

Research on the Application of Machine Learning Algorithms in Green Economy Indicator Modeling and Sustainable Development Evaluation

Ziqi Zhang*

School of Economics and Management, Chongqing Jiaotong University, Chongqing, China,
400074

* Corresponding Author Email: 13873711067@sina.cn

Abstract. This study presents a comprehensive modeling and analysis framework for investigating the impact of green GDP on climate factors and its potential for promoting sustainable development. Our model utilizes the entropy weight method (EWM) and grey correlation analysis (GRA) to optimize and process data, while employing a BP neural network for model training. Results indicate that green GDP leads to smaller global climate damage compared to traditional GDP, indicating its potential to alleviate the global climate crisis and promote green development. Furthermore, we built a green GDP prediction model using LSTM to forecast future changes. From the perspective of economy and management, the results indicate that transitioning from GDP to green GDP initially leads to a decrease in the index, followed by an increase. This suggests that green GDP development has short-term drawbacks but long-term benefits, including reduced resource consumption, improved economic conditions, and contribution to sustainable development. Finally, we analyzed the learning rate, number of iterations, and thresholds of related parameters through Logistic binary classification. Results demonstrate that our model is relatively stable, highlighting how green GDP addresses ecological challenges while promoting economic prosperity. These findings underscore the urgency of adopting the concept of green GDP in the contemporary era for achieving sustainable development goals. Overall, this research provides critical insights on the potential benefits and feasibility of green GDP as a crucial tool for mitigating climate risks and enhancing global prosperity.

Keywords: Machine learning, LSTM prediction model, Green GDP, Green development.

1. Introduction

Gross domestic product (GDP) is one of the most famous and the most commonly used modulus of a country's economic health indicator. Although GDP is an important indicator to measure the economic development of a country or region, it cannot fully reflect the losses caused by external diseconomic behaviors in the process of economic development^[1]. Needless to say, GDP is a poor measure of a country's true economic health because it fails to credit natural resources and takes into account the long-term development of the planet^[2].

As mentioned in the existing literature, green GDP is an important indicator reflecting the trade-offs between ecosystems and economic systems. GDP is an important indicator reflecting the trade-off between ecosystems and economic systems, and we should pay attention to its future changes^[3-4]; introduces machine learning techniques and data mining techniques to establish a comprehensive accounting system for resources, environment, and economy and green GDP^[5].

Now, we propose a new green GDP (Hereinafter referred to as GGDP), often referred to as GGDP, that is consistent with the sustainability perspective, to analyze and study green economic indicators through machine learning algorithms; therefore, it is particularly important to reflect on the disadvantages and problems of the traditional GDP, and to find out new economic indicators that are consistent with green and sustainable development.

2. Model building and data processing

2.1. GGDP calculation method based on climate factors

According to incomplete statistics, the existing measurement methods are as follows table 1:

Table 1. GGDP calculation methodology

GGDP calculation method	Calculation idea
Production method Income method	GGDP=Total output -Intermediate input - Environmental cost GGDP=Net production tax+ Fixed capital depletion+ Worker's remuneration+ (Operating surplus - Virtual environment costs)
Expenditure method	GGDP = Final consumption + Net exports + (Capital formation - Virtual environment cost)
Traditional calculation method	GGDP=Traditional GDP - Imaginary number of natural part - Imaginary number of human part
General calculation method	GGDP = GDP index - Depletion of unproductive economic assets - Downgrade of unproductive natural assets

Under comprehensive consideration, we choose the general calculation method to calculate GGDP. On this basis, the impact of climate change is taken into consideration. Based on different climate factors^[6], the depletion of non-productive economic assets and the degradation of non-productive natural assets are respectively replaced with the depletion of direct climate factors and the depletion of indirect climate factors:

$$GGDP = GDP - A_1 - A_2 \quad (1)$$

A1 refers to the depletion of direct climate factors; A2 refers to the depletion of indirect climate factors.

