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Establishing a Green Economy Accounting Method with Modified GDP

Jingwei Zhang [1], Zheyi Yuan [2], Hao Liang [3], Tao Liu [4, 5, a], Lianjun Guo [6], Jiabo Zhang [6], Yunfei Qi [6]

[1] School of Economics, Northeastern University at Qinhuangdao, Qinhuangdao, 066004, China;

[2] School of Computer and Communication Engineering, Northeastern University at Qinhuangdao, Qinhuangdao, 066004, China;

[3] School of Control Engineering, Northeastern University at Qinhuangdao, Qinhuangdao, 066004, China;

[4] School of Mathematics and Statistics, Northeastern University at Qinhuangdao, Qinhuangdao, 066004, China;

[5] School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore;

[6] Eighth Geological Brigade of Hebei Bureau of Geology and Mineral Resources Exploration, Qinhuangdao, 066000, China.

[a] liutao@neuq.edu.cn; tao.liu@ntu.edu.sg; math.taoliu@gmail.com

Abstract. The purpose of this paper is to give a method for calculating GGDP, namely the Environmental Economic Accounting System (SEEA), which can measure the impact of climate environment on GDP, and can be used as an indicator to replace GDP as whether economic development is green and healthy. Meanwhile, establishing a simple nonlinear statistical model to estimate the impact of GGDP on climate environment. Among them, the weight of pollutants is solved by parameter iteration method. After it, the change of pollutants (including water pollution, air pollution, solid waste pollution, etc.) is used to measure the impact of GGDP on climate and environment compared with previous.

Keywords: Carbon Leakage, Statistical Model, Environmental Economic Accounting System.

1. Introduction

GDP does not accurately reflect changes in a country's wealth [1-4]. The total amount of fixed capital formation in GDP belongs to the increase of the value of the current fixed capital, while the fixed capital formed in the previous period cannot be used normally due to quality problems and other aspects, so the lost value belongs to the reduction of fixed capital. Thus, whether a country's wealth can grow effectively depends not only on the size of gross fixed capital formation in GDP, but also on its quality [5-8].

Meanwhile, GDP emphasizes economics over sociality. While a realistic measure of progress should distinguish between costs and benefits, GDP treats all transactions as a sum of positive value. For example, disease [9,10], crime [11,12], traffic accidents [13,14], bad decisions [15], and natural disasters [16,17] can all add to GDP because money is spent on treating the wounded, locking up the criminals, and repairing the damage. Thus, despite the decline in society and quality of life, GDP continues to rise, completely ignoring all activities and services for which money is not spent [18].

These factors will mislead some countries or regions to pursue GDP growth alone and follow the traditional economic development model, forming the characteristics of high prices of products, low prices of resources and priceless environment, leading to serious resource destruction and environmental pollution, posing a great threat to human health and development, and increasing gap between GDP and its attempt to reflect the social welfare of a country's residents [19-21].

This paper makes an analysis of environmental and economic losses including environmental and natural resource losses, which are shown in Figure 1.

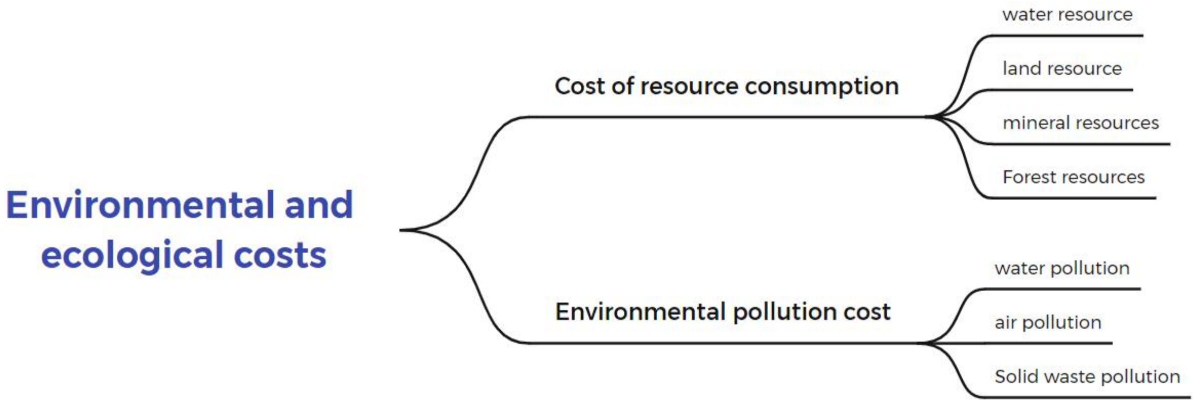

Figure 1. Green GDP accounting framework

After that, these factors are added to the accounting of GGDP [22,23], and the nonlinear statistical model [24-26] is used to estimate the impact of GGDP and pollutant changes on the climate and environment.

