

Is it worthwhile to implement the reform in green GDP accounting?---- Analysis From an ARMA-based Model

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Abstract. Compared with the internationally accepted national income accounting method, green GDP takes environmental governance and protection costs into account economic indicators, which is of great significance to the new era of sustainable development. On the premise of comprehensive consideration of economic and environmental benefits, we predict the green GDP growth curve after the reform through the time series method. We find that the reform of accounting methods can indeed promote sustainable development and have a more positive impact on economic development itself.

Keywords: Green GDP, Time series, Forecasting, Sustainable development.

1. Introduction

Since the 1930s, Gross Domestic Product (GDP) has been the most prominent measure of a nation's economic health and welfare. Observed from the perspective of market transactions, it comprehensively measures the overall strength and prosperity of the economy and is an important basis for macroeconomic decision-making. Even today, GDP growth remains a top concern for both governments and citizens alike.

However, there are some insurmountable defects in the current GDP accounting methods, including the difficulty of eliminating the impact of price fluctuation, the inability to accurately depict the unfair distribution of income, and the predicament to take externality into account. In light of the growing emphasis on environmental protection and sustainable development, it is highly significant and urgent to optimize economic health indicators and their accounting methods. The proposal and application of green GDP allows governments to consider both the rapidity and sustainability of economic growth in the policy formulation process, while also urging them to develop environmentally friendly strategies that promote sustainable growth.

In the new era of increasing significance of sustainable development, there have been more and more heated discussions as to whether replacing GDP with green GDP as an indicator of economic health is a sensible choice. The 2023 Report on the Work of The Government pointed out that The 2023 work report of the Chinese government pointed out that the policy system supporting green development should be perfected[1]. In addition, some representatives proposed to establish a novel green GDP accounting system in China to promote the overall awareness of green development.

Obviously, the government's attitude towards using green GDP as measurement of economic health is supportive, but it is still necessary to prove that this reform will indeed have positive results from a more precise and rigorous perspective. Through the prediction of ordinary GDP and green GDP under different policy environment settings, we look forward to proving the necessity of this reform in accounting method and providing a scientific basis for policy-makers[2].

2. Literature Review

Before our research, many studies have revealed why GDP still has room for optimization in measuring economic health, which could serve as a premise that we may use GGDP instead of GDP for economic health measuring. Song Xiaochuan (2007) reveals the ignorance of the increasingly important intangible investments and knowledge economy when it comes to GDP accounting[3]. Zheng Zhijie (2015) also pointed out many shortcomings in GDP indices[4].

With respect to official document, the Green GDP Accounting Guidelines published by the Environmental Planning Institute of the Chinese Ministry of Ecology and Environment pointed out that environmental economic accounting is a modification of GDP for the national economy, whose accounting principles should be consistent with GDP. That is to say, the accounting of Green GDP should adhere to the principles of consistency, scientificity, operability, and data availability.

At present, accelerated consumption of resources and the trend of green transformation allow green GDP to be more and more valued. Wang Hongbing et al. (2022) pointed out that green GDP has attracted high attention from governments and international society around the world[5]. Way ahead of his research, the United Nations and other organizations have already attempted to calculate Green GDP back in the 20th century, which indicates that Green GDP had attracted social attention for quite long.

So far the academic community has built many evaluation methods of green economic benefits. Currently, the most popular approach is to integrate the additional input costs of the economic production process into the evaluation of green economic benefits[6]. In order to simultaneously consider the "good" and "bad" outputs (expected and unexpected outputs) generated in the production process, direction distance functions are used to evaluate economic and green economic benefits (Tu, 2008; Zhou et al., 2010; Jin & Zhang, 2013). To overcome the shortcomings of traditional directional distance functions, non-radial directional distance functions are widely used (Sahoo & Tone, 2009). Brock and Taylor (2010) added environmental factors to the Solow model and tested the Environmental Kuznets Curve using OECD country data[7]. However, the essence of economic-environment relationship can be affected by industrial structure and technological progress on the environment, so simply considering the relationship between economic growth and environmental pollution cannot fully explain economic phenomena[8].

