Research on Economical Evaluation Model for Guaranteeing Environmental Factors

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Abstract. At present, Gross Domestic Product (GDP) has become an essential evaluation metric for economic development. However, existing evaluation models only concentrate on enhancing the accuracy and ignore the environmental influence for continuous development. In this work, we initially involve the material flow analysis method under the framework of SEEA- CF accounting system, and then establish the SEEA-MFA accounting system to define Green Index to measure the economic health of a country. After selecting four indicators that can represent climate change, we analyze correlation among them and GI. Additionally, we collect 18 sets of data from 20 countries to evaluate the impact of GI on global climate mitigation, we select 8 quantifiable secondary indicators from three dimensions of current economic development, ecological damage, ecological improvement and establish a climate mitigation score evaluation model. We utilize Analytic Hierarchy Process and Entropy Weight Method to calculate the weight of each index in three dimensions. After that, we conduct a cost-benefit analysis based on the externality theory finding that the adoption of green GDP (GGDP) will produce a net benefit to the environment. After using lasso regression to screen variables, we conduct multiple regression analysis between GI, ln GDP and climate change indicators separately. When GDP and GGDP both grow by 1%, the former will bring more serious harm to the climate and environment.

Keywords: SEEA-MFA Model, Green Index, 3D Coordinate Model, Externality Theory.

1 Introduction

Economic evaluation is a critical tool in assessing the efficiency and effectiveness of various policies, programs, or interventions within the realm of economics. It provides a systematic approach to understanding the costs and benefits associated with different courses of action, aiding decision-makers in allocating resources wisely and maximizing societal welfare. Additionally, economic evaluation can provide a guiding framework for policymakers, businesses, and organizations to make informed choices about resource allocation. By quantifying both the financial and non-financial impacts of

© The Author(s) 2024
F. Cao et al. (eds.), *Proceedings of the 2023 5th International Conference on Economic Management and Cultural Industry (ICEMCI 2023)*, Advances in Economics, Business and Management Research 276,
https://doi.org/10.2991/978-94-6463-368-9_9

alternative strategies, economic evaluation offers a comprehensive perspective that extends beyond simple cost considerations [1].

Further, the downstream application of economic evaluation extends across diverse sectors, including healthcare, environmental policy, education, and public infrastructure. Whether evaluating the cost-effectiveness of a new medical treatment, assessing the economic impact of environmental regulations, or comparing the efficiency of educational programs, economic evaluation plays a crucial role in informing evidence-based decision-making.

With the current environmental problems becoming more and more serious, for example, global warming, rising sea levels, and the depletion of non-renewable resources. Environmental protection has been highly valued by countries around the world, and numbers of environmental protection agreements and future development goals have been created, such as the 17 SDGs of the United Nations [2]. However, there is no available measuring for global green economy. While for the sustainable development of mankind, all aspects of society need to be integrated with environmental protection, so that the combination of economic development and environmental protection can be effectively realized. Hence, humanity desperately needs green economy metrics.

The intricate relationship between the environment and the economy is a subject of increasing significance in contemporary discourse. As societies navigate the complexities of sustainable development, the influence of the environment on economic dynamics has become a focal point for policymakers, businesses, and communities alike [3]. This intersection between ecology and economics is pivotal, as it underscores the critical interdependence of human prosperity and the health of the planet. Economic activities include the industrial production to resource extraction and consumption patterns, have profound implications for the environment [4]. Simultaneously, environmental conditions, such as climate change, pollution, and resource depletion, exert a reciprocal influence on economic systems. Recognizing this intricate interplay is essential for crafting policies that promote both economic growth and environmental sustainability.

The impact of environmental factors on the economy is multifaceted. Climate change, for instance, poses risks to agriculture, infrastructure, and overall productivity, while natural resource depletion challenges traditional models of economic growth. On the flip side, economic activities contribute significantly to environmental degradation, with carbon emissions, deforestation, and pollution reflecting the costs of unchecked development [5]. Striking a balance between economic aspirations and environmental stewardship is a formidable challenge, but it is increasingly evident that the two are not mutually exclusive. Sustainable development practices, circular economy models, and eco-friendly innovations are emerging as pathways to harmonize economic growth with environmental preservation. Understanding the nuances of this relationship is crucial for developing policies that foster resilience, mitigate risks, and propel societies toward a more sustainable and equitable future [6].