(1) A1 the depletion of direct climate factors

It mainly includes national mineral resource loss (DMRC), national comprehensive energy loss (DCEC), net forest resource loss (DFRC) and annual fresh water extraction (DAFW) (1 billion cubic meters). The specific formula is as follows:

$$A_1 = DMRC + DCEC + DFRC + DAFW \quad (2)$$

(2) A2 the depletion of indirect climate factors

It is mainly aimed at the loss of other factors indirectly caused by climate change fluctuations affecting mining, energy, forests and fresh water, including nitric oxide emission changes caused by forest depletion (InDNOE), population density changes caused by freshwater resource depletion (InDPD)^[7], electricity rate changes caused by energy and mineral resource depletion (InEDR). The specific formula is as follows:

$$A_2 = InDNOE + InDPD + InEDR \quad (3)$$

2.2. The weight analysis of the model is carried out based on entropy weight method

① Weight calculation result as shown in table 2

Table 2. Entropy weighting method weight calculation results

Item	Entropy weight method		Weight(%)
	Information entropy value 'e'	Information utility value 'd'	
GDP	0.874	0.126	33.416
DMRC	0.977	0.023	6.086
DCEC	0.965	0.035	9.160
DFRC	1.000	0.000	0.000
DAFW	0.907	0.093	24.684
InDNOE	0.968	0.032	8.576
InDPD	0.959	0.041	10.978
InEDR	0.973	0.027	7.101

Chart description: The figure above shows the weight calculation results of the entropy method. According to the results, the weight of each index is analyzed^[8]. The weight calculation result of entropy method shows that, The weight of GDP (USD) is 33.416%, that of DMRC 6.086%, that of DCEC 9.16%, that of DFRC 0.0%, that of DAFW 24.684%, that of InDNOE 8.576%, that of InDPD 10.978% and that of InEDR 7.101%, where the maximum index weight is GDP (USD) (33.416%), and the minimum value is DFRC (0.0%).

2.3. Grey correlation analysis of the model

① Grey correlation coefficient

According to the relevant data, we can calculate the grey correlation coefficient of each index. Gray relational degree analysis was conducted on 8 evaluation items (GDP (USD), DMRC, DCEC, DFRC, DAFW, InDNOE, InDPD, InEDR) and 22 data, and GGDP was taken as the "reference value" (mother sequence). Study the correlation (correlation degree) between 8 evaluation items (GDP (USD), DMRC, DCEC, DFRC, DAFW, InDNOE, InDPD, InEDR and GGDP, and provide analysis reference based on the correlation degree^[9]. In the case of grey correlation analysis, the resolution coefficient is 0.5. The correlation value is calculated according to the correlation coefficient formula, and then the correlation degree value is calculated for evaluation and judgment.

② Grey correlation degree as shown in table 3

Table 3. Gray correlation analysis results

Relevance results		
Evaluation items	Relevance	Ranking
GDP (USD)	0.993	1
InDNOE	0.777	2
DAFW	0.759	3
DCEC	0.752	4
InEDR	0.728	5
InDPD	0.723	6
DMRC	0.722	7
DFRC	0	8

Chart description: According to the above correlation coefficient results, the weighted processing is carried out to obtain the correlation degree value, and the correlation degree value is used to evaluate and sort the 8 evaluation objects. As can be seen from the above table, among the 8 evaluation items, GDP (USD) has the highest evaluation (correlation degree: 0.993), followed by InDNOE (correlation degree: 0.777).

2.4. Model-based estimates of expected global impacts on climate mitigation

After the model is trained, we then analyze the influence of GGDP data on the change of temperature and carbon dioxide. GDP and other seven influencing factors (including four factors in A1 and three factors in A2 respectively) are taken as input variables, and temperature and carbon dioxide are taken as output variables. BP neural network is used again to train the model. On this basis, GGDP is calculated and brought into the model for verification, and then the actual change trend of temperature and carbon dioxide and the change trend of temperature and carbon dioxide after GDP is replaced by GGDP are analyzed.

