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Study on Carbon Emission Control in the Development of Industry Greening Based on the Interval Optimization Model

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Abstract. Global warming has been widely concerned. As an effective way to balance carbon emissions and economy development, green low-carbon economy development model has been widely accepted. Countries have also shifted from traditional economy to green low-carbon economy. Based on the analysis of low-carbon economy theory, this paper uses the interval planning method to construct an optimization model from the perspective of controlling the total carbon emission, and makes an empirical study on the carbon emissions in the process of China's Industry Greening.

1. Introduction

In the process of promoting industrialization, countries around the world often overlook the protection of the ecological environment. The development of high-carbon emission industry is an important cause of climate warming. The rise in greenhouse gases has led to a series of vicious cycles, such as Greenhouse Effect, flooding, biodiversity change and sea level rise. Since the concept of "low-carbon economy" was put forward in 2003, it has become an effective development model for balancing economic development and carbon emissions, and has been widely accepted and promoted[1].

Low-carbon economy cannot only effectively reduce carbon emissions, but also promote the reform of traditional industries, and bring about an overall change in people's way of life. Ren et al[2]made a comprehensive analysis on the measures and achievements of developing low-carbon economy in Britain, pointed out the existing problems in the development of low-carbon economy in Britain, and put forward that Britain should implement an effective low-carbon economic development model. Jia et al [3] introduce the process of Denmark's transition to low-carbon economy from the aspects of opportunities and challenges, approaches and potentials of developing low-carbon economy, and put forward relevant suggestions on the development of low-carbon economy at the macro level.

Domestic scholars have also done a lot of research on the control of carbon emissions in the development of low-carbon economy. Zhang Lei et al [4] analyzed carbon emissions from the aspects of social economy and technology by means of diversification index method. The results show that the use of diversified energy structure can promote the transformation from traditional economy development model to low-carbon economy development model. This paper intends to analyze the quantitative analysis, combine the low-carbon economic theory, and use the interval planning method to construct an optimization model to empirically study the carbon emissions of low-carbon economic development in China.

2. Constructing interval linear optimization model

2.1. The definition of Interval linear programming

Interval linear programming is a mathematical programming method for solving the interval uncertainty contained in the model. It uses a small amount of information to describe the uncertainty of the interval variable, thus obtaining the upper and lower bounds of the variable [5]. Moore [6] proposed an interval analysis method to solve the problem of calculation error in automatic control, and then derived the interval linear programming model step by step. The optimal value of linear interval programming can be obtained by using this method.

Definition: $m^{\pm}$, $sign(m^{\pm})$ is:

$$sign(m^{\pm}) = \begin{cases} 1, & m^{\pm} \geq 0 \\ -1, & m^{\pm} \leq 0 \end{cases} \tag{1}$$

$$m^{\pm} = [m^{-}, m^{+}] = \{t \in m | m^{-} \leq t \leq m^{+}\} \tag{2}$$

in the above formula: m^{+}, m^{-} is the upper and lower bounds of m, When $m^{+} = m^{-}$, $m^{\pm}$ represents a certain number, that is $m^{\pm} = m^{+} = m^{-}$.

Construct the objective function from the definition above:

$$\max g^{\pm} = C^{\pm} M^{\pm} \tag{3}$$

Constraint condition:

$$A_i^{\pm} M^{\pm} \leq B_i^{\pm} \tag{4}$$

$$A_i^{\pm} \in A^{\pm}, B_i^{\pm} \in B^{\pm}, i = 1,2,\cdots,k \tag{5}$$

$$m_j^{\pm} \geq 0, m_j^{\pm} \in M, j = 1,2,\cdots,h \tag{6}$$

Among the above, $A^{\pm} \in \{R^{\pm}\}^{h\times k}, B^{\pm} \in \{R^{\pm}\}^{k\times l}, C^{\pm} \in \{R^{\pm}\}^{l\times h}, M^{\pm} \in \{R^{\pm}\}^{h\times l}$ ($R^{\pm}$ is the number of interval combinations).

