

Research of Green GDP Evaluation System Based on AHP Model

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Abstract. GDP (Gross domestic product) is of extraordinary significance in measuring national economic development, while it tends to have inaccuracy. The concept of Green GDP (hereinafter referred to as GGDP), which introduces environmental factors into the accounting system, is more conducive to sustainable development and the building of a harmonious economy. This paper selects main factors and establish a GGDP evaluation index system using the AHP model, then conducts the robustness test by one-dimensional linear regression model and "children dropping out of school" model. Finally, a sensitivity analysis is carried out to prove the accuracy. The results indicate that GGDP system contributes to improving environmental conditions and promoting sustainable development.

Keywords: GGDP, GDP, AHP Model, Sustainable Development.

1. Introduction

GGDP is an alternative indicator of economic growth that incorporates environmental consequences of that growth by including the depletion of natural resources and degradation of the environment [1]. Traditional GGDP prediction methods are based on two components of the green economy: quantitative feature (standard methodological algorithm) and qualitative feature (opportunity costs) within a common GGDP accounting framework [2]. Or adopt the emergy analysis method to estimate sustainability and calculate the environmental cost [3]. Some also selected GGDP as the output index to calculate the eco-efficiency of a certain region and further evaluate its sustainable development level by the super-SBM model [4]. The innovations of this paper lie in the selection of research indicators and the methodology used to analyze them.

2. Exploring the GGDP Model: A new attempt

2.1. Main Factors and Data Selection

(1) Main factors

The core content and concept of GGDP is the final result of all economic activities in a certain country or region within a specified period, calculated after considering various factors such as economy, natural resources, and natural environment [5]. To reveal the relationship between economy and ecology, GGDP represents the ideology and requirements of sustainable development [6]. For a sustainable and healthy economic system, economic growth needs to account for the decline in buffering capacity, self-cleaning capacity, resilience and environmental pollution in the economy. Moreover, energy consumption is found to be an important influence, and it decreases green growth [7]. Based on the above definitions, this paper selects seven factors, which are land depletion, forest depletion, mineral depletion, water depletion, exhaust emissions and solid waste discharge.

(2) Data selection

Green accounting indicators such as GGDP and natural resource value frequently appear in media reports and government documents, and are often compared with GDP. However, issues such as confusion in the concepts and unclear relationships of several indicators are prominent [8]. Environmental costs are generally considered to include two main components, one is the value of resource depletion and the other is the value of environmental degradation [9]. This paper collected

data globally for 19 indicators from sources including, but not limited to, the World Intellectual Property Organization, the World Bank, the World Energy Council, Weather Spark and other authoritative organizations or institutions.

2.2. AHP: Establish GGDP Evaluation Index System

(1) Establishing a hierarchical model

The decision problem is decomposed into three levels, the top level is the objective level M, i.e., the selection of suitable indicators to construct the GGDP evaluation system; the bottom level is the indicator level, i.e., the 18 influencing factors P1, P2...P18; the middle level is the criterion level, including Natural Resources C1, Social Sustainable C2, GDP C3, Environmental Protection C4 and Ecological Benefits C5.

By performing gray correlation analysis on the secondary indicators of the primary indicators other than GDP, and sorting the correlation coefficients in descending order and taking the first few secondary indicators with larger weights(Fig 1) , this paper established the index system for evaluating GGDP(Fig 2).

