Research on Green Gross Domestic Product Accounting Based on a Comprehensive Evaluation Model

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Abstract. Traditional gross domestic product ignores environmental and resource costs, making it difficult to reflect the sustainability of economic activities. This study constructs a green GDP accounting model based on the United Nations System of Environmental-Economic Accounting, integrating resource consumption, environmental degradation losses, and pollution control costs. It quantifies the economic impact on the environment through 12 indicators. Using a green restoration rate model and the analytic hierarchy process, it assesses the potential for global climate mitigation using rainfall, greenhouse gas emissions, sea level, and biodiversity as indicators. Weighted analysis shows that biodiversity and greenhouse gas emissions have the greatest impact. Based on data from 2015 to 2023, the study uses China as a case study to combine climate impact models and entropy analysis in examining the multidimensional impacts of green GDP, with results showing that the environmental dimension holds the highest weighting at 39.2% and a projected 4.3% reduction in fossil fuel consumption over the next five years.. The study validates the application value of green GDP in global and Chinese climate mitigation efforts, providing scientific basis for optimizing resource allocation and formulating environmental policies, thereby contributing to the achievement of sustainable development goals.

Keywords: Green GDP, SEEA framework, Green Remedy Rate, Analytic Hierarchy Process, Sustainable development.

1. Introduction

Gross Domestic Product has long served as the primary metric for assessing national economic performance, guiding policy decisions and international comparisons. However, its neglect of environmental costs—such as resource depletion, ecological degradation, and pollution—renders it inadequate for evaluating sustainable development amid global challenges like climate change and resource scarcity. The Green Gross Domestic Product, or Green GDP, addresses these limitations by integrating environmental and resource costs into economic accounting. The United Nations System of Environmental-Economic Accounting provides a standardized framework for Green GDP, enabling a comprehensive assessment of economic health by balancing growth with environmental sustainability[1].

The escalating climate crisis, marked by rising greenhouse gas emissions, biodiversity loss, and sea level rise, underscores the need for metrics that capture the environmental consequences of economic activities. Existing studies demonstrate Green GDP’s potential to reduce carbon intensity and promote sustainable resource use, but challenges remain in developing standardized accounting models and applying them across diverse economic contexts, particularly in major economies like China. Current Green GDP frameworks often lack detailed indicator systems and robust methodologies for multidimensional impact assessment, limiting their global applicability[2-3].

This study constructs a Green GDP accounting model based on the SEEA framework to evaluate its climate mitigation potential globally and in China. The model incorporates a 12-indicator system to quantify resource consumption, environmental degradation losses, and pollution control costs. The Green Remedy Rate model and Analytic Hierarchy Process assess global climate impacts across four key indicators: precipitation, greenhouse gas emissions, sea level rise, and biodiversity. In China, the Climate Impact Model and Entropy Weight Method evaluate economic, social, and environmental impacts[4]. This research aims to provide a scientific foundation for integrating Green GDP into economic accounting systems, offering policy insights to achieve the United Nations Sustainable Development Goals.

2. Model Construction

2.1. Green GDP Accounting Framework Based on SEEA

The Green GDP accounting model is built on the SEEA framework, which integrates economic and environmental data to assess sustainability comprehensively. The model adjusts traditional GDP by subtracting environmental costs, defined as:

$$GGDP = GDP - COR - EDL - CPT \quad (1)$$

where COR represents Consumption of Resource, EDL denotes Environmental Degradation Loss, and CPT signifies Cost of Pollution Treatment, which contains cost of waterpollution treatment index (CWPT), cost of air pollution treatment index(CAPT), cost of solid wastepollution treatment index(CSWT), and cost of soil pollution treatment index(CSPT).

Resource Consumption (COR) is calculated as:

$$COR = DV_W + DV_A + DV_T + DV_M \quad (2)$$

where:DV_W: Depletion value of water resources, computed as $DV_W = PW_i \times DW_i$, with PW_i as the price of water and DW_i as depletion amount.

DV_A: Depletion value of arable land, given by $DV_A = S_T \times \frac{S_G}{S_M}$, where S_T is depleted arable land area, S_G is gross regional agricultural product, and S_M is total arable land area.

DV_T: Depletion value of forest resources, calculated as $DV_T = Q_A \times P_A + S_C \times P_M$, where Q_A is timber reserves, P_A is timber price, S_C is forest area change, and P_M is forest resource price.

DV_M: Depletion value of mineral resources, expressed as $DV_M = M_Y \times P_Y + P_Z + P_T$, where M_Y is mineral weight, P_Y is mineral price, P_Z is product price, and P_T is mineral tax.

