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Integrating Environmental Concerns: Evaluation of GGDP Innovation Economy Based on Entropy Weight and Coefficient of Variation

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Abstract: This study responds to the environmental repercussions of emphasizing Gross Domestic Product (GDP) over ecological concerns, like excessive resource depletion. With a pressing need for a more sustainable economic measure, we advocate for "Green" GDP (GGDP) as a holistic substitute. Our focus lies in integrating natural resource preservation into economic evaluations and promoting global accord on sustainable economic progress. Strategically selecting key economies worldwide, we redefine resource depletion and environmental degradation costs within GGDP assessments. Using methods like Entropy Weight and Coefficient of Variation, we establish a robust GGDP model. We also evaluate climate mitigation indicators across various countries, showcasing GGDP's positive impact through methods like BP neural networks. Additionally, we assess GGDP's resilience to fluctuations using predictive models like LSTM, highlighting its effectiveness in climate mitigation compared to GDP. This transition gains support from cosine similarity analysis, emphasizing GGDP's alignment with environmental indices. Enhancing the GGDP model through various analyses and incorporating indicators like GNI and research expenditure, our proposed framework emerges as a comprehensive, stable alternative, supporting sustainable economic growth while curbing environmental impact.

1. Introduction

1.1. Research Background

Gross domestic product (GDP), traditionally used to gauge economic health, ignores environmental costs and resource depletion, questioning its effectiveness as an economic vitality measure. The emergence of Green GDP (GGDP) seeks to rectify this by incorporating environmental sustainability into economic evaluations for a fuller picture of economic strength[1].

This study, motivated by the urgent need to prioritize ecological preservation alongside economic progress, leans on utility-value theory to argue for GGDP's adoption. GGDP aims to align economic indicators with the true value of natural resources, promoting a shift towards sustainable and inclusive economic measures.

1.2. Contribution of the Research

1.2.1. Global Climate Mitigation Indicator Selection and Analysis

Relevant indicators are selected to assess global climate mitigation, standardize the data, and calculate the weight of each assessment indicator through the principal hierarchy analysis method.

Pearson correlation analysis is applied to establish a learning model of GGDP and climate association through BP neural network and to derive the impact of GGDP on temperature and CO2 after replacing GDP. Then, a binary regression model is constructed between GGDP and GDP in terms of temperature and CO2 concentration, comparing their impacts on temperature and CO2 under their respective economic indicators.

1.2.2. LSTM Neural Network Prediction Model for GGDP Volatility

A prediction model of GGDP volatility is established based on LSTM neural network, emphasizing that GGDP is more sensitive to fluctuations.

1.2.3. Global Climate Mitigation Indicator Selection and Analysis

Using the cosine similarity model, the similarity between GGDP and environmental indices is compared, emphasizing that the correlation between GGDP and the environment is larger and much higher than that of GDP.

1.2.4. Model Improvement Based on Gray Correlation Analysis

To improve the model, indicators such as Gross National Income (GNI), the ability to support future generations (N1), future consideration of research expenditures (N2), and hospital expenditures (N3) are introduced. These indicators are then combined with the TOPSIS method to obtain the new GGDP.

2. Method

2.1. The Establishment of GGDP Accounting Model

2.1.1. Preliminary Selected GGDP Accounting Model

Green Gross Domestic Product (GGDP) refers to the environmentally adjusted Gross gross Domestic Product (GDP) after deducting the consumption of natural capital. It is a comprehensive index of sustainable development and one of the new indexes to evaluate sustainable development. That is, it is related to the total value of resources consumed by the country and the total cost of environmental governance.

2.1.2. Improved Models Based on Climate-Related Indicators

To concentrate on GGDP's climate relevance, we focus on indicators related to climate effects, like resource loss and environmental degradation. This involves replacing traditional environmental cost assessments with those for direct and indirect climate impact costs. The refined GGDP formula incorporates these factors, aiming for a holistic economic measure that reflects environmental impacts:

$$GGDP = GDP - M_1' - M_2' \tag{1}$$

In the above formula, M_1' refers to the consumption cost of direct climate influencing factors and M_2' refers to the consumption cost of indirect climate influencing factors[2].

