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A Regional Comparison of Sustainability and Innovative Capability of Enterprise Efficiency

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Abstract—With the development of science technology and social economy, green sustainable innovation has become an important power to promote rapid economic development. The regional green sustainable innovation efficiency is different because our country regional economic level and industry structure are different. Increasing the expected output indicators based on expected output index, we using the radial, the angle of SBM - DEA model to build enterprise green sustainable innovation efficiency evaluation index system and model. A comparative analysis is made on the sustainable innovation efficiency of enterprises in Middle East and west regions By analyzing panel data from 2011 to 2015 in China.

Key words—green sustainable innovate; undesired; efficiency in different regions

I. INTRODUCTION

In the report of the 19th National Congress of the Party, the economy of China grows rapidly and steadily, making a great contribution to the economic growth of world. China's GDP grew from 54 trillion to 80 trillion, the second largest in the world, and its contribution to world economic growth exceeded 30 percent. At the same time, the concept of ecological civilization construction in implementing the green development consciousness and initiative significantly enhanced, the concept of ecological environment protection is more and more strong, the green innovation strategy is of great significance to the enterprise. China is in the critical moment of economic system and social reform, narrowing the regional gap and achieving regional balanced and balanced development is an important economic and social problem to be solved. Green sustainable innovation of enterprise innovation power shortage caused by high input, low output, it is necessary for green sustainable innovation efficiency analysis, by building the enterprise green sustainable innovation efficiency evaluation index system and model, to evaluate enterprise case analysis, to find the reason why there are regional differences of green sustainable innovation efficiency, and then puts forward the corresponding countermeasures and policy reference.

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II. LITERATURE REVIEW

At present, on the research of enterprises green sustainable innovation's efficiency, scholars at home and abroad mainly pay attention to the definition of concept and the choice of evaluation index and so on.

A. Review on the define of green sustainable innovation of enterprises

The definition of green sustainable innovation in enterprises has gone through from "green innovation" to "sustainable innovation" and then "green sustainable innovation". Research on the concept of green innovation, Liuwei [1] summarized the green innovation that the technical innovation, the green system innovation and the green culture innovation are unified. Eliana Andrea Severo [2] expressed that sustainable innovation was mainly in the production of products, as reflected in cleaner production and environmental management. The concept of green sustainable innovation of enterprises was first developed by Xiang Gang [3]. He put forward that in the pursuit of sustainable innovation and development, enterprises should not only pursue sustainable innovation financially, but also seek sustainable innovation and development in social and ecological area based on sustainable development theory.

B. A Review of the Evaluation Method of Sustainable Innovation Efficiency in Enterprises

The research of the evaluation method of enterprise's green sustainable innovation mainly focuses on the following aspects: Firstly, the research of traditional DEA model. The traditional DEA model can only be used for cross-sectional data to compare and analyze the efficiency of decision-making units. Secondly，the research of improved DEA model. The BCC analysis method overcomes the assumption that the scale of CCR is constant, but the scale of compensation is variable, thus avoiding the possibility that the decision unit may be increasing or decreasing in size and the measured efficiency is more accurate. Thirdly, DEA-Total factor productivity model.

Malmquist, also known as TFPCH, the DEA-Malmquist model is mainly applied to the measurement of production efficiency, which can be evaluated vertically.

C. Research Reviews

To sum up, based on the studies that green continuous innovation efficiency for enterprises, this article makes the definition about enterprise green sustainable innovation, using the undesired SBM-DEA model to build evaluation system of green sustainable innovation efficiency. On the input index, combining with the production department and R&D department, from the labor, capital, and technology four aspects to analyze the energy consumption. On the output, we consider mainly desired output of economic benefit, and look environmental pollution as the undesired output. In terms of output index, the expected output is mainly economic benefit, while the non-expected output is mainly concerned with environmental pollution and economic loss.

III. Enterprise Green Sustainable Innovation Efficiency Evaluation Model Construction

A. Construction of the Undesired SBM-DEA Model

This article selects SBM-DEA model to build green sustainable innovation efficiency evaluation model of DEA method is different from general single input and output, but contains a variety of elements in the input and output, to analyze the related the relative efficiency evaluation of [4].Tone [5] SBM model is put forward, namely the slack variable to join into the objective function, the efficiency measurement, is not only a common variables, at the same time contains a slack variable as a result, which is very good to solve problems when the expected output efficiency measurement, and the measurement does not exist weak efficient problem effectively. Based on the undesired SBM-DEA model, this paper constructs an enterprise green continuous innovation efficiency evaluation model. The detailed model is as follows:

$$\rho = min \frac{1 - \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{io}}}{1 + \frac{1}{S_{1+}S_2}\left(\sum_{r=1}^{S_1}\frac{s_r{}^g}{y_{ro}{}^g} + \sum_{r=1}^{S_2}\frac{s_r{}^b}{y_{ro}{}^b}\right)}$$

s.t.

