

Research on the Evaluation of Low Carbon Economic Development by Fuzzy Algorithm

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Abstract: The global economy has entered the era of rapid industrialization, especially in developing countries; however, under the dual constraints of resources and environment, the extensive economic growth mode will probably seriously affect the process of China's industrialization and modernization. To keep a balance between industrialization and environment and energy requirements, the development of low-carbon economy is an inevitable strategic choice. Through practical algorithm application, we are trying to verify the rationality and validity of fuzzy algorithm in the evaluation of low carbon economic development level. Model evaluation results can not only classify the low carbon industries, but also demonstrate the relationship among different industrial indexes. *Copyright © 2013 IFSA.*

Keywords: Low-carbon economic, Fuzzy algorithm, Evaluation index system.

1. Introduction

Nowadays, with the development of modern science and technology and the increasing environmental awareness, global economy is gradually becoming the general trend of regional economic development. The industrial revolution is the result of science and technology to improve the quality of life of people, but with the development of industrial economy, population growth, human greed and the desire of the production mode of consumption excesses, caused serious damage to the ecological balance. With the doubling of carbon dioxide, ozone layer of the earth is suffering from a hitherto unknown crisis, global catastrophic climate change appears repeatedly, all of which has serious harm to human survival environment and health and safety.

Through the World Meteorological Organization and the United Nations Environment Programme organized by the Intergovernmental Panel on Climate

Change (IPCC) who released its fourth assessment report, confirmed that "global warming is an indisputable fact", the world's energy problem and low carbon development develops into an attractive hot issue. Since 2003, the earliest in the form of government documents in the "UK energy white paper" to "low carbon economy" to 2009 for six years. Although the academic circles at home and abroad research on low carbon economy is like a raging fire, but the concept of "low carbon economy" definition is still not completely conclusive. Treffers and other scholars of Germany in 2050-1990 based on the reduction of GHG emissions by 80 % [1], proposed by the relevant policies and measures, strong economic growth and reduced GHG emissions to achieve is possible. In the British white paper "our energy future: creating a low carbon economy", low carbon economy is supposed to be realized by new ways of production with less consumption of natural resources and less environmental pollution while more economic output; they thought low carbon

economy to be the way to the quality of life and the chance to create higher and better standards of living, in which opportunities also could be created for the development of advanced technology, application and output, as well as new business opportunities and job chances [2, 3].

This paper aims at finding a suitable model for evaluation of low carbon economy development level to make a more clearly concept framework of the new style of economy development.

2. The Concept Framework of Low Carbon Economy

Low carbon economy is the new development mode and economic form of the way the international community uses to deal with the problem of increasingly large amount of fossil energy consumption caused by global industrialization, resulting in worldwide climate catastrophic change. It is commonly characterized by lower energy consumption, less pollution, fewer emissions, and lower carbon content but with higher performance, higher efficiency and more environment optimization, compared to traditional economy development mode, all of which can promote the harmonious development of human and nature is the basic characteristic the economic and social development [4]. In the field, most scholars generally believe that low carbon economy and stage of development, resources, consumption patterns and the level of technology driving factors are closely related, and through process of lowering carbon emissions (or decarbonization) to achieve [5].

2.1. The Origin and Development of Low Carbon Economy Research

From the 1992 "United Nations Framework Convention on climate change" to the 1997 "Kyoto Protocol", then to 2007 "Bali Island road map", many countries and organizations are actively to curb global warming, reducing CO₂ and other greenhouse gas emissions, seeking effective ways and means. In 2003 the British government published the "Energy white paper-our energy future: creating a low carbon economy", and put forward the concept of low carbon economy [6]. This was the first time that low carbon economy was formally proposed in official documents, making itself a hot topic and promoting low carbon economy evolved into the world's attention. Not only governments launched a series of low carbon action, domestic and foreign scholars related concept of low carbon economy to carry on the positive research [7].

In recent years, the domestic scholars have studied a lot to make low carbon economy an academic issue from different angle in various fields, mainly in: the development of low-carbon economy,

the importance of low carbon economy development path and strategy, foreign low-carbon economic development status and enlightenment, low carbon technology, low carbon finance and its platform, low carbon economy and consumption mode, and low carbon economy system construction etc. [8, 9].

On the basis of previous research, ecological crisis can be summed up in a vicious spiral between low carbon concept is based on the development of industrial economy and the natural environment has been destroyed because of the. The essence of the target of low carbon economy is in the premise of economic development, to achieve low carbon. The development of low-carbon economy is a mode of production, life style, values and national interests of the global revolution [10]. Therefore, we propose that low carbon economy is the development process of human society to a higher social economic form a certain stage, its development model in technological innovation and policy measures to support, in order to establish an efficient low row of low carbon industry chain as the way, so as to realize the economic development mode of low carbon, low consumption mode of human life carbonization, its core is the premise of steady economic growth, the ultimate goal is to realize the coordinated development of ecological environment and social economy [11].