2. General Assumptions and Notations

The following basic assumptions are made to simplify problems.

(1) Regardless of other causes of the depletion of the earth's natural resources;

(2) Revisions to traditional GDP do not significantly affect how much emphasis countries place on GDP indicators;

(3) Ignoring the GDP growth from non-market exchanges.

Additional assumptions are made to simplify analysis for individual sections. These assumptions will be discussed at the appropriate locations.

Table 1. Symbol and description

Symbol	Description
X_1	SO_2 Emissions
X_2	Smoke and dust emission
X_3	Dust emission
E_1	General industrial solid waste
E_2	Industrial hazardous waste
E_3	Domestic waste production
R_t	Loss of natural resources
E_t	Environmental pollution loss
MC_s	Marginal cost of water pollution
MC_f	Marginal cost of industrial dust pollution

3. ModelI: A Method for Calculating GGDP

Green GDP is the supplement and perfection of GDP. It is the remaining GDP of a country (or region) after subtracting the value of natural resource loss and environmental pollution loss in a certain period of time. The Sustainable Development Research Group of the Chinese Academy of Sciences pointed out in the Report on China's Sustainable Development Strategy 1999 that the so-called green GNP starts from the simplest formula, which is the "imaginary number" that deducts the two basic parts of the current statistical GNP. Therefore, the formula of green GDP can be simply expressed as:

GGDP = Green GDP = Current GDP- imaginary number of natural component - imaginary number of human component = total consumption + total investment + net exports - imaginary number of natural component - imaginary number of human component

Among them, the imaginary number of the natural part includes: (1) the decline of environmental quality caused by environmental pollution; (2) the degradation and imbalance of natural resources; (3) loss caused by long-term degradation of ecological quality; (4) losses caused by natural disasters; (5) cost caused by resource scarcity; (6) the loss caused by the irrational use of material and energy. The following figure is a schematic diagram of green GDP accounting index system.