$$\begin{cases} x_o = \gamma X + S^-, \\ y_o{}^g = \gamma Y^g - S^g, \\ y_o{}^b = \gamma Y^b - S^b, \\ S^- \geq 0, S^g \geq 0, S^b \geq 0, \gamma \geq 0. \end{cases}$$

Among them, $X=[x_1,x_2,x_3\ldots,x_n]$, $Y^g=[y_1{}^g,y_2{}^g,y_3{}^g\ldots y_n{}^g]$, $Y^b=[y_1{}^b,y_2{}^b,y_3{}^b\ldots y_n{}^b]$, ρ represents green sustainable innovation efficiency of DMU; x, y^g, y^b represent input, desirable output and undesirable output in turn; γ as a weight of input and output; s_i^- is the kind of excess inputs; $S^g$and S^brepresent the slack variables, which are desired and undesired expected output.

B. Sample Selection and Index Build

In accordance with the "no greater than the total of all elements combined indicators (including input elements and expected output indicators elements with the expected output indicators) a third of the" principle of [6], at the same time consider by the difficulty of data acquisition and the concept of industrial energy consumption is the main industry, this paper

TABLE I. Input-output Index of Green Sustained Innovative Efficiency

Level index	Second index	Thrid grade index	Symbol
Input	Labor	The number of R&D	X_1
	Capital	Investment in industrial fixed assets	X_2
		Fund of R&D	X_3
		Fund of developing new product	X_4
	Technology	The number of R&D project	X_5
		The number of applying for patents	X_6
		The number of new product	X_7
	Energy	Coal consumption	X_8
		Industrial water consumption	X_9
Desired output	Economic	Business profit ratio	$Y_1{}^g$
		Sales revenue of new products	$Y_2{}^g$
Undesired output	Water and gas	Wastewater total amount	$Y_1{}^b$
		Emission load of so_2	$Y_2{}^b$

selected industrial enterprises above designated size as sample data, selecting industrial enterprises above designated size of the panel data of 31 provinces, and building enterprise efficiency evaluation model of green sustainable innovation. Data from China statistical yearbook from 2011 to 2015 30 provinces (because of the lacking of the Tibet autonomous region data seriously, therefore rejecting) data, the data is also a lack of energy consumption in zhejiang province in 2014, using linear interpolation method for interpolation and supplement. To sum up, the enterprise green continuous innovation efficiency evaluation system constructed in this paper is shown in table 1.

C. Index Processing

The analysis of the data, input, in order to handle the convenience, the scientific nature and rationality of index system design, in this paper, the data is as follows: 1) the input index in the capital, the expected output of the waste water exhaust unified unit. 2) the profit margin index in the expected output is calculated from the ratio of the total net profit to the main business income, and the total net profit is deducted from the total operating profit minus the income tax. 3) for the technical input indicators, due to the inconsistency of their units, factor analysis is adopted to reduce the relevant data, and then the next step is analyzed according to the results.

IV. Study Result and Analysis

A. Evaluating Results

Based on the enterprise green sustainable innovation efficiency input-output index system, this paper analyzes the panel data of 30 provinces in China for 2011-2015 based on the undesired SBM-DEA model, including M = 4, S_1 = 1, S_2 = 2. In order to analyze green sustainable innovation efficiency more comprehensively, it is combined with technological efficiency(TE), pure technological efficiency(PTE) and scale efficiency(SE).

B. Regional Analysis of Enterprise Green Sustainable Innovation Efficiency

According to the results of table 1,the following graph is obtained :

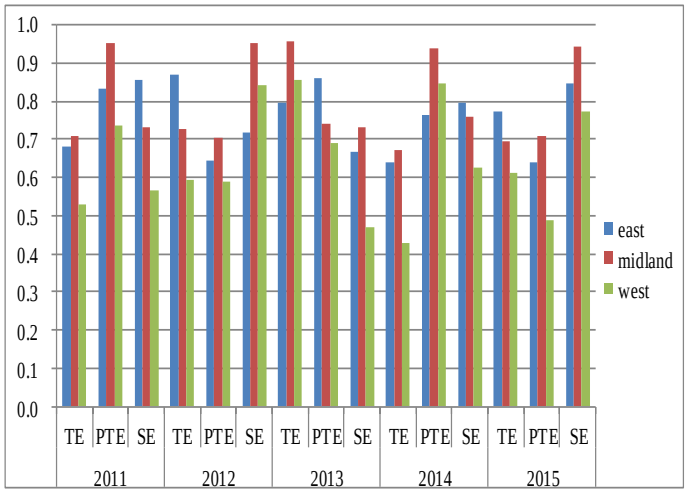

Fig. 1. The different regions of green sustainable innovative efficiency

Firstly, the efficiency of green sustainable innovation technology for enterprises in the east, middle and west regions is 0.802, 0.948 and 0.81 respectively, which shows that the