2 Related Works

The original idea of green GDP accounting came from a study by Costanza in 1997. A critical step of this green GDP accounting is the integration of ecosystem valuation with traditional economic accounting. And a study made by Li informs that both policy-makers and the public about national green GDPs and encourage them to incorporate these values into policy decisions [7]. At present, academic research on it can be divided into three categories: green GDP concept and accounting system, green GDP development opportunities and challenges, green GDP impact on the economy and the environment.

Initially, Jiang Ya uses the dynamic research method to analyze the reform of the green GDP accounting system in the United States, Japan and analyzes and deals with the shortcomings of the traditional SNA accounting system [8]. Further, Wang Yan and Liu Bangfan calculated China's green GDP based on the SEEA-2012 framework and explained the spatial and temporal situation of China's green development [9]. After that, Jens V. Hoff's further approach to public policy orientation based on political science summarizes the opportunities and challenges of green GDP development through the analysis of Denmark [10]. Finally, Nawapanan found out the relationship between GGDP indicator and the development of sugar industry in Thailand to learn about the balance of environment and economy [11].

3 Preliminaries

Given the complexity of the practical problem, we make the following assumptions to simplify our model, each containing its basic explanation.

- Assumption: Only climate change caused by human activities is considered. Explanation: The factors affecting climate change are very complex, and this article does not consider climate change caused by non-human factors such as the position of the sun and the earth, solar activity.
- Assumption: Take the coordinated development of economic growth and environmental protection as the development goal of a single economic system. Explanation: For the sustainable development of mankind, all aspects of society need to be integrated with environmental protection.
- Assumption: People in the economic system are rational and aware of the environmental costs of economic activity. Explanation: Take a Brazilian lumberjack as an example: suppose he fells a tree 10 meters tall and 2 meters in circumference at the bottom and earns $180 to sell to a lumber mill, but the environmental cost of cutting the tree is $30. The final gain was $150.
- Assumption: In the coming period, world peace and stable development will not break out of large-scale war. Explanation: War will lead to large-scale exploitation of resources by the country, which will also cause severe damage to the environment, which will have a greater impact on GGDP accounting.

- Assumption: All data collected is accurate and reliable. Explanation: The data in this article is obtained from international websites and we believe that the data sources are reliable. Therefore, we apply it to our model to obtain accurate and objective results.

Additionally, we summarize the primary parameters in following Table 1.

Table 1. Notations Description.

Notions	Explanation
V_I	Input resource consumption minus value
V_O	Output resource consumption minus value
V_W	Comprehensive utilization value of waste resources GI
GI	Green GDP/GDP, represents green economy level FE
FE	Fossil energy surplus
HI	Happiness Index
GHI	Green Happiness Index
Sl	Average global sea level
T	Average global temperature
CO_2	Average global carbon dioxide emission
EW	The number of extreme weathers per year
SC	Climate change mitigation degree score
CED	Current economic development
ED	Economic damage
EI	Economic improvement
θ	Angle of difference from the optimal vector

4 Method ologies

4.1 Transforming of Green GDP Measuring Standard

SEEA-CF (2012) is the first international statistical standard published by the United Nations for systems in the field of environmental-economic accounting. SEEA-CF (2012) expands the concept of environmental assets under the basic accounting framework of SNA's "stock-flow". The SEEA-based criteria cover resource and environmental assets that are not economic assets, such as the high seas; Physical quantity accounting is carried out on environmental assets that cannot participate in market transactions and do not have a direct market value. SEEA-EEA (2014) is basically consistent with SEEA-CF in terms of accounting framework and accounting level, covering the same environmental assets as SEEA-CF. Its innovation lies in the interpretation of environmental assets from the perspective of ecosystems, focusing on the analysis of the interaction between environmental assets within ecosystems, as well as the material and non-material benefits derived by economic and other human activities from the flow of ecosystem services, and proposing ecosystem services, which undoubtedly gives a more comprehensive measurement method by the SEEA. Following Figure 1 demonstrates the evolution of GDP accounting system framework.

Fig. 1. The evolution of the GDP accounting system.

4.2 SEEA-MFA Accounting System

However, since the requirements of the question pay more attention to the impact of green GDP on climate slowdown, this paper will make some modifications based on SEEA's GGDP calculation model to make the model more prominent on climate issues. Considering that the main factors of global climate change. To better measure the changes brought about by Green GDP on global climate mitigation, this paper only takes human factors as the main impact indicators. The general framework of proposed accounting system is shown in following Figure 2.