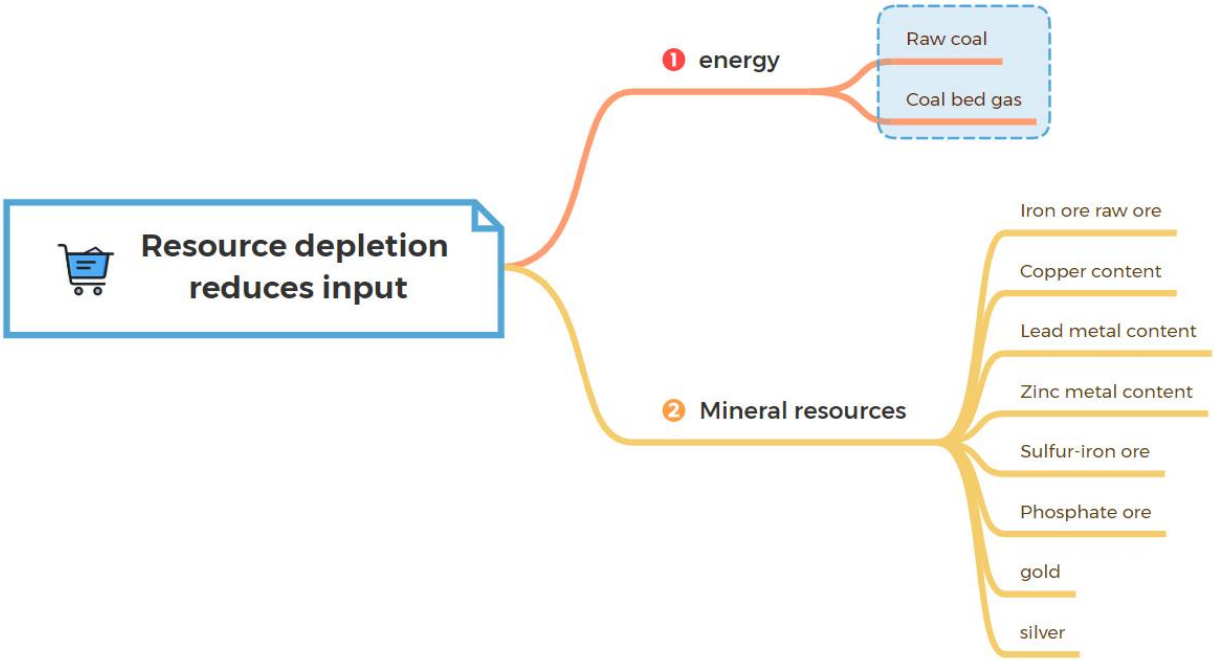

Figure 2. Schematic diagram of green GDP accounting index system

In the calculation formula of green GDP, a considerable part of the imaginary number of the natural part is caused by the production of export commodities, but this part of the cost has not been added to the price of export commodities, that is, this part of the cost is borne by the country itself. Obviously, if we continue to maintain the original mode of high carbon trade, it will have a negative effect on our green GDP. Only by developing low carbon trade, reducing the imaginary number of natural parts such as environmental cost and energy consumption cost, can green GDP realize real growth.

4. Model II: Calculating the Weight of Each Pollution

Considering the GGDP model as the main indicator to measure the economic health of a country, before the calculation, and then a nonlinear model is established. Then, through the change of the policy from GDP to GGDP, the reduction degree of pollutants can be predicted. Used as criteria for impact assessment on climate mitigation.

Table 2. Weight of various environmental pollutants

Pollutant class	weight
Chemical oxygen demand	24.41
Smoke (powder) dust	13.78
Nitrogen oxide	10.19
Sulfur dioxide	10.01
Ammonia nitrogen	21.61
Total phosphorus	0.69
petroleum	0.31
Volatile phenol	1.08
cyanide	0.62

The entropy method is used to calculate the weight of environmental pollution index. The specific method is as follows:

Let b_{ij} be the value of the jth environmental pollutant in period i $(i = 1,2, \ldots, n; j = 1,2, \ldots m)$, the matrix of environmental pollutants is f_{ij}. Then, the specific gravity f_{ij} of the J-th pollutant in period i is $[b_{ij}]_{nm}$,

$$f_{ij} = \frac{b_{ij}}{\sum_{i=1}^{n} b_{ij}}$$

Transformation of environmental pollutant matrix into dimensionless environmental pollutant matrix $[b_{ij}]_{nm}'$. The formula for calculating the entropy value of the j-th pollutant is

$$e_j = -\frac{1}{\ln n}\sum_{i=1}^{n} f_{ij}\ln f_{ij}$$

The entropy weight of the j-th pollutant is

$$w_j = \frac{1 - e_j}{n - \sum e_j}$$

The environmental pollution index of region j in period i is

$$B_j = \sum_{i=1}^{n} b_{ij} w_j$$

Like linear least squares, nonlinear regression is based on the criterion of minimizing the sum of the squares of the residuals to determine the parameter values, but for the nonlinear case, the parameter is solved in an iterative manner.

Gauss-Newton method is an algorithm that minimizes the sum of squares of residuals between data and nonlinear equations. A key concept in this method is to use Taylor series expansion to approximate the original nonlinear equation in a linear form. The least squares theory can then be used to calculate a new estimate of the parameter, which gradually minimizes the residuals.

