Research on GGDP evaluation system based on DPSIR and Grey prediction model

Zhuochen Li *, Beiyu Yuan #, Zhihua Wang #

Department of Electronic and Electrical Engineering, Brunel University London, London, United Kingdom, UB83PH

* Corresponding Author Email: 2161113@brunel.ac.uk

#These authors contributed equally

Abstract. The GGDP (Green GDP) index is revised and innovated based on the traditional GDP index. It not only inherits the advantages that the traditional GDP can measure the economic level well, but also makes up for the shortcomings that the resources and environment are not considered in the measurement process of the traditional GDP. This paper concentrates on the problem that the traditional GDP algorithm cannot provide credit for natural resources. By combining the United Nations GGDP theory, various factors such as environment, climate and GDP were considered to get the formula for calculating GGDP. Based on DPSIR model, GGDP evaluation index system is constructed from five aspects: driving force, pressure, state, influence and response. The China’s data set is selected for the specific numerical calculation of GGDP, the GGDP evaluation index system is analyzed, and a simple grey prediction is made for the future trend. This paper takes China as an example for application analysis, the evaluation indicators reflect the development level of China's GGDP consistent with the actual situation, indicating that the GGDP evaluation indicator system based on the DPSIR model is scientific and operable. The average relative error of the grey prediction model is 6.776%, which means that the DPSIR model has a good fitting effect.

Keywords: GGDP Evaluation Index; DPSIR Model; Grey Prediction.

1. Introduction

GDP is an important indicator to measure the economic development of a country or region. With the rapid development of the economy and the constant emergence of various situations. GDP cannot fully reflect the losses caused by external uneconomic behaviors in the process of economic development. A new indicator, GGDP, was born. GGDP is an important indicator to measure the economic development of a country or region based on the consideration of environmental pollution. It may be a better indicator than GDP to measure the health of a country's economic development [1].

The GGDP index is revised and innovated based on the traditional GDP index. It not only inherits the advantages that the traditional GDP can measure the economic level well, but also makes up for the shortcomings that the resources and environment are not considered in the measurement process of the traditional GDP and overcomes the disadvantages of the traditional development model that is too keen to catch up with the economic growth while ignoring the environmental and resource conditions. The accounting theory of GGDP is constantly developing, and the content of the accounting system is constantly enriched. Although there are still many accounting systems, and the accounting content is also different, the system and content basically cover the cost of resource consumption including water, energy, and cultivated land resources, the cost of environmental degradation including the cost of environmental pollution consumption and environmental protection expenditure, and the benefits of resource and environmental improvement; In terms of empirical research on GGDP accounting, scholars are moving towards the direction of enrichment as a whole due to regional differences and differences in the content of different key estimates in different historical periods [2].

GGDP research has a history of several decades in the international community, and different countries and institutions are exploring accounting methods and indicator systems suitable for their own national conditions and needs. The United States began the pilot work of GGDP accounting in

1995, mainly using the asset value accounting method. Japan has carried out GGDP comprehensive accounting every year since 1992, mainly using the maintenance of environmental cost valuation method, first single and then comprehensive, first pilot and then national. Some other countries and regions, such as the European Union, Canada, Australia, New Zealand, etc., are also carrying out relevant research and practice [3].

In view of the global impact of climate change, this paper decides to choose DPSIR model to evaluate the GGDP framework index system. The advantage of this model is that multiple factors of climate influence can be weighed to determine the combined impact of multiple factors on the GGDP.

2. Materials and Methods

2.1. Data source and processing

The data in this paper are from the following websites: Berkeley Earth (berkeleyearth.org/), National Data Statistics Network of China (http://www.stats.gov.cn/), Department of Energy's Office of Energy Statistics (www.eia.gov) and other official websites. The GGDP evaluation index values all come from China’s 2010-2017 Statistical Yearbook, Environmental Status Bulletin, and Ecological Environmental Quality Status Report. Different indicators have different dimensions and units, which will affect data analysis and comparability between indicators. According to the calculation steps of the entropy method, it is first necessary to standardize the original data of the GGDP indicators. The data matrix $A=\left(x_{ij}\right)_{m\times n}$ refers to the index value of the x_i indicator in the i-th year:

For the positive index, the bigger the better, let:

$$y_{ij}=\frac{x_{ij}-min\{x_i\}}{max\{x_i\}-min\{x_i\}} \tag{1}$$

For the negative index, the smaller the better, let:

$$y_{ij}=\frac{max\{x_i\}-x_{ij}}{max\{x_i\}-min\{x_i\}} \tag{2}$$

In the formula, $max\{x_i\}$ and $min\{x_i\}$ are the maximum and minimum index values of the i-th index in n-th years. After the data is standardized, the information utility value of multiple indicators is obtained by calculating the entropy value, and then the weight of each indicator is obtained [4].

2.2. DPSIR model

The DPSIR model was first proposed by the OECD (Organization for Economic Co-operation and Development) in 1993 after revising the PSR model and DSR model and has gradually become an effective tool to solve the problem of the relationship between environment and social development. The DPSIR model includes five major factors: driving force, pressure, status, impact, and response. A schematic diagram of the model is shown in Figure 1.

This model is often used for the management of water resources and land resources. At present, it has also made progress in the management of marine resources and can also be used for the evaluation of regional sustainable development capacity.

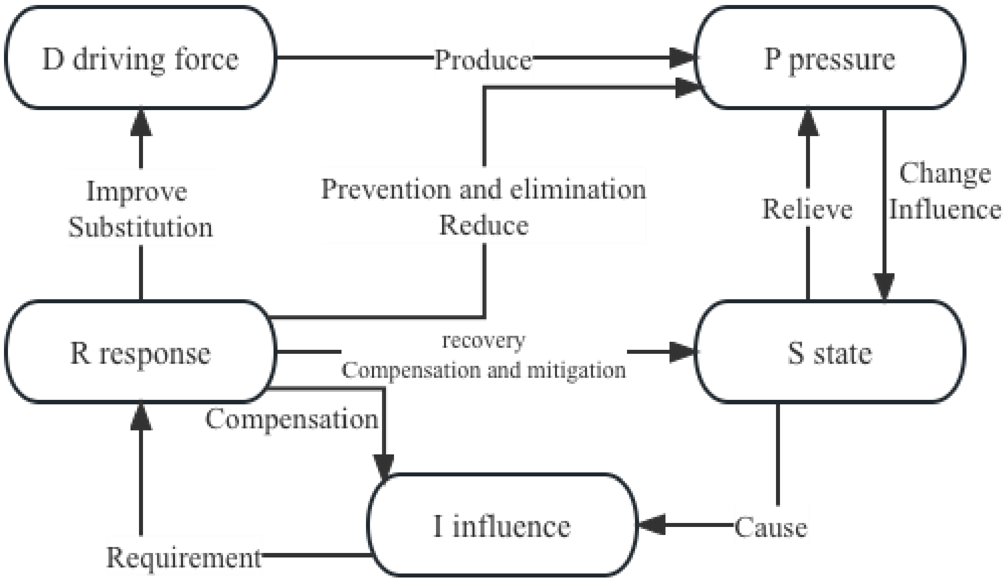

Figure 1. DPSIR model.

Based on the DPSIR model (Driving Force-Pressure-State-Impact-Responses), the evaluation index system of GGDP is constructed from five aspects: driving force, pressure, status, impact and response, and China is taken as an example to evaluate the objectivity and operability of the index system.

2.3. Grey prediction model

The brief principle of GM (1,1) prediction model (grey prediction model) is that: firstly, the cumulative technology is used to make the data have the exponential rule, then the first-order differential equation is established and solved, and the results are reduced and reduced again, which is the gray predicted value, to predict the future.

Based on the GGDP evaluation index proposed in this paper, it can be believed that the value of GGDP can be obtained through the evaluation index, and the actual value of future GGDP can be obtained through the actual calculated value of GGDP in 2010 and the grey prediction of the evaluation index [5].

3. Model construction and solution

3.1. Construction and solution of the DPSIR model

Assume that a certain first-level indicator has m second-level indicators, and n years of teaching data have been obtained, which is recorded as a matrixY_{ij}.

