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The Evaluation of Low-Carbon Economy Jiangsu, China

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***Abstract*—**Low-carbon economy means the energy conservation and emission reduction. How to measure and evaluate the regional low-carbon economy is an important problem which should be solved immediately. This paper proposed the eco-efficiency ratio based on the ecological efficiency to evaluate the current situation of the low-carbon economy in Jiangsu province and to analyze the efficiency of the low-carbon economy in Jiangsu and other provinces, compared both advantages and disadvantages. And then this paper put forward some advices for the government to formulate the correct development policy of low-carbon economy, to improve the technology innovation capacity and the efficiency of resource allocation.

***Keywords*—**Eco-efficiency ratio, Jiangsu, China,Low-carbon economy.

I. Introduction

THE earth can meet the needs of the human, but cannot satisfy the human greed. said by Mahatma Gandhi. Since the industrial revolution, human have been greedily pursuing the economic development and the material needs, endlessly using fossil energy and letting the Carbon dioxide emission alone. People gradually put themselves from the agricultural "original" low carbon economy system into the industrial "high carbon economy" system, and now they face an awkward dilemma of the global warming. So they proposed the low carbon economy development concept. A Low Carbon Economy refers to the Low energy consumption, the Low pollution and the Low emission which can make the economic and social development and the ecological environment protection to achieve a win-win result through the technical and system innovation, as well as the industrial transformation and the new energy development under the guidance of the sustainable development.

II. Methods of Low Carbon Economy Evaluation

A. Ecological Efficiency

Low carbon economy means the energy conservation and the emission reduction. How to measure and evaluate the effect is an important problem in the specific practice process which has to be solved immediately. So the domestic scholars generally introduced the concept of ecological efficiency index.

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1) Ecological Efficiency Model

$$\text{EcologicalEfficiency}=\frac{\text{the value of your products/services}}{\text{Environmental Influence}} \quad (1)$$

"The ecological efficiency " first put forward by the World Business Council for Sustainable Development (WBCSD), and its core is “to provide competitively priced products and services to meet basic needs and bring a better quality of life, while minimize the use of natural resources and gradually reduce the impact on the environment over the life cycle, so as to consistent with the earth’s bearing capacity, not to jeopardize the needs of future generations” [1]. Ecological efficiency links the index of the resources, economy and environment; establishes the best link between the best economic goals and the most excellent environmental objectives [2]. We has taken a series of evaluation index system such as "ecological city, circulation economy, ecology industrial park" in the area of the regional environmental assessment [3].

2) The Index Selection of Regional Ecological Efficiency

According to the index selected to calculate ecological efficiency in the German environmental economic account and considering the scientific nature of the index, the accessibility of the data and other factors, this article establishes the regional ecological efficiency index system shown in the table I on the basis of domestic practice. According to the definition of ecological efficiency, the output represents the value of the products or services, generally described by the gross domestic product (magnitude of value), and design practical method for measuring the resource consumption and the impact of environmental pollution.

3) The Determination of the Index Weight

i. Constructing hierarchy structure model, as shown in table I.

ii. Setting up judgment matrixes, as shown in table II.

iii. The relative weight calculation of the elements under a single standard. The method is as follows: Comparing the line factor and column factor, scoring these factors according to their relative importance to the production and operation activities, as table III shows:

iv. Find out the biggest characteristic root in the comparative matrix λmax and the corresponding feature vector $W=\{W1,W2\}$ for normalization.

v. Make the consistency check. If $CR<0.1$, the degree of inconsistency which the weights derived from is in the allowed range.

vi. Weight the second-class index Wij in the same way.

Although the ecological efficiency can measure the resource utilization in the region, problems remain exist only using the ecological efficiency index. For example, the index is lack of comprehensive and cannot unify the unit , etc.