Decomposed the interval linear programming formula (3) - (6) into two deterministic sub models g^{-} and g^{+}, solved it by interactive algorithm. If the objective function model is the maximum, obtained the sub-model g^{+}, and then established another sub-model on the basis of the first sub-model.

The specific result can be based on the above arrangement, find the sub-model first, for example:

$$\max g^{+} = \sum_{j=1}^{h_1} c_j^{+} m_j^{+} + \sum_{j=h_1}^{h} c_j^{+} m_j^{-} \tag{7}$$

Constraint condition:

$$\sum_{j=1}^{h_1} |a_{ij}|^{-} sign(a_{ij}^{-}) m_j^{+} + \sum_{j=h_1+1}^{h} |a_{ij}|^{+} sign(a_{ij}^{+}) m_j^{-} \leq b_i^{+}, \forall_i \tag{8}$$

$$m_j^{\pm} \geq 0, m_j^{\pm} \in M, j = 1,2,\cdots,h \tag{9}$$

$$c_j^{\pm} \geq 0,\ j = 1,2,\cdots,h_1 \tag{10}$$

$$c_j^{\pm} \leq 0,\ j = h_1+1, h_1+2,\cdots,h \tag{11}$$

By using the formula (7) - (11) to solve the above sub-model g^+, we can find g_{opt}^+, $m_{jopt}^-(j = h_1+1, h_1+2,\cdots,h)$ and $m_{jopt}^+(j = 1,2,\cdots,h_1)$.

3. Empirical study

3.1. Empirical Analysis of Carbon Emission Control of Low-Carbon Economy based on Interval Optimization Model

In order to study the carbon emission control in the process of Industry Greening, this paper introduces the carbon emissions from the development of low carbon economy with structural emission reduction. In this paper, we select 9 industries and fill in the two variables of GDP added value and total energy consumption value in the base year of these 9 industries, which is as shown in the table 1. Based on the interval optimization model, the expected annual economic growth and carbon emissions of 9 major industries are obtained, which is as shown in the table 2.

Table 1. Results of interval optimization model of carbon emission determination based on structural emission reduction and green economy development

Industry belong	Value added and composition of GDP in the base year	Total energy consumption in the base year/10000 ton standard coal
Agriculture	60 165.70	8 094
Manufacturing	195 620.30	93 257.26
Transportation	28 500.9	36 336
Energy	14 819.0	43 683.35
Construction	44 880.5	7 520
Extractive	23 026.02	13 563.86
Residents' living consumption	67 105.9	47 212
Accommodation and Sale	11 158.5	10 873
other	92 694.48	20 084

Source: China Statistical Yearbook (2014)

Table 2. Quantitative carbon emission total control optimization scheme based on structural emission reduction

Industry belong	Expected annual economic growth/100 million yuan	Expected annual optimization of carbon emissions /Ten thousand tons
Agriculture	75 485.65	27 543.15
Manufacturing	214 382.36	821 538.24
Transportation	35 792.35	186 432.51
Energy	24 863.62	10 473.21
Construction	50 654.31	15 432.95
Extractive	35 421.5	62 418.26
Residents' living consumption	70 134.21	12 641.28
Accommodation and Sale	63 186.73	18 321.43
other	114 632.42	42 167.53