For fossil fuel resources, oil was selected due to its price sensitivity and data availability, with calculations adjusted for production fluctuations based on international market trends.Climate mitigation is shown in figure 1.

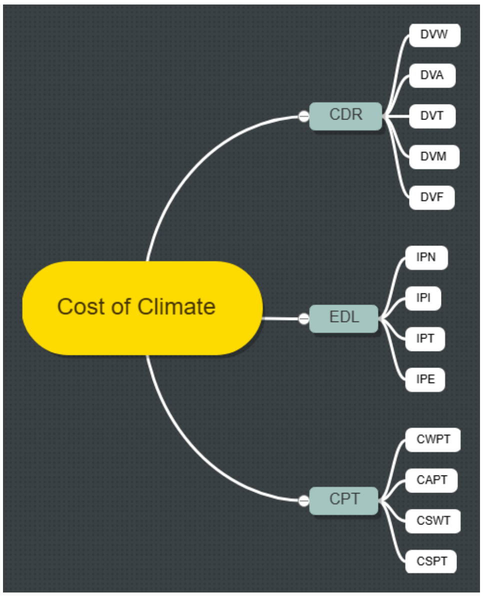

Figure 1 Climate mitigation under the GGDP accounting system

Environmental Degradation Loss (EDL) accounts for ecosystem deterioration and is linked to socio-economic factors using the IPAT equation[5]:

$$I = P \times A \times T \quad (3)$$

where I is environmental impact, P is population, A is affluence, and T is technology. Specific indicators include:

IPN: Impact on population, reflecting dynamic, non-linear effects of population growth on resource depletion.

IPI: Impact on poverty, capturing resource dependency in ecologically fragile areas.

IPT: Impact on international trade, incorporating the Pollution Haven Hypothesis, where dirty industries migrate to developing countries.

IPE: Impact on economic development, modeled via the Kuznets curve, which posits an inverted U-shaped relationship between economic growth and environmental degradation.

Cost of Pollution Treatment (CPT) is calculated as:

$$CPT = PC_L + PC_D + PC_{ID} + PC_M + IWG_A + LWG_A + IV_W + LV_W + IB + ID \tag{4}$$

where:

$PC_L = \sum K_i \times P_i \times S_i \times F_i$: Water pollution from agriculture, with K_i as livestock species, P_i as removal rates, S_i as treatment methods, and F_i as contamination from feed cleaning.

$PC_{ID} = \sum IPK_i \times IVW_i \times IM_i \times F_i + \sum IMA_i \times IMAW_i$: Industrial water pollution, with IPK_i as pollutant types, IVW_i as contaminated water volume, IM_i as treatment cost, IMA_i as production substances, and $IMAW_i$ as water treatment cost.

$IV_W = QW \times PW + CW \times (PW - RW)$: Industrial solid waste pollution, with QW as emission, PW as disposal cost, CW as storage capacity, and RW as storage cost.

$LV_W = D \times DM \times QM \times HM + F \times FM$: Domestic solid waste pollution, with D as transport distance, DM as transport cost, QM as waste quantity, HM as disposal cost, F as incineration amount, and FM as incineration cost.

Data were sourced from UNEP, World Bank, and national reports, standardized using z-score normalization:

$$z = \frac{x-\mu}{\sigma} \tag{5}$$

A dynamic weighting mechanism adjusts indicator weights based on regional resource endowments, ensuring adaptability across economic contexts.

2.2. Green Remedy Rate Model and Analytic Hierarchy Process

The Green Remedy Rate model quantifies Green GDP's climate mitigation potential across four indicators: rainfall (C1), greenhouse gas emissions (C2), sea level rise (C3), and biodiversity (C4)[1]. The GRR is defined as:

$$GRR = \sum_{i=1}^{4} w_i \cdot E_i \tag{6}$$

where E_i is the standardized environmental impact value, and w_i is the weight determined via the Analytic Hierarchy Process.

AHP constructs a pairwise comparison matrix:

$$A = (a_{ij})_{n\times n}, a_{ij} > 0, a_{ji} = \frac{1}{a_{ij}} \tag{7}$$

The matrix for the four indicators is:

$$A = \begin{pmatrix} 1 & 7 & 5 & 5 \\ \frac{1}{7} & 1 & \frac{7}{5} & \frac{7}{3} \\ \frac{1}{5} & \frac{5}{7} & 1 & \frac{5}{3} \\ \frac{1}{5} & \frac{3}{7} & \frac{3}{5} & 1 \end{pmatrix} \tag{8}$$

In the above calculation, the eigenvector is normalized to determine the weight using the eigenvalue method, and the calculation of weight is as followed table 1:.