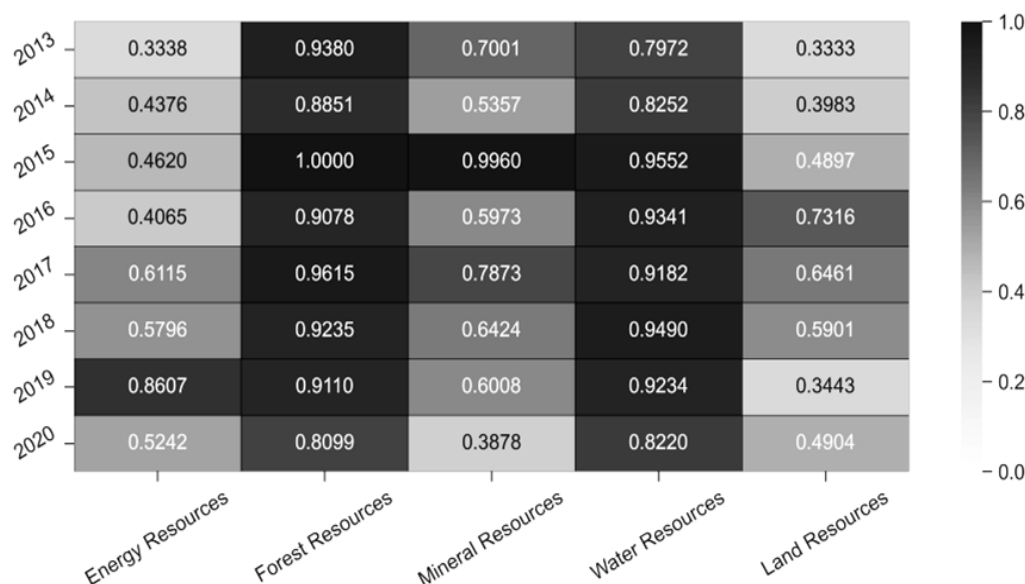


Fig 1. Gray off Coefficient Heat Map Related to Natural Resources

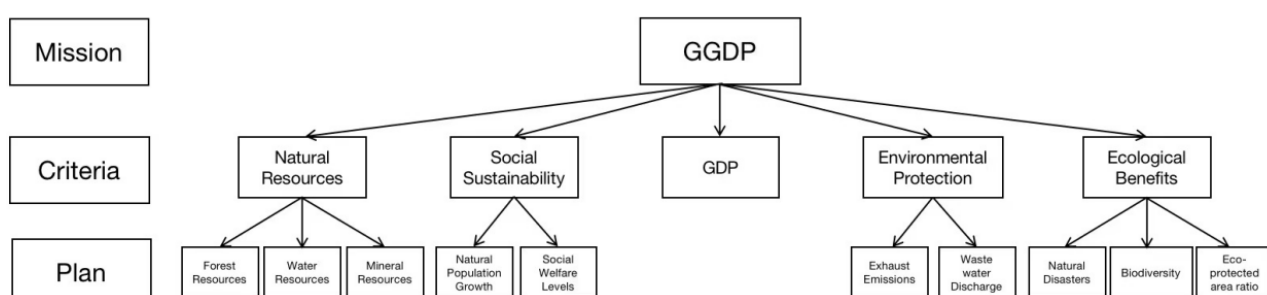


Fig 2. Weighting Indicators

(2) Model solving

Construct the judgment matrix M-C: compare the elements in the base layer C to obtain the pairwise comparison matrix.

It is easy to solve the eigenvalues of M-C for $\lambda_{\max}=5.2913$ and the weight vector $\omega_i=(0.1939, 0.0807, 0.5052, 0.1688, 0.0514)^T$

According to the formula $CI = \frac{\lambda_{\max}-n}{n-1}$, and so according to $CR = \frac{CI}{RI}$, this paper calculated that $CR = 0.0046 < 0.1$, which passed the consistency test.

The weight vectors calculated from the above two judgment matrices, the maximum eigenvalues CR_j and the consistency index CR_j are listed in the table. From the values of CR_j in the table, it can be seen that the matrices C-P all pass the consistency test.

Other calculations analogous to the above equation.

The specific results are shown in the Table 1.

Table 1. Calculation of Indicator Weights

Criteria	M			
	Arithmetic Average	Geometric Average	Eigenvalue	Average
C1	0.1912	0.1847	0.1939	0.1899
C2	0.0836	0.0769	0.0807	0.0804
C3	0.4924	0.4813	0.5052	0.4929
C4	0.1805	0.1608	0.1688	0.1700
C5	0.0523	0.0489	0.0514	0.0509
λ_i		5.291293701118392		
CR_j		0.06502091542821255		

(3) Differences in the impact of GDP and GGDP on climate mitigation

Table 2. Results of Regression

Results n=61									
	Non-standardized coefficient		Standardized coefficient	t	P	VIF	R^2	Adjusted R^2	F
	B	Standard error	Beta						
Constants	0.115	0.071	-	1.609	0.113	-	0.034	0.018	F=2.106
GDPGR	-1.049	0.723	-0.186	-1.451	0.015	1			P=0.152
Constants	0.103	0.071	-	1.44	0.155	-	0.025	0.009	F=1.535
GGDPGR	-1.056	0.852	-0.159	-1.239	0.022	1			P=0.220

Dependent variable: Sea Level GR

Note: ***, **, * represent 1%, 5%, 10% significance levels, respectively

Table 2 demonstrates the regression results. The analysis of the results of the F-test can be obtained that the significance P-value is smaller than 0.05, which presents significance at the level and rejects the original hypothesis that the regression coefficient is 0. Therefore, the model basically meets the requirements.

