A study on global national green GDP accounting based on the System of Integrated Environmental-Economic Accounting

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Abstract. In recent years, green GDP has been widely used but not precisely defined, and the measurement methods are mostly vague and confusing. In order to accurately account for global green GDP, this paper adopts the latest international standard system, the system of integrated Environmental-Economic Accounting: a central framework (SEEA-2012), to construct a model of global GGDP accounting system. Based on SEEA-2012, the global green GDP accounting system is established, which takes into account the negative impacts caused by the depletion of natural resources and losses due to environmental pollution, as well as the positive impacts caused by the improvement of resources and environment on the basis of the traditional GDP. Finally, the values of 26 countries are specifically substituted into the accounting model to obtain the exact values of green GDP for 26 countries worldwide.

Keywords: Green GDP, Integrated environmental-economic accounting system, Natural resource depletion, Environmental pollution depletion.

1. Introduction

Probably the most dominant economic indicator in the world is GDP, which is the core economic indicator of developed economies abroad and is gradually used as a statistical tool for macroeconomic planning in the world, but it is impossible to understand the ecological damage and environmental pollution caused during the development process through GDP. At this stage, no country in the world has a clear corresponding accounting system for the ecological costs brought about during the development of the economy, and no relevant data exist to give an idea of the actual ecological damage and environmental pollution. Therefore, some statisticians and economists have started to try to add natural environmental elements to the national economic accounting system, with the aim of building a new national economic accounting system, namely Green GDP, which represents the Green GDP, the GDP that exists as an adjustment to the GDP indicator, after excluding the environmental costs of economic activities. For Green GDP, it focuses more on economic development and environmental protection, and aims to present a comprehensive picture of the real net welfare of the people.

In order to build a model of global GGDP accounting system, scholars at home and abroad have been making painstaking exploration. In 1971, the Massachusetts Institute of Technology (MIT) first proposed the "Ecological Demand Indicator (ERI)".In 1972, Tobin and Nordhaus proposed the Net Economic Welfare Indicator (NEW) [1]. In terms of practical exploration, Norway was the first country to start accounting for natural resources, and in 1994 the handbook of *Integrated Environmental and Economic Accounting* (SEEA1933) was officially published, putting forward the basic framework of economic and environmental accounting and the concept of green GDP. The United States was the earliest country in the world to conduct research on green GDP. The U.S. has experienced the system of national economic accounting (SNA) to the system of integrated environmental-economic accounting (SEEA), and has now formed the IEESA environmental-economic accounting system [2] in line with its national conditions. Cross-referencing SNA with IEESA can reflect to a certain extent the relationship between economic growth and environmental resource consumption and social service costs and other variables in the U.S.;In Japan, since 2007, the NAMEA matrix calculation framework has been used to calculate the cost of maintaining the environment, following the United Nations SEEA-CF accounting system, and the estimated cost of compensating for the environmental degradation [3] that has occurred. In 2004, China launched the "China Green National Economic Accounting Research" project, and gradually established the framework of China's green national economic accounting system. At present, the international community is mostly based on the UN SEEA accounting system, and is still exploring and piloting in terms of resource categories, accounting methods, and the construction [4] of value-volume accounts.

2. A study on global national green GDP accounting based on the System of Integrated Environmental-Economic Accounting

2.1. Mathematical notations

The variable symbols are shown in Table 1.

Table 1. The variable symbols

Notations	Explanations
CDM	Average volume-weighted price of carbon
T waste	Total (commercial and industrial) waste (expressed in tonnes)
P elect	Price of 1 kWh calculated as the average of commercial and industrial prices in each country (in PPP terms)

2.2. Accounts for the Global Equity Model

We adopt the latest international standard system, the System of Integrated Environmental-Economic Accounting: A Central Framework (SEEA-2012), to construct the model of global GGDP accounting system. Integrating the accessibility of data and information, we further select the resource and environmental value loss method for the global green GDP accounting study, which converts the qualitative factors affecting the environment into quantified and monetized factors through calculation, so as to account for the positive and negative benefits of resources [5] and environment on economic development. Based on the literature review and exhaustive consideration, we have selected the following key factors in seven different dimensions.