Calculating the regional ecological efficiency index, the GDP of the area is usually chosen as the molecule and each index actually reflects the contribution of the unit consumption of natural resources to the total regional GDP. However, due to the different focus of economy between the different regions, the different natural resource consumption corresponds to the different economic value. When dividing the weight of eco-efficiency indicators, common indicators for all regions should be weight different values based on local realities and actual conditions, with the different regions for different weights.This paper use analytic hierarchy process to distribute the weight, which is a kind of qualitative and quantitative, systematic and hierarchical analysis method. It set the weight of the first-class index for W = { W_1,W_2}, which contains the second-class index weight for W_{ij} (i = 1, 2; j =1,2,3). The main steps to determine the index weight are as follows:

TABLE I
REGIONAL ECOLOGICAL EFFICIENCY INDEX SYSTEM

First-Class Index and Weight	Second-Class Index and Weight
Resources Utilization Efficiency (W_1)	Construction land productivity(W_{11})
	Energy productivity(W_{12})
	Water consumption productivity(W_{13})
Waste Emissions Efficiency(W_2)	Sulfur dioxide emissions productivity(W_{21})
	Waste water discharge productivity(W_{22})
	Waste discharge productivity(W_{23})

B. Ecological Efficiency Ratio

In order to compensate for the lack of ecological efficiency evaluation in the region, this paper get the ecological efficiency ratio as regional environmental efficiency evaluation index based on the ecological efficiency index system.

1)The calculation of the regional eco-efficiency ratio

TABLE II
JUDGMENT MATRIXES

Resources Utilization Efficiency	Resources Utilization Efficiency	Waste Emissions Efficiency
Waste Emissions Efficiency	a_{11}	a_{12}
Resources Utilization Efficiency	a_{21}	a_{22}

TABLE III
RELATIVE IMPORTANCE SCALE

Scale	Definition
1	Factor i and j are the same important
3	Factor i is slightly more important than factor j
5	Factor i is obviously more important than factor j
2,4,6	Between the scale 3 and scale 5
Reciprocal	Results of Comparison, which value describe as $a_{ij}=1/a_{ji}$

Eco-efficiency ratio=The year's eco-efficiency/Last year's eco-efficiency [4]. Regional eco-efficiency ratio R is expressed as:

$$R_i = \frac{\text{The eco - efficiency of this year's index in the region}}{\text{The eco - efficiency of last year's index in the region}} = \frac{X_a}{X_b}\cdot\frac{Y_b}{Y_a} \quad (2)$$

R_i represents the sub-indicators of that eco-efficiency;
Y represents the value of regional GDP;
X represents the actual amount of the indicators;
b represents this year;
a represents last year.

The eco-efficiency ratio of each pollutant can be obtained from the model(2):

$$R_{ij} = \frac{X_{aij}}{X_{bij}}\cdot\frac{W_{ij}W_iY_b}{W_{ij}W_iY_a} = \frac{X_{aij}}{X_{bij}}\cdot\frac{Y_b}{Y_a}, (i=1,2;j=1,2,3) \quad (3)$$

The regional eco-efficiency ratio is available from the model(3):

$$R=\sum_{i=1}^{5}\sum_{j=1}^{3} W_iW_{ij}R_{ij} \quad (i=1,2;j=1,2,3) \quad (4)$$

When the R-value above or equal to 1, it indicates that the output this year is greater than last year in consuming the same unit of resources, which thereby proves that the utility of resource has been improved and the environmental management has obtained the good effect; When 0 < R < 1, it explains the same output has consumed more unit of resources this year than last year, which proves the utility of resource has been reduced and the environmental management has not worked well. Thus it can be seen that the bigger R value is, the more effective the environmental management is, and the more the utility of resources have improved.

2) The realization method of the eco-efficiency ratio for the policy advice

$\hat{R}$ represents the ratio of the highest eco-efficiency across the country to the eco-efficiency in a certain area.

$$\hat{R} = \frac{\text{The optimal value of that year's eco - efficiency across the country}}{\text{That year's eco - efficiency in that region}} \quad (5)$$

The higher the value is, the greater the gap is between the region's resource utilization and the optimal efficiency, which means more room for promoting on the utilization of resources in this region. The local government should refer to this index in the choice of environmental management reform program and choose the emissions with the largest $\hat{R}$ -value as a corrective object, which can clarify the direction of the government policy-making and the technology reform, give full play to the government's control functions.

