Definition and forecasting of GGDP in the landscape of climate issues

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Abstract. In this paper, we propose a GGDP assessment system for climate mitigation, analyze its ecological impacts, and discuss the potential advantages and disadvantages of the GDP transformation. Firstly, the definition and traditional calculation of GGDP are elaborated, and eight indicators are divided into direct and indirect factors for climate mitigation. Then, five rep-presentative countries are selected and the data of indicators are substituted. Besides, the weights corresponding to the indicators are calculated by the entropy weighting method and the coefficient of variation method respectively. Next, the comprehensive weighting coefficients of the indicators are figured out by the combined method. The established GGDP system based on the CV-EWM evaluation model is used to obtain the GDP and GGDP change of five countries from 2001 to 2022. Additionally, the BP neural network algorithm is used to predict the trends of CO2 and temperature under the two systems of GDP and GGDP, respectively. Finally, the neural network was optimized by a genetic algorithm to establish the global climate impact assessment model based on GA-BP neural network prediction, and the global effect of the GGDP system on climate mitigation issues was studied.

Keywords: CV-EWM model, GGDP, GA-BP model.

1. Introduction

GDP is an important indicator to measure the level of economic development. Many countries blindly pursued economic efficiency, which caused ecological damage and degradation. In turn, this phenomenon led to climate problems. In this context of the increasing demand for environmental protection, it is the requirement and task of each country and multilateral organization to develop more accurate, efficient, and universally eligible indicators. Based on GDP, GGDP takes environmental protection into account to mitigate environmental deterioration.

The concept of green GDP was first introduced in the Handbook of Integrated Environmental and Economic Accounting published by the United Nations Statistics Department, which stipulates that green GDP accounting refers to the inclusion of resource consumption and environmental damage in the framework of the original national economic accounting system and provides systematic accounting data for decision-making, analysis and evaluation of sustainable development policies by describing the relationship between resources, environment and economic growth.[1]

There is much relevant literature available on the research of green GDP accounting and assessment system. Previous studies have mainly focused on theoretical and qualitative analysis of accounting methods and proposed many methods and approaches to traditional GGDP accounting. For example, the SEEA system proposed by the United Nations Bureau of Statistics in 1993, and the National Economic Accounting Matrix with Environmental Accounting (NAMEA) developed by the European Union, etc. [2] At present, there are two primary ways to calculate GGDP, one is to add the cost information reflecting natural resources and environment to the traditional national economic account table and obtain GGDP by adjusting the traditional GDP; the other is to describe and calculate green GDP by using the input-output technique. Both ways have the problem of monetization of resource consumption and environmental losses. Currently, there is no common and understandable metric for monetizing the valuation of resource and environmental losses. [3]

The current analysis on the way of GGDP accounting takes relatively single environmental factors as indicators, for example, Fuhua Sun et al [4] use water resources as indicators to study industrial green GDP accounting underwater environmental constraints. Guoping Mei and Xiaobing Mao [5] use the number of beneficial and harmful products manufactured per unit of resource consumption to improve GDP and evaluate the performance of natural resource use. Na Liu and Chunsheng Chen [6] adopt the sum of depletion costs of natural resources as a proxy variable for the consumption of resources and concluded that environmental protection investment has a significant positive effect on both economic growths.

Simultaneously, most of the assessment models on GGDP are limited to a specific region or country, which makes the application of GGDP in different regions of the world difficult. For example, Lei Min et al [7] study the GGDP accounting model for resource-based cities in Yulin, Shaanxi Province, China. Luo Xilian [8] launches research on GGDP accounting in the direction of industrial pollution in Hebei Province and takes the governance cost method to account for the value amount of industrial pollution losses in Hebei Province. Obviously, the accounting method of using GGDP instead of traditional GDP is not suitable for every country in the world, and it is necessary to analyze the application of GGDP in different countries by classifying the global country types.

In summary, the existing environmental indicators used in the assessment model about GGDP are single, which leads to the analysis of specific regions is often partial. Meanwhile, in terms of the application of the GGDP model, most of the extant articles take a single region as the research subject, which has limitations in the global application of GGDP and measuring the worldwide impact. Therefore, this paper absorbs the experience of previous papers, summarizes the deficiencies of the study, adopts eight environmental indicators for specific analysis, applies the model to five different types and globally representative countries, finally establishes a global climate impact assessment model based on GA-BP neural network prediction, and investigates the global impact of the GGDP system on climate mitigation issues.