For the performance of variable co-collinearity, VIF is less than 10, so the model has no problem of multiple co-collinearity and the model is well constructed.

From the three aspects of sea level, CO₂, ocean heat, and temperature, the results are shown in Fig 3, 4, 5 and 6.

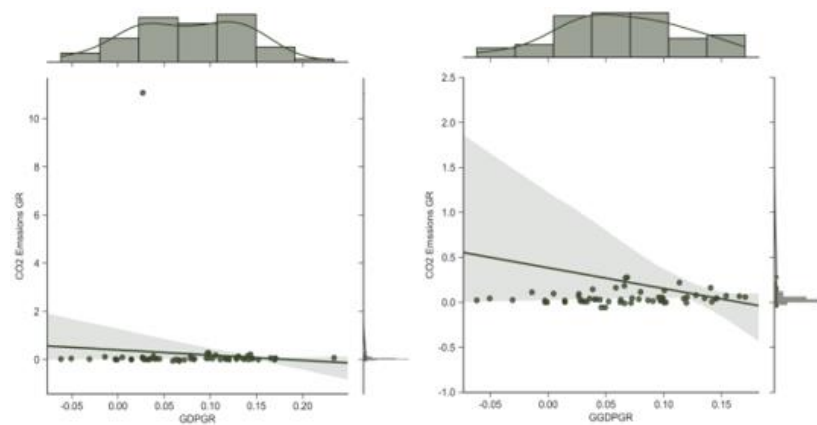


Fig 3. Results of Sea Level

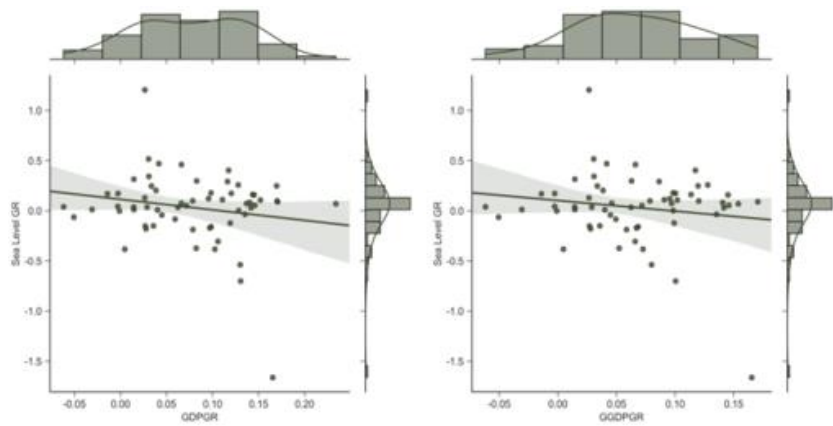


Fig 4. Results of CO₂

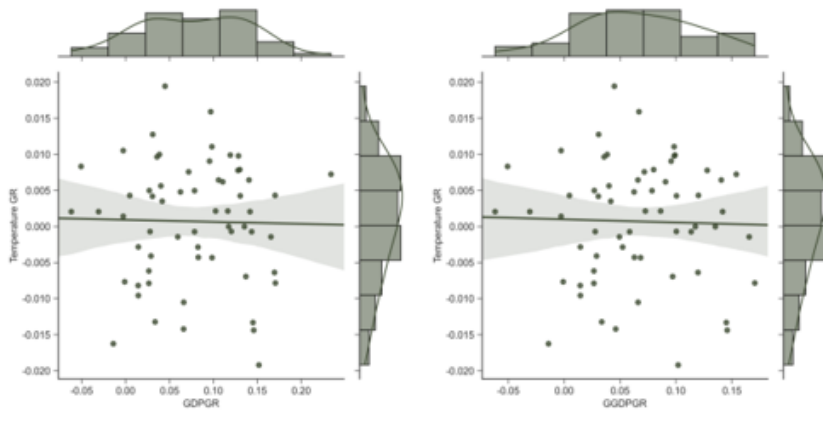


Fig 5. Results of Ocean Heat

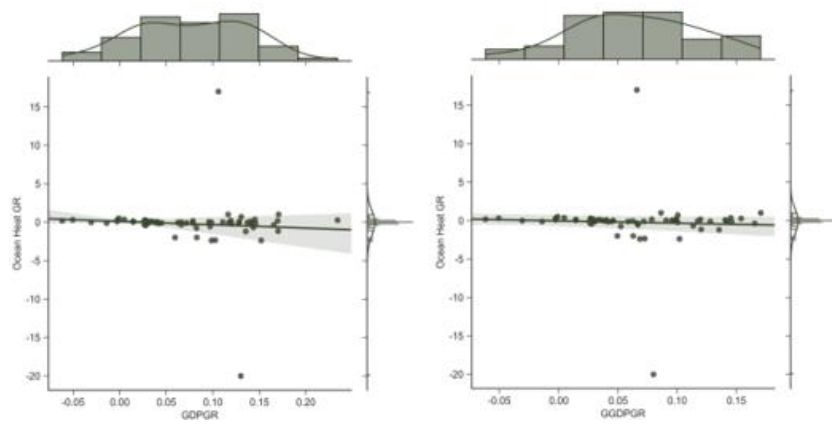


Fig 6. Results of Temperature

According to the results, compared with the GDP model, the GGDP model has a significant promoting effect on the sustainable development of climate, which can be concreted on sea level, CO₂, ocean heat, and temperature.

3. Robustness test

3.1. Simple Linear Regression and Lowess

Simple linear regression of selected climate indicators and GDP large countries.

In the grid plot below, simple linear regressions are performed for four meteorological indicators including CO₂ emissions, sea level height, ocean heat and temperature. In addition, this paper also calculated the GGDP for the US, China and Japan and performed a comparison and simple linear regression(Fig 7). Finally, there are simple linear regressions of each climate indicator and GGDP on the way. This all illustrates the high correlation between GGDP and climate indicators and that GGDP can be used to influence global climate mitigation.