III. LOW-CARBON ECONOMY EVALUATION IN JIANGSU PROVINCE

A. The Determination of Index Weight

According to the multi-level index system and the experts' consultation, it compares on the basis of the data from table II and table III the efficiency of resource utility, the two first-class

indexes of "three wastes" emissions efficiency, three second-class indexes of resource utilization efficiency and the importance of "three wastes" emissions efficiency, constructs three comparative matrixes. The results show in table IV-VI:

Among them, λ_{max} is the biggest characteristic value, and RI is the average random consistency index; CI is the consistency index; CR is the random consistency ratio. Then, we calculate the maximum eigenvalue and eigenvectors from the judgment matrixes applying the Sum\Product Method. At the same time, consistency has been checked and the eigenvector is the relative

TABLE IV
FIRST-CLASS INDEX MATRIX

Index	Resources Utilization Efficiency	Waste Emissions Efficiency	Weight (W_i)
Resources Utilization Efficiency	1	1	0.50
Waste Emissions Efficiency	1	1	0.50

Plus：λ_{max}=2.0;RI=0;CI=0;CR=0<0.10

TABLE V
SECOND-CLASS INDEX MATRIX OF RESOURCES UTILIZATION EFFICIENCY

Index	Construction Land Productivity	Energy Productivity	Water Consumption Productivity	Weight (W_{1j})
Construction Land Productivity	1	1/2	2	0.30
Energy Productivity	2	1	3	0.53
Water Consumption Productivity	1/2	1/3	1	0.17

Plus：λ_{max}=3.0093;RI=0.58;CI=0.0047;CR=0.008<0.10

TABLE VI
SECOND-CLASS INDEX MATRIX OF WASTE EMISSIONS EFFICIENCY

Index	Waste Water Discharge Productivity	Waste Discharge Productivity	Sulfur Dioxide Emissions Productivity	Weight (W_{2j})
Waste Water Discharge Productivity	1	1	2	0.40
Waste Discharge Productivity	1	1	2	0.40
Sulfur Dioxide Emissions Productivity	1/2	1/2	1	0.20

Plus：λ_{max}=3.0;RI=0.58;CI=0;CR=0<0.10

important weight to the corresponding elements of the same level to the upper level. After ordering the value in single level and doing the overall consistency check, the result shows a good consistency with all the value of CR is less than 0.1.

B. The Comprehensive Index of Eco-efficiency Ratio

This paper calculates the ecological efficiency of the index from Jiangsu province in the year from 2003 to 2008, which is from China's statistics yearbook, and the results shows in the table VII-VIII.

Therefore, the eco-efficiency ratio of the sub-index in Jiangsu can be got from the model (2), as shown in tableIX-X.

From the table, the sub-indexes of ecological efficiency are all in dimensionless treatment. Then the weight coefficient determined in the table IV-VI and the composite index of Jiangsu province's eco-efficiency ratio of each year from 2004 to 2008 is considered, as shown in table XI.

TABLE VII
ECO-EFFICIENCY OF SUB-INDEX OF JIANGSU PROVINCE IN 2003-2008 (1)

Year	Construction Land Productivity (Ten thousand Yuan/ha.)	Energy Productivity (Yuan/t standard coal)	Water Consumption Productivity (Yuan/t)
2008	156.72	12453.30	54.29
2007	65.42	11723.33	22.29
2006	115.30	16827.99	38.97
2005	99.95	10834.71	35.22
2004	88.44	11713.20	30.95
2003	78.73	12598.57	32.93

TABLE VIII
ECO-EFFICIENCY OF SUB-INDEX OF JIANGSU PROVINCE IN 2003-2008 (2)

Year	Sulfur Dioxide Emissions Productivity (Ten thousand Yuan/t)	Waste Water Discharge Productivity (Yuan/t)	Waste Discharge Productivity (Yuan/t)
2008	268.19	594.71	35009.24
2007	102.15	246.10	15312.42
2006	163.71	414.28	26331.80
2005	133.33	352.42	27770.35
2004	128.96	342.86	29313.14
2003	112.38	331.51	28541.64

TABLE IX
ECO-EFFICIENCY RATIO OF SUB-INDEX OF JIANGSU PROVINCE IN 2004-2008 (1)

Year	Construction Land Productivity	Energy Productivity	Water Consumption Productivity
2008	2.396	1.062	2.436
2007	0.567	0.697	0.572
2006	1.154	1.553	1.107
2005	1.130	0.925	1.138
2004	1.123	0.930	0.940

TABLEX
ECO-EFFICIENCY RATIO OF SUB-INDEX OF JIANGSU PROVINCE IN 2004-2008 (2)