Natural resource depletion value account: It mainly includes four dimensions: depletion value of arable land resources, depletion value of forest resources, depletion value of water resources and depletion value of energy resources, aiming to objectively and truly reflect the proportion of natural resource depletion in the process of socio-economic development of each country in the world, so as to play a guiding and alert role in the rational development and utilization of natural resources in the process of human socio-economic development.

Environmental Pollution Reduction Value Account: It mainly includes the cost of air pollution control, water pollution control and solid waste control, and aims to objectively reflect the proportion of environmental pollution reduction in the socio-economic development process [6] of each country in the world, so as to raise people's awareness of environmental protection.

We have selected seven indicators from the two accounts, which are detailed in Table 2.

Table 2. Specific indicators of natural resources and environmental pollution

Account	Indicators
Depletion value of natural resources(-)	Depletion value of arable land resources
	Depletion value of forest resources
	Depletion value of water resources
	Depletion value of energy resources
Value of environmental pollution loss(-)	Cost of air pollution
	Cost of water pollution
	Fixed Pollution Costs

Note:
+: The more benefit indicators, the better
-: The better the lack of cost indicators
Therefore, we construct a global GDP accounting model based on the resource value environmental loss approach.

$$Green\ GDP = Traditional\ GDP - Value\ of\ natural\ resource\ depletion - Value\ of\ environmental\ pollution\ loss \quad (1)$$

2.3. Green GDP accounting methodology for Three Types of Accounts

2.3.1. Natural resource depletion value accounting method

We use the asset classification mentioned in SEEA as a blueprint, and modify the categories of distinction by taking into account the situation of different countries around the world: four types of resources: cropland resources, forest resources, water resources, and energy and mineral resources [7], and the detailed method is as follows.

$$C_{Natural\ resources} = C_{Arable\ land\ resources} + C_{Forest\ resources} + C_{Water\ resources} + C_{Energy\ resources} \quad (2)$$

- **Method of accounting for depletion value of arable land resources**

The use of land can usually be divided into arable land, forest land, garden land, residential land, transportation land, etc., which present geographical differences in the world and cannot be measured by a unified standard to measure its market value, therefore, we use the depletion value of arable land resources to represent the depletion value of land resources, and the specific formula is as follows.

$$C_{Arable\ land\ resources} = S \times \frac{P}{r} \quad (3)$$

Where, C represents the depletion value of arable land resources in each country; S is the data of arable land area reduction in the accounting period; P is the simple input within the unit area of land in the period; r is the reduction rate, which is modeled on the interest rate in the calculation, while considering the price increase, as follows.

$$r = \frac{i}{a} \quad (4)$$

Where,a is the price index; i is the one-year fixed interest rate of the bank.

- **Methodology for accounting for depletion value of forest resources**

We believe that Mori-Li provides more than just timber resources, but also has additional environmental services [8] and other resources to provide. Therefore, we choose the market approach to account for both the value of forest land and the value of forest trees with the following formula.

$$C_{Woodland} = Q_{Woodland} \times P_{Woodland} \quad (5)$$

Where we make a specific analysis of the stock and nuclear volume, Crepresenting the depletion value of forest land resources; Q is the area of newly created forest land in the current period; and P represents the flow price of forest land in the accounting period.

$$C_{Forest} = Q_{Forest} \times P_{Forest} \quad (6)$$

In the formula, the depletion value of forest resources is mainly caused by wood cutting in the period. C represents the depletion value of forest resources; Q is the area of wood harvesting in the period; P represents the comprehensive average price of wood in the accounting period.

- **Water resources depletion value accounting method**

When accounting for the value of water resources, we divide water resources into three main areas: industrial water, residential water and urban public water. Since the selling price of water resources does not reflect their true price, we value water resources through the market method, with the following formula.

$$C_{Water\ resources} = \sum_{i=1}^{n} Q_{Water} \times P_{Water} \tag{7}$$

Where,C is the amount of depleted value of water resources;Q is the actual amount of depleted water resources in the current period;P represents the market price price per unit of water resources in the accounting period; n is for each sector (industrial, urban and domestic water).

- **Energy resource depletion value accounting method**

We use the net price method to calculate the mineral resources extracted in each country by the following formula.

$$C_{Energy} = \sum_{i=1}^{n} Q_{Energy} \times P_{Energy} \tag{8}$$

Where,C is the amount of depleted value of mineral resources;Q is the physical amount of depleted mineral resources in this period; P is the net price of mineral resources unit in the accounting period; n is various minerals.