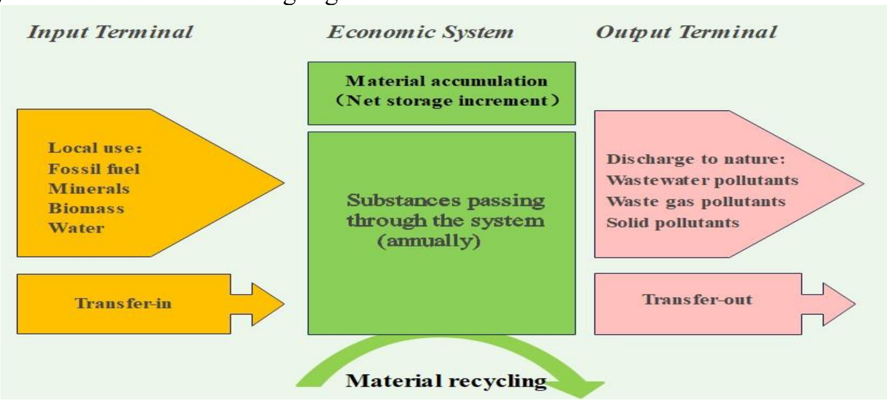

Fig. 2. Framework for the flow of matter in economic systems.

Material Flow Analysis (MFA) is an important research paradigm and basic technology platform for transforming production and consumption patterns, improving material utilization efficiency, and promoting sustainable development by studying the changes in the physical quantity of input, storage, and output between the environment and the economic system, revealing the flow characteristics and conversion efficiency of substances in a specific area. Compared with traditional research methods, material flow analysis technology takes the principle of conservation of mass as the principle for material balance, and the results of material flow analysis can always achieve the final material balance through all its input, storage, and output processes, so new solutions are proposed in following Equation 1.

$$\text{Green GDP}=\text{Current GDP}-VI-VO \quad (1)$$

The influencing factors of the input and output ends are basically consistent with the climate- related factors required in this paper, and only some irrelevant content at the output end needs to be deleted, and then MFA and SEEA can be combined to obtain the SEEA-MFA environmental and economic comprehensive accounting system for climate change. The consumption value of the input is accounted for, the environmental clip loss value is calculated for the pollutants at the output end, the following formula is finally adopted as Equation 2.

$$GGDP=\text{Current GDP}-V_I-V_O+V_W \quad (2)$$

4.3 Practical Application of SEEA-MFA Models

To better understand the application of this accounting system in practice, we take the United States as an example to calculate its green GDP in 2020, in order to solve the problem of disagreement between data units, this paper decides to convert data units into tons, which are shown in Equation 3.

$$V_I= N_{fossil\text{-}fuel}\times P_{fossil\text{-}fuel}+ N_{minerals}\times P_{minerals}+ N_{wood}\times P_{wood}+ N_{water}\times P_{water}+ N_{transfer\text{-}in}\times P_{transfer\text{-}in}$$

$$V_O= N_{CO2}\times P_{CO2}+ N_{waste\text{-}water}\times P_{waste\text{-}water}+ N_{solid\text{-}pollutants}\times P_{solid\text{-}pollutants}$$

$$V_w=N_{recycling}\times P_{recycling} \quad (3)$$

In consequence, $GGDP=GDP-V_I-V_O+V_W$=18.29 trillion dollars. Besides, according to the data released by the US Bureau of Statistics, the US GDP in 2020 is 21.43 trillion dollars, so GGDP accounts for about 85% of GDP, which is more realistic, not only reflects the results of US environmental protection in recent years, but also highlights the accuracy of the SEEA-MFA model cited in the paper.

4.4 Green Index

Green GDP is based on GDP, deducts the depreciation of fixed assets, the loss of natural resources and environmental resources, considers economic factors and natural factors, considers economic cost input and resource and environmental cost input, and the allocation of economic production factors and natural factors. The higher the share of green GDP in GDP, the higher the positive effect of economic growth and the lower the negative effect, and vice versa. In consequence, the percentage of Green GDP accounting for GDP could directly indicate global trend, especially when we use the SEEA-MFA measuring GGDP, the percentage could even depict the global climate situation.

To study the impact of GGDP on global climate, the global CO! concentration average temperature, sea level altitude, and the average annual occurrence of extreme weather were selected to represent the changes in global climate. As we all know, greenhouse gases and atmospheric pollute on are the main causes of global warming in the process of human industrial production, and gas emissions and pollution are mainly caused by the combustion of fossil fuels, the abuse of metal minerals, and the discharge of industrial sewage and waste. Therefore, the amount of fossil fuels, metal minerals, biomass energy, exhaust gas emissions, sewage discharge, and solid waste is selected as secondary indicators to evaluate a country's green development level.