The final result is shown below Fig1:

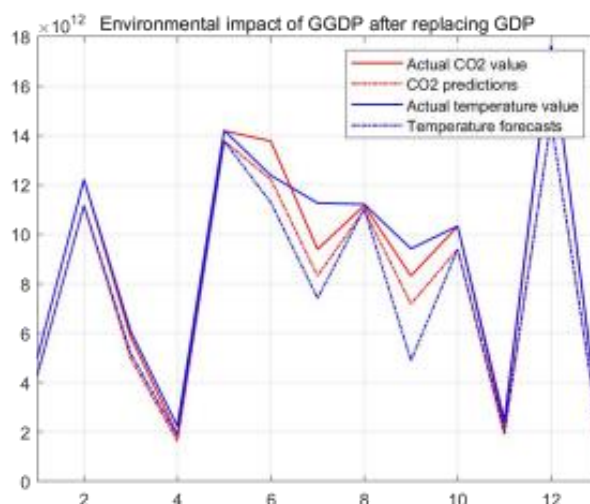


Fig. 1 Comparison of GDP and GGDP

According to the predicted results, it can be found that the impact of GGDP on CO₂ is less than that of GDP on CO₂ and that of GDP on temperature. It shows that under the influence of GGDP, global temperature reduction is less than GDP. The implementation of GGDP can slow down global warming and improve global environmental quality.

The global GGDP value in the next few decades will show a steady upward trend. This indicates that the transformation from GGDP to GDP is conducive to economic development and ecological balance restoration at the same time.

2.5. Resistance analysis and advantages and disadvantages analysis of the transformation from GDP to GGDP

There may be resistance to replacing GDP with GGDP. In order to analyze this resistance, we use the LSTM network to forecast GGDP in the next few decades, and analyze whether the transformation is worthwhile in the global scale through the predicted results as shown in Fig 2.

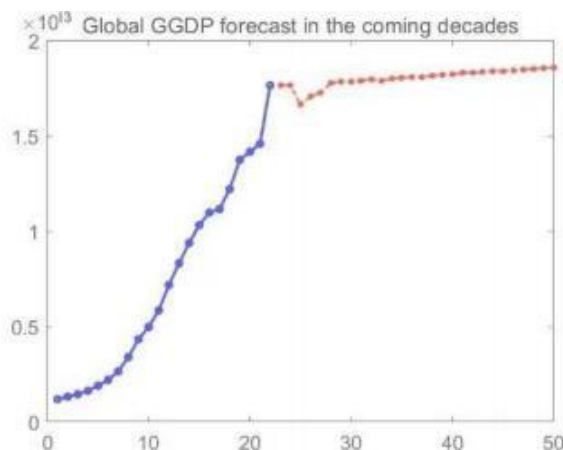


Fig. 2 GGDP prediction

It can be clearly seen from the future forecast chart of GGDP that in the future development, GGDP has a trend of first declining and then rising, which indicates that the development of GGDP has short-term disadvantages and long-term advantages^[10]. The detailed analysis is as follows:

(1). Potential advantages of climate mitigation

1) Traditional GDP pays too much attention to rapid economic growth, ignoring not only the consumption of natural resources, but also the decline of environmental quality and the imbalance of ecosystem caused by pollution.

2) If this change is implemented, it will effectively control the global CO₂ emissions, slow down the greenhouse effect and be extremely beneficial to the improvement of the environment.

3) On the basis of the development of economic production activities to meet people's material living standards, environmental quality has been improved, and people's living quality has been further improved, which is conducive to promoting a good development trend of population structure.

4) With the continuous popularization and development of GGDP in the later stage, more environmental problems around the world will be solved, thus enhancing people's happiness index.

(2). Potential disadvantages (resistance) of efforts needed to replace the status quo

1) As a comprehensive reflection of social production, traditional GDP is the central total index of national economic accounting system. It plays an important role in national economic analysis, and its position is difficult to shake in the short term.

2) Most countries in the world still use the traditional way of calculating GDP, and there is no definitive way to calculate GGDP, making this shift harder in the short term.

3. Conclusions

Based on the background that traditional GDP can no longer satisfy the indicators of a country's real economic health, this paper establishes a new GGDP model which can satisfy the sustainable development.

Through the data collected by the WorldBank and the National Bureau of Statistics of China, the entropy weight method and grey relational analysis are used to process and optimize the model, and then the BP neural network is used to train the model, so as to achieve the prediction effect. Then the index in the formula is replaced according to the specific task to improve the overall accuracy and flexibility of the model.

Last but not least, we analyzed the learning rate and iteration times of the model through neural network, and analyzed the threshold values of related parameters through Logistic binary classification, which showed that the model we established was relatively stable, thus proving that the transformation from GDP to GGDP is feasible and worthwhile.

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