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Green GDP measurement of Shenyang city based on energy value analysis

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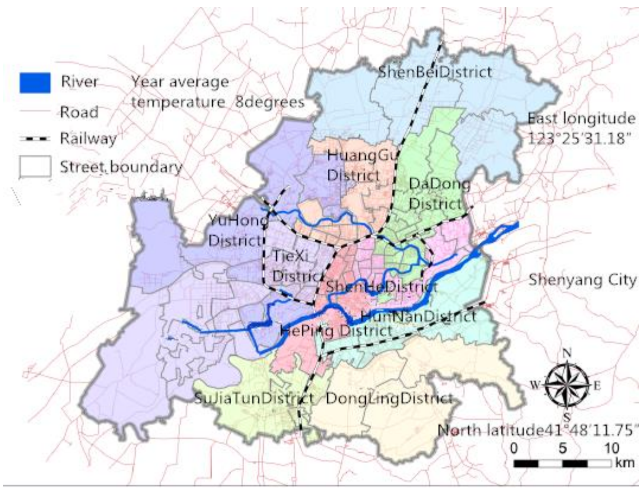
Graphical abstract



Abstract

The resource environment loss has been evaluated using energy value and monetary value adopting complex ecological system analysis framework, Odum's eco-econo mic system energy theory, and energy value analysis. The total amount of green ecological economy of Shenyang city from 2007 to 2016 was calculated in the paper. The results were shown as following: (1) Economic growth in Shenyang city was relied on resources consumption (including natural resources and the input resources) heavily and it was about 40%, which had brought about serious environment pollution from 2007 to 2013; (2) The mode of economic growth had been changed in Shenyang city between 2014- 2016 and the ecological environment had been improved, however, it was not obvious. The present economic development model in Shenyang city is unsustainable. The development mode depending on resources and environment cost should be brought to develop ecological industry and circular economy, to avoid the economy into a vicious cycle.

Keywords: Energy value, green GDP, ecological environment, renewable environmental resources, sustainable development, EMA.

1. Introduction

According to Liu (2012), in 1970s, environmental problems was concerned, some study were carried out on green GDP accounting in western countries, that is, the contribution to economic development of resource factors was put into re-consideration, resource account was established. Environmental factors are also included in accounting scope, and the basic framework of SEEA accounting was constructed. From European Commission (2002), found in 1972, James Tobin and Moor house William Nord, the economics professors of Yale University, put forward the "Economic Welfare Measure" (MEW). Then, Samuelson referred to the "Economic Welfare Net" (NEW) in his book "economics". Daly (1989) and Cobb (1989) discovered that environment was all included in the GDP accounting in the study, which could reflect the welfare of the national economy. Zhu (2001), thought that in 1973, the Japanese government put forward the "National Welfare Net" (NNW), which mainly targeted at the environmental pollution factors. Wang (2006) considered in 1987, the UN Environment and Development Committee proposed the idea of "sustainable development", which had become a comprehensive index to evaluate the sustainable development of economy and society. In 1989, Herman Daly and John B. Cobb (1989), the economist, proposed index of sustainable economic welfare (ISEW), in which the cost of losses caused by social factors were considered, and the costs and benefits in economic activities were distinguished. Ding *et al.* (2005) deemed the system of integrated environmental and economic accounting was put forward by the UN Statistical Commission (SEEA). SEEA was developed based on system of national accounting (SNA). In 1994, IEESAS was introduced by the USBEA which was based on some key experiences of social accounts and the framework of SEEA in 1970s. Haripriya *et al.* (2007) summed up the commodity economy concept of market transaction was paid attention to and the interaction between economy and resource environment was examined in IEESAS. Zhang (2005) considered in 1997, "green GDP national economic accounting system" was adopted by the World Bank to measure the real national wealth after deducting the loss of natural assets (including the environment), a SEEA based green GDP accounting was also launched in South Korea in 1990s. European Commission (2002) noticed SERIEE system was developed by European Bureau of statistics, which could do environmental expenditure accounting and extent the SNA. Zhang (2009) caught sight to Holland set up national accounting matrix environmental accounts (NAMEA) to investigate comprehensively the indicators change on economic and environmental in a certain period. Internationally, research model of the green GDP accounting had been made great progress, based on the basic framework of the SEEA and the actual situation of the country (Jegatheesan and Zakaria, 2018; Jubaidur and Mukaddasul, 2020; Kishan *et al.*, 2020; Sofia *et al.*, 2018).