Under the same indicator, calculate the proportion of the value of each year to the total value, the formula is as follows:

$$p_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}} (i = 1,2,\cdots,n; j = 1,2,\cdots,m) \tag{3}$$

According to the definition of information entropy in information theory, the information entropy of a set of data is:

$$E_j = -\ln{(n)^{-1}} \sum_{i=1}^{n} p_{ij} \ln p_{vj} \; (if\ p_{ij} = 0, set\ \ E_j = 0\ ) \tag{4}$$

According to the calculation formula of information entropy, the information entropy of each index is calculated as E_1, $E_2 \ldots E_m$ And calculate the weight of each index through information entropy:

$$w_j = \frac{1 - E_j}{k - \Sigma E_j} \tag{5}$$

Here k refers to the number of indicators, that is, k=m.

The weight is calculated by calculating the information redundancy:

$$D_j = 1 - E_j \tag{6}$$

Then calculate the index weight:

$$w_j = \frac{D_j}{\sum_{j=1}^{m} D_j} \tag{7}$$

The composite score of each scheme can be calculated as follows:

$$s_i = \sum_{j=1}^{m} w_j^* y_{ij} \tag{8}$$

3.2. Construction and solution of grey prediction model

Before establishing the gray prediction model, the feasibility of the modeling method must be guaranteed, that is, the known original data needs to be tested by level ratio. Let the initial non-negative data sequence be:

$$X^{(0)} = \left\{x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)\right\} \tag{9}$$

Only when all σ (k) fall into the range of computation can the model be established. The calculation and judgment formulas of stage ratio are as follows:

$$\sigma(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)}, \sigma(k) \in \left(e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}}\right) \tag{10}$$

The disturbance of $x^{(0)}$can be weakened by obtaining the first-order cumulative sequence of $x^{(0)}$after the accumulation operation:

$$x_k^{(1)} = \sum_{i=1}^{k} x_i^{(0)}, k = 1,2, \cdots, n \tag{11}$$

$Z^{(1)}$Is the sequence generated by the adjacent mean of? $X^{(1)}$

$$Z^{(1)} = \left\{z^{(1)}(2), z^{(1)}(3), \cdots, z^{(1)}(n)\right\} \tag{12}$$

Therefore, the differential equation corresponding to GM (1, 1) model can be obtained as follows:

$$x^{(0)}(k) + az^{(1)}(k) = b \tag{13}$$

Where $z^{(1)}$ is the background value of GM (1, 1) model?

Construct data matrix B and data vector Y, respectively:

$$\boldsymbol{B} = \begin{bmatrix} -z(2) & 1 \\ -z(3) & 1 \\ \vdots & \vdots \\ -z(n) & 1 \end{bmatrix} \boldsymbol{Y} = \begin{pmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{pmatrix} \tag{14}$$

Then the least square estimation parameter column of grey differential equation satisfies

$$\boldsymbol{u} = [a \quad b]^{\mathrm{T}} = (\boldsymbol{B}^{\mathrm{T}}\boldsymbol{B})^{-1}\boldsymbol{B}^{\mathrm{T}}\boldsymbol{Y} \tag{15}$$

Among them, a mainly controls the development situation of the system, which is called development coefficient; the size of b reflects the relationship between data changes, which is called the grey action [5].

4. Results and Analysis

4.1. Analysis of the DPSIR model

After determining the weight of each index in the evaluation model, use the evaluation index formula.Formula (8) to obtain the evaluation index of each factor layer, and then obtain the GGDP comprehensive evaluation index. In the formula, y_{ij} is the standardized index value, $w_i$and W_i are the weights of index layer and factor layer respectively. Analyze and evaluate China's GGDP development level from 2010 to 2022 from the comprehensive evaluation index of GGDP [6].

Table 1. Comprehensive evaluation index of each country.