2. Definition and common calculation methods of GGDP

Green GDP (GGDP) is derived from the current GDP, which represents a more comprehensive economic level of a country or region based on SNA system[9]. GGDP does not fundamentally change the original concept or framework of the SNA, but it takes original external influences and natural resources into account. As for GGDP, environmental costs and benefits, natural resource assets, and environmental protection expenditures are integrated into a satellite account and expressed in a way that is consistent with accounting methods[10].

It is commonly acknowledged that the methods of calculating GGDP are as follows.

2.1. Production Method

The intermediate inputs are deducted from the total output of each industrial sector, where the intermediate inputs indicate the economic and natural assets consumed in the production of each industrial sector. It can be expressed by the formula:

$$GGDP = \sum(TO - Inputs_{intermidiate} - NA_{non-produced} - CFC) \tag{1}$$

Where, TO stands for the toatal output of all sectors. $NA_{non-produced}$ stands for non-produced natural assets. CFC means the consumption of fixed capital.

2.2. Expenditure Method

It is calculated depending on the final usages of domestic ecological GGDP, including both consumption and accumulation.[3] The calculation formula is:

$$GGDP = Final\ consumption + Total\ accumulation + (exports - imports) \tag{2}$$

Where, $Total\ accumulation$ is equal to the accumulation of productive assets plus the accumulation of non-productive natural assets, and minus the reduction in the stock of other non-productive natural assets.

2.3. SEEA System:

The formula is:

$$GGDP = GDP - COST_{Resources} - COST_{Environment} \quad (3)$$

Where, $COST_{Resources}$ and $COST_{Environment}$ respectively represent the cost of natural resource depletion and the cost of environmental degradation.

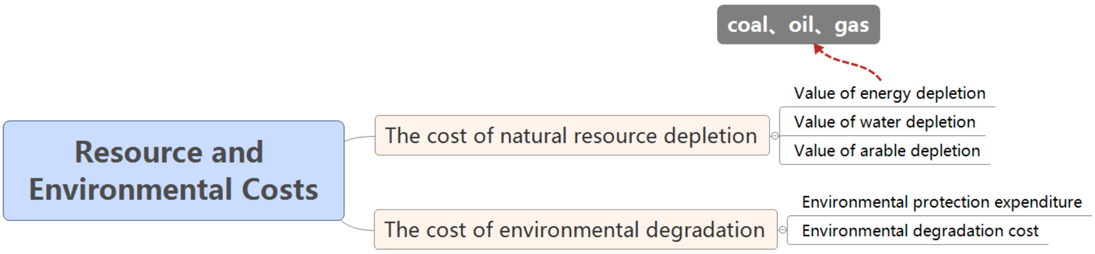

Figure 1. Estimation system of environmental cost

2.4. Evaluation Model of Climate Mitigation Based on GGDP

In this article, according to different climatic factors, the accounting method based on GGDP considers its impact on climate change, and replaces the cost of natural resource depletion and the cost of environmental degradation into the cost of climate factors directly impact and the cost of climate factors indirectly impact. The formula can be depicted as:

$$GGDP = GDP - A_1 - A_2 \quad (4)$$

Where, A_1 represents the cost of direct impact climate factors and A_2 represents the cost of indirect impact climate factors.

2.5. The Selection of GGDP Indicators

2.5.1 The cost of climate factors directly impact

Among the factors that directly affect climate, this article generally considers mineral resource extraction (MRE), combined resource depletion (CRD), forest resource depletion (FRD), and freshwater resource withdrawal (FRW) as necessary indicators for the calculation by integrating globally. The formula is:

$$A_1 = MRE + CRD + FRD + FRW \quad (5)$$

MRE: It mainly refers to the number of mineral resources such as oil, coal and natural gas extracted, the process of which generates waste water and gas that directly affect the local climate and also leads to negative phenomena such as energy depletion;

CRD: It mainly refers to the consumption of mineral resources, which directly emit carbon dioxide, sulfur dioxide, ozone and other gases in the process of utilization, causing the greenhouse effect, acid rain and the destruction of the ozone layer;

FRD: It mainly refers to the amount of abuse and depletion of forest resources, the process of deforestation of which can directly lead not only to climatic impacts such as soil erosion, but also to the destruction of wildlife habitats and the reduction of biodiversity.