Additionally, this essay chooses sea level, CO2 concertation, average temperature, and the number of extreme climates during the period from 2000 to 2020 of United States to represent the climate situation of US. Then according to the correlation coefficient plot, we filter out that high correlations among these coefficients, and it is likely that closer relationships among them, which means that GI calculated by SEEA-MFA Model maybe a great metrics of global climate situation. Following Figure 3 shows the correlation analysis for coefficients.

Fig. 3. Correlation analysis results.

4.5 Analytic Hierarchy Method

According to the ranking of the above indicators on the degree of environmental impact, the judgment matrix is obtained in following Equation 4.

$$A = \begin{bmatrix} 1 & 5/4 & 1 & 5/4 \\ 4/5 & 1 & 4/5 & 4/5 \\ 1 & 5/4 & 1 & 5/4 \\ 4/5 & 5/4 & 4/5 & 1 \end{bmatrix}$$

After the consistency test of the judgment matrix, the consistency ratio CR is 0.0023 (less than 0.10), so the evidence is consistent, and the eigenvectors of the solution matrix can be accepted, and the weights can be obtained. Then, through arithmetic average method, geometric average method, and eigenvalue method are used to calculate the weights separately, and finally the average of the three is used as the final weight in following Table 2.

Table 2. Final Weights.

Weights/Methods	Arithmetic	Geometric	Eigenvalue	Mean
w1	0.2774	0.2776	0.2774	0.2775
w2	0.2103	0.2100	0.2102	0.2101
w3	0.2774	0.2776	0.2774	0.2775
w4	0.2350	0.2348	0.2350	0.2349

5 Experiments

5.1 Unavoidable Flaws of Green GDP

From the cost-benefit analysis diagram under the externality theory, it can be seen that when choosing green development and peaceful coexistence of economic activities, some economic decisions have to be abandoned, such as industrial production and large-scale resource utilization. Therefore, when green GDP is chosen as a measure of economic health, it slows down the country's economic growth.

To test the plausibility of the above explanation, we use GDP as the level of economic growth under normal conditions, so we take the magnitude of change growth rate of GDP and GGDP to the back of OLS to observe the relationship between the two. The results show in following Figure 4.

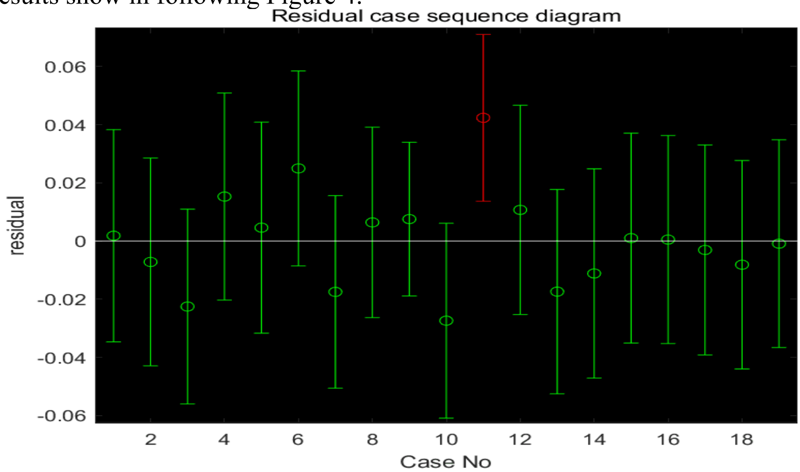

Fig. 4. Residual diagram of regressing growth rate of GDP and GGDP.

A negative correlation coefficient means that the two are inversely correlated, for example, when the GGDP shows rapid growth in the future, while GDP grows slowly in the future. Therefore, Green GDP measures after considering environmental protection sacrifice part of economic development.

5.2 Evaluation of Green Development Level in the US

The environment in the United States has been deteriorating for 20 years, and problems such as rising sea levels and large fluctuations in the green index are obvious. Then, we use SEEA-MFA model to calculate the US GGDP from 2000 to 2020, and draw the following comparison in Figure 5.