2.3.2. Environmental pollution loss value accounting method

We take the classification of assets mentioned in SEEA as a blueprint, and make changes to the categories distinguished by combining different countries around the world: three kinds of waste gas rectification, waste water rectification and solid waste rectification [9], and the detailed methods is as follows.

$$C_{EP} = C_{Atmospheric\ pollution\ control} + C_{Water\ Pollution\ Control} + C_{Solid\ Waste\ Pollution\ Treatment} \tag{9}$$

- **Cost accounting for air pollution control**

We take the pollutants such as soot, sulfur dioxide and nitrogen dioxide as the objects of air pollution treatment cost accounting, and adopt the restoration cost [10]method, combined with the technical guidelines of environmental economic accounting of different countries, the specific formula is as follows.

$$V_{Exhaust\ gas} = \sum_{i=1}^{n} Q_{Exhaust\ gas} \times P_{Exhaust\ gas} \tag{10}$$

Where,V represents the pollution degradation cost of exhaust gas; Q represents the emission of exhaust gas in this period; P represents the average unit treatment cost price of exhaust gas in the accounting period; n represents various pollutants.

- **Water pollution treatment cost accounting**

The polluted water is often interspersed with ammonia nitrogen and other impurities [11], if you want to calculate the cost of treatment of one of the impurities is more difficult, therefore, we choose to calculate all the treatment costs required to treat wastewater, the specific formula is as follows.

$$V_{Waste\ water} = \sum_{i=1}^{n} Q_{Waste\ water} \times P_{Waste\ water} \tag{11}$$

Where, V represents the pollution degradation cost of wastewater; Q represents the discharge of wastewater in this period; P represents the average unit treatment cost price of wastewater in the accounting period; n represents all kinds of wastewater sources.

- **Accounting of solid waste pollution treatment cost**

We still use the restoration cost method to derive the annual cost required to treat the average unit of solid waste [12] according to the technical guidelines for environmental economic accounting in different countries, as follows.

$$V_{Solid\ wastes} = \sum_{i=1}^{n} Q_{Solid\ wastes} \times P_{Solid\ wastes} \tag{12}$$

Where, V represents the pollution degradation cost of solid waste; Q represents the amount of solid waste generated in this period; P represents the average unit treatment cost price of solid waste in the accounting period; n represents all types of solid waste.

2.4. Data Processing

2.4.1. Data Screening

The amount of raw data is large, so we need to screen the data from more than two hundred countries worldwide. We selectively collected data from the World Bank and Eurostat databases for a sample of 26 countries, covering EU countries and some selected countries, and divided them into three standard groups.

- 12 developed countries: Belgium, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, the Netherlands, Portugal, Iceland, and the United Kingdom.
- 12 developing countries: Bulgaria, Estonia, Croatia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia, Montenegro, Moldova, and Turkey.
- 2 underdeveloped countries: Albania and North Macedonia.

Next, we collect GNP, CO2 emissions, tons of waste, price per unit of kWh of electricity (the average of commercial and industrial prices in the country), GNI, and natural resource depletion as a percentage of GNI for each of the 26 countries over the last two decades. For the average volume-weighted price of CDM, we collect the global annual inflation rate based on the USD11.07/ton calculated by academics for 2006, and project the carbon price forward to 2000 and backward to 2021 using the progressive inflation rate method.

3. Results

3.1. Green GDP Calculation for A Sample of Twenty-six Countries

In the previous section, we established a global green GDP accounting system based on SEEA-2012, which is a complex system that takes into account the negative effects caused by depletion of natural resources, losses due to environmental pollution, and also the positive effects caused by the improvement of resources and environment on the basis of the traditional GDP. Due to valuation problems and data availability, we cannot measure in monetary terms the damage to the ecosystem (depletion costs of water, air, forests, energy, etc.) obtained from economic development. Since the consumption of resources generates polluting gases represented by carbon dioxide and the emissions of carbon dioxide can reflect the degree of environmental pollution, for the sake of computational simplicity of the green GDP accounting system, under the previous accounting model we measure greenness by constructing a new quantitative indicator as an alternative environmental prism model. Under this indicator, we multiply carbon dioxide emissions by the carbon market price as the first carbon dioxide pollution cost to be deducted, followed by a measure of the opportunity cost of tons of waste in terms of electrical energy, and finally by deducting the adjusted natural resource depletion savings as a percentage of each country's national income, as follows.