FRW: It mainly refers to the amount of freshwater resources that are extracted and used in human production and life, which can cause water pollution, scarcity, and then lead to the depletion of water resources.

2.5.1 The cost of climate factors indirectly impact

The cost of climate factors indirectly impact is indicators that affect direct factors and then climate, mainly including change in population density (CPD), change in the number of fuel vehicles (CFV), change in the number of factories (CNF), and change in the number of livestock (CNL). The formula is:

$$A_2 = CPD + CFV + CNF + CNL \quad (6)$$

CPD: Is has led to a significant increase in the number of natural resources needed in various areas and a simultaneous increase in the emission of carbon dioxide in the air, which in turn has resulted in climate deterioration;

CFV: It has led to the massive exploitation of energy sources such as oil and gas, while the emission of exhaust gases has caused a rapid decline in air quality;

CNF: It has led to an expansion of the required raw material resources and the deterioration of the environment due to illegal discharge of waste gases and wastewater;

CNL: It has led to huge clearing and occupation of forests and arable land, and the balance of the ecosystem is disrupted by the reduction of forest resources.

2.6. BP neural network-GGDP global impact prediction model based on GA

BP neural networks are multilayer feedforward neural networks based on error back propagation, which are relatively mature in machine learning. However, the traditional BP neural network has the disadvantage of easily falling into local minima, and there is a need to improve the accuracy of this model. On such a basis, this paper employs a genetic algorithm to optimize the BP neural network.

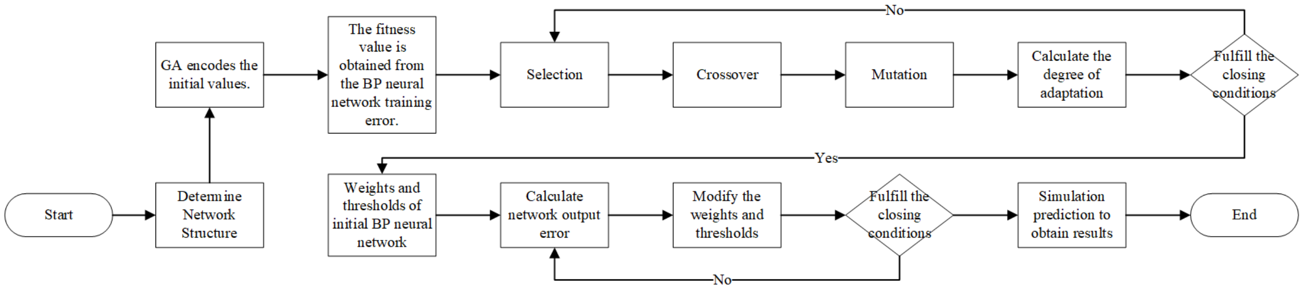

Figure 2. Flow chart of GA-BP model

In this paper, we use MATLAB for the initial construction of BP neural network, and adopt the default training function, Levenberg - Marquardt algorithm, to train the network, and continuously modify the weights and thresholds through training to make the output error of the network get smaller and smaller. After the training, relevant data from 2001-2022 are collected, and the first 11 years of data are used as a sample data matrix for network's training and learning. For the genetic algorithm, this paper establishes an initialized population, calculates the number of weights and thresholds, and constructs individual codes; in order to make the residual difference between the predicted and expected values as low as possible, the fitness function is also constructed, and the norm of the error matrix between the predicted and expected values is regarded as the output of the objective function.

3. Results

3.1. GGDP: Indicator weights

In order to determine more accurate values of weights, this article adopts the entropy variance coefficient method process the data.

