Climate-friendly GGDP: GDP's path to environmental transformation

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ABSTRACT

Against the backdrop of the current environmental problems and increasing pressure on resources, the sustainability of economic development paths and the rationality of their assessment methods have received widespread attention. Green GDP (GGDP), as a more integrated and sustainable economic assessment indicator, takes into account environmental costs and resource consumption, and can better reflect the true state of economic development. The sustainability of economic development can be more accurately assessed through the use of GGDP, which promotes the development of green industries and the optimisation and transformation and upgrading of economic structure.

In this context, this paper studies the impact and influence of green GDP on climate through the following methods.

Through reviewing literature and information, this paper collects China's ecological gross domestic product data (EDP) and data about climate from 2000 to 2014, and then establishes the least squares method to obtain the model of the impact of GGDP on climate, and the function expression is shown in Equation 5.

Then we use the grey prediction model to predict GDP and GGDP, and choose the metabolism GM(1,1) with the smallest SSE to solve the problem, and the results show that the development trend of the two is basically the same, and in the use of Kendall's consistency test to test our conjecture, in which the Kendall's coordination coefficient W has a value of 1.0, and therefore the correlation between the two of the degree is almost perfect consistency, indicating that there is no significant hindrance to economic development when considering ecology and resources, so it is worthwhile to replace GDP with GGDP. Then, through the study of climate mitigation and the previous global impact analysis, the advantages and disadvantages of climate mitigation are compared.

Therefore, we believe that GGDP is one of the most important tools to promote green development and harmonious coexistence between human beings and nature. In future economic development, we should pay more attention to the application and promotion of GGDP to better achieve the goal of sustainable development.

Keywords: GGDP; Least Squares; GM(1,1); Kendall Consistency Test

1 INTRODUCTION

In the current social context, environmental problems and resource pressures are becoming more and more significant, which has aroused widespread concern about the sustainability of economic development paths and the way they are assessed. In this context, Green GDP (GGDP) has attracted much attention as a new economic assessment indicator because it not only takes into account environmental costs and resource consumption, but also more accurately reflects the true state of economic development [1]. The importance of GGDP lies in its ability to better measure the impact of economic activities on the environment and to provide support in addressing challenges such as climate change and resource depletion.

By using GGDP to assess the sustainability of the economy, we can better recognise the relationship between economic growth and climate protection. The introduction of GGDP not only helps to promote the development of green industries and the optimisation and transformation and upgrading of the economic structure, but also helps to reduce carbon emissions and resource wastage, and realise a virtuous circle between economic growth and environmental protection [2]. Therefore, the role of GGDP has become more important in the current climate change context, providing useful reference and guidance for us to think more comprehensively about how to achieve sustainable economic development.

2 GLOBAL CLIMATE IMPACT MODELLING BASED ON THE LEAST SQUARES METHOD

Firstly, to choose a method for calculating GGDP to replace GDP as the main measure of economic health, we chose ecological gross domestic product (EDP) as GGDP. Ecological gross domestic product (EDP) refers to the assessment of the total value of economic activities taking into account environmental and resource factors [3]. EDP can be calculated by multiplying GDP by an index of ecological losses and an index of resource depletion difference to calculate it. The specific formula is:

$$\text{EDP (GGDP)} = \text{GDP} * (1 - \text{Ecosystem loss index}) * (1 - \text{Resource consumption index}) \tag{1}$$

By reviewing the information, the following data can be obtained:

Table 1: China EDP data

Year	Environmental damage index	Resource consumption index	EDP in China
2014	0.1217	0.1152	13781491925521.00
2013	0.1066	0.1127	11643122078540.80
2012	0.0968	0.1076	11509853534908.80
2011	0.0904	0.1011	11360950839972.50
2010	0.0879	0.0932	10181844554305.10
2009	0.0665	0.0842	9603320247963.05
2008	0.0601	0.0748	9619076560040.60
2007	0.059	0.0653	9213915197152.78
2006	0.0573	0.0555	8521299739667.57
2005	0.053	0.0463	7705916788450.26
2004	0.0486	0.0381	6910767874154.91
2003	0.0471	0.0324	5612523602047.55
2002	0.0403	0.0274	4761951177605.48
2001	0.0386	0.0239	4311401275129.40
2000	0.0259	0.022	3382304305199.57