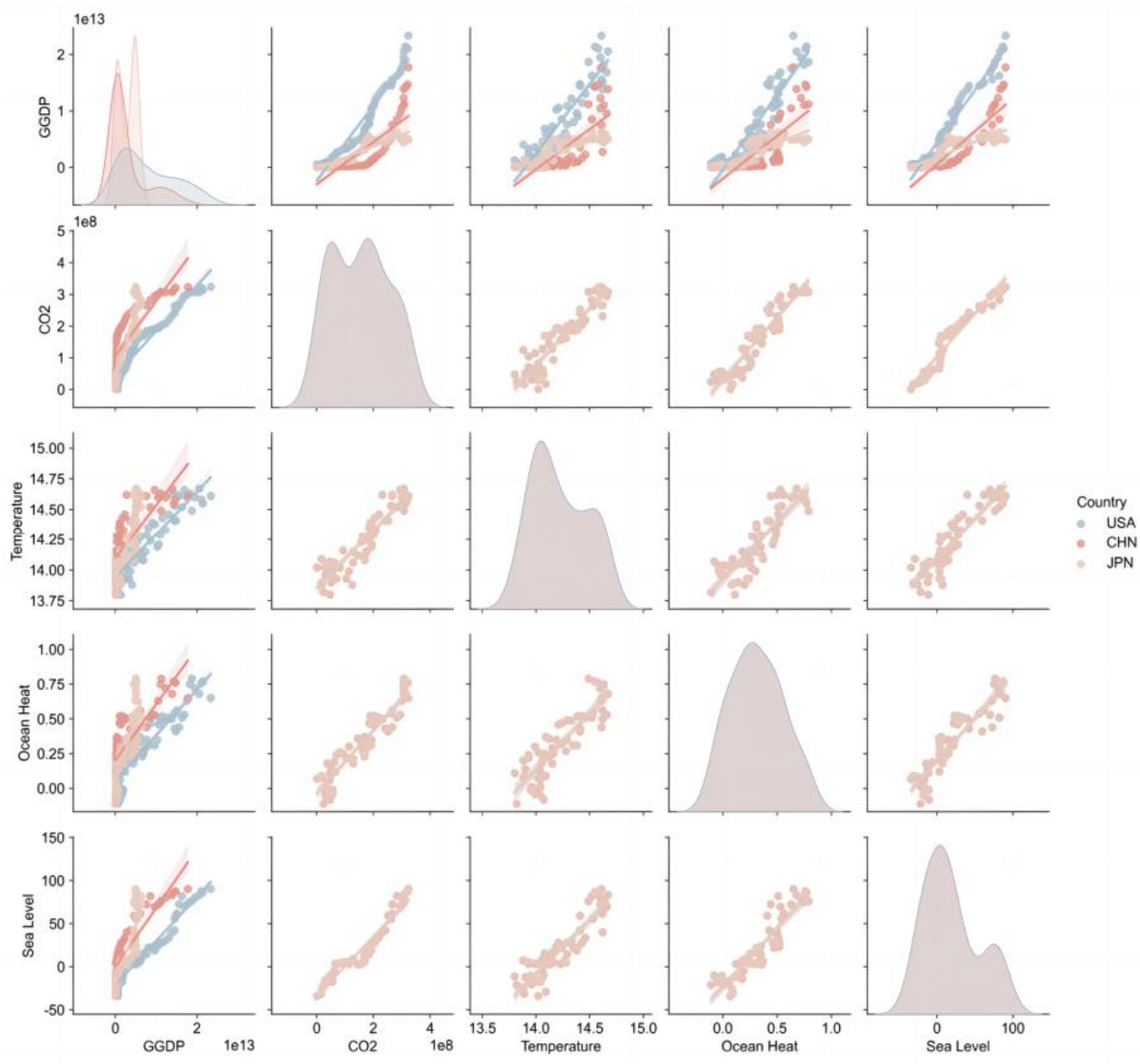


Fig 7. Combination Diagram

3.2. "Children Dropping out of School" Model

In order to further test the stability of the model, this paper creates a new model of "children dropping out of school", which