Table 1 The index weight using the eigenvalue method

Evaluation index	Weight
C1	0.1292
C2	0.5069
C3	0.4396
C4	0.7301

Environmental governance costs are quantified as:

$$P_i = GDP - GGDP \tag{9}$$

$$P_i' = GDP_n' - GGDP_n' \tag{10}$$

$$GRR = \frac{P_i}{P_i'} \tag{11}$$

Where:

$$GGDP_n' = GGDP_{n-1} \times s \tag{12}$$

$$GDP_n' = \frac{GGDP_n' - \beta_0}{\beta_1} \tag{13}$$

Here, s is the GDP growth rate, and β_0, β_1 are parameters from the linear regression:

$$GGDP = \beta_0 + \beta_1 GDP + \varepsilon, E(\varepsilon) = 0, Var(\varepsilon) = \delta^2 \tag{14}$$

Lower P_i values indicate sustainable development[6-7], while GRR categorizes climate mitigation sensitivity: high if GRR is much greater than 1, moderate if GRR is greater than 1.

3. Multidimensional Impacts on China based on CIM

3.1. Analysis of climate mitigation

After a comprehensive reflection on GDP per capita, state territory, environmental quality of the country, international influence and economic development speed, this paper considers China as a target worthwhile for investigation as it continues to grow its influence globally. Therefore, this paper selects China as a clear example to conduct a more in-depth analysis to measure how this shift may influence different factors. China is relatively sensitive to GGDP, which means adopting GGDP as G can boost the country's development. Moreover, it will not only improves the environment but also improve the national industrial structure.

3.2. Analysis of shift on natural resources in China

This paper has reviewed, selected and integrated data from China in the last two decades and figured out the proportion in GDP of four representative natural resources, which can indicate how deeply they are affected by GGDP. Among the natural resources in China, fossil fuel is the most significant proportion, followed by forest, arable land, and water resources[8-9]. In addition, the proportion of fossil fuel is more significant than the combination of the other three resources. Thus, the shift in G will significantly impact Chinese fossil fuel resources, which means China will devise policies to adjust the consumption rate of energy resources so that lots of fossil fuels can be saved. Moreover, these policies will change the industry structure of China and strengthen the ability of sustainable development in multiple aspects[].

we choses Marcov Forecasting Model to predict China's future development.

In the short term, the consumption of Chinese fossil fuel resources will reduce significantly by 4.3% in five years. In addition, the consumption of other natural resources, such as water resources, will decrease, and the ecology will develop positively. The industry structure of China will also change with more new energy industries in the market[10].

In the long run, the industry structure of China will be different but remain relatively stable with positive growth in indicators for measuring citizens' quality, such as water per capita and cultivated land per capita. In other words, the country is capable of sustainable development, and the quality of citizens also increases equally at the same time.

3.3. Analysis of the Advantaged Degree using GGDP

3.3.1 Advantaged Degree Model based on the EWM

To crete Advantaged Degree Model(ADM) conduct, this paper selected China as equidistant sampling. In order to quantify the impact on climate, this paper selects three dimensions: economic, environment and society, the source of data are from data.un.org and ourworldindata.org. In these dimensions, this paper selects 16 specific indicators. After the calculation of entropy weight method, we get the final conclusion. As an objective weighting method, the Entropy Weight Method determines the weights of indicators according to the information provided by the data of each indicator. Based on the objective and accurate characteristics of entropy weight method, this paper applied it to make a reasonable calculation.

First, this paper calculates the proportion p_{ij} of the j-th indicator of the i-th aspects.

$$p_{ij} = \frac{v_{ij}}{\sum_{i=1}^{n} v_{ij}} \tag{15}$$

Then this paper gets the Entropy Value E of the jth indicator as below.

i represents the ordinal number of the 3 aspects.

j represents the ordinal number of the different indicators.

v_{ij} means the value of the corresponding indicator.

n represents the number of the countries.

$$E_j = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij}, k = \frac{1}{\ln n} \tag{16}$$

So that this paper can get the weight q_j of the j^{th} indicator. where m is the number of the indicators. Finally this paper gets the weights of these four indicators as the table below shows.

3.3.2 Economic Sustainability

Economically, In the same way as above, in order to increase GGDP as much as possible, the state will try to reduce the cost of its own resource depletion. In this way, the country needs to develop a sustainable economic development model, and the country's economic structure will become more reasonable, which will have a considerable positive impact on economic development. The weights of 16 indicators is shown in table 2. The source of data are from data.un.org and ourworldindata.org.

