GGDP Research Based on Structural Equations And DEA Model

Haoqi Fan [1, *], Chao Ma [2], Yeqing Li [1]

[1] Faculty of Statistics and Mathematics, Shanghai Lixin University of Accounting and Finance, Shanghai, China, 201209

[2] Faculty of Finance, Shanghai Lixin University of Accounting and Finance, Shanghai, China, 201209

* Corresponding Author Email: fhq2060541375@hotmail.com

Abstract. With the advancement of globalization, the climate problem has gradually spread to the world, causing serious effects such as shrinking glaciers. So, we introduced GGDP to calculate economic health to improve the environment. After that, we use fuzzy mathematics to deal with the potential variables affecting climate to obtain a linear relationship between carbon emissions and green resource loss based on a structural equation model. Then we collected data from the World Bank and related data from some countries, and built a Network DEA model based on the traditional data envelopment analysis model. By analyzing data from China, Germany, and Australia, we conclude that using GGDP as a measure does not significantly affect economic strength in the long run, while also protecting the environment. Therefore, expanding GGDP accounting to the whole world has its advantages.

Keywords: Structural Equation; Data Envelopment Analysis; Network DEA.

1. Introduction

After the 60th century of the 20th century, GGDP came into being as the global resource shortage and ecological environment deteriorated to mankind brought unprecedented challenges.[1] The promotion of GGDP to measure economic health standards is important for environmental protection and the national economy. While GDP is a reliable indicator of a country's economic performance, it still largely ignores the environmental damage caused by asset depreciation, non-market economies, and especially growth.[2] GDP captures only a part of what is important about an economy[3]. GDP does not consider environmental externalities and depletion of natural resources, and do not reflect the decline in the environment's ability to slow down, reduce self-purification capacity, and reduce resilience, but instead includes the benefits of economic activities that produce environmental pollution in GDP, and even counts environmental pollution as a contribution to the economy. [4] However, GGDP considers the environmental costs of economic growth.[5] It can reflect the changes of natural resources and environment, especially the cost of resource consumption and environmental loss caused by economic development, which is in line with the requirements of China's scientific outlook on development.[6]

2. Establishment of models

2.1. GGDP model

Due to extensive externalities in the economy, there are many links in the use and loss of natural resources in output and final consumption, and it is difficult to trace the root cause in practice. At present, no country in the world has calculated a complete green GDP for all the cost of resource depletion and all the cost of environmental damage. One of the most important reasons is that many resource depletion costs and environmental loss costs are difficult to be estimated.

According to the components of different resources and environment, the actual accounting Structure of GGDP with different contents and levels can be reflected. When selecting the GGDP

accounting model, we analyzed all kinds of important factors affecting the environment and carried out the estimation quantification appropriately in the calculation. Finally, we found a suitable GGDP accounting model. This accounting method divides the environmental loss cost in GGDP into three dimensions, namely resources, production, and governance.

$$GGDP = TGDP - C - DNR - ECM \quad (1)$$
$$= TGDP - EC - MC - FC - CED - PED$$

2.2. Establishment of structural equation models

Based on GGDP calculation model, considering that greenhouse gases are an important factor that affecting global climate change, in the expected impact assessment of global climate change mitigation, we predict greenhouse gas emissions and use this factor to determine the impact on global climate change under the GGDP model. Considering that the calculation of green resources is difficult and accurate, we make a simple estimation. We use CE (Carbon emissions) as the independent variable and GD (Green resource loss) as the dependent variable. Because there is a relatively obvious logical relationship between them, it is a good practice to analyze the linear relationship between them by structural equation model.