is also a major innovation of this paper, as shown in Fig 8. Table 3, on the other hand, shows the names, equation, and explanations of the main variables.

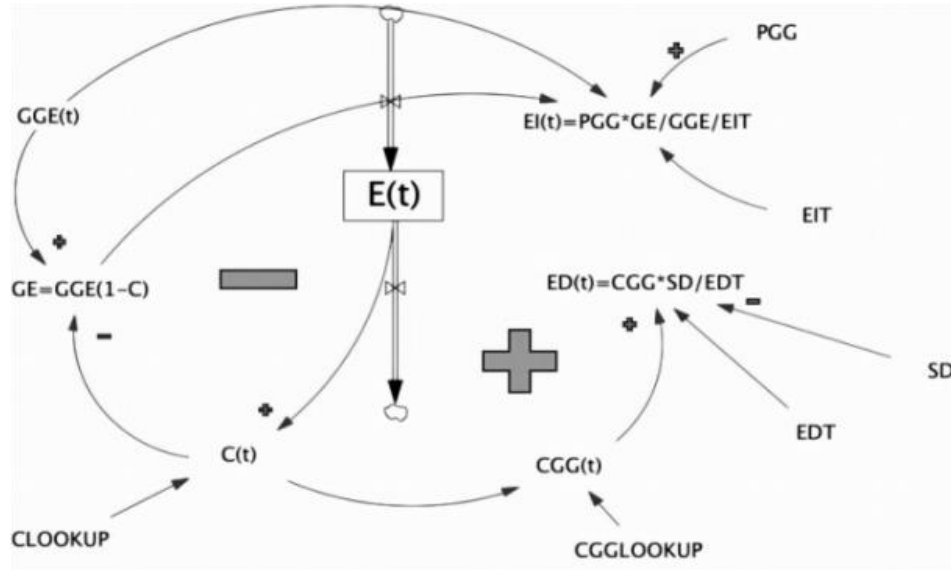
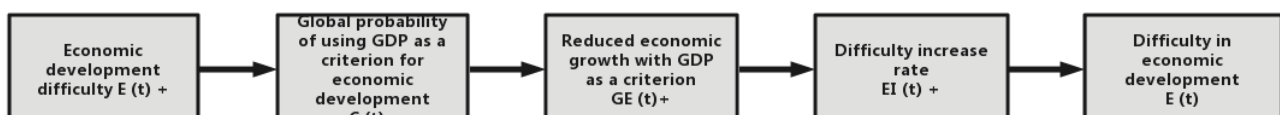