TABLE II. THE Result of Green Sustainable Innovative Efficiency

Year	Index	East	Midland	West
2011	TE	0.679	0.709	0.530
	PTE	0.834	0.953	0.738
	SE	0.854	0.731	0.566
2012	TE	0.868	0.728	0.591
	PTE	0.645	0.704	0.590
	SE	0.716	0.950	0.842
2013	TE	0.797	0.957	0.854
	PTE	0.861	0.739	0.688
	SE	0.667	0.733	0.469
2014	TE	0.641	0.672	0.427
	PTE	0.765	0.939	0.845
	SE	0.797	0.758	0.628
2015	TE	0.771	0.692	0.610
	PTE	0.640	0.709	0.487
	SE	0.847	0.945	0.772

development of green sustainable innovation technological efficiency of enterprises in our country is better and should be paid attention. The technological efficiency of the enterprise in the east area is not the best. In the process of the enterprise development, we should pay attention to the proportion of input and output, and take some way to promote the sustainable innovation of the enterprise.

Secondly, the net technical efficiency of green and sustainable innovation in the east, central and west regions is 0.654, 0.705 and 0.501, respectively. This shows that, in terms of pure technological efficiency, the west region is seriously short of technical investment. This is due to the shortage of scientific and technological personnel, the backwardness of technology and the inaccessibility of conditions. Although the central and eastern regions are higher than the western regions, they do not achieve the 0.75 green sustainable innovation pure technical efficiency. For the eastern region, the low efficiency of pure technology is mainly due to the problem of undesired output. In the process of technical input, attention should be paid to environmental protection and risk prevention, so that the undesired output should be reduced and unnecessary losses reduced. For the central region, the general reason for pure technical efficiency is the lack of scientific input and pollution of output.

Finally, the scale efficiency of green sustainable innovation is 0.83, 0.729 and 0.617, respectively. It reflects the decreasing trend of the scale efficiency of green sustainable innovation from the east to the west. In this paper, the scale efficiency of green sustainable innovation is used as the criterion for sustainable development of enterprises. The scale efficiency increases gradually between 0 and 1, and its sustainable development decreases gradually. However, the general scale of 0.5 or more is considered as a basic condition for sustainable development, especially for smaller enterprises, which are more efficient in terms of technology and pure technology. To a certain extent, the scale structure and resource allocation of enterprises with low and high efficiency of pure technology are reasonable. Such enterprises need to increase their technical investment to promote their sustainable development.

V. CONCLUSIONS AND SUGGESTIONS

In this paper, we use the undesired, non-radial SBM-DEA model to collect the panel data of 30 provinces in China for 2011-2015, construct the evaluation model of sustainable innovation efficiency and evaluate it. In data processing, factor analysis is used to reduce the dimension of relevant index, eliminate the influence of random error in efficiency evaluation, and measure the efficiency of green sustainable innovation as real, accurate and effective as possible. The conclusion is as follows: there is a significant regional gap in the efficiency of green sustainable innovation in enterprises, which shows a better overall situation in the East and a decreasing trend in the middle and West. the highest technical efficiency was 0.948 in the central region and 0.008 in the western region compared to the eastern region. Pure technical efficiency from high to low in order of the central, Eastern and western regions. Scale efficiency is higher in the East than in the middle and lowest in the West.

In view of this, this paper puts forward the following suggestions: At first, we should invest in labor, capital and resources rationally, and actively guide enterprise structure, optimize innovation development, pay attention to environmental issues. What's more government need to increase the proportion of expenditure on environmental protection, and pay attention on energy conservation and emission reduction, related apartment should improve the ability to deal with environmental pollution. Entrepreneurs have to focus on how to expand the scale of enterprises, and actively promote the development of enterprises towards green and sustainable innovation. Secondly, enterprises in the central and western regions should make full use of the support policies of the state, draw on the advanced green technology and scientific management experience of enterprises in the eastern regions, optimize the allocation of resources, eliminate backward production capacity, adjust production scale and narrow the gap with advanced enterprises in the pursuit of green and innovative benefits. Thirdly, enterprises in the central and western regions should take environmental issues into account in their development process, pay attention to adjusting their development strategies, pay attention to environmental pollution, and truly achieve green and sustainable innovation.

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