At the same time, our structural equation model may also be affected by other factors, so we also add random perturbations to the calculation to make our estimation more accurate. Since the amount of GD data shows an exponential growth mode, the logarithm of GD is taken to make its data distribution approximate to a straight line, which is convenient for the calculation of subsequent equations.

$$CE = \alpha_0 + \alpha_1 \ln GD + u_t \quad (2)$$

In addition, considering that the traditional statistical analysis methods cannot properly handle the potential variables affecting the environment, the structural equation model can handle these latent variables and their indicators well at the same time, helping us to make more accurate climate impact predictions. At the same time, the structural equation model can estimate the structural relationship between factors, making the prediction more efficient. Therefore, on the basis of Equation 2, we introduce Equation 3 based on the dependent variable GD.

$$\begin{cases} CE = \alpha_0 + \alpha_1 \ln GD + u_t \\ \ln GD = \beta_0 + \beta_1 \ln GGDP + v_t \end{cases} \quad (3)$$

2.3. Analysis of Carbon Emissions Based on CE Model

After bringing in the global data that obtained from the previous question, it can be brought into the structural equation model for calculation. The results are shown in table1:

Table 1: Structural equation model estimation

CO2 emission skt	Coef.	Std. Err.	z	P>z	95% Conf.	Interval
CE	137981.3	4358.76	31.66	0.00***	129438.2	146524.3
Time fixation effect	Control					
Constant term	-2821567	110485.2	-25.54	0.00***	-3038115	-2605020
GD						
ln $GGDP$	0.9974284	0.0037297	267.43	0.00***	0.9901184	1.004738
Time fixation effect	Control					
Constant term	-1.522988	0.0996349	-15.29	0.00***	-1.718269	-1.327708

As can be seen from the table that α 1 > 0, which means that ln GD and CE are proportional to each other. When the loss of green resources increases, carbon emissions will increase significantly, the pace of global climate change will accelerate. Conversely, when the loss of green resources declines, carbon emissions are greatly reduced, the global climate change slows down. To sum up,

when countries can realize the seriousness of the climate problem and start using the GGDP accounting method, they can control the consumption of green resources, effectively reduce greenhouse gas emissions and slow down global climate change. Meanwhile, it can be seen from p=0.00*** that shows a high degree of significance.

The final equation is as follows:

$$\begin{cases} CE = 137981.3 \ln GD - 2821567 \\ \ln GD = 0.9974284 \ln GGDP - 1.522988 \end{cases} \tag{4}$$

3. Solved based on CCR and DEA models

3.1. Collection of Data

We collected data from the World Bank, including the adjusted net national income of some countries from 1990 to 2020 and related green resource depletion data. It was made into a four-quadrant map with an average adjusted national net income as the x-axis and an average green resource loss ratio as the y-axis. The first quadrant represents higher economic benefits, but its average green resource loss ratio is relatively large. Countries in the second quadrant have lower economic benefits and heavier average green resource depletion. The third quadrant represents lower economic benefits and green resource loss, and the fourth quadrant represents higher economic benefits and lower green resource loss. The data is shown in Figure 1.

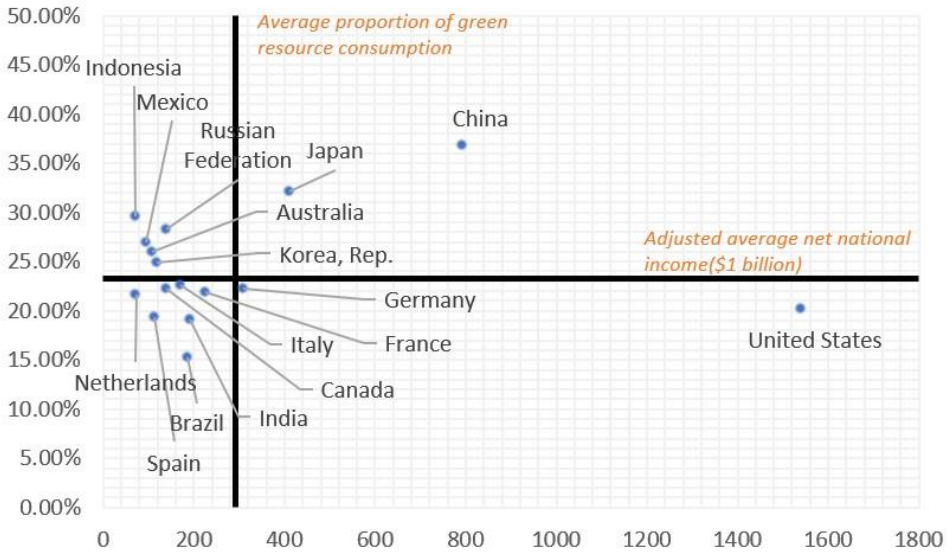


Figure 1. The relationship between GGDP and green resource loss from 1990 to 2020