2.1 Modelling of the expected global impact of GGDP on climate mitigation

The main idea of the least squares method is to minimise the sum of squares of the errors (also known as residuals) of the true and predicted values by determining the unknown parameter θ (usually a parameter matrix), which is calculated as:

$$E = \sum_{i=0}^{n} e_i^2 = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \tag{2}$$

Where y_i is the true value $\hat{y}_i$ is the corresponding predicted value.

In linear regression, usually we use the mean square error as the loss function, and the mean square error can be regarded as E divided by m (m is the number of samples) in the least squares method, so the optimal solution derived from the least squares method is the optimal solution derived by using the mean square error as the loss function [4]. Our fitting function is:

$$h_\theta(x) = \theta_0 + \theta_1 x \tag{3}$$

The loss function is:

$$J(\theta_0, \theta_1) = \sum_{i=0}^{m} (y^{(i)} - h_\theta(x^{(i)}))^2 = \sum_{i=0}^{m} (y^{(i)} - \theta_0 - \theta_1 x^{(i)})^2 \tag{4}$$

The simulated pathways are given in terms of average precipitation, average temperature and CO2 emissions (in kilotonnes) as climate factors:

Mean precipitation	0.017	GGDP
Mean air temperature	0.289	
Carbon dioxide emissions	0.71	

Figure 1: Model path diagram

Using SPSSPRO software, the fitting results were obtained as:

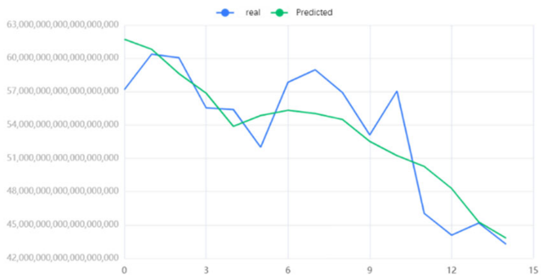

Figure 2: Fitting effect diagram

The data were analysed:

The analysis of the results of the F-test can be obtained that the significance P-value is 0.002***, which presents significance at the level and rejects the original hypothesis that the regression coefficient is 0. Therefore, the model basically meets the requirements [5].

For the covariate covariance performance, VIF is all less than 10, so the model has no multicollinearity problem and the model is well constructed.

The formula of the model is as follows:

y=1.177e+19 + 3.1584e+15* Average precipitation + 2.380e+18* average temperature + 1.794e+13* carbon dioxide emissions. (5)

3 RESEARCH ON THE VALUE OF GGDP USE

3.1 Introduction to the use of models

3.1.1 Grey prediction model

The GM(1,1) model is a predictive model. It uses the original discrete non-negative data columns and obtains new discrete data columns with more regularity where randomness is attenuated by a single accumulation. It is then solved using a differential equation model, which gives an approximate estimate of the initial data obtained by accumulating the solutions at the discrete points, thus allowing a more accurate prediction of the original data [6]. The model can be classified into a first-order unitary prediction model GM(1,1) and a first-order multivariate prediction model GM(1,N) based on the demand for the number of predictors.

3.1.2 Kendall consistency test

When measuring the degree of correlation between variables, common methods used in non-parametric statistics include the Spearman rank correlation coefficient and the Kendall-τ correlation coefficient. These two methods are only applicable in the case of two variables. Whereas, the Kendall coefficient of concordance, also known as the Kendall W coefficient, was introduced by M.G. Kendall and B. Babington Smith in 1939 to test the correlation between multiple variables. The coefficient is based on the multivariate rank-sum test and is mainly used for testing two-factor design or area group design problems [7].

