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Research on Optimization of Investment in China's Industries under Low-Carbon Constraints

Ya-Nan WANG[1], Qun XU[1,a,*], Sui GUO[1]

[1]School of Humanities and Economic Management, China University of Geosciences, Beijing, 100083, China

[a]xuqun@cugb.edu.cn

*Corresponding author

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Abstract. Nowadays, China is continuously advancing its low-carbon economic development strategy. However, problems such as unbalanced development of the industrial structure have impeded China's economic low-carbon development. Most existing research just consider the relationship between industrial structure and economic development, this article optimizes the industrial structure under low-carbon background from the perspective of macro investment.We select five major sectors- agriculture; industry; construction; transportation; and wholesale, retail, housing and catering- as research objects, and use factor analysis methods to analyze the current status of low-carbon development in their industrial structures. Through a multi-objective optimization model, industrial structure optimization objectives are presented, and investment is then optimized based on the matching relationship between the industrial and investment structures. This study found that the proportion of investment in Chinese sectors has gradually improved over the past five years, but problems remain. The government needs to regulate and control at a macroeconomic level: control the proportion of investment in industry and transportation; increase investment in agriculture, construction, and wholesale, retail, housing and catering; and gradually increase the degree of adaptation of industrial and investment structures.

Introduction

China is a country with high energy consumption. Although its economic growth mode has begun to shift from "high growth, high consumption, and high emission" extensive economic growth to low-carbon economic growth, fossil energy continues to dominate. The heavy consumption of fossil fuels, which mainly consist of coal, oil and natural gas, has caused China to rank among the countries with the largest greenhouse gas emissions in the world; pressure is also increasing in the areas of economic growth and