By analyzing the Figure 1, we draw a conclusion that GDP is the basis of GGDP, which plays a very important role in formulating macroeconomic policies, testing the rationality of macroeconomic policies, and judging the operation of macroeconomics. Without GDP, there can be no GGDP. Only by combining GGDP with GDP, the cost of resource consumption and environmental loss will be clearly revealed.

3.2. Simple CCR model

To further analyze whether GGDP accounting is beneficial to different countries, several represent active countries are selected. We analyze the panel data of China, Germany, and Australia from 2000 to 2019, and obtains the relative efficiency index through the input-output model.

We choose a simple CCR model to analyze the relative effectiveness of traditional GDP. It can calculate the efficiency of resource allocation under the condition of constant returns to scale. We can use the CCR model to determine whether technical efficiency and scale efficiency are valid at the same time, as shown in Figure 2.

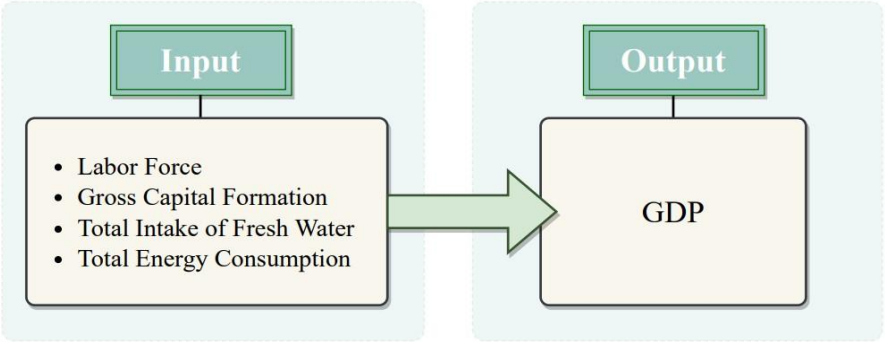


Figure 2. CCR model

The weights used in data envelopment analysis are the best weights, which are not necessarily equal to the actual weights. Therefore, it has certain idealization, but it still has good reference value. Under a given input, assuming constant returns to scale, we can obtain the maximum output of GDP. In GDP accounting, the government generally only takes into account labor, total capital, total energy consumption and total fresh water availability.

After bringing the data into the model, it can be found that. Since 1998, China 's traditional GDP has grown rapidly since 2021. In recent years, China 's economy is still in a relatively good state. Nearly 7.5 % growth is still faster than other countries. The growth of GGDP is shown in Figure 3, and the technical efficiency of CCR efficiency values is shown in Figure 4.

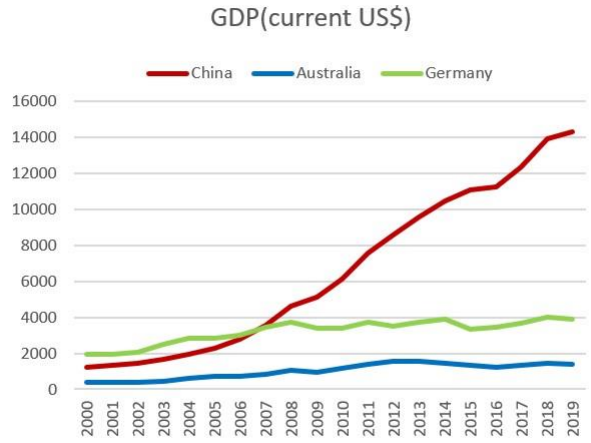


Figure 3. GDP of China, Australia, and Germany from 2000 to 2019

According to the data analysis, it can also be seen that China 's CCR technical efficiency is about 1, and the efficiency value of the first stage is very high. Under the traditional GDP accounting, China's input-output efficiency is 'high', and the total GDP has exceeded Australia and Germany since 2007.

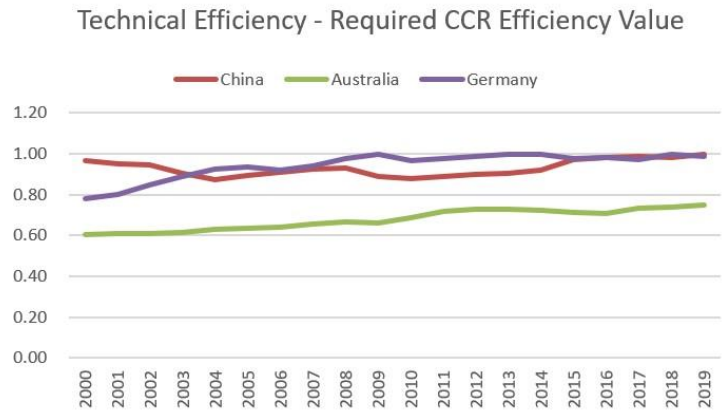


Figure 4. Technical efficiency of CCR efficiency values

3.3. DEA Model

In the previous model, we illustrate the first stage efficiency of each country under GDP accounting. The traditional CCR model does not assume the elements within the process, and simply regards the decision-making unit as a single process that only considers the initial input and final output. The intermediate structure of the decision-making unit is ignored. Therefore, the CCR model is difficult or even impossible to explain the specific reasons for the inefficiency of decision-making units. On this basis, we introduce the Network DEA model. Based on the traditional data envelopment analysis model, the whole process including decision making units is decomposed into several sub processes or stages. Each stage is distinguished by its own input and output processes, and all stages are associated through intermediate elements. The DEA model is shown in Figure 5.

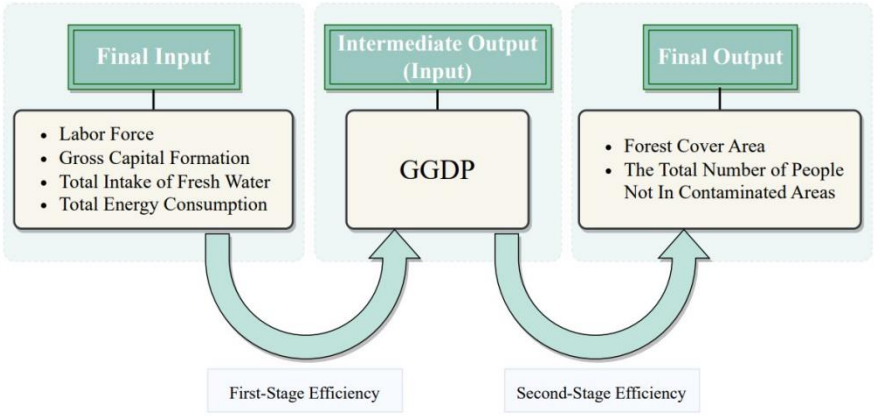


Figure 5. DEA Model

Through the Network DEA model, we want to know the relative efficiency under GGDP. In the Network DEA model, we introduce the second stage efficiency index, that is, green efficiency. The first stage efficiency represents economic efficiency. We use the calculation method of GGDP to evaluate. The closer the first stage efficiency is to 1, the higher the economic efficiency of the country is. In the second stage, forest coverage area and α were selected to evaluate green efficiency. The closer the efficiency of the second stage is, the higher the green efficiency of the country is. Through one-stage and two-stage efficiency analysis, we can evaluate the country's overall efficiency in the development process. Efficiency analysis of two phases in China, Australia and Germany is shown in Figure 6 and Figure 7.

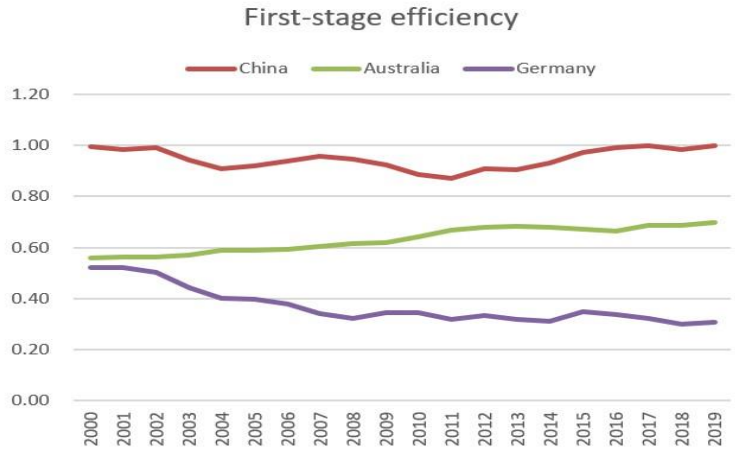


Figure 6. First-Stage Efficiency

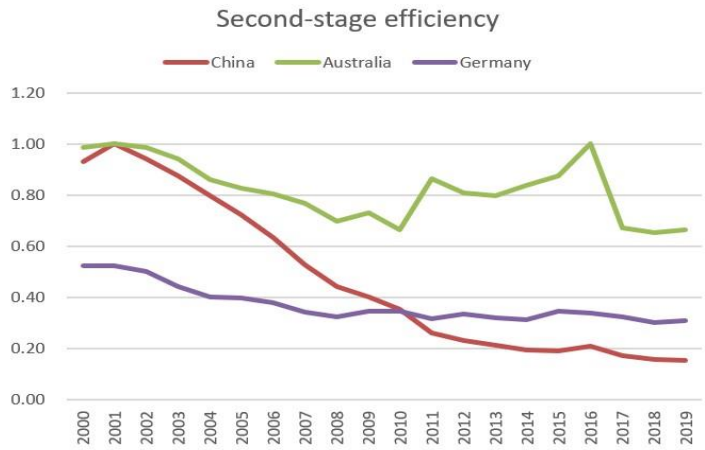


Figure 7. Second-Stage Efficiency

The efficiency of China's first stage is very high, but the efficiency of the second stage gradually decreases with the increase of years, possibly due to the environmental pollution brought by large-scale industrialization during the country's development process.

In the first stage, the efficiency of Australia is not high among the three countries, but in the second stage, the efficiency of Australia is high. In the development process, the country pays more attention to green efficiency.

The efficiency of Germany in the first stage gradually changed from slightly lower than that of China to equal with that of China, while the efficiency in the second stage changed from far lower than that of China to slightly higher than that of China.

From the perspective of overall efficiency, the overall efficiency of China and Germany is declining along with the ecological efficiency, while the overall efficiency of Australia continues to rise. Thus, we can see the importance of ecological efficiency in comprehensive efficiency,that is, economic development.

By establishing the regression model of China's second stage efficiency and GDP growth. It is concluded that the second stage efficiency is positively correlated with GDP growth. The improvement of green efficiency will promote the increase of GDP growth. The p-value of the regression equation is 0.022, which is significant. Therefore, it is also critical for countries to focus on second phase efficiency.

$$GDPgrowthrate = 2.0128 * Second - stageefficiency - 5.1034 \quad (5)$$

The second phase of slower efficiency growth in China may be because sustainable development was not taken into account in previous years. Take China as an example, the accounting method of

GGDP is more beneficial to the country. According to the data, China's per capita GGDP and traditional GDP data have been rising synchronously year by year over the evolution of time, and the rising speed is roughly the same, as shown in Figure 8.

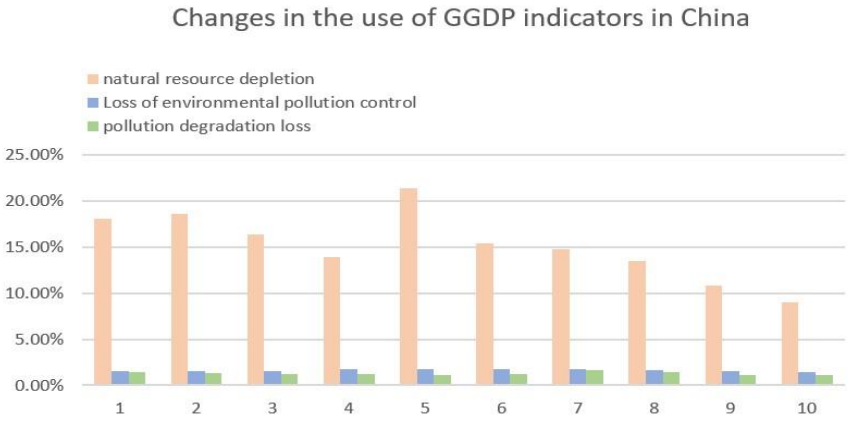


Figure 8: Changes in the use of GGDP indicators in China

4. Conclusions

In conclusion, after the construction of GGDP, the loss of China's natural resources, the cost of environmental pollution control, and the loss tend to decrease, especially the loss of natural resources. Therefore, we can conclude that taking China as an example, as a large consumer of natural resources, China will greatly contribute to the improvement of ecological benefits after the establishment of GGDP accounting.

The accounting method of GGDP reflects the consumption of resources in economic activities in the calculation, which changes people's ideas. Let people realize the price of resources. The problem solved by green efficiency is to realize the win-win of economic development and resources and environment, and its core is to realize the unity of maximizing economic value and minimizing resource consumption and environmental load. So it has its advantages to extend the GGDP accounting to the whole world.

5. Model promotion and evaluation

Firstly, the model fully considers the actual situation of each country. It combined with national conditions to analyze the application effect of GGDP model. What's more, the model considering the complexity of GDP accounting, we select the appropriate index accounting method through analysis. Besides, we use Data Envelopment Analysis to obtain the relative efficiency, and the direction and degree of improvement are obtained by projection. Provides leaders with information for making decisions.

However if the price of environmental pollution factors is set high enough and the principle of 'strong sustainability' is adopted, all the value of economic production can be offset, and GGDP may be negative. In the realistic society of pursuing short-term benefits, the concept of sustainable development of GGDP accounting may not be generally recognized and accepted by the whole society.

References

[1] Yang Duogui, Zhou Zhitian." International background of "green GDP" accounting and progress of China's practice [J]. Soft Science,2005(05):27-30

[2] Stjepanović S, Tomić D, Škare M. A new approach to measuring green GDP: a cross-country analysis [J]. Entrepreneurship and sustainability issues, 2017, 4: 574-590.

[3] Hoff J V, Rasmussen M M B, Sørensen P B. Barriers and opportunities in developing and implementing a Green GDP [J]. Ecological Economics, 2021, 181: 106905.

[4] Boyd J. Nonmarket benefits of nature: What should be counted in green GDP?[J]. Ecological economics, 2007, 61(4): 716-723.

[5] Wang J. Revive China's green GDP programme [J]. Nature, 2016, 534(7605): 37-37.

[6] Choi Zhaowen Analysis of green GDP [J] Science and Technology Wind, 2012(19): 256.DOI:10.19392/j.cnki.1671-7341.2012.19.217.

[7] Michael Appiah. Study on the influencing factors and implementation path of sustainable development in Ghana. Jiangsu university, 2021. DOI: 10.27170 /, dc nki. Gjsuu.2021.000096.

[8] Zhang Jian, Yang Jiawei and Cui Haiyang. Evaluation of regional eco-efficiency in China based on network DEA model [J].Soft Science, 2016,30 (08) : 15-19.DOI : 10.13956 /j.ss.1001-8409.2016.08.04.

[9] Zhao Zelin. Exploration, comparison and optimization path of green GDP performance evaluation algorithm, [J]. Statistics and decision-making, 2019,35 (03) : 25-29.DOI :10.13546 / j.cnki.tjyjc.2019.03.006.

[10] Qiu Dong. Should the subversive risk-climate change economic model of economic measurement encounter’systemexternalshock’wintheeconomicsNobelPrize[J].Statistical theory and practice, 2020 (01) : 9-15.