3.2 model solution

First, we can use the grey prediction model to predict the future trends of GDP and GGDP in China, and by comparing their development trends, we can determine whether there is any obvious obstacle to economic development by considering the ecological environment and resources, in order to assess whether it is possible to replace GDP with GGDP, which is a relatively more reasonable method. Secondly, we can also compare the advantages and disadvantages of GGDP and GDP one by one in conjunction with previous climate mitigation studies and global impact analyses [8].

When using the grey prediction model for forecasting, we need to first determine whether the data has a quasi-exponential pattern. Specifically, we can start with the following two indicators:

Indicator 1: Percentage of data with a smooth ratio < 0.5;

Indicator 2: Percentage of data with a smooth ratio < 0.5 excluding the first two periods.

(Reference standard: Indicator 1 should generally be greater than 60%, and Indicator 2 should be greater than 90%)

Use MATLAB to solve the smooth ratio, and the results obtained by MATLAB:

Indicator 1: The percentage of data with a smooth ratio <0.5 is 85.1064%%;

Indicator 2: The percentage of data with a smooth ratio <0.5 excluding the first two periods is 100%.

The data meets the criteria of two indicators with quasi-exponential laws, so the data collected in this paper can be predicted using the grey system.

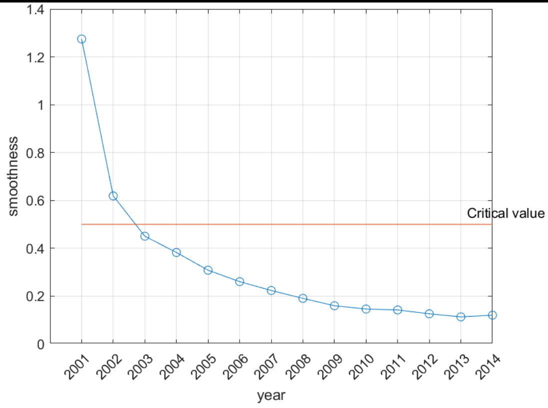

Figure 3: Smoothness of raw data

When we use the GM(1,1) model to model and reduce the original data, the effectiveness of the model fit needs to be assessed in order to determine whether the model is suitable for making predictions for future data. For the prediction of future data, the effectiveness of the GM(1,1) model for the reduction of the original data needs to be assessed first [9]. For this purpose, we can use two methods for model evaluation: residual test and rank deviation test.

Residuals test

Mean relative residuals.

$$\bar{\varepsilon_r} = \frac{1}{n-1}\sum_{k=2}^{n}|\varepsilon_r(k)| \tag{6}$$

For the evaluation criteria of the fitting effect of the GM(1,1) model to the original data, it can be judged by the magnitude of $\bar{\varepsilon_r}$. When $\bar{\varepsilon_r}$ is less than 20%, it indicates that the model fits the original data in an average way, while when $\bar{\varepsilon_r}$ is less than 10%, it indicates that the model fits the original data in an excellent way.

The relative residual results for each time point are shown below.

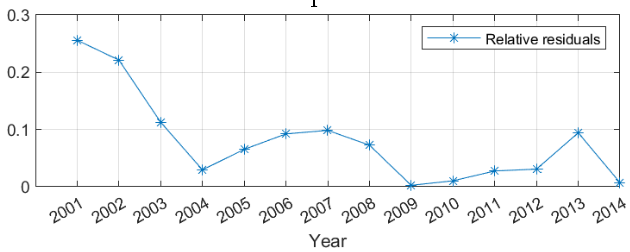

Figure 4: Relative residual results

According to MATLAB calculations, the average relative residual of the GM(1,1) model is 0.080071, indicating that the model fits the original data very well.

Grade ratio deviation test

Mean cascade deviation.

$$\bar{\eta} = \sum_{k=2}^{n}\eta(k)\Big/(n-1) \tag{7}$$

The criteria for assessing the effectiveness of the GM(1,1) model in fitting the original data can also be judged by the magnitude of $\bar{\eta}$. When $\bar{\eta}$ is less than 20%, it indicates that the model fits the original data in an average way, while when $\bar{\eta}$ is less than 10%, it indicates that the model fits the original data in an excellent way [10].