(1) The Consumption Cost of Direct Climate Influencing Factors (M_1')

Considering the different regions of the five continents, it is determined that climate change will directly affect the Domestic Mineral Resource Cost (DMRC), the Domestic Comprehensive Energy Cost (DCEC), the Domestic Forest Resource Cost (DFRC) and the Domestic Annual Fresh Water extraction (DAFW) (1 billion cubic meters). The specific formula is as follows:

$$M_1' = DMRC + DCEC + DFRC + DAFW \tag{2}$$

(2) The Consumption Cost of Indirect Climate Influencing Factors (M_2')

It is mainly for the loss of other factors indirectly caused by climate change affecting mining, energy, forest, and freshwater, mainly including the change in Nitrous Oxide Emissions due to the Depletion of forest resources (***InDNOE***), the change in Population Density due to the depletion of freshwater resources (InDPD), and the change in Energization Rate due to the depletion of energy and mineral resources (***InDER***), as shown in the following equations:

$$M_2' = InDNOE + InDPD + InDER \tag{3}$$

2.1.3. Futher Improved Model Based on Combined Empowerment Method

Immediately afterwards, the model is improved. Different weights and model improvement formulas are assigned for direct and indirect influencing factors as follows:

$$GGDP = GDP - \propto_1 \times \bar{M}_1' - \propto_2 \times M_2' \tag{4}$$

Then a combination of **the Entropy Weight Method** and **the Coefficient of Variation Method** are used to assign weights to the searched models to determine the coefficient models.

2.2. Modelling the Defense of GGDP

On the basis of the model established above, and on the premise of the need to establish our own criteria for **measuring climate mitigation**, this study analyzes the relationship between climate impact factors on the change in climate cuts, constructs a **nonlinear mapping relationship** between the two, uses a **BP Neural Network Learning Model** to solve, and uses the **United States** as a **test** of the **stability** as well as **accuracy** of the model under different weighting factors.

2.2.1. Screeing climate mitigation indicators based on AHP

The measure of the suitability of the climatic environment is closely related to indicators such as CO_2 concentration, vegetation cover, average temperature, pollution gas content, and sea level altitude related.

After normalization of the data, we believe that CO_2 content and environmental goodness have the greatest relationship, followed by temperature, while the pollution gas content concentration has the least influence, because CO_2, as a greenhouse gas, has a considerable degree of influence on global warming and temperature change. In summary, we define **the fuzzy evaluation matrix** and obtain the maximum characteristic root $\boldsymbol{\lambda_{max} = 5.1074}$, corresponding to the normalized eigenvector as:

$$\mathbf{w}_0 = [0.3690, 0.1090, 0.1832, 0.0722, 0.2665]^T \tag{5}$$

The corresponding weights of CO_2 concentration, vegetation cover, pollution gas content, sea level height, and average temperature are **0.3690**, **0.1090**, **0.1832**, **0.0722**, and **0.2665**, respectively. Therefore, **CO_2 concentration and average temperature are selected here as climate change rating indicators**.

2.2.2. BP Neural Network-Based Model for Expected Climate Mitigation Impacts

For climate change, we choose **CO_2** and **temperature** as rating indicators and construct a functional relationship between climate impact factors[3]:

$$(Y_1, Y_2) = f(X_1, X_2, \ldots\ldots, X_8) \tag{6}$$

(In the above formula, $X_1 \sim X_7$ refer to the corresponding resource depletion cost and environmental management cost, X_8 refers to the GDP data)

Next, **Pearson Correlation Analysis** was used to test for the presence of **co-integration** between the variables.

It can be proved that $|\boldsymbol{\rho_{XY}}| \leq \mathbf{1}$,besides, when $\boldsymbol{Y = aX + b}$, $\boldsymbol{\rho_{XY}} = \begin{cases} \mathbf{1}, & \boldsymbol{a > 0} \\ \mathbf{-1}, & \boldsymbol{a < 0} \end{cases}$.

On this basis, we use 8 climate impact factors as input variables and two climate change indicators as output variables to **build a BP neural network model for training**. The data samples are all the data of four representative countries (China, Germany, South Africa, and Australia) from 1991 to 2020, and the four data sets are merged, and the size of the merged data set is 114*8.

2.3. Modelling the Assessment of GGDP as it Replaces GDP

2.3.1. Analysis of the Impact of GGDP on Temperature and CO2 Concentration:

(1) Binary regression modeling

This involves describing the process of building binary regression models for GDP and GGDP based on temperature and carbon dioxide concentration, respectively. The process includes model selection and parameter estimation.

(2) Model Comparison

Comparing and contrasting the climate impacts of GDP and GGDP using their respective economic indicators, it is highlighted that GGDP as an economic indicator has a more significant mitigating effect on climate.