The above studies explain in detail the shortcomings of the current GDP accounting method, clarify the necessity of incorporating the environmental impact into the economic development indicators, and comprehensively explore the scope and quantitative method of the evaluating indicators of green GDP on the basis of considering both the economic and environmental significance. However, the previous literature only demonstrated the significance of the emergence and promotion of green GDP on the theoretical level, but hardly proved the feasibility of the reform of economic growth accounting method from the perspective of policy practice, thus difficult to translate the theory into policy effectiveness and actual social development impetus. It is of urgent need to synthetically evaluate the environmental benefits and institutional costs brought about by the change of accounting methods, and demonstrate whether it is necessary to implement this change from the practical level.

3. Model Selection and Optimization

3.1 Accounting Method of Our Research

At present, the official green GDP accounting methods of various countries mainly include the GGDP, GeGDP and GrGDP. Considering the data availability and the policy implementation environment, we select *The Technical Guideline on Green Gross Domestic Product(GGDP)or Environmentally-adjusted Domestic Products(EDP)(Trial)* issued by Chinese Academy of Environmental Planning in December, 2020 as the benchmark of our accounting method. Specifically, we employ four indicators for our GGDP measurement: *GDP*, *EnDC*, *EcDC*, and *EaC*. *EnDC* comprises three indicators: land, water, and air, with carbon dioxide and nitrous oxide selected to represent air quality. *EcDC* includes four indicators: afforestation area, grassland, garden land, and crop sown area. This paper infers that the GGDP indicators partially represent the positive effect of national economic growth, which not only overcome the shortcomings of the original GDP accounting method, but also indirectly reveal the ability of sustainable development of economies.

We have selected easily measurable indicators as the primary reference data for quantitative description. The economic coefficients of these indicators have been obtained by summarizing

previous studies in the literature, with the aim of monetizing environmental statistics (refer to Table .1.).

$$GGDP = GDP - EnDC - EaC \quad (1)$$

$$EnDC = EnDC_s + EnDC_w + EnDC_a \quad (2)$$

$$EcDC = EcDC_f + EcDC_g + EcDC_w + EcDC_a \quad (3)$$

Table.1. Variable name interpretation

Indicators	Quantitative Variables
<i>EnDC</i>	
<i>EnDC_s</i>	Desertification area
<i>EnDC_w</i>	Amount of freshwater extracted per year
<i>EnDC_a</i>	CO ₂ emission and CO ₂ equivalent of NO _x
<i>EcDC</i>	
<i>EcDC_f</i>	Reduction of forest area
<i>EcDC_g</i>	changes of grassland
<i>EcDC_w</i>	changes of field
<i>EcDC_a</i>	changes of arable land

3.2 Monetization Process for GGDP Accounting Indicators

3.2.1 Environmental Degradation cost of Air

We use the economic impact caused by CO₂ and SO₂ to measure *EnDC_a* with a total value of \$422,453 million.

We utilize the photosynthesis equation to estimate that 1 g of dry matter requires 1.62 g of CO₂ and releases 1.20 g of oxygen, and use the net primary productivity (NPP) of different ecosystems to calculate the dry matter mass[9]. The carbon sequestration and oxygen release value of the ecosystem are then determined using the silvicultural cost method and the industrial oxygen production cost method, respectively.