In 1980s, the green GDP accounting research was carried out in China. Yang Youxiao and Cai Yunlong (2000) accounted rural resources environmental accounts from 1990 to 1996 and measured its sustainable development with the SEEA accounting system, who provided an effective reference for the study of green GDP accounting. In 2001, the National Bureau of statistics accounted on the natural resources, mainly including four kinds of natural resources forest, land, water and mine. Zhang Ying (2006) accounted green GDP of forest of Daxinganling in Heilongjiang Province from 1997-2003. He proposed the forest green GDP accounting model. Cao *et al.* (2014) considered that in 2004, the green GDP accounting system research was launched by the joint research group made up of the National Bureau of statistics, the former State Environmental Protection Administration, the National Development and Reform Commission, the State Forestry Administration and so on to start ", which has laid an important theoretical foundation for the implementation of the green GDP accounting system in China. Taking Yulin City of Shanxi Province as an example, Lei (2009) put forward a new green GDP accounting method for resource based urban. Zhang Hong *et al.* (2010) accounted green GDP of Fujian province from 2001 to 2006 with Energy Analysis Method (EMA), they found that the growth of green GDP in Fujian province was lower than the growth of the traditional GDP, and environmental pressures increased. Zhang *et al.* (2013) made a study on the green economy level and its space distribution the 108 counties in Henan province in 2009 using the integrated energy analysis and material flow analysis method. The results were put forward that ecological system played an important role in the economic and social development; the space difference of energy value index was obvious as well. Ma *et al.* (2014) simulated the cost of energy compensation and theoretical price to analyze its impact on the national economy according to the theory of green input and output accounting. Guo *et al.* (2015) counted green GDP of Shangluo City, which is national key ecological function area of Shaanxi Province. Using, they discovered that its economic development depended heavily on resource consumption and Social development was unsustainable. Li (2017) announced the green GDP research work was restarted by Environmental Protection Department in March 2015, who was the director of Policies & Regulations Department of Ministry of Environmental Protection pointed out that: Green GDP research mainly includes environmental cost accounting, environmental capacity calculation, and Ecosystem production value accounting etc., which indicated the direction of green GDP accounting research. Based on the above, great progress had been made in China, and there were fruitful results, but no consensus. Further study should be done based on the actual situation, with the advanced technology in the world, to reach a unified standard of green GDP accounting (Anish and Samata, 2018; Fariha et al, 2018; Mahmuda *et al.*, 2019; Siew *et al.*, 2019).

Based on the current literature, energy value analysis method was rare used to account regional green GDP accounting the green GDP from 2005 to 2014 of Shenyang city, an old heavy industrial base in Northeast China, was accounted in the paper, drawing lessons from data prepared by (Ma *et al.,* 2014; Zhang *et al.,* 2010; Zhang *et al.,* 2013), green GDP accounting of Shangluo city, the key ecological function area using energy value analysis method. The economic development problem existed in Shenyang city in the ten years would be reflected from the macro view. Suggestions for the sustainable development for Shenyang City would be presented. This is the first attempt to calculate the green GDP in heavy industry city using the EMA.

2. Material and methods

2.1. Study area

Shenyang city is located in the south of Northeast China, Mid-Liaoning Province. It is mainly in the plain, and mountains and hills are concentrated in its southeast. Liao River, Hun River and Xiushui River pass. It belongs to temperate semi-humid continental climate. Annual temperature varies from -350°C to 360°C, and the mean temperature is 8.3 0°C, an average of 546.9 millimeters of precipitation and 183 days of frost free season., affected by the monsoon, there is concentrated rainfall, large temperature difference, distinct seasons. Shenyang has area of there are 14.7 million hectares forest and 8.2 million hectares grassland in Shenyang City. The total water resources are 32.6 billion cubic meters, which contains 11.4 billion cubic surface water and 21.2 billion cubic groundwater. 36 kinds of minerals have been found, among them of 13 minerals reserves had been proven, with 20 tons coal, 10 billion 700 million cubic meters of natural gas (Shenyang Statistical Bureau, 2018) (Figure 1).