Fig 8. System Power Circuit

Table 3. Specification of primary variables

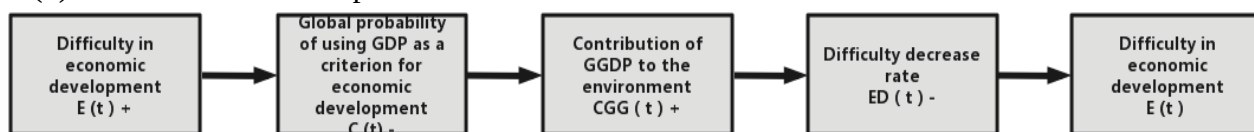
Name	Equation	Explanation
Inflow rate	$EI(t) = PGG * GE / GGE / EIT$	The article assumes that the impact factor of the difficulty of economic development due to the GGDP requirement is PGG, and again, due to an adjustment time, the article assumes EIT.
Outflow rate	$ED(t) = I * SD / EDT$	It is assumed here that the reduction of environmental management costs and economic losses from climate extremes has an impact factor of SD on the overall reduction of economic development difficulties. The paper assumes an adjustment time of EDT.
Economic development reduced for the environment under the GDP criterion	$GE(t) = GGE * (1-C)$	If the ratio of countries with global GDP as a criterion is C, the global economic growth sacrificed for the environment in the case of GGDP as a criterion is only 1-C of the economic growth sacrificed for the environment in the case of GDP as a criterion.
Impact factor 1	$I1 = 0.3$	Impact factor of GGDP requirement on the difficulty of economic development
Impact factor 2	$I2 = 0.7$	The impact factor of reducing the cost of environmental management and the economic loss caused by extreme weather on the reduction of the overall economic development difficulties
Adjustment time	$EDT(t) = 10$ years	/
Adjustment time	$EIT(t) = 5$ years	/
Initial value of flow level	$E(0) = 1$	/
Contribution of GGDP to the environment	$GGE(t) = 100$ billion yuan/year	/

(1) Negative feedback loop:



Since the economy can be developed at the expense of the environment to a greater extent under the GDP requirement, there can be less economic sacrifice and therefore to some extent, especially for developing countries, a short-term economic development boost.

(2) Positive feedback loop:



Although GDP-based economic development achieves greater economic growth in the short term, it simultaneously reduces environmental factors such as climate mitigation and green development, leading to a reduction of GGDP criteria to the environment and increasing the cost of future environmental management and economic losses due to climate extremes in the long term, thus proving that GDP does not reduce the difficulty of economic development relative to GGDP. The shift from GDP to GGDP indicators reflects that top-level design not only focuses on economic growth, but also on how to effectively reduce environmental damage while promoting stable economic growth^[10].

The article performs two parameter modulations. Regardless of the status quo economic development, $C(t)$ decreases to zero, that is, not just seek the economy with resources, although the short term may cause economic development pressure is higher and the process is slower, but due to the high degree of environmental protection, in the future development of GGDP to the environment, and eventually will slow down the economic development is difficult. If $C(t)$ is 1, although temporarily the pressure of economic development is slowed down and the rate is faster. However, starting from a long-term perspective, it will cause environmental problems such as increased climate change, increased climate extremes, and sharply reduced resources, thus showing that the potential disadvantage of using GGDP are much less than its benefits, and there is great value in using GGDP as a measure of economic health on a global scale, once again testifying to the previous point.

4. Sensitivity Analysis

This paper conducted a sensitivity analysis on the five indicators. The Figs of each indicator were changed by 5% and 10% and each obtained a new score. This process illustrated a linear relationship between the scores and Figs of indicators. The total score for a higher education system also response to the five scores linearly.