$$Green\ GDP = GDP - (KtCO_2 \times PCDM) - (Twaste \times 74kWh \times Pelect) - \left(\frac{GNI}{100} \times \%NRD\right) \tag{13}$$

Where, CDM is the average volume-weighted price of carbon, based on the average annual volume-weighted price, adjusted to each year by cumulative inflation; $74kWh$ is the amount of electricity that can be converted per ton of waste, derived from studies by the Australian Energy Regulator, among others; and $Pelect$ is the price per kilowatt-hour, derived from the average of commercial and industrial prices in each country, expressed in U.S. dollars.

After calculation, we obtained the values of green GDP for 26 countries around the world, as shown in the following chart.

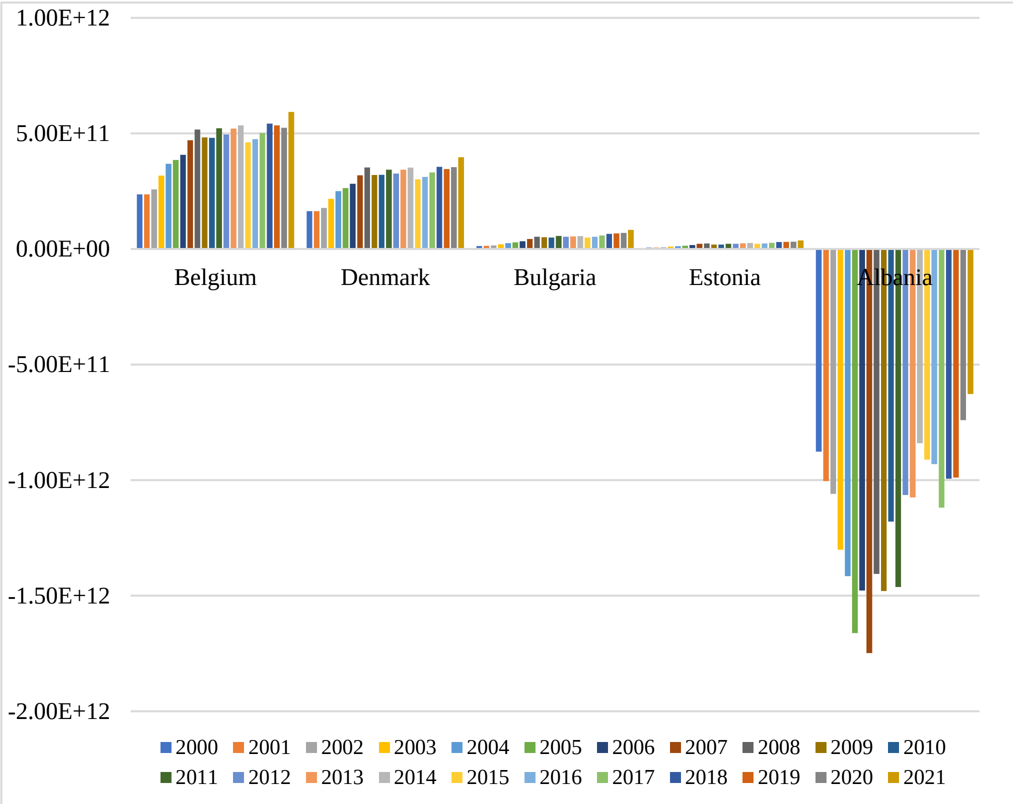

Figure 1. Histogram of the global GGDP values

4. Conclusion

Probably the most dominant economic indicator in the world is GDP, which is the core economic indicator of foreign developed economies and gradually used as a statistical tool for macroeconomic planning in the world, but it is impossible to understand the ecological damage and environmental pollution caused by the development process through GDP. Despite many in-depth analyses and studies on global green GDP and its related issues, a complete green GDP accounting model is still needed. For this reason, we use the latest international standard system, the System of Integrated Environmental-Economic Accounting: A Central Framework (SEEA-12), to construct a model of the global GGDP accounting system. Integrating the accessibility of data and information, we further select the resource and environmental value loss method for the global green GDP accounting study, which converts the qualitative factors affecting the environment into quantified and monetized factors through calculation, so as to account for the positive and negative benefits of resources and environment on economic development.

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