In the first year of 13th Five-Year plan, the innovations such as full green development, industrial structure adjustment, supply-side structural reform, eliminating corpse enterprise, and weeding out outdated productivity strategy were implemented. As one of the old heavy industrial base, Shenyang City is to bear the brunt and affected, obviously. GDP growth rate was 16% in 2012, and only 2.5% in 2013. Shenyang City, known as "eldest son of the People Republic of china", is the economic center of Liaoning Province, the success of failure of its economic transformation would relate directly to Liaoning Province, even the northeast region, therefore, more attention should be paid to its sustainable development, GDP growth rate, growth rate of the first industry, the second industry and the third industry of Shenyang City from 2005 to2015 were shown as the following (Figure 2). From the figure growth rate of the third industry in 2013-2015 was much higher than others.

Figure 1. The district of Shenyang city

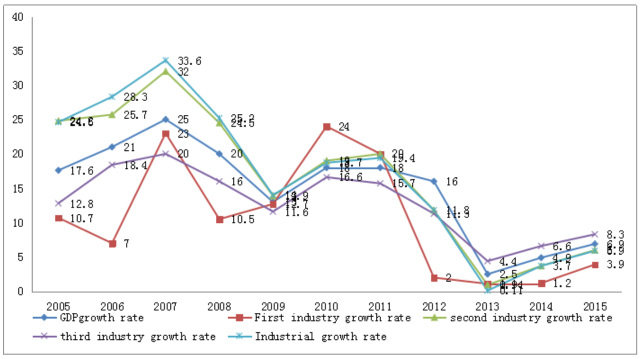


Figure 2. The industry changes from 2005 to 2015

2.2. Concept of EMA

1980s, the famous American ecologist Oldm founded energy analysis method, by the solar value (resource or product formation required for direct and indirect application of solar energy) as the same standard and selected products resource indicators and indicators of environmental resources, should be transformed into a unified energy value, because energy flow, logistics and money flow of different measurement units, such as product resource index and environmental resource index, and then the quantitative analysis is carried out (Environmental Accounting, 1996). Energy value is a kind of effective energy that can be used directly and indirectly in the form of resources or products. Solar energy conversion rate unit energy (resources or products) contains the amount of solar energy. Its advantages can unit measurement through a series of product resource indicators and indicators of environmental resources (by energy/money ratio and currency value conversion), and expand the scope of indicators selected, from a macro point of view, a comprehensive accounting of green GDP, more accurate and reasonable. Energy value theory is widely used in the evaluation of sustainable development, ecological economy, green agricultural development, urban and human settlements, land consolidation benefit evaluation and other fields.

2.3. Energy conversion ratio

According to the research results of Odum, Brown, Brandt-williams, Lan, Jiang, Huang et al (1996), paper get the ratio of the energy conversion (Table 1).

2.4. Research method

In this paper, refer traditional SEEA method to calculate the green GDP formula which we have used, from the traditional GDP minus the natural resources consumption and environmental losses of the two part of the results of the content of the real green GDP, expressions are as follows:

$$\text{Green GDP} = \text{tradition GDP} - \sum A - \sum B \quad (1)$$

In the Eq. (1) formula: $\sum A$ is a system consumption of all natural resources, $\sum B$ is for all system environment loss.

In this paper, resources consumed by the system are divided into the consumption of the resources consumed in the system, and the consumption of the external resources of the input system, so the new formula expression is as follows:

$$\text{Green GDP} = \text{tradition GDP} - \sum A - \sum B - \sum C \quad (2)$$

In the Eq. (2) formula: $\sum A$ is internal natural resources consumed in the system (including non-renewable resources, non-renewable resources) and the monetary value. $\sum B$ is the energy of the external input system (including the non-renewable resource products from the external input system and the energy value of the new product that cannot be renewed) subtract the sum of monetary value. $\sum C$ is environment system (loss of waste water, waste gas and solid waste emissions including system) subtract the sum of the monetary value.