To illustrate the above process, the relationship between the nonlinear method and the data is first expressed in a general form:

$$y_i = f(x_i, a_0, a_1, \ldots, a_m) + e_i$$

where y_i is the measured value of the dependent variable, $f(x_i, a_0, a_1, \ldots, a_m)$ is the measurement equation, which is a function of the independent variable x_i and the parameters $a_0, a_1, \ldots, a_m$, the nonlinear function of y_i and the random error e_i. For convenience, the parameters in the above model are ignored and expressed in a simplified form:

$$y_i = f(x_i) + e_i$$

At the parameter values, the above nonlinear model is expanded by Taylor series around the parameter values, and the term after the first derivative is omitted. For example, for the case with two parameters:

$$f(x_i)_{j+1} = f(x_i)_j + \frac{\partial f(x_i)_j}{\partial a_0}\Delta a_0 + \frac{\partial f(x_i)_j}{\partial a_1}\Delta a_1$$

Among them, the subscript for j is the initial parameter values, the subscript is predicted for $j + 1$, $\Delta a_0 = a_{0,j+1} - a_{0,j}$, $\Delta a_1 = a_{1,j+1} - a_{1,j}$. Therefore, the parameters of the original nonlinear model are linearized. By the above equations, we get

$$y_i - f(x_i)_j = \frac{\partial f(x_i)_j}{\partial a_0}\Delta a_0 ++ \frac{\partial f(x_i)_j}{\partial a_1}\Delta a_1 + e_i$$

Expressed in matrix form as

$$\{D\} = [Z_j]\{\Delta A\} + \{E\}$$

where $[Z_j]$ is the matrix composed of the partial derivative of the function at the initial parameter value of step j:

$$[Z_j] = \begin{bmatrix} \partial f_1/\partial a_0 & \partial f_1/\partial a_1 \\ \partial f_2/\partial a_0 & \partial f_2/\partial a_1 \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ \partial f_n/\partial a_0 & \partial f_1/\partial a_1 \end{bmatrix}$$

where the number of n data points, $\partial f_i/\partial a_k$ is the partial derivative value of the function with respect to the KTH parameter at the i th data point, and the vector {D} consists of the difference between the measured value and the function value:

$$\{D\} = \begin{Bmatrix} y_1 - f(x_1) \\ y_2 - f(x_2) \\ \cdot \\ \cdot \\ \cdot \\ y_n - f(x_n) \end{Bmatrix}$$

The vector {ΔA} consists of the difference between the parameter values of two successive iterations:

$$\{\Delta A\} = \begin{Bmatrix} \Delta a_0 \\ \Delta a_1 \\ \cdot \\ \cdot \\ \cdot \\ \Delta a_m \end{Bmatrix}$$

Applying linear least squares theory, the following normal equation is obtained

$$\left[[Z_j]^T[Z_j]\right]\{\Delta A\} = \left\{[Z_j]^T\{D\}\right\}$$

Therefore, this method can obtain {ΔA} by solving equation (8), and {ΔA} can be used to calculate the improved parameter values:

$$a_{0,j+1} = a_{0,j} + \Delta a_0$$

As well as

$$a_{1,j+1} = a_{1,j} + \Delta a_1$$

Repeat the above process until the solution converges, that is, until

$$|\varepsilon_a|_k = \left|\frac{a_{k,j+1} - a_{0,j}}{a_{k,j+1}}\right|$$

is less than an acceptable termination condition.

One potential problem with the Gauss-Newton method is that the partial derivatives of functions can be difficult to calculate. So, many computer programs use difference equations to approximate the partial derivatives. One method is

$$\frac{\partial f_i}{\partial a_k} \cong \frac{f(x_i; a_0, a_1 \ldots, a_k + \delta a_k, \ldots, a_m) - f(x_i; a_0, a_1 \ldots, a_k, \ldots, a_m)}{\delta a_k}$$

where δ is a small disturbance.

The above steps are used to calculate two times respectively. When calculating the weight of major pollutants, m=5 and 5 major pollutants are considered; when calculating other pollutants, m=20 and 20 other pollutants are considered. m=14 when calculating the weight of major pollutants and other pollutants. That is, the expected global impact of GGDP on the climate environment (for example, pollutants) can be calculated.

5. Conclusion

International trade is an important part of GDP growth, and the "carbon leakage" caused by export trade seriously affects the growth of green GDP. Especially in the context of low-carbon economy, the development of low-carbon trade will undoubtedly become one of the important ways to drive the growth of green GDP. Through the calculation method of GGDP and nonlinear statistical model, we modify the traditional GDP accounting method. After calculating the weight of each pollutant, we can measure the impact of the change of pollutants in GGDP on climate and environment. This studying green GDP and low carbon trade has certain theoretical significance and practical significance for the sustainable development of Chinese economy even the global economy.

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