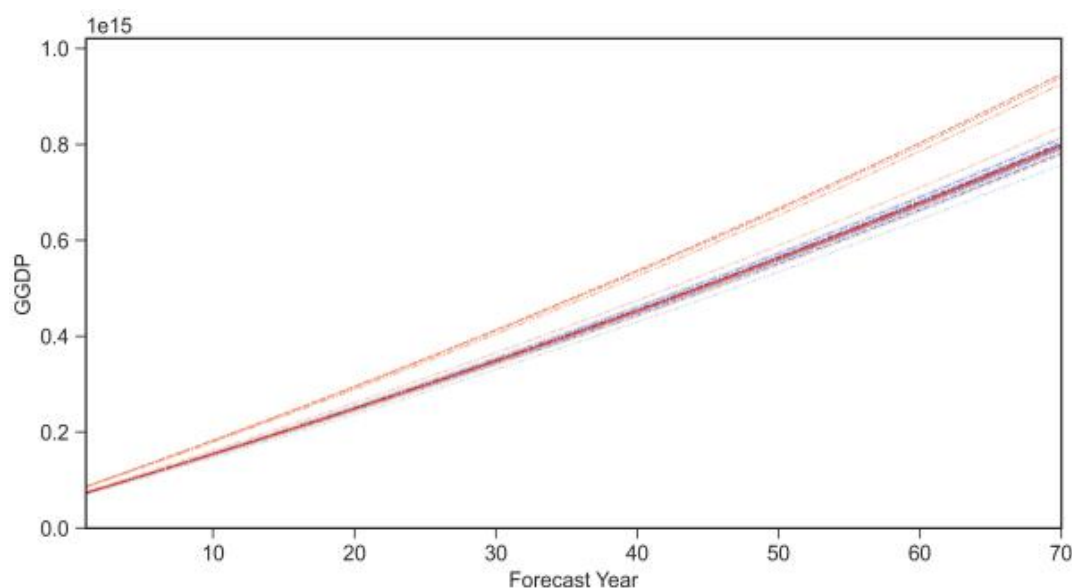


Fig 9. Sensitivity Analysis

Fig 9 indicates that there is no change in the trend of GGDP growth when five indicators change, which shows that our model is stable.

5. Conclusion

In this paper, the GGDP model was produced according to AHP, which passed the stability test and sensitivity test. The test results show the high correlation between GGDP and climate indicators compared with the GDP model. At the same time, GGDP helps to mitigate climate change and promote environmental sustainability, which is manifested in sea level, CO₂, ocean heat and temperature. Therefore, this paper suggests that the government incorporate environmental factors into GDP accounting and use the GGDP model, which can reduce the consumption and destruction of natural resources, alleviate environmental problems, and improve environmental conditions.

References

- [1] Stjepanović, S., Tomić, D., & Škare, M. Green GDP: An analysis for developing and developed countries [J]. *E+M Ekonomie a Management*, 2019, 22(4), 4–17.
- [2] Stjepanović, S., Tomić, D., & Škare, M. A new database on Green GDP; 1970-2019: a framework for assessing the green economy [J]. *Oeconomia Copernicana*, 2023, 13(4), 949975.
- [3] Hu, Jiangfeng, Lyu, Jingjing, Zhang, Xinyuan. Evaluating Agricultural Sustainability and Green GDP in China: An Emergy Analysis [J]. *International Journal of Environmental Research and Public Health*, 2022, 19(24).
- [4] Yi, QG, Chen, HT, Li, X, Ma, C, et al. Comprehensive assessment of regional sustainability via emergy, Green GDP and dea: A case study in GuiZhou province, China [J]. *Applied Ecology and Environmental Research*, 2021, 19(1):597-609.
- [5] Zhuo Wenjuan. Research on the Impact of Environmental Regulation Policies on China's Green GDP [J] *Financial Literature*, 2023, (06): 123-127.
- [6] Wei, Yigang, Li, Yan, Liu, Xinjing, et al. Sustainable development and green gross domestic product assessments in megacities based on the emergy analysis method-A case study of Wuhan [J]. *Sustainable Development*, 2019, 28(1).
- [7] Hussain, Z., Mehmood, B., Isimisaraka, RSM. Green Growth, Green Technology, and Environmental Health: Evidence From High-GDP Countries[J]. *Frontiers in Public Health*, 2022, 9.
- [8] Zhang Qi. Research on the Relationship between GDP and Green GDP, GEP, and Natural Resource Value [J] *China Statistics*, 2023, (01): 11-14.
- [9] Gao Minxue. Review and evaluation: "Green GDP" accounting was once a hot topic China Statistics, 2022, (07): 35-38.
- [10] Yang Qijie. The Path Selection of Promoting Green Development with Green GDP [J] *Journal of Hebei Youth Management Cadre College*, 2022, 34 (05): 84-88.