2.5. Data sources and processing

2.5.1. Data sources

Since 2017 years, Shenyang Province, Liaoning Statistical Yearbook has not been officially announced, only get part of the data. In order to unify the research data, so the study period is selected in 2007 to 2016 years, basic data from 2007 to 2016 Shenyang and Liaoning Province statistical yearbook. Energy value analysis should be carried out by the energy conversion rate, the energy conversion rate of various substances is determined by the specific global energy benchmark (Liaoning Statistical Bureau, 2015; Shenyang Municipal Bureau of statistics, 2017).

2.5.2. Data processing

Data classification. Classified the existing basic data, divided into 7 categories including renewable environmental resources, non-renewable environmental resources, renewable resources products, non-renewable resources products, input resources, currency flows and waste flows.

Table 1. Ratio of resource to value conversion

Energy	Conversion rate	Energy	Conversion rate
The solar energy (J)1	1	Oil (J)	5.4×10^4
Wind (J)	2.45×10^3	Natural gas (J)	4.8×10^4
The rain potential energy (J)	4.7×10^4	Electric power (J)	1.59×10^5
The rain chemical energy (J)	3.05×10^4	Pig iron (g)	1×10^9
Earth loop can (J)	5.8×10^4	Steel (g)	1×10^9
Surface soil loss can (J)	7.4×10^4	Service ($)	1.66×10^{12}
Sand and gravel (g)	8.5×10^9	Agricultural products (J)	1.43×10^5
Coal (J)	4×10^4	Animal by-products (J)	9.15×10^5
Metal minerals (g)	1×10^9	Aquatic products (J)	2×10^6
Cement (g)	9.5×10^9	Waste gas (g)	3.8×10^5
Fertilizer (g)	7.7×10^6	Waste water (J)	6.66×10^5
Pesticide (g)	2.49×10^{10}	Solid waste (J)	1.8×10^6
Plastic (g)	3.2×10^9		

Renewable environmental resources (including solar energy, wind energy, rain water chemical energy, rain water potential energy, earth's rotation energy and water energy) and non-renewable environmental resources (including 1 items of surface soil loss) energy obtained by the calculation formula provided by Ulgiati.

Renewable resource products can be achieved from Shenyang city by all kinds of products (including food, oil, fruit, vegetables, meat, etc. a total of 18) of the yield calculation.

Nonrenewable resources products (including non-renewable resources and non-renewable energy products, such as coal, steel, cement, oil, natural gas and metal mineral) calculated according to all kinds of products by the whole year, thermal power energy consumption included in amount of the coal energy consumption amount.

Input value accounted according to the city products (gasoline, diesel oil and lubricating oil) sales and agricultural production data (chemical fertilizer, pesticide and plastic film).

Renewable resource product energy and non-renewable resource products along with input energy value's calculation formula follows: all products of solar energy value=product consumption (production) * energy conversion factor * solar energy conversion rate.

Data processing method. The calculation formula of the solar energy's money flow (including imported commodities, foreign capital, tourism income, labor input and export commodities 5) follows: solar value of the money flow=the amount of money flow (by the dollar) * energy/money ratio. Waste flows (including waste water, waste gas and solid waste) of the solar energy value calculation formula follows: solar energy value of waste logistics=waste discharge * energy conversion factor * solar energy conversion rate. The energy/money ratio is the proportion of the total solar energy used in the region to the gross domestic product (in USD), Energy value - monetary value can be got by variety of resources and products of the solar energy value which divided by the energy/currency ratio.

3. Result

3.1. Draw the Shen yang city environment eco-economic system flow chart

Applying Odum "energy systems language" to draw Shenyang environmental eco-economic system energy flow chart. Liu (2013) thought that Solar energy, wind energy and water energy are the most important energy sources in agricultural system, as well as the basic environmental resources for other social and economic activities. Natural ecosystem and economic system interact each other. And the value of the constant accumulation, the money flow is also increasing (Figure 3).