2.2. The Evaluation of Low Carbon Economy

Low carbon economy is a revolution of the mode of economic development and the pattern of human life, its goal is to mitigate climate change and promote sustainable human development, it covers the natural, social, environmental and other aspects. In this paper, from the initial resource to the final consumer market this path according to the industry chain, to put forward a low carbon economy evaluation logic framework, as shown in Fig. 1.

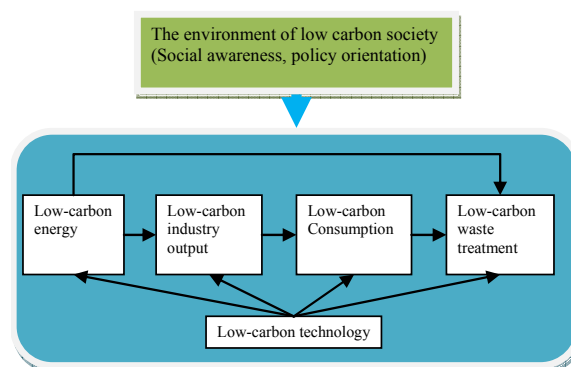


Fig. 1. The logical framework of low carbon economy evaluation.

3. The Evaluation Index System of Low Carbon Economic Development

In order to evaluate the implementation stage of development, the low carbon economy in the process of the gap and can take the policy tool, based on clearing the low carbon economy connotation, the need to establish a multi-dimensional, scientific measurement of the level of development of the scale, namely low carbon economy evaluation index system. The low carbon economy evaluation index system, a comparison to far away countries or

economies from the goal of low carbon economy, on the other hand, to be able to compare countries or economies to efforts of the transition to a low carbon economy. The core elements of low carbon economy is to evaluate whether a region to achieve the most important factors of low carbon economy or whether in low carbonization process, we will focus on 4 core elements and exhaust emission of low carbon economy as an index to construct low carbon economy evaluation system, as shown in Table 1 [12].

Table 1. The indexes of low carbon economy evaluation.

Target layer	Criterion layer	Index layer	Index direction
The level of low carbon economy development (D)	D1 Low carbon energy index	D11 The ratio of zero energy	positive
		D12 The ratio of clean energy	positive
		D13 CO ₂ emissions in per unit of energy consumption	negative
	D2 Low carbon industrial output index	D21 CO ₂ emissions in per unit of GDP	negative
		D22 Energy consumption in per unit of GDP	negative
	D3 Low carbon consumption index	D31 The per capita carbon emissions	negative
		D32 The per capita living carbon emissions	negative
		D33 Ratio of consumer goods with low carbon labels	positive
	D4 Low carbon waste treatment index	D41 Living garbage harmless treatment rate	positive
		D42 Comprehensive utilization rate of industrial solid waste	positive
	D5 Low carbon environment and society index	D51 The per capita housing area	negative
		D52 The number of buses owned by every 10,000 people	positive
		D53 Ratio of low energy consumption architecture	positive
		D54 The public low carbon economy knowledge popularization rate	positive
		D55 Human development index	positive
		D56 The forest coverage rate	positive
	D6 Low carbon technology index	D57 The per capita green area	positive
		D61 Ratio of cogeneration of heat and power	positive
		D62 Ratio of R&D investment accounted for the fiscal expenditure	positive
		D63 Ratio of capture and sequestration (CCS) of greenhouse gas	positive

4. The Fuzzy Factors in Evaluation of Low Carbon Economic Development

4.1. The Economic Factors

The economic factors of low carbon economy basically contain two meanings: the first one is that the low carbon economy should be in accordance with the principles and mechanisms of market economy to develop; the second is that the development of low carbon economy should not lead to a decline in people's life and welfare. That is to say, both oppose extravagance and waste of energy consumption type and the need to constantly improve people's standard of living.

4.2. The Technological Factors

Technological factors of low carbon economy, through technological progress in improving energy efficiency at the same time, also reduce carbon dioxide and other greenhouse gas emissions intensity. That is to say, in the premise of as much as possible to reduce energy consumption, and the original equivalent economic output; or to the same amount of energy consumption, was more effective than the original economic output.

4.3. The Objective Factors

The target of a low carbon economy, namely, the development of low carbon economy is the goal of atmospheric concentrations of greenhouse gases to be maintained at a relatively stable level, and it will not

bring about the impact of rising global temperatures in the survival and development of human beings, the harmonious development of man and nature to achieve [13].