2.3.2. GGDP and environmental index similarity analysis:

(1) Cosine similarity model

Using the cosine similarity model is able to distinguish the differences between individuals between dimensions, and then calculate the similarity between GGDP and GDP and the environmental index.

(2) Interpretation of results

Cosine distances reflect relative differences in direction. From the results of the model calculations, it is emphasized that GGDP is more similar to the environmental index relative to GDP, providing evidence of the environmental friendliness of GGDP in place of GDP.

2.4. Improvement of the Model Based on Gray Correlation Analysis

Taking **the United States** as an example, we delve into the factors that influence the GGDP in the United States, so as to obtain what changes would be brought about in their conservation of natural resources if the GGDP were used as an economic indicator in the United States, and what role it would play in the country.

The core of gray correlation analysis is to calculate the correlation using a leveling process, but since the degree of influence of individual features on the results is different, we weight the relevant feature dimensions in order not to lose the potential features hidden in the data.

After considering GNI, future ability to provide for future generations considering research expenditures, and hospital expenditures, a more comprehensive model of GGDP considering national economic status as well as future ability to provide for future generations is derived by adding the characteristic dimensions over the period 1980-2020:

$$GGDP_C^{'} = GDP - \alpha_1 \times M_1^{'} - \alpha_2 \times M_2^{'} + \beta_1 N_1 + \beta_2 N_2 + \beta_3 N_3 \quad (7)$$

3. Result and Analysis

3.1. Modelling the Defense of GGDP

The following figure shows Network structure parameters and neural network model flow chart:

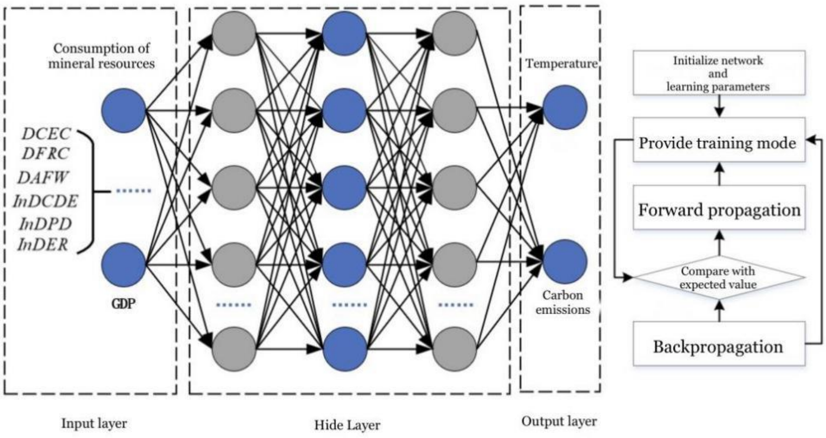

Figure 1: Neural network model structure and calculation process.

In the model training process in figure 1, the data set is shuffled to adjust the ratio of the data set and validation set to **0.80:0.20**, and after normalization and denormalization, the final model training results obtained show that the difference between the predicted value and the true value is not significant.

3.2. Modelling the Assessment of GGDP as it Replaces GDP

3.2.1. GGDP prediction model based on LSTM neural network

After training, the variation of GDP and GGDP over time is obtained.

GDP forecast: Showing exponential growth, the forecast is closely in line with past data, suggesting a steady expansion of the economy. Modeling suggests that long-term growth may be leveling off.

GDP forecast: Initially in line with GDP growth, then flattens out and falls sharply, possibly reflecting the impact of environmental costs on economic activity. The model predicts a significant decline in GGDP, suggesting a shift towards sustainable development.

GDP is predicted to continue to grow while GGDP is constrained, which may be due to environmental sustainability factors. This suggests that while economies may expand, they will increasingly need to balance economic growth with environmental health.

3.2.2. Cosine Similarity Model

We calculate the correlations of GGDP and GDP with the environmental index separately, and here we use cosine similarity as a measure. First, the correlation $\boldsymbol{r_{GGDP}}$ between GGDP and environmental index is calculated. Next, calculating the correlation between GDP and the environmental index, $\boldsymbol{r_{GDP}}$, which gives.

$$r_{GGDP} = \frac{\mathbf{x}_{GGDP} \cdot \mathbf{y}}{\|\mathbf{x}_{GGDP}\| \cdot \|\mathbf{y}\|} = 0.86, r_{GDP} = \frac{x_{GDP} \cdot y}{\|x_{GDP}\| \cdot \|y\|} = 0.65 \tag{8}$$