3.2. Shenyang city's environment and the total solar energy system input

As Table 2 showing, 2007 to 2016, Shenyang city's solar value continued increasing, 2016 solar put into energy values the total about 1.15×10^{25}seJ, increased about 2.5 times than 2007 year. It reached the peak value in 2015, while in it increased rapidly during 2011 and 2012 (Shalmashi and Khodadadi, 2019). Renewable environmental resources solar energy changed in a downward trend, and its annual fluctuation was mainly caused by the variation of precipitation and wind; the fluctuation range of the solar energy of the non-renewable environment resource is obvious, and it has a certain contribution to the change of the total solar energy; the solar energy value of renewable resource products was small, which indicated that Shenyang's agricultural products, animal products, as well as services, tourism, maintained a stable development in these 10 years, it made a great contribution to Shenyang's green economy; Both of the annual nonrenewable resources products and solar energy input values kept rising. Especially, nonrenewable resources increased rapidly, from $2.41* 10^{24}$seJ in 2007 year, while increased to $5.54 * 10^{24}$seJ in 2016, a total increase of 23 times, which made a greater contribution to total solar energy, becoming one of the main factors influencing the change of green GDP in Shenyang; The growth trend of money flow is also very obvious. Except the increase of the total amount of labor, the actual utilization of foreign capital and the total value of import and export commodities in Shenyang have also increased significantly. The development of urban tourism and rural tourism developed rapidly, and the income increased rapidly. Money flow made a great contribution to the rate of economic development; Waste flow EAM is another important factor that causes the change of green GDP accounting, and its solar energy value increased obviously which increased from 2007 year's 1.88×10^{24}se J to 2016 year's 3.88×10^{24}se J, totally increasing about 2.1 times. It implied that with the development of economy of Shenyang, the environmental problems become increasingly prominent, but gradually improved.

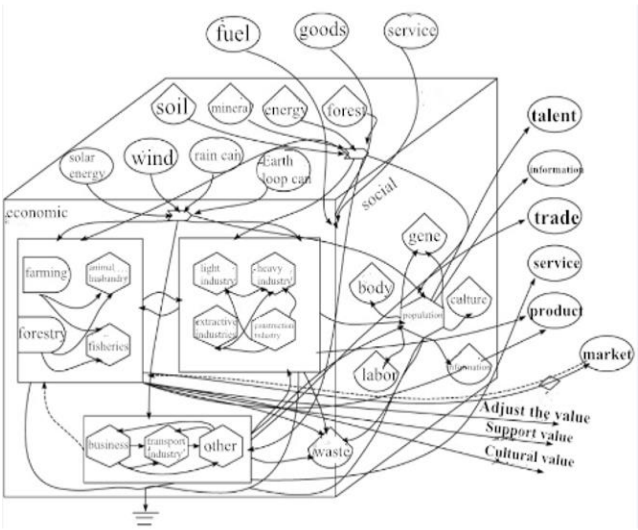


Figure 3. The energy flow diagram of the environment of Shenyang

3.3. Account the Green GDP

3.3.1. Calculate the value of natural resources consumption

The renewable resources environment of Shenyang Environmental and Eco-ecological System includes solar energy, wind energy, rainfall chemical energy, and potential energy of water, earth rotation energy and water resources energy, which all belong to renewable resources. For these consumptions of resources, the system can recover on its own. The natural resources consumption of the system includes non-renewable environmental resources (topsoil loss) and non-renewable resource products (coal, cement, steel, natural gas, oil and metal minerals). In the short term, the topsoil loss could not recover by itself in the natural environment. Use the energy/money ratio to transform the annual energy consumption of natural resources into its macroeconomic value. From table 3, we can see that the value of its energy value increased from 1.6* 10^5 in 2005 to \$1.79*10^5 in 2016, which changed very little. Its value accounting was small which made less impact influence on GDP (Emir and Bekun, 2019). The most important part of the system of the consumption of natural resource value accounting is nonrenewable resources. Through the area of the energy/money ratio conversion, this kind of resource consumption and economic value reached a total of 3.66 * 10^{10}\$ in 2016, which is nearly 15 times than in 2007. The traditional GDP increased from 2.55*10^{10}\$ in 2007 to1.14 * 10^{11} \$ in 2014, which increased 4.5 times. But 10 years of natural resource consumption is 3 times faster than GDP growth rate. The rate clearly stated that consumption of natural resources of economic development was much faster than the growth rate of GDP in Shenyang. In addition, the value of this kind of resource itself is very large, energy consumption accounted for proportion of energy increasing from 49% to 55% during 2007 - 2016 year's has very important significance of accounting.