Due to the above and low carbon economy development level evaluation factors have ambiguity series, so the low carbon economic evaluation index also has blurred the corresponding. Qualitative indicators for goal of subjective judgment, is determined by the subjective judgment of the judge. In essence, it has interval fuzziness. Then fuzzy evaluation and low carbon economy process plus related, namely the final result of the evaluation of expert evaluation were analyzed, and the evaluation index is the interval fuzzy quantity, so the evaluation process can only be applied to fuzzy approach to draw objective results.

Based on the above reasons, we think that the AHP and Fuzzy set of fuzzy comprehensive evaluation method of combining method of low carbon economy development level of evaluation is more reasonable, the weight of ambiguity can handle evaluation index and can be more scientific distribution of evaluation indexes.

5. The Fuzzy Algorithm in Evaluation of Low Carbon Economic Development

Due to that current research on low carbon economy evaluation system is not abundant, the scholars of this field still have no common sense with the methods to establish the evaluation system of low carbon economy; therefore, the study on the evaluation index system is only an attempt, and we are hoping to play a role in this field [14]. We also hope that all continue to strengthen the study of these aspects, to build up the index system of low carbon economy evaluation is scientific and reasonable, feasible, and promote the construction of the theoretical system of low-carbon economy and improve, promote low carbon economy accelerated from the advanced concept of development into practical economic operation mode.

5.1. The Establishment of the Hierarchical Structure Model and the Judgment Matrix

On the basis of previous literature, we think that

the low carbon economy should include 4 key elements: stage of development, resource endowment, technology level, and consumption patterns. Therefore, the level of low carbon economy can be expressed as the following concept model:

$$LCE = f(E, R, T, C)$$

Wherein, E represents the stage of economic development, mainly in the industrial structure, per capita income and city etc.; R represents resource endowment, including the traditional fossil energy, renewable energy, nuclear energy, and carbon resource; T is the representative of the technical level, which refers to the main energy consumption of product and process level carbon efficiency; C represents the consumption patterns, mainly refers to the different consumption habits and the quality of life of carbon demand or emissions. All the indexes listed in Table 1 can be sorted into E, R, T and C respectively with the AHP method in the following steps.

The analytic hierarchy process (AHP) is a multi-objective decision analysis is a combination of qualitative and quantitative analysis method. This method is suitable for the problems more complex in structure, decision rule and not easy decision problem of quantization. It is a complex problem to the ordered hierarchical structure. Through people's judgment, decision analysis on social economic system. We plan to use AHP to determine the index weight. The index is positive and the dimensionless treatment, using the linear weighted method (standardized index multiplied by index weights) to calculate the level of low carbon economy development evaluation in different regions with specific data from statistical yearbooks.

As shown in Table 1, the indexes have been sorted into three levels of different layers, the target layer, the criterion layer and the specific index layer. According to the hierarchical structure is established, above a layer element as criterion, the next layer under the control of the elements according to the important degree of a standard numerical expression into matrix form. About how to determine the value of the elements in comparison matrix, we use the method Saaty proposed, known as 1-9 ratio scale method, namely each element in the range of comparison matrix will be marked as 1, 2, 3,....., 9, and 1, 1/2, 1/3,, 1/9, as listed in Table 2.

Table 2. The meaning of 1-9 ratio scale method.

Scale	Meanings
1	The former and the latter factor affect the target to the same extent
3	Compared to the former factor, the effect of the latter is a little stronger
5	Compared to the former factor, the effect of the latter is obviously stronger
7	Compared to the former factor, the effect of the latter is much stronger
9	Compared to the former factor, the effect of the latter is absolutely much stronger
2, 4, 6, 8	The influencing level is between the two scale above respectively
Reciprocal	When the former and the latter change their sequences

By comparing the judgment matrix quantization of each of the two adjacent factors, for example, the criterion layer D_n, with indexes, D11, D12... and D63. Compare these indexes in one-to-one mode, and then all the results can be represented in the comparison matrix D:

$$D = (d_{ij})_{n \times n}$$

Wherein, the d_{ij} is the comparison importance of the individual index to the target D in one-to-one mode. Obviously, d_{ij} > 0, and d_{ij} = 1/d_{ji} (i=1, 2...n; j=1, 2...n).

5.2. The Calculation of Relative Weights and Consistency Check

From the criterion layer judgment matrix D, we can mark the vector V, and

$$V = (v_1, v_2, v_3 \dots v_n)^T$$

So, V is the feature vector of indexes (D_{ij}) under the criterion layer (D_n). The feature vector is the respective evaluation index ratio according to the importance of a layer of criteria ranking, which is also called the weight distribution.

Through the specific data calculation and index normalization, we will get

$$V = (v_1, v_2, \dots, v_n)^T = (0.32, 0.27, 0.21, 0.14, 0.09, 0.18)$$

The results will be stated more clearly with the data listed in Table 3.