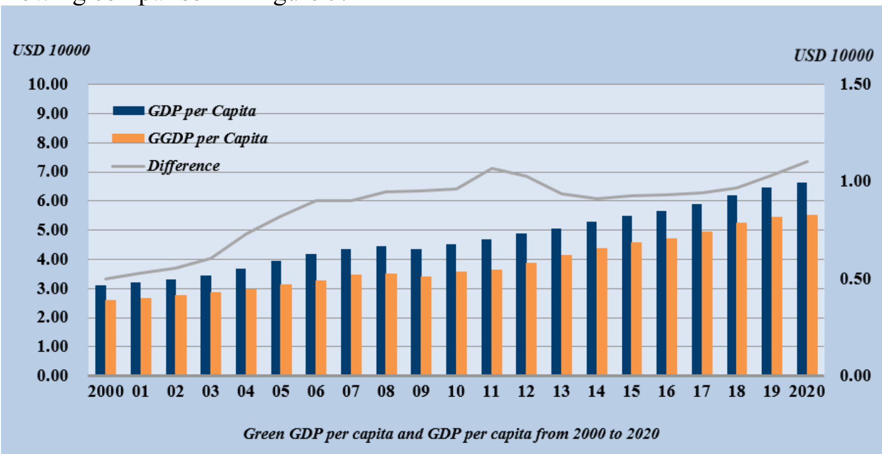

Fig. 5. Green GDP per capita and GDP per capita from 2000to 2020.

From above results, we can observe that the per capita green GDP and per capita GDP of the United States show a synchronous growth trend, and the increase rate of the two is basically the same. Per capita GDP increased from 30,900 US dollars in 2000 to 66,200 US dollars in 2020, with an average annual growth rate of 4.72%, and per capita green GDP increased from 26,000 US dollars in 2000 to 55,200 US dollars in 2020, with an average annual growth rate of 5.62%, and the difference was between 0.5 million US dollars ~ 11,000 US dollars.

5.3 Resident happiness index Under Different Standards

Based on the US GDP per capita and green GDP per capita obtained above, we calculate the happiness index and green happiness index of the United States from 2000 to 2020 represent as $\boldsymbol{HI_t} = \boldsymbol{HI_{t\%n}} \times (\mathbf{1} + \mathbf{4.72}\%)^{\boldsymbol{n}}$ and $\boldsymbol{GHI_t} = \boldsymbol{GHI_{t\%n}} \times (\mathbf{1} + \mathbf{5.63}\%)^{\boldsymbol{n}}$, respectively:

Consequently, if the GGDP standard is used from 2021, the GHI will be temporarily lower than the HI under the GDP standard. However, with the passage of time, the ecological environment has an increasing positive effect on the economy, and the GHI will surpass HI in 2231. It has been calculated that after 2231, GHI will remain greater than HI, reflecting the long-term benefits of using GGDP for U.S. residents. In other words, using GGDP can really improve the happiness of American residents by considering the happiness index of future generations. Following Figure 6 demonstrates the prediction comparison for HI and GHI.

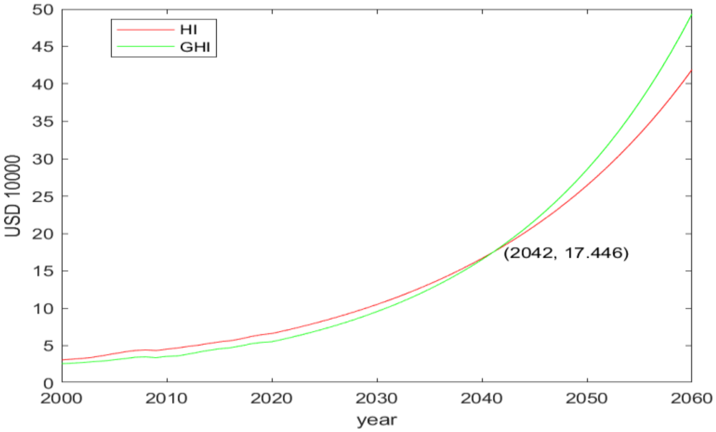

Fig. 6. Comparisons of HI and GHI.

6 Conclusion

In conclusion, the green economy development level evaluation model is a comprehensive evaluation system with three levels of indicators. To make the indicators in the model scientifically comprehensive, this paper collects 18 sets of data from 20 countries, which represent the main factors influencing climate change and economic development. the combination of analytic hierarchy method and entropy weight method is used to determine the weights of each index, which not only alleviates the influence of subjective factors on the accuracy of the model, but also considers the needs of national economic development. As for future improvements, considering the complexity of the problem and the unpredictability of non-human factors, in order to maintain the robustness and accuracy of the model, this model does not consider the impact of non-human factors on global climate change.

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