3.3.2. Account input system resource consumption value

Input resources is part of the external purchase of energy products in Shenyang, mainly including steel, oil, coal, cement, natural gas and other minerals. The other part is production of chemical fertilizers, pesticides and agricultural films, and other inputs agricultural facilities needed and so on. As shown in Table 3, after Energy/money ratio conversion, its energy value - the value of the currency summation was 3.15×10^8\$ in 2005. In 2016 it increased to 1.50×10^9 \$, an increase of 5 times. In 2005 and 2016, the proportion of the total resource consumption was respective 4% and 19%. Because Shenyang is a heavy industrial city, it consumes a large amount of resources, the impact on the green GDP accounting in Shenyang city is significant.

3.3.3. Calculate of the cost reduction of environmental resources

The value of environmental loss in Shenyang city is mainly composed of wastewater, waste gas and solid waste discharged from the economic production and processed to the natural environment. Saw from the table 3, the city's total discharge of wastewater, waste gas and solid waste are in an increasing trend, which increased by more than 10 times than the amount of exhaust emissions from 2007 to 2016, slightly higher than solid waste. But solid waste is the main factor of the consumption value accounting of environmental resources. Because once discharged into the natural environment, it is difficult to get governance relying on the natural purification capacity in a short period of time. So, Energy conversion factor and solar energy conversion ratio is higher than that of wastewater and waste gas. By using the system energy/money ratio conversion, the total macro-economic value of environmental resources consumption was 5.80 * 10^{10} \$ in 2016, which increased by nearly 6.6 times. As Shenyang is a heavy industry city, the large consumption of non-renewable resource products and environmental resources is one of the important reasons for the change of green GDP accounting.

3.3.4. Account the green GDP

Using natural resources value consumed by eco-economic system, input resource energy and environmental resources value system, as well by transforming the annual energy/currency ratio of the system to the macroeconomic value, deducted from the traditional GDP, we can get Shenyang's Green GDP value. From 2007 to 2016, the total amount of green GDP in Shenyang was increased from about 1.56 * 10^{10} $ to 7.41 * $10^{10}$$. But the traditional GDP increased only from 2.54* $$10^{10}$ to 1.14* $10^{11}$$. Seen from the total amount of green GDP, an increasing trend year by year was shown, with a larger increase in 2012-2016 years, it has increased 2.87 × $10^{10}$$ in 5 years; From the point of view of green GDP accounting for the proportion of the traditional GDP, the proportion of green GDP was in a state of continuous fluctuation, from 61.1% in 2007 to 58.9% in 2010, increased from 60.9% into 65.2% in 2011; from the overall point of view, the green GDP of Shenyang only increased by 4% in 10 years, mainly due to the adjustment of industrial structure in 2015-2016 (Wang *et al.,* 2018a). Shenyang's consumption of the natural resources and environmental resource contributed to a large proportion of traditional GDP: nearly 40% of the traditional GDP was exchanged by natural resources and the ecological environment consumption, still has a big gap about the green development.