For sake of illustrating the above model more clearly, this paper selects representative countries with different characteristics in each of the five continents and brings in the data from 2001-2022 to calculate relevant values, as shown in the following table:

Table 1. Relevant values of weight of different countries with two methods

Country	Method	MRE	CRD	FRD	FRW	$inCPD$	$inCFV$	$inCNF$	$inCNL$
China	CV	0.088	0.099	0.133	0.132	0.083	0.164	0.130	0.171
	EWM	0.074	0.088	0.124	0.125	0.060	0.191	0.140	0.198
America	CV	0.144	0.154	0.111	0.139	0.124	0.100	0.129	0.099
	EWM	0.156	0.154	0.102	0.174	0.118	0.089	0.126	0.082
German	CV	0.052	0.110	0.357	0.163	0.066	0.053	0.098	0.102
	EWM	0.034	0.099	0.450	0.170	0.047	0.030	0.084	0.089
Brazil	CV	0.103	0.129	0.097	0.169	0.112	0.161	0.122	0.108
	EWM	0.081	0.128	0.074	0.216	0.099	0.199	0.112	0.091
Australia	CV	0.143	0.111	0.117	0.135	0.147	0.102	0.131	0.114
	EWM	0.148	0.111	0.106	0.139	0.172	0.089	0.140	0.095

According to the composite weighting formula, the ultimate integrated weighting coefficients of different countries can be found as Figure 2 shows:

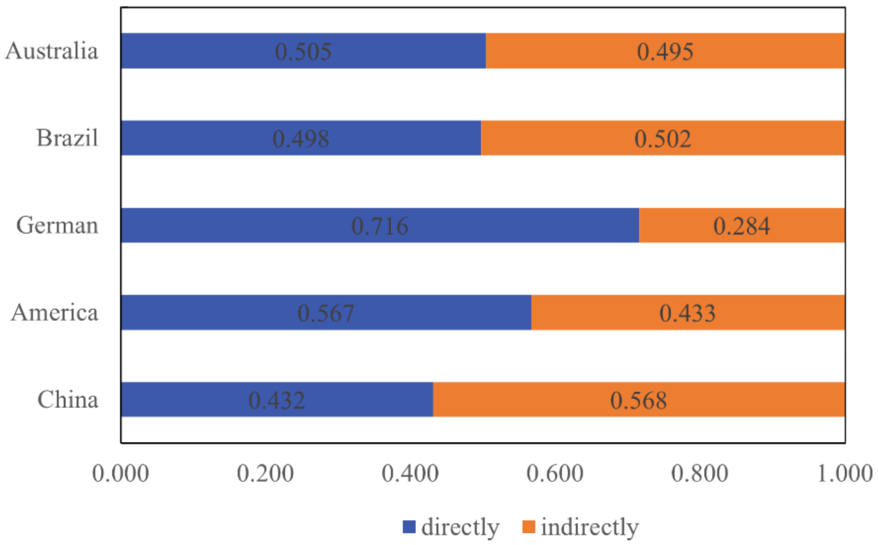

Figure 3. Integrated weighting coefficients of different countries

As the figure shows, for Australia and Brazil, values of factors that directly and indirectly affect GGDP is similar, whiles those of America, China and Germany vary quite a lot. It is easy to explain this phenomenon for China owns the largest population in the world, which causes many indirect results.

3.2. Exploring the relationship between GGDP and GDP

According to the analysis, graphs of the relationship between GDP and GGDP from 2001-2022 in five different countries under the combined weighting method can be obtained:

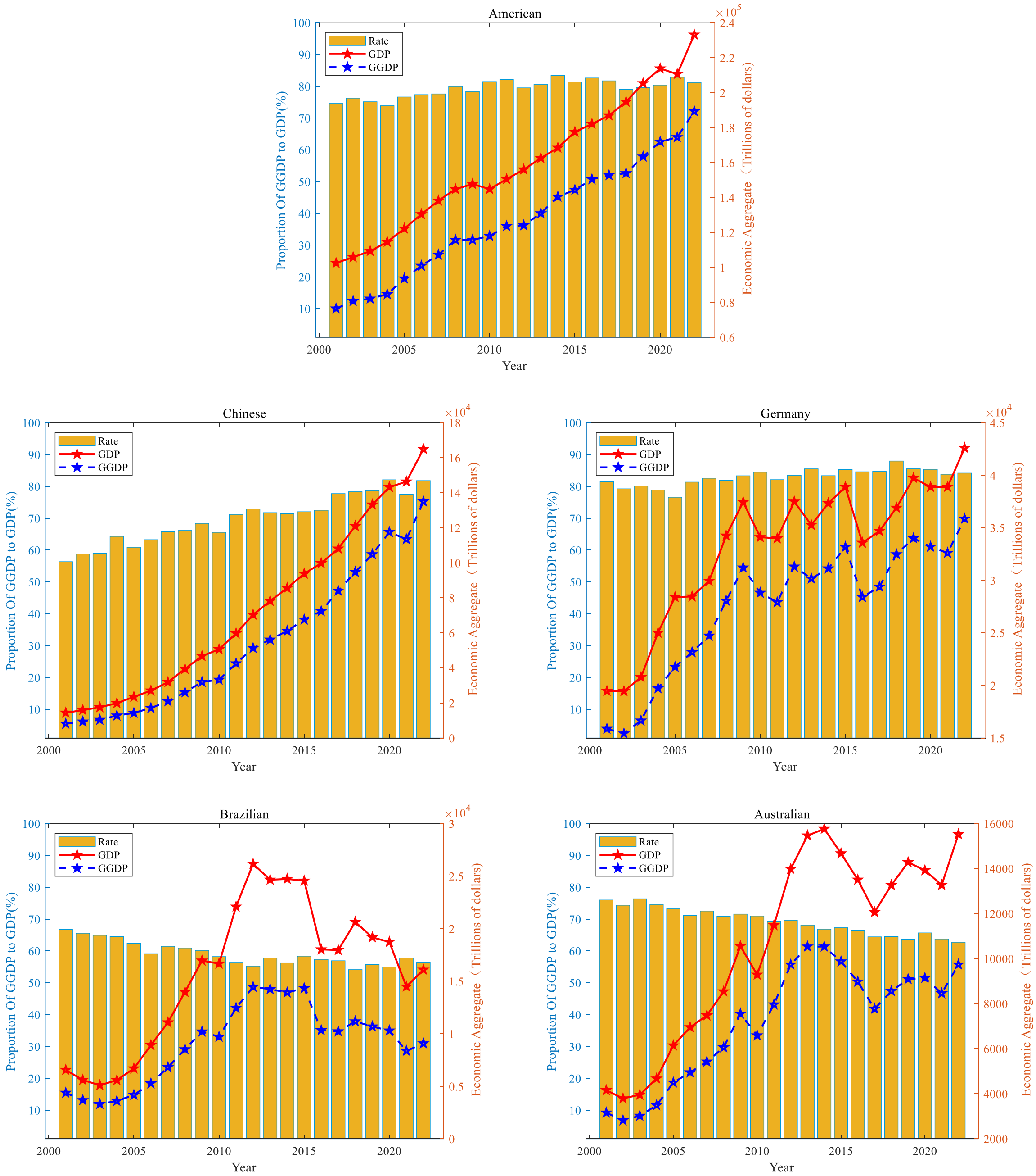

Figure 4. Relationship between GDP and GGDP from 2001-2022 in five countries

According to the figure 4, it is meaningful that some attributes in each country can be witnessed. In America, its GDP has always been the largest and the growth rate has been fast. Meanwhile, the US has paid full attention to the protection of the natural environment while developing the economy, and GGDP has grown simultaneously with GDP and accounted for about 75%-85% of whole share. As for China, it initially devoted itself too much to eco-nomic development and neglected the protection of ecological environment, so the proportion of GGDP in China's GDP was only about 55% at first. As environmental problems be-came more prominent, however, China realized the importance of environment and strengthened its investment in GGDP. With regard to Germany, it has a good environmental condition and has always taken care to maintain a high input in GGDP in order to sustain a high ecological quality, regardless of the GDP development status. Brazil and Australia are similar in that they have over-consumed natural resources for economic development in re-cent years, resulting in a significant decline in the share of GGDP.

3.3. Results of GA-BP model

Follow steps mentioned above, some parameters of this model can be obtained and visualized:

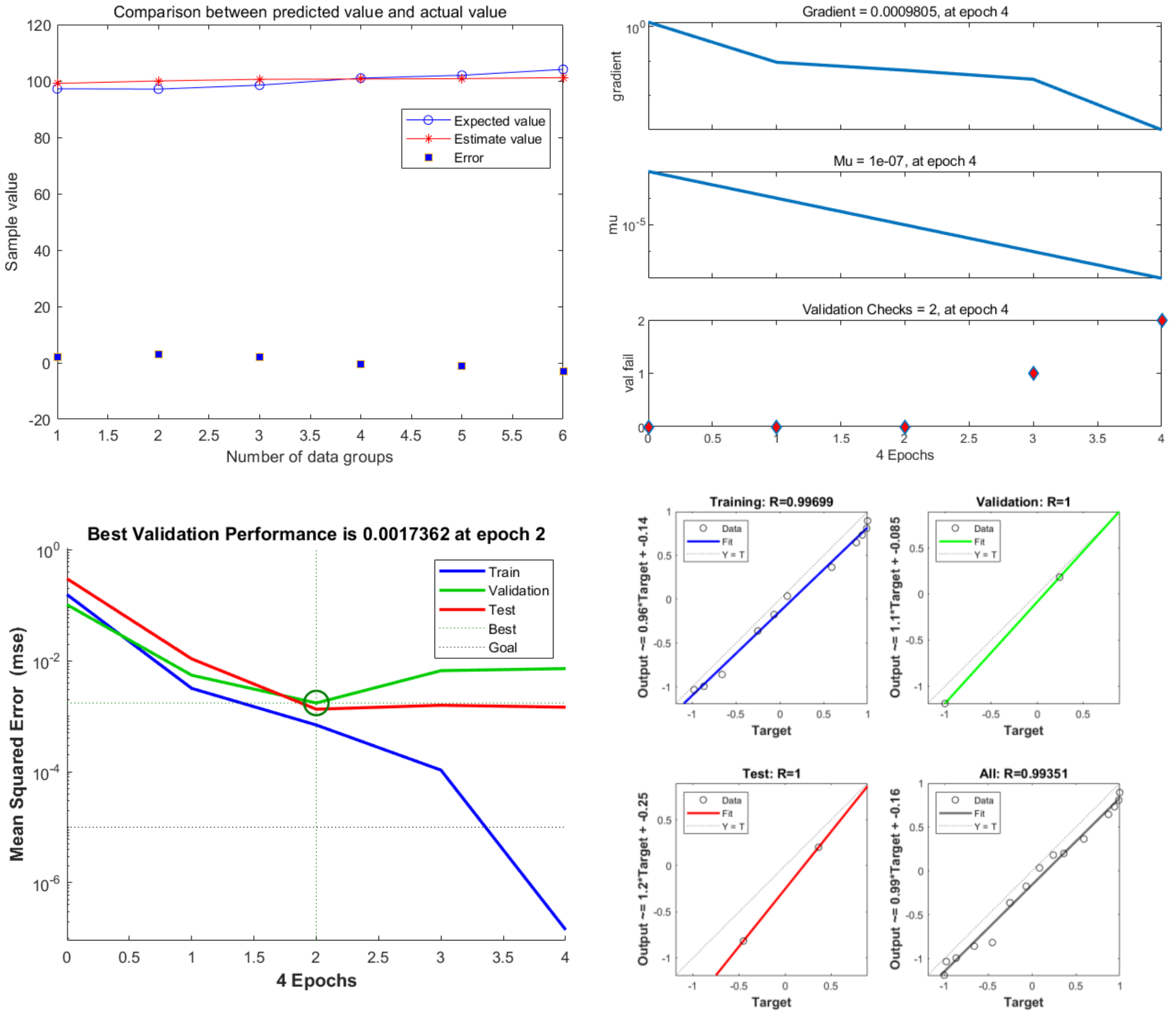

Figure 5. Several parameters in process of calculation

The parameters of the training process of the model show that the model has a high degree of suitability for the problem with such constraints. The fitting effect is accurate, and the data trend and development direction can be accurately depicted. The number of iterations of the neural network is rational, and the prediction of the data can be completed in a more reasonable way.

Table 2. Indicators of the algorithm

GA-BP Algorithm	MSE	RMSE	MAE	MAPE	R^2
Training set	0.027	0.079	0.052	7.742	0.992
Test set	0.015	0.056	0.043	6.266	0.673

Table 2 demonstrates that R^2 of training set is 0.99 which is really close to 1, and that of test set is 0.67 which is acceptable. These exemplify the efficiency and accuracy of this algorithm.

In order to analyze the influence of GGDP on the amount of temperature and carbon dioxide changes in different countries, this article uses four continents to represent four countries with different characteristics, takes GDP and seven other influencing factors as input variables, and temperature and carbon dioxide as output ones, and uses GA-BP neural network to train the model.