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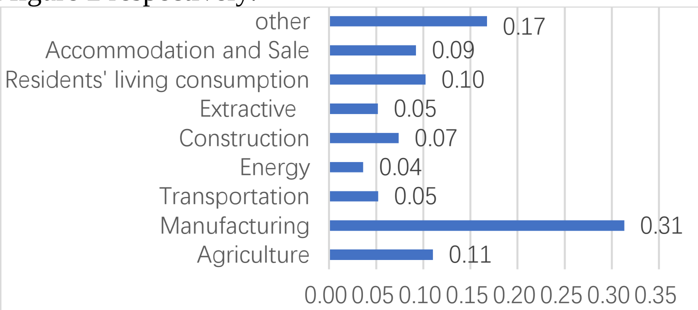
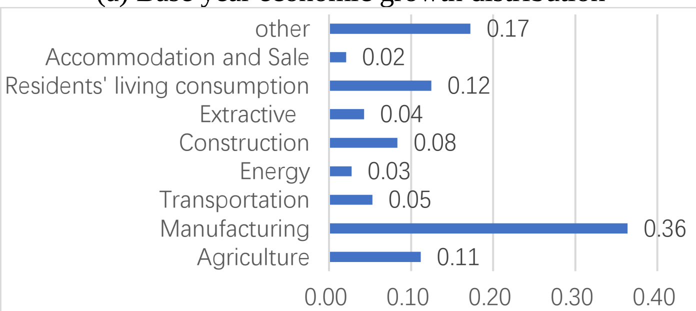
3.2. Optimal interval model of carbon emissions based on structural emission reduction

The base year, the nine major industries, the expected annual economic growth, carbon emissions are shown in figure 1 and figure 2 respectively.



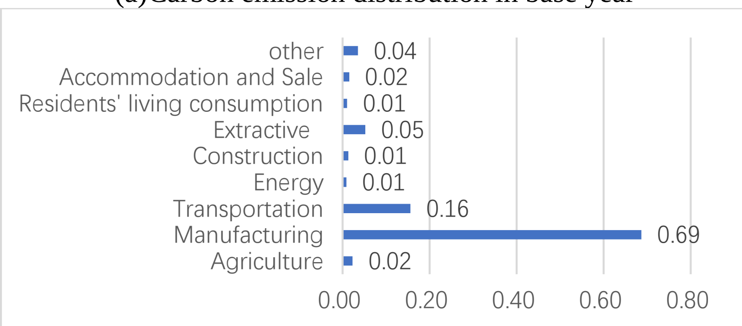
(a) Base year economic growth distribution



(b)Expected annual economic growth distribution

Figure 1. Comparative Diagram of Economic growth Distribution under deterministic Optimization Scheme based on structural Emission reduction

(a)Carbon emission distribution in base year



(b)Expected annual carbon emissions distribution

Figure 2. Comparative Diagram of carbon Emission Distribution under deterministic Optimization Scheme based on structural Emission reduction

It can be seen from figure 1 and figure 2 that the proportion of agriculture decreases, while the proportion of carbon emissions does not change obviously in the total economy growth. Residential consumption, construction and sales of residential catering industry, compared with other industries have better economic growth, lower carbon emissions. The proportion of transportation industry in the total economic growth remains unchanged, which indicates that in the process of social and economic development, transportation industry has become the primary force, but the transportation industry has also brought serious obstacles to the development of low-carbon economy. Therefore, emphasis should be placed on the implementation of carbon emission limits for high-carbon emission industries and the implementation of low-carbon cleaning technologies to compensate for the development of low-carbon economies in other industries. Not enough. At the same time, we should devote ourselves to the application and innovation of new energy and new technologies, improve the utilization rate of public transport, promote the sharing of bicycles and new energy vehicles, advocate green travel and lifestyle, and promote the development of green low-carbon economy.

3.3. Analysis of unit carbon emissions distribution based on interval optimization model

The base year and expected annual unit GDP carbon emissions are shown in Figure 3 and Figure 4:

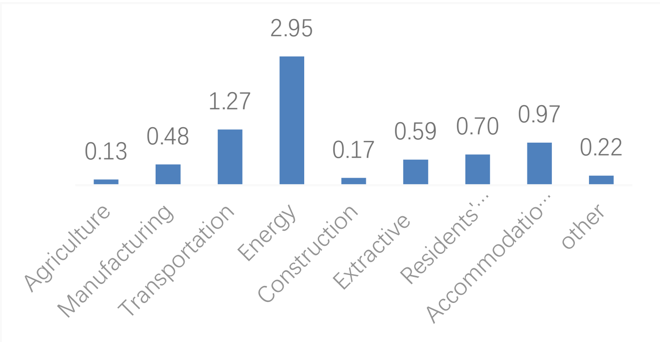


Figure 3. Base year per unit carbon emissions (unit: 10,000 tons)