Table 3. The judgment matrix of criterion layer.

D	D1	D2	D3	D4	D5	D6	V
D1	1	1	1/2	1/2	1/4	1/2	0.32
D2	1	1	1	1/2	1/3	1/2	0.27
D3	2	1	1	1/2	1/2	1	0.21
D4	2	2	2	1	1/2	1	0.14
D5	4	3	2	2	1	2	0.09
D6	2	2	1	1	1/2	1	0.18

Besides,

$\lambda_{max} = 8.2154$, $CI = 0.0082$, $RI = 1.32$, $R = CI/RI = 0.0062 < 0.1$
So, it is in accordance with the consistency check.

5.3. The Index Standardization and the Comprehensive Calculation

Due to the different methods of each index, have different dimension, direct operation will make the evaluation index system is not reasonable, must be based on the. According to Table 1, of the 20 second-level indicators, some indicators of numerical value

is greater, the regions of low carbon economic development level is better, the index is called the positive indicators; on the contrary, some indexes and the level of low carbon economy development area are negatively correlated, called negative index. At the same time, because the dimension of each index between different, in order to make them more, it needs to carry on the dimensionless processing of all indicators. To use treatment of dimensionless, the normalization method in this study, the formula is:

$$d_{ij} = \frac{D_{ij}}{\max D_{ij}} (i = 11, 12, \dots, 63; j = 1, 3, \dots, 30)$$

Wherein, D_{ij} is the actual value of a certain index of a certain province; i means the index layer (of the 20 indexes from Table 1) and j means the 30 provinces of China (except Tibet). MaxD_{ij} is the maximum of the index of all the provinces. d_{ij} is the standardized value of each index in each province after the nondimensionalization. Also, to the negative indexes, we have to make them positive by the formula as below:

$$d_{ij}' = 1 - d_{ij} (i = 11, 12, \dots, 63; j = 1, 3, \dots, 30)$$

Then we use the weighted linear method with the weight of the 20 indicators multiplied by the standardized value of the indexes respectively to work out the comprehensive value of LCE which can determine the level of low carbon economy development of each region, the formula is as follows:

$$LCE = \sum_{n=1}^{20} v_n \times d_{ij}' (j = 1, 2, \dots, 30)$$

Wherein, v_n is the weight of each index listed in Table 1 and d_{ij}' is the nondimensionalization of the value of each index.

Therefore the final consequence of the calculation is shown in the Table 4.

From the results in the table above, we can see that the top ten are the regions whose economy is also more developed compared to other regions, on the basis of which it can be deduced that the economy development level is positively related with the low carbon economy development, that is, the higher the region's economic development level is, the better the process of low carbon economy promotion is. The eastern and the western provinces also can be seen clearly that the low carbon development is different at levels to a great extent.

What's more, with higher economic development, the awareness of the local government and the citizens of environment protection and low carbon development is stronger compared with the regions whose political leaders are still eager for quick

success and instant benefits that are at the expenses of sacrifice of the environment and the ecological energy, both of which are hard to recover once destroyed.

Table 4. The LCE of different regions.

Regions	LCE	Regions	LCE	Regions	LCE
Beijing	0.808	Hubei	0.573	Sichuan	0.484
Shanghai	0.693	Shaanxi	0.561	Shanxi	0.478
Tianjin	0.661	Hainan	0.553	Henan	0.477
Zhejiang	0.647	Jiangxi	0.550	Inner Mongolia	0.468
Fujian	0.618	Anhui	0.542	Hebei	0.444
Chongqing	0.617	Jilin	0.540	Gansu	0.436
Hunan	0.588	Guangxi	0.536	Qinghai	0.401
Jiangsu	0.577	Shandong	0.533	Ningxia	0.380
Heilongjiang	0.576	Yunnan	0.519	Xinjiang	0.359
Guangdong	0.575	Liaoning	0.496	Guizhou	0.344

6. Conclusions

On the basis of the existing research results, we define the concept of low carbon economy as below: low carbon economy is the development of human society to a higher social economic form a certain stage, with its development model in technological innovation and policy measures to support, with the objective to establish a high efficiency and low emission of low carbon industry chain way, in which the economic development mode of low carbon life consumption can be realized. Its core is the premise of steady economic growth, the ultimate goal is to realize the coordinated development of ecological environment and social economy. This concept has a broad connotation; it contains the low-carbon energy, low carbon industry, low carbon technologies and low carbon policy etc. From this point of view and connotation of low-carbon economy and industry chain construction path, follow the principle of evaluation index system of low carbon economy, this paper constructs a low carbon economy evaluation index system with fuzzy algorithm.

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