Comprehensive evaluation index	2010	2011	2012	2013	2014	2015	2016	2017
China	0.2467	0.4099	0.3488	0.4962	0.4823	0.5269	0.5324	0.5907
U.S.A	0.0511	0.2654	0.3603	0.3892	0.4515	0.723	0.568	0.615
South Africa	0.3002	0.6017	0.7081	0.7594	0.6304	0.4891	0.4186	0.3934
Britain	0.1875	0.2635	0.363	0.4868	0.6461	0.605	0.6519	0.7303

It can be seen from the Table 1: The weight of each factor is approximately the same. The cost of resources and environment is an important factor affecting the level of GGDP.

Based on the DPSIR model, the author constructs the regional GGDP evaluation index system from five aspects: driving force, pressure, status, impact, and response. Among them, driving force and impact indicators are used to evaluate the national economic level in GGDP, pressure and status indicators are used to evaluate environmental costs, and response indicators are used to evaluate environmental benefits. As the fundamental driving force to promote the growth of GGDP, the driving force determines the national economic level of a region; Pressure and state are the changes and realities of the ecological environment under the driving force. Economic development will increase the loss of resources and pollution emissions, resulting in the reduction of resource reserves and the decline of environmental quality, which will lead to the generation of environmental costs; The impact is the reaction of the changes in the ecological environment to the national economy after years of accumulation, which will have an impact on the living standards of local residents and even the development of the whole region; The response is that human beings take measures to deal with environmental and economic problems, and produce certain ecological benefits while improving the ecological environment [7].

Through the five factors of the DPSIR model, the internal mechanism of GGDP is described in detail, and the national economy, environmental costs, and environmental benefits of GGDP are linked into a causal chain to ensure the scientific rationality of the evaluation index. So, we **can use** this model to replace GDP as the main measure of economic health [8].

4.2. Analysis of grey prediction model

The model is built, and the generated and reduced values are solved. The prediction model can be obtained by solving the formula:

$$\hat{x}^{(1)}(k) = \left[x^{(0)}(1) - \frac{b}{a}\right] \mathrm{e}^{-a(k-1)} + \frac{b}{a} \qquad (16)$$
$$k = 1,2,\cdots,n$$

After the reduction, the reduction predicted value is as shown in Figure 2.

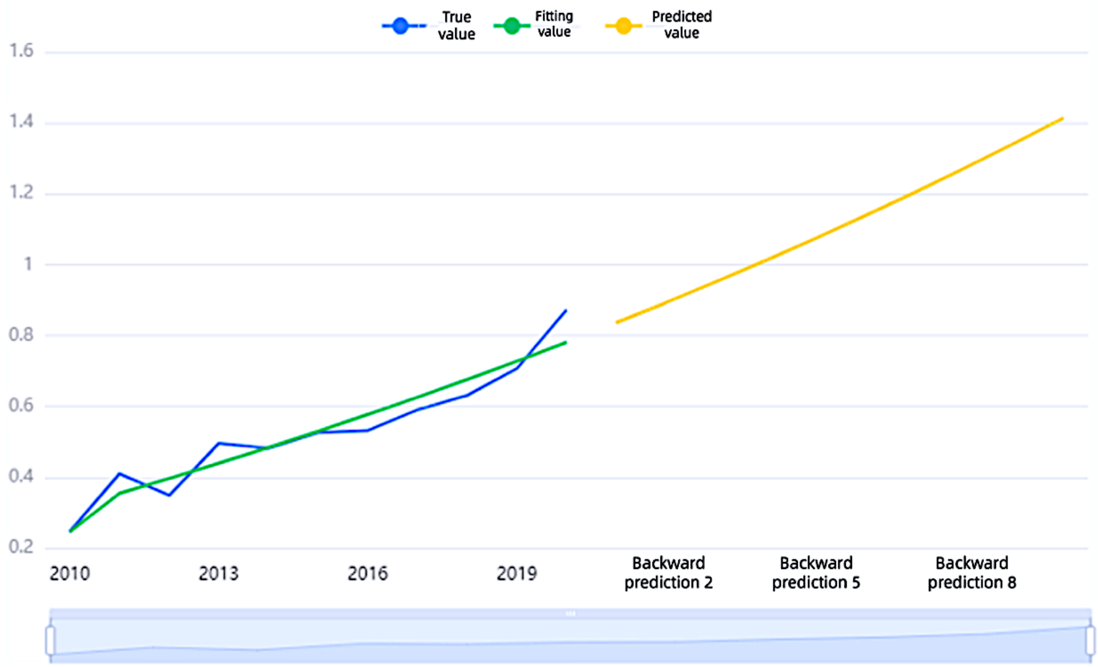

Figure 2. Model fitting prediction graph.