Table 2 The weights of 16 indicators by EWM

Factor	Information entropy value	Information utility value
Temperature	0.893	0.107
precipitation	0.821	0.179
Proportion of cultivated land area	0.638	0.362
Proportion of forest area	0.879	0.121
Proportion of grassland area	0.9	0.1
Proportion of water area	0.931	0.069
Proportion of tertiary industry	0.853	0.147
GDP per capita	0.775	0.225
Average wage of workers	0.837	0.163
Disposable income of rural households per capita	0.837	0.163
Natural population growth rate	0.882	0.118
Arable land area per capita	0.794	0.206
grain output per capita	0.852	0.148
Number of beds in hospitals per 1,000 people	0.88	0.12
Satisfaction Index	0.747	0.253
CO2 emission	0.916	0.084

3.3.3 Social Sustainability

In the social domain, social impacts must be grounded in environmental and economic factors, with people's satisfaction largely depending on these indicators. This creates a chain reaction where positive developments in the environment and economy naturally elevate the social life happiness index. Moreover, using GGDP as a measure of national economic health promotes more equitable resource distribution, satisfying aspirations for equality and enabling broader societal advancement.

3.3.4 Envirnmental Sustainability

In terms of the environment, When GGDP is used as a measurement index, the country will change the economic mode, and the conservation-oriented society will become the ideal social state, based on this, scientific development and green focus index system will be established. In order to increase its GGDP, the state will implement a series of measures to reduce the cost of its own resource consumption. It is clear that these measures will have many beneficial effects on the environment.

4. Conclusion

This study examines the limitations of traditional Gross Domestic Product (GDP) in overlooking environmental and resource costs, proposing a Green GDP accounting model based on the United Nations System of Environmental-Economic Accounting (SEEA). The model integrates resource consumption, environmental degradation losses, and pollution control costs through a 12-indicator system, and assesses climate mitigation potential using the Green Remedy Rate model and Analytic Hierarchy Process across indicators such as rainfall, greenhouse gas emissions, sea level rise, and biodiversity. Data from 2015 to 2023, sourced from UNEP, the World Bank, and other reports, are analyzed for China as a case study, incorporating the Climate Impact Model and Entropy Weight Method to evaluate multidimensional impacts across economic, social, and environmental dimensions. The framework highlights the role of Green GDP in promoting sustainable development, with applications demonstrated through models like the Advantaged Degree Model for China, providing a basis for policy optimization and alignment with global sustainable development goals.

References

[1] Zhao Kefei, Fu Zexin, Lin Lijie. A Study on the Development Level of Green Buildings in Eastern Chinese Provinces Based on the DPSIR Model [J]. Construction Economics, 2024, 45(05): 93-99. DOI: 10.14181/j.cnki.1002-851x.202405093.

[2] Dong Xin. Foundations and Pathways for the Green Transformation of China's Real Estate Industry [J]. China Prices, 2024, (01): 53-56+71.

[3] Li Juan. A Study on the Impact of the Digital Economy on Regional Green Development [J]. Modern Business, 2023, (19): 44-47. DOI: 10.14097/j.cnki.5392/2023.19.038.

[4] Wang Hongbing, Liu Yijun, Song Dawei. Using the Think Tank Double Helix Method to Construct a Green GDP Evaluation System [J]. Chinese Academy of Sciences Bulletin, 2022, 37(06): 783-793. DOI: 10.16418/j.issn.1000-3045.20220306001.

[5] Liu Xilin. Striving to Become Green Enterprises and Builders and Managers of Ecological Civilization [J]. Modern Enterprise, 2022, (04): 32-33.

[6] Editorial Department of this Journal. 2022 Two Sessions: High-Quality Development Bolsters China's Confidence [J]. Fiscal Supervision, 2022, (07): 5-12.

[7] Gao Sihan. The Technological Rivalry Between China and the United States in the 21st Century [J]. World Science, 2022, (03): 39-40.

[8] Wang Hongru. Where Does Consumer Demand Come From Under the Pandemic? [J]. Consultation Forum, 2022, (02): 32-34.

[9] Wang Kang, Zhou Jun. The Impact of Environmental Regulations, Energy Structure, and GDP on Industrial Investment: A Sectoral Perspective [J]. Research on Technology, Economy, and Management, 2021, (10): 113-118.

[10] Zhang Junfeng, Xu Wenjuan, Wang Yueqi, et al. Survey and Analysis of China's Carbon Emissions Status Toward Carbon Neutrality [J]. Huadian Technology, 2021, 43(10): 1-10.