Based on data from the National Bureau of Statistics of China (NBSC), the CO₂ emissions in 2020 were 318220 million tons, resulting in a lost carbon sequestration and oxygen release value of 28.61billion RMB (with a conversion factor of 0.899). We also consider NO_x as the main representative component of atmospheric pollutants, and estimate that the global NO_x content in 2020 was 10196.6 kiloton CO₂ equivalent. Using the cost of prevention and control, we estimate the value of air purification to be 490.081 billion RMB.

$$EnDC_a = 0.899 * CO_2 + 4.533 * NO_x \quad (4)$$

3.2.2 Environmental Degradation Cost of Water

We quantify the health damage caused by biological pollutants using indicators that combine freshwater extraction, water pollution level, and per capita income. According to National Bureau of Statistics of China (NBSC), China water usage in 2020 was 581.29 billion cubic meters and the water pollution level was 14% (coefficient of 0.14). Using these indicators, we estimate an economic value loss of 81.38 billion Yuan.

$$EnDC_w = 0.14 * \text{water usage per year} \quad (5)$$

3.2.3 Environmental Degradation Cost of Desert

Taking China as an example, the cost to prevent desertification of one mu (666.67 m²) of land is US\$1237. However, since the area of land deserts in China's National Bureau of Statistics has remained at 2,611,600 square kilometers for more than ten consecutive years without significant changes, it does not contribute to the amount of change in GGDP in this paper. Therefore, we assign a value of 0 to the desert coefficient.

3.2.4 Ecological Deterioration Cost of Forest

According to research by Kelly Chen et al. (2020)[8], the coefficient of GDP on forest area is 40.304, indicating that the effect of forest area on GDP is 0.0248. In 2020, the total afforestation area was 786.52 square kilometers. Based on this, the GDP growth attributed to forest area is estimated to be 19.663 billion yuan, with a coefficient of 0.36 million dollars per square kilometer or 0.025 billion yuan per million hectares.

$$EcDC_f = 0.025 * \text{total afforestation area per year} \quad (6)$$

3.2.5 Ecological Deterioration Cost of Arable Land

Based on the research of Zhao Minning et al. (2012), the coefficient of GDP on arable land area is calculated to be 40.34, indicating that the impact of arable land area on GDP is 0.247. With Chinese available arable land area of 167487 hectares in 2020, the resulting GDP growth is estimated to be 4136.9 billion yuan (using a conversion factor of 0.36 million dollars per square kilometer or 0.247 billion dollars per thousand hectares).

$$EcDC_a = 0.247 * \text{arable land} \quad (7)$$

3.2.6 Ecological Deterioration Cost of Grassland

The cost of grassland conservation can provide insight into the opportunity loss caused by grassland ecology. Direct costs of grassland conservation can be divided into two categories: market item inputs and labor inputs for planting grass. Market item inputs include purchases before planting, such as seeds, seedlings, fertilizers, pesticides, and land equality inputs, as well as inputs during the planting stage, such as fertilizer application, drug spraying, weeding, and irrigation, and inputs during the harvesting stage, such as the cost of harvesting, transportation, and storage. Labor inputs for planting grass include wages paid to workers.

The grassland area is about 256798.4 thousand hectares in 2020, and the empirical article by Zhenpeng Xu (2022) shows that the total cost of grassland conservation in China is about 7.45 RMB (1.08 USD) per m² (with a factor of 1.08). This translates to 0.745 billion RMB/1000 hectare.

$$EcDC_g = 0.745 * \text{changes of grassland} \quad (8)$$

3.2.7 Ecological Deterioration Cost of Wet Land

According to Wang Xianjin et al. (2022), the average willingness to pay of the people around the Qianwan New Area in Ningbo, China, using the conditional value based method (CVM) is 24.07 yuan/year. The wetland area in the Qianwan New Area is approximately 109.46 km², resulting in a wetland coefficient of 0.219 (24.07/109.46). We can use this coefficient as an analogy to estimate the value of garden plot.

$$EcDC_w = 0.219 * \text{changes of garden plot} \quad (9)$$

To validate our economic model of GGDP, we perform correlation analysis using the Ordinary Least Squares (OLS) methods. We calculate annual GGDP estimates by monetizing the value of each indicator in the GGDP accounting model, and subtracting the monetized value of these indicators from the statistical value of China's GDP in that year.