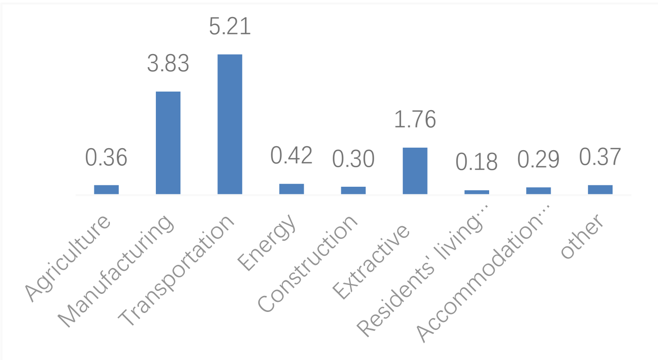


Figure 4. Expected annual carbon emissions per unit of GDP (unit: ton / 10,000 yuan)

By comparing with figure 3 and figure 4, it is found that the expected annual GDP carbon emissions are 34.54% lower than those of the base year, but the control of the carbon emissions is still some distance away from the goals that China expects at the Copenhagen. The GDP carbon emissions of each industry unit obtained by using interval optimization model method are relatively good, among which:

(1) The high carbon emissions of mining industry units are not conducive to the development of green economy. Therefore, in the interval optimization model, it is necessary to focus on the extractive industry in order to reduce the total amount of carbon emissions, thereby reducing the carbon emissions per unit of GDP, which is conducive to the realization of green economy.

(2) The carbon emissions per unit of GDP in manufacturing are relatively high relative to other industries. Reducing carbon emissions will have a significant adjustment and control effect on overall carbon emissions. Therefore, in the process of economic development, manufacturing should be listed as one of the carbon emission reduction industries, and actively promote the development and application of low-carbon technologies in manufacturing.

(3) With the popularization of clean energy, green and low carbon, the carbon emissions of the construction industry have not changed much. This shows that the construction industry has made a great contribution to the promotion of a green and low-carbon economy in economic development.

(4) The carbon emissions of transportation industry units are higher than those of other industries. Transportation has become the primary force for economic and social development, which in turn will result in huge carbon emissions. In response to the above problems, hybrid technology and clean energy can be applied to the transportation industry to achieve carbon emission control for green and low carbon economy development.

(5) In the process of economic development of agroforestry, the unit carbon emissions have increased slightly, indicating that the implementation of green and low-carbon economy requires the active use of new technologies.

(6) In the two industries of household consumption and sales of accommodation and catering industry, the proportion of carbon emissions per unit of GDP has been significantly reduced, indicating that the concept of low-carbon environmental protection is being accepted by more and more people, which is an important basis for continuing to realize the development of low-carbon economy.

4. Conclusion

Taking the "green low-carbon" economic development model, we need to clarify the relationship between carbon emissions, energy consumption, and economic development.

In order to achieve carbon emission control under the development of a green and low-carbon economy, the government should increase policy support for various industries, further innovate energy-saving and emission reduction technologies, and contribute to reducing carbon emissions. In addition, the government should also promote relevant low-carbon upgrades through relevant policy incentives, such as accelerating the implementation of carbon emission trading or tax rebates. At the same time, it is also possible to strengthen technology research and development, improve the efficiency of energy use, and accelerate the adjustment of industrial structure. This not only guides the low carbonization direction of investment, but also promotes the development and application of low carbon technology, which is conducive to the development and transformation of China's low carbon industry.

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