3.3. Improvement of the Model Based on Gray Correlation Analysis

In figure 2, the model was improved by combining the TOPSIS method. The resulting four resource indicators compared to the combined gray correlation coefficients of GNI, research expenditures, and medical expenditures are shown below:

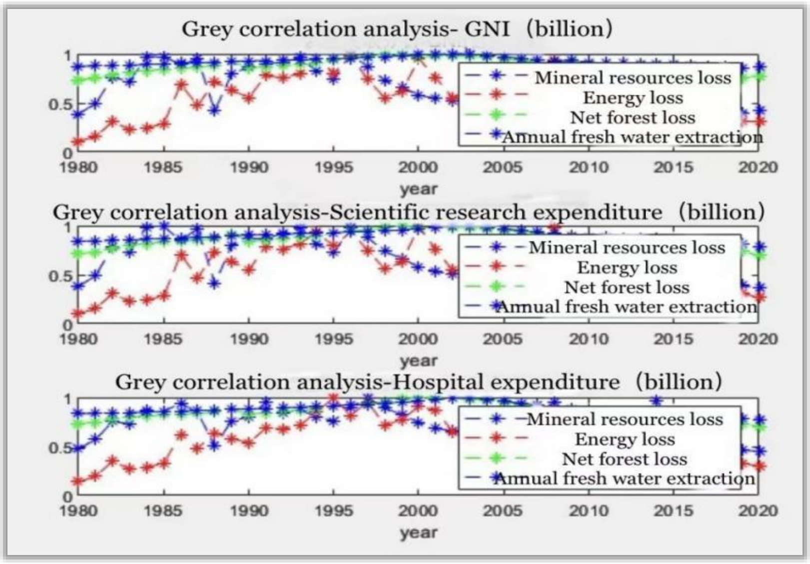

Figure 2: Indicators compared to the combined gray correlation coefficients.

4. Conclusion and Discussion

4.1. The Establishment of GGDP Accounting Model

The Entropy Weight Method combined with **the Coefficient of Variation Method** objectively calculates the weight of the direct influence factor in the model as **0.521** and the indirect influence weight as **0.479**. Therefore, we can conclude that the main factors affecting climate mitigation in different countries are **some indicators that directly affect climate**.

Finally, **the relationship between GDP and GGDP** for the five representative countries under the combined weighting is shown in figure 3:

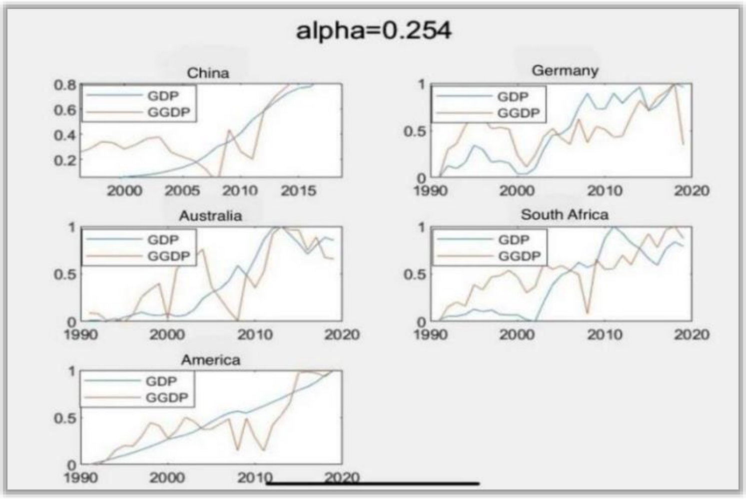

Figure 3: Relationship between GDP and GGDP for five representative countries.

4.2. Modeling the Defense of GGDP

This section evaluates GGDP's impact on climate change mitigation by modeling and validating GGDP against actual environmental data. We represent global diversity through four continents (as proxies for countries) with distinct characteristics, using GDP, temperature, CO2, and seven other factors as inputs. The BP neural network model calculates GGDP and assesses its correlation with climate change indicators.

4.2.1. Validation of the Model with GGDP Data

We validate the model using GGDP data, applying weights from Problem 1 to analyze temperature and CO2 trends. The analysis suggests that substituting GDP with GGDP flattens the transformation trend, supporting GGDP's role in global climate mitigation.

4.2.2. Validation of Model Accuracy with US Data

Further validation with US data checks the model's adaptability to Americas' data. The US data, aligned with other countries' results, confirms the model's consistency. The observed trends indicate that GGDP reflects effective climate change attenuation, showcasing its potential as a comprehensive economic and environmental metric[4].

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