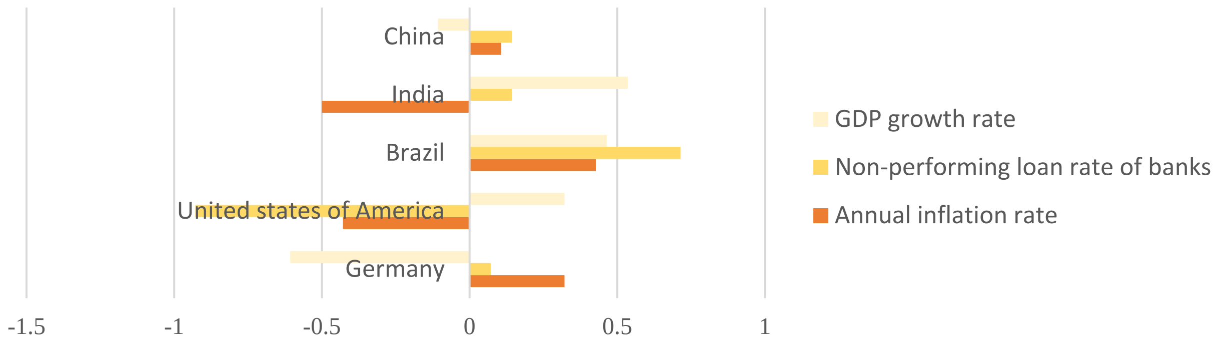

Figure.4. Comparison of Economic Correlation Efficient

The study found that GGDP is negatively correlated with the growth rate of GDP per capita in the More Developed Country and Developing Country, and positively correlated with the growth rate of GDP per capita in the middle countries. The other two indicators have completely different correlations for different types of countries, and corresponding analysis is needed for specific countries.

In addition, the GGDP representing five different categories of countries are ranked from largest to smallest as the United States, Germany, Brazil, India and China. When impacted by the level of environmental protection, the level of economic development drops rapidly in the early stage and then rises slowly[11]. This conclusion is in good agreement with our GGDP ranking: The United States and Germany are economically developed countries, so GGDP is higher; China is in a critical period of development, so correspondingly, GGDP is the lowest. This shows that this system established by us can well measure the economic and environmental level of a country.

4. Conclusion

In this paper, GGA System Model is established to evaluate the relationship between economic development and ecological environment. Rigorous mathematical methods such as Spearman's correlation coefficient and K-Means clustering algorithm are used to analyze the impact of the GGA System Model on climate and economy, and convincingly proved that using our established system to measure the development of a country can mitigate global climate problems.

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