The results of the rank deviation at each time point are shown below:

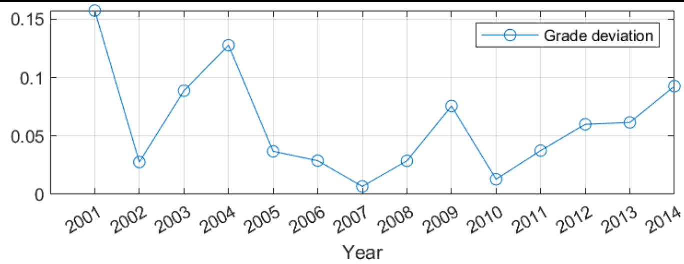

Figure 4: ranking deviation

According to MATLAB calculations, the average rank deviation of the GM(1,1) model is 0.060251, indicating that the model fits the original data very well.

The GM(1,1) model will be used next for prediction. In order to evaluate the prediction performance of different grey prediction models, three different GM models (traditional GM model, new news GM model and metabolic GM model) will be used to assess the fit to the data and the best performing model will be selected for prediction. In order to assess the performance of the models more accurately, we divided the data into training and validation groups. Due to the small amount of data for the grey prediction model, we will use the last three sets of data as the validation group and the rest of the data as the training group.

During the training process, we will use MATLAB to reflect the model's prediction effect on the validation group data using the error squared SSE as the evaluation metric. The following table shows the evaluation results of the three models:

Table 2: Results of the model evaluation

Model Type	SSE
Traditional GM(1,1) model	7.84500e+2
New information GM(1,1) model	8.02074e+2
Metabolic GM(1,1) model	6.07556e+2

From the evaluation results of the validation set, it can be seen that the metabolic GM(1,1) model has the smallest SSE, this is because the model can be timely supplemented with new news and reflect the current characteristics of the system, which may have less bias on the prediction results, after considering the results, we preferentially chose to use the metabolic GM(1,1) model for the data prediction.

We can substitute the existing n-period data into the metabolic GM(1,1) model for predicting the n+1th period. Then, we can eliminate the earliest period of data, add the n+1st period of data, and again use the metabolic GM(1,1) model for predicting the n+2nd period of data. This was done using the metabolic GM(1,1) model again for prediction of the n+2nd period data, and so on until the n+5th period data was predicted. Using MATLAB to make predictions, the results of GGDP prediction for China in the next 5 years were obtained as shown in Figure 6:

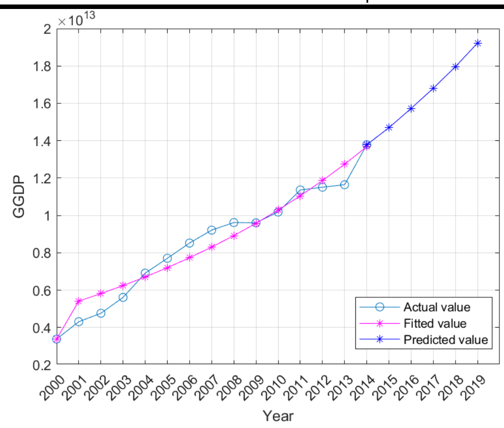

Figure 5: Projected results for GGDP

GDP is then analysed using a metabolic GM(1,1) model to obtain forecasts of GDP for the next five years.

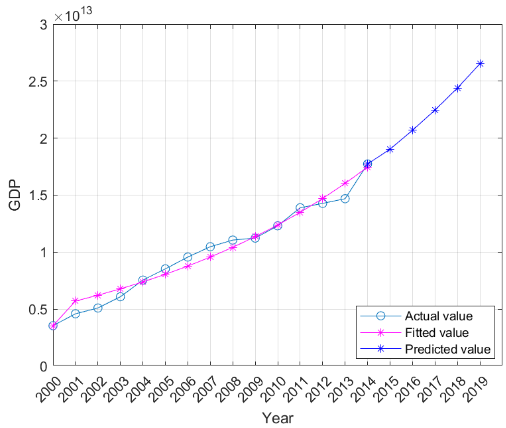

Figure 6: GDP projection results

Since the time frame of the data collected is 2000 to 2014, the next five years would be 2015 to 2019.