Year	Sulfur Dioxide Emissions Productivity	Waste water Discharge Productivity	Waste Discharge Productivity
2008	2.625	2.417	2.286
2007	0.624	0.594	0.582
2006	1.228	1.176	0.948
2005	1.034	1.028	0.947
2004	1.147	1.034	1.027

TABLE XI
COMPOSITE INDEX OF ECO-EFFICIENCY RATIO OF JIANGSU PROVINCE IN 2004-2008

Year	2008	2007	2006	2005	2004
Composite Index of Eco-Efficiency Ratio of Jiangsu Province	2.0510	0.6158	1.2262	1.0098	1.0218

The composite index of Eco-efficiency ratio reflects the rate of progress of the comprehensive regional ecological efficiency. When the value of R is greater than 1, the results show that the efficiency of using resources in this year has been improved; when the value of R is less than 1, the contrary is the case. Above shows that Jiangsu province's overall ecological efficiency showed a rising trend during 2004-2008, and each year's eco-efficiency ratio is larger than 1 in addition to 2007, and the growth increased year by year: the efficiency of using resources has been smoothly improved in Jiangsu province during2004-2006, especially in 2006 it has made great progress. By the year of 2007, however, R value dropped sharply. There should be two reasons: first, along with the rapid economic development of Jiangsu province, the total amount of pollution emissions will continue to increase, and the improvement of efficiency of using resources cannot keep pace with the speed of economic expansion, which lead to a drop of the ecological efficiency index; Second, the stock market's crash at the end of 2007 proved the landslide of real economy. The product in occurrence factory is slow-moving; the consumption of resources isn't followed by the increase of the economic income, which leaded to comprehensive eco-efficiency status slipping. The comprehensive value of eco-efficiency ratio in 2008 ramping up greatly is mainly due to the decline in 2007, compared with a higher growth rate, and virtually probably due to the cautious of the real economy on the output scale, which rebound the efficiency of using resources.

C. The Realization of the Eco-efficiency Ratio for the Policy Advice

According to the China statistical yearbook, this article gets the 31 provinces' ecological efficiency index, and finds out the optimal value of the 31 provinces' ecological efficiency index, as shown in table XII-XIII.

TABLE XII
ESTIMATING AND RANKING THE VALUE OF $\hat{R}$ OF JIANGSU PROVINCE (1)

Index	Construction Land Productivity	Energy Productivity	Water Consumption Productivity
The Optimal Value	310.56	15105.74	298.97
The Value in Jiangsu	156.72	12453.30	54.29
$\hat{R}$ Value	1.9816	1.2130	5.5069
Rank of $\hat{R}$ Value in 31 Provinces	4	6	2

TABLE XIII
ESTIMATING AND RANKING THE VALUE OF $\hat{R}$ OF JIANGSU PROVINCE (2)

Index	Sulfur Dioxide Emissions Productivity	Waste Water Discharge Productivity	Waste Discharge Productivity
The Optimal Value	1979.55	1157.63	136520.69
The Value in Jiangsu	268.19	594.71	35009.24
$\hat{R}$ Value	7.38115	1.9465	3.8996
Rank of $\hat{R}$ Value in 31 Provinces	1	5	3

The value of $\hat{R}$ represents the ratio of the optimal value of the national ecological efficiency to the ecological efficiency in Jiangsu, which reflects the gap between the Jiangsu province's efficiency of resource utilization and the optimal efficiency.Through the above table, it can be find that the largest gap is the sulfur dioxide emissions productivity, which also means more room for promoting, followed by water consumption productivity. Therefore, the government should first consider the improvement of sulfur dioxide emissions productivity at the time of constituting the relevant policies. That means the government should reinforce the technological reform of production which contains sulfur dioxide emissions. And the government should also consider the utilization efficiency of water resource, and improve the efficiency of water resources so that to maximize the ascension of the whole ecological efficiency in Jiangsu province.

IV. CONCLUSION

At present, Jiangsu province is in the acceleration period of industrialization and urbanization, and at the stage of development in the heavy chemical industry and the peak of infrastructure construction, which need to consume the massive resource. The problem of resources and environment are increasing, and has become the constraint conditions for social and economic development. If we continue to follow with the traditional mode of economic development characterized by "high investment, high growth and low benefits", resources will not meet our needs, and the environment will also be difficult to support our rapid development. To develop a low-carbon economy and to promote the transformation of the economic development pattern will be the only way for the development of Jiangsu province in the future.

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