Table 2. The energy value analysis of environmental and eco-economic system of Shenyang city in 2007 to 2016 years

Year category	Renewable environmental resources/ se J	Non-renewable environmental resources/ se J	Renewable resource products/ se J	Non-renewable resource products/ se J	Input energy value/ se J	Money flow/ se J	Waste flow/ se J	Total solar energy/ se J	Energy/ currency ratio/ se J
2007	3.11×10²²	1.08×10¹⁹	6.08×10²²	2.41×10²⁴	9.41×10²¹	3.03×10²³	1.88×10²⁴	4.61×10²⁴	1.02×10¹⁵
2008	3.14×10²²	1.64×10¹⁹	6.46×10²²	2.61×10²⁴	1.04×10²²	3.46×10²³	2.15×10²⁴	5.11×10²⁴	9.7×10¹⁴
2009	3.33×10²²	2.05×10¹⁹	6.57×10²²	3.06×10²⁴	1.39×10²²	4.56×10²³	2.30×10²⁴	5.82×10²⁴	1.27×10¹⁵
2010	2.97×10²²	2.43×10¹⁹	6.61×10²²	3.94×10²⁴	1.40×10²²	4.5×10²³	2.58×10²⁴	6.97×10²⁴	1.29×10¹⁵
2011	3.03×10²²	2.57×10¹⁹	6.90×10²²	4.29×10²⁴	1.51×10²²	5.42×10²³	2.84×10²⁴	7.65×10²⁴	1.32×10¹⁵
2012	2.75×10²²	3.11×10¹⁹	7.18×10²²	4.87×10²⁴	1.62×10²²	7.80×10²³	3.63×10²⁴	9.28×10²⁴	1.35×10¹⁵
2013	3.24×10²²	3.97×10¹⁹	7.20×10²²	5.42×10²⁴	1.49×10²²	1.17×10²⁴	3.90×10²⁴	1.08×10²⁵	1.34×10¹⁵
2014	3.35×10²²	3.90×10¹⁹	7.25×10²²	5.63×10²⁴	1.48×10²²	1.45×10²⁴	4.1×10²⁴	1.11×10²⁵	1.37×10¹⁵
2015	3.18×10²²	3.88×10¹⁹	7.29×10²²	5.60×10²⁴	1.54×10²²	1.67×10²⁴	3.96×10²⁴	1.17×10²⁵	1.36×10¹⁵
2016	2.99×10²²	3.73×10¹⁹	7.31×10²²	5.54×10²⁴	1.65×10²²	1.79×10²⁴	3.88×10²⁴	1.15×10²⁵	1.37×10¹⁵

Table 3. The value of resource consumption in Shenyang city during 2007to 2016 years

Year category	Natural resources		Input resource	Environmental resource			Total resource consumption
	Non-renewable environmental resources	Non-renewable resource products	Input resource	Waste water	waste gas	solid waste	
2007	1.60×10⁵	3.18×10⁹	3.15×10⁹	1.63×10⁷	8.74×10⁷	1.86×10⁹	7.96×10⁹
2008	1.68×10⁵	3.78×10⁹	4.28×10⁹	3.78×10⁷	6.26×10⁷	2.50×10⁹	9.76×10⁹
2009	1.71×10⁵	5.79×10⁹	4.32×10⁹	5.18×10⁷	2.17×10⁸	6.05×10⁹	1.26×10¹⁰
2010	1.54×10⁵	8.34×10⁹	6.02×10⁹	4.34×10⁷	2.37×10⁸	9.07×10⁹	1.83×10¹⁰
2011	1.30×10⁵	1.33×10¹⁰	8.77×10⁹	1.34×10⁸	3.65×10⁸	1.19×10¹⁰	2.66×10¹⁰
2012	1.33×10⁵	1.61×10¹⁰	1.02×10¹⁰	1.46×10⁸	1.50×10⁹	2.19×10¹⁰	4.07×10¹⁰
2013	1.49×10⁵	1.49×10¹⁰	9.18×10⁹	1.28×10⁸	1.21×10⁹	2.27×10¹⁰	3.99×10¹⁰
2014	1.74×10⁵	2.53×10¹⁰	1.03×10¹⁰	1.26×10⁸	1.20×10⁹	2.02×10¹⁰	4.8×10¹⁰
2015	1.64×10⁵	2.92×10¹⁰	1.02×10¹⁰	1.06×10⁸	8.7×10⁸	1.74×10¹⁰	4.86×10¹⁰
2016	1.79×10⁵	3.66×10¹⁰	1.10×10¹⁰	1.22×10⁸	9.8×10⁸	1.85×10¹⁰	5.80×10¹⁰

Based on the accounting of green GDP in Shenyang city from 2007 to 2016, the following were found:

1. During 2007-2014, Shenyang's economic growth overly relied on oil, iron and steel and other natural resources consumption. And the serious loss of ecological environment led to in the creation of the value of economic growth less than the traditional GDP value.