Table 3: Comparison of GDP and GGDP over the next 5 years

Year	GDP	GGDP
2015	19037964763801.92	14693638532984.53
2016	20544430019663.44	15586809833816.27
2017	22091627263988.73	16469459205349.56
2018	23756791206257.78	17399060756460.67
2019	25655866600347.52	18474482094979.26

By looking at the projected data for China's GDP and GGDP for the next 5 years, it is clear that they are both trending upwards and at an increasing rate. The above figure shows that China's GDP and GGDP remain highly consistent in their trends.

In order to verify our conjecture more accurately, we can use SPSSPRO to carry out Kendall consistency test on GDP and GGDP. Firstly, we need to test the significant relationship between the statistics (GDP and GGDP) to determine whether the P-value presents significance ($P<0.05$). If it presents significance, it means that the data are consistent. Based on this, we also need to analyse the positive and negative Kendall coefficients as well as the degree of correlation in order to arrive at the final test results.

Table 4: Kendall's W Analysis Results

Name	Rank Mean	Median	Kendall's W factor	X^2	P
GDP	2	10475682920594.5	1	15	0.000***
GGDP	1	9213915197152.78			

Note: ***, **, * represent 1%, 5%, 10% significance levels, respectively

The results of the Kendall coefficient consistency test show that the significance p-value of the overall data is 0.000***, which indicates that the data show consistency at the significant level and the original hypothesis is rejected, therefore GDP and GGDP show consistency, while the Kendall coefficient of concordance of the model W has a value of 1.0, therefore the degree of correlation between the two is almost complete consistency. It indicates that the development trend of the two is basically the same, then there is no obvious obstacle to economic development when considering the ecological environment and resources, and it does not affect economic growth, which indicates that it is reasonable to use GGDP instead of GDP.

Finally, we analyse the advantages and disadvantages of climate mitigation. The potential advantages of climate mitigation are: the same period of rain and heat is favourable to the growth of crops and forests, etc., which can promote the development of agriculture and forestry; the complexity and diversity of climate types make it possible for most crops and forest tree species to find suitable growing places, which makes our country richer in species; some meteorological landscapes can be developed into very good tourism resources, which promotes the development of the tourism industry; the coastal areas can be exploited for wind energy resources, and the Inland areas can develop solar energy resources, which is conducive to promoting the development of new energy industry. At the same time, the potential disadvantages of the efforts needed to replace the status quo are: improving the environment and protecting mineral resources requires a large amount of human and financial resources, for example, large-scale afforestation will consume a lot of manpower and time; the development of new energy sources instead of extracting mineral resources will also require a large amount of expenditure on research; the implementation of climate mitigation measures may have a certain impact on the operation of certain industries and enterprises, such as energy, manufacturing, agriculture and transport. agriculture and transport, among others. Therefore, these impacts need to be taken into account when implementing climate mitigation measures, and appropriate measures need to be taken to mitigate the risks in order to ensure sustainable economic development. For example, measures such as technological innovation, transformation and upgrading, energy saving and emission reduction can be taken to alleviate the pressure on enterprises.

4 CONCLUSION

In this paper, the rationality of green GDP (GGDP) as an economic assessment indicator and its impact on climate are discussed in depth in the context of the current environmental problems and increasing pressure on resources. By collecting China's ecological gross domestic product (EDP) and climate data in recent years, a model of GGDP's impact on climate is established. The grey prediction model is further used to predict GDP and GGDP, and the high consistency of their development trends is verified by the Kendall consistency test, which indicates that GGDP is not an obvious obstacle to economic development when ecological environment and resources are taken into account, and thus it is reasonable to use GGDP as an assessment indicator. In addition, the article explores the advantages and disadvantages of climate mitigation through a comparative study. In conclusion, GGDP, as an important tool to promote green development and harmonious coexistence between human beings and nature, should be more widely applied and promoted in future economic development in order to achieve the goal of sustainable development.

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