On this basis, the GGDP in the four different countries are calculated separately, and the weights calculated using the combined weighting method are brought into the model for validation, and then the actual trends of temperature and CO2 are analyzed with the trends of temperature and CO2 after replacing GDP with green GDP.

As shown in the figure 6:

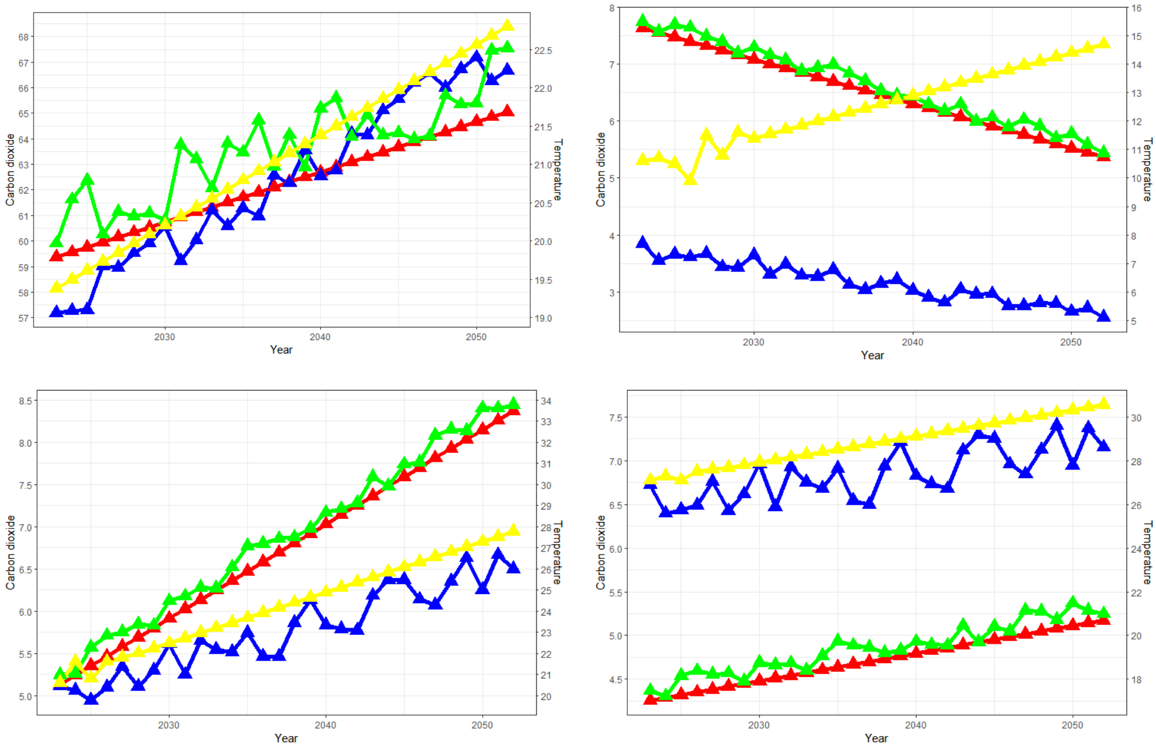

Figure 6. Four items of different countries

4. Conclusions

In a nutshell, this paper gets two kinds of factors directly influencing climate and indirectly influencing climate through related literature. Based on the selected indicators, we get their combined weights by entropy-variance coefficient method, and finally calculate the GDP and GGDP growth curves from 2000 to 2020. The result suggest that there is a positive correlation betweent GDP and GGDP. Also, the trend of carbon dioxide and temperature are obtained by a BP neural network prediction model based on genetic algorithm, and this is used as an entry point to predict that the world's major economies around 2050 If the GGDP system is adopted, it will be able to avoid the above situation and effectively reduce CO2 emissions.

We cannot deny the merits of GDP in leading development, but at the meantime, we should also pay attention to the problems caused by the single-minded pursuit of GDP development. Under the development model that focuses exclusively on GDP, natural resources are heavily exploited in order to provide sufficient raw materials, energy, sites, labor, etc. For production, the environmental is deteriorating, and the biological balance is forced to break. At a time when the concept of "community of human destiny" is gradually being strengthened worldwide, maintaining the health of the ecological environment and pursuing sustainable development are the demands and aspirations of all human beings.

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