2. 2015-2016, although Shenyang's economic increased slowly, the green GDP growth rate increased year by year, which reflected Shenyang's economic transformation achieved a good result, still has gap between the ecological and sustainable development. Due to different accounting methods, the proportion of green GDP may have some small differences.

This paper puts forward the following suggestions to the economic development of Shenyang city: First, speed up the transformation and reform of supply. Eliminate backward production and serious pollution of zombie companies as soon as possible. Establish circulation, intelligent and green industrial system with low energy consumption. Improve resource utilization. Reduce waste emissions and pollution of the environment. Second, Government management agencies, social organizations support the production enterprises under some conditions including green credit, green production, green management. At the same time, speed up the research and introduction of environmental accounting management guidelines, from the macro and micro levels, two pronged support and management of green development. Again, improve the organizational structure and service function of the production industry, adopt clean production technology, and improve the system of ecological restoration. Finally, Geographical position of Shenyang City is unique. It is located in the transportation hub in Northeast, vigorously tap the history and culture (Qing Dynasty palace, Marshal Mansion) and such tourism resources and the develop leisure agriculture, construct the ecological tourism urban to improve green economic income and to realize the sustainable development.

4. Discussion

Using the EMA to unify the consumption indicators and environmental depletion index measurement units, calculating Shenyang's 2007- 2016 Green GDP growth, we found that the total amount of green GDP is increasing, but the traditional GDP growth rate increased more than green GDP growth rate from 2007 to 2014. And during 2015-2016, traditional GDP grew slowly, but green GDP grew rapidly. 2016, green GDP growth rate was close to the traditional GDP growth for the first time (Wang *et al.,* 2018b). This shows that the traditional GDP accounting for 2008-2014 does not have the value of resource consumption and environmental depletion, which lead to certain defects: first, if we ignore the problem of saving resources and protecting the environment, it would take disadvantage to the sustainable development of regional economy and society; second, the traditional GDP accounting exaggerated the economic growth rate in some areas whose development heavily relies on natural resources, which cannot reflect the real benefits.

5. Conclusions

At present, there is no unified approach to the international accounting method of green GDP, some countries use the framework of SEEA combined with the actual situation to account the green GDP. Using the energy value analysis method to calculate the regional green GDP, that emphasizes the important role of resources and environment on the sustainable development of social economy from the perspective of environment and ecological economy system, which is an effective complement and improvement of other accounting methods, and it is helpful to develop the actual situation of the green economy from the macroscopic observation area.

The use of the EMA is the first time to measure the development of green GDP in heavy industry city. in the accounting process we found a number of imperfect and immature place: first, the accounting process is cumbersome and jumbled, huge data has difficult trade-offs, need large amount of calculation; second, energy standard calculation of the conversion rate and are not same as the case, because of the ecological environment of the natural area difference, we need to implement the amendments of the solar energy conversion rate according to the actual situation of regions, so it would be one of the important issues in the future, which calculated with the standard value of the conversion rate is the use of EMA for accounting; second, the energy analysis focuses on the analysis of in the economic activities of resource consumption and environmental loss accounting, but in the calculation, recycling and environmental remediation resources could not show the economic and ecological benefit's value. If the local vigorously develop the circular economy, using EMA will produce a greater error. Again, the EMA lacks the measure of price changes and exchange rate and other related factors. Therefore, if the time span is relatively large, it will result in a larger error. Finally, using EMA for green GDP accounting is still in the stage of exploration, and need to combine with the domestic and foreign theory and practice of in-depth study.

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