Table 2. Grade ratio test result table.

Index item	Original value	Stage ratio	Translation sequence value after conversion	Translational ratio after conversion
2010	0.247	-	1.247	-
2011	0.41	0.602	1.41	0.884
2012	0.349	1.175	1.349	1.045
2013	0.496	0.703	1.496	0.901
2014	0.482	1.029	1.482	1.009
2015	0.527	0.915	1.527	0.971
2016	0.532	0.99	1.532	0.996
2017	0.591	0.901	1.591	0.963

It can be concluded from Table 2 that: the average relative error of the model is 6.776%, which means that the model has a good fitting effect. It indicates that the actual value of GGDP can be estimated by the comprehensive evaluation index from 2010 to 2020. It can be seen from the above that the two parameters are correlated and can be considered to change in direct proportion at the same time [9].

5. Conclusions

Through the five factors of the DPSIR model, the internal mechanism of GGDP is described in detail, and the national economy, environmental costs and environmental benefits of GGDP are connected into a causal chain to ensure the scientific rationality of the evaluation index. Therefore, we can use the DPSIR model to establish a comprehensive evaluation index system for GGDP.

Through the results of the grey prediction model, it is shown that the actual value of GGDP can be estimated by the comprehensive evaluation index, and the two parameters are related and can be considered as a simultaneous proportional change [10].

The main contribution of this paper is to provide an accurate and comprehensive GGDP evaluation system based on the DPSIR model, which can help policy makers and researchers better understand the tradeoffs and synergies between economic development and environmental protection. This paper also shows the applicability and effectiveness of the grey prediction model in estimating GGDP, which can reduce the uncertainty and complexity in the calculation process. It is hoped that this study will stimulate more research on GGDP and promote its wider use as a measure of regional or national economy, which will benefit the green and sustainable development of the world.

References

[1] Guo Peiyuan, Fang Renye. Green Revolution of GDP [J]. China Development, 2002(4):12-20.

[2] Talberth J, Bohara A K. Economic openness and green GDP [J]. Ecological Economics, 2006, 58(4): 743-758.

[3] Liu Y, Ali M S, Cong P T. Nexus between economic policy uncertainty and green growth in BRICS countries: evidence from panel quantile regression [J]. Environmental Science and Pollution Research, 2023: 1-12.

[4] Hongxian X. Influence's energy consumption has on green GDP growth in China[C]//IOP Conference Series: Earth and Environmental Science. IOP Publishing, 2018, 113(1): 012125.

[5] Zhang Peng. Research on Key techniques of Grey Prediction for Small sample time Series [D]. Sichuan: University of Electronic Science and Technology of China, 2020.

[6] Guo Wenjuan. K-means clustering algorithm based on Optimizing initial Clustering Center [J]. Science and Technology Wind, 2022(4):63-65.

[7] Sun Y, Gao L, Shen R. Definition and forecasting of GGDP in the landscape of climate issues [J]. Highlights in Science, Engineering and Technology, 2023, 43: 11-19.

[8] Shen J Q, Sun Y. Regional green GDP evaluation index system based on DPSIR model [J]. Journal of Hohai University (Philosophy and Social Sciences), 2016, 18(06):56-61+95-96.

[9] Yang Cundian, Zhang Yan, Wang Yi. Improvement and application of Grey prediction model GM (1, 1) [J]. Journal of Shangluo University, 2021, 35(2):48-52.

[10] Liao H, Shi Y, Yu Z. A study on the impact of GGDP on climate mitigation based on grey prediction [J]. Highlights in Science, Engineering and Technology, 2023, 49: 48-54.