4. Reform Effect Forecasting

The resistance to the promotion of GGDP at present is that if we adopt the method of GGDP, the exact value for governmental performance measurement will be smaller than before due to series of deductions, so GGDP is not as popular and acceptable as GDP, especially for policy makers and government officials[10]. But considering the promising prospect and great necessity of sustainable development, we assume that GGDP will show a continuous upward trend and will exceed the previous GDP forecast line eventually[11].

To verify our assumptions, we introduce an ARMA-based model for better understanding of the relationship between economic growth and environmental sustainability[12]. The ARMA model has obvious advantages in processing typical time series data such as GDP and green GDP, which contains more comprehensive and accurate information, with better results in dealing with both smooth and non-smooth time series. In addition, we introduce the VAR model for stability testing and dynamic relationship estimation[13]. Since the OLS estimates of the VAR model parameters are consistent and the economic interpretation of individual parameter estimates is difficult, an impulse response function is adopted, which describes the response of a variable to an error shock, that is, the effect on the current and future values of the endogenous variable following a shock of one standard deviation size in the random error term.

4.1 Stability Test and Dynamic Relationship Estimation

Firstly we conducted a stability test and found that the GDP and GGDP dataset fit the stationary assumption pretty well, which means that the data do not fluctuate extremely over time, and that our forecasting is relatively stable. Figure 1 displays the result of our stability test.

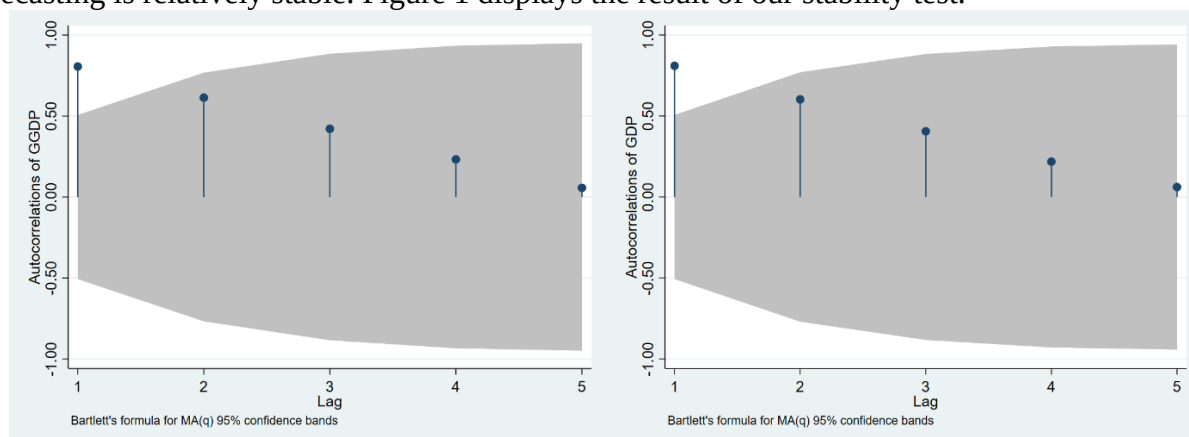


Figure 1. Self-correlation testing

We then perform the VAR-testing for GDP and green GDP(GGDP), respectively. As is shown in Figure 2., there is an optimal lag order for GDP and GGDP autoregression, and it will NOT lag indefinitely and produce a situation that is difficult to measure.

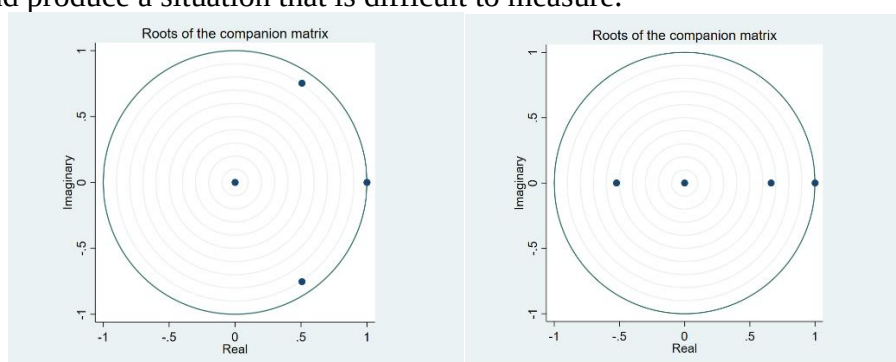


Figure 2. Var-testing

Moreover, the data satisfies the hypothesis of impulse analysis, which means that the sum of all past perturbation terms has less and less influence on our predicted output values.

To summarize, our data has good stability and is able to withstand the impact of random disturbance on the model prediction results.

4.2 Forecasting Result in ARMA-based Model

Our above analysis all indicate that the data meets the condition of autoregressive time series, so it is reasonable and effective of us to use the time series data of GDP for predictions of the economic

growth curve without the GDP-GGDP reform[14]. Figure 3. showed the forecasting result of our ARMA-based model.

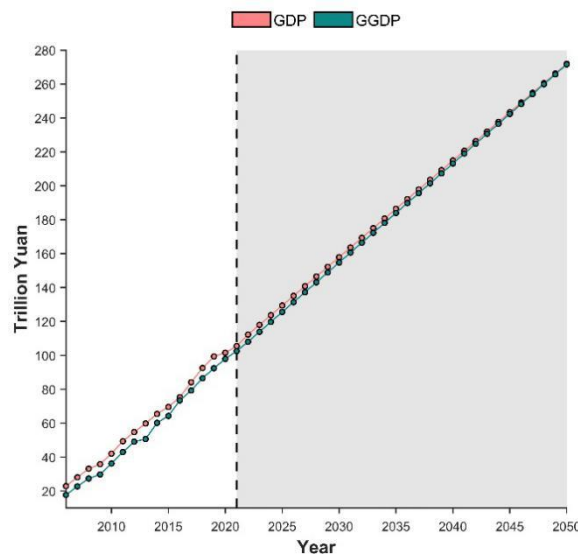


Figure 3. Forecasting result

As can be seen from the forecast chart, the green GDP forecast curve (after the reform) is constantly approaching the GDP growth curve (without the reform), the two curves will eventually converge in around 2050. Since green GDP itself is derived from the deduction of varieties of costs from GDP, the actual GDP after the implementation of this accounting method reform will be higher than that without the reform[15]. That is to say, the reform of accounting method is not only conducive to the idea of sustainable development, but also can promote faster economic growth itself, although this latter effect can only be clearly observed in a relatively long period of time.

5. Conclusion

5.1 Forecasting Result Evaluation

Our prediction results show that the reform of economic growth accounting method can also show the promotion of economic growth itself in the long term, in addition to the obvious environmental benefits. This proves to a certain extent that the relationship between natural environmental protection and sustainable economic development is mutually reinforcing and is a gratifying result. However, we should also see that the economic benefits brought by the reform may not be reflected in the short term, which requires us to adhere to the long-term perspective, promote the reform with enough patience and perseverance and actively safeguard its results.

5.2 Extensions

We have made some innovations in the method of forecasting the policy effect, but in view of the lack of data and the difficulty in estimating, the forecasting process itself has obvious shortcomings.

We made different assumptions about the policy environment during the forecast, and based on the constraint that the real green GDP value at the same time must not be greater than the GDP value, we indirectly deduced the conclusion[16]. However, the time series data used for prediction is just selected from the year of China's rapid economic growth. It is difficult for us to take into account the impact of policy orientation such as economic structure optimization and growth slowdown in the prediction; Because different assumptions are made for different curves, it is also insurmountable to directly determine the exact time when the reform will produce direct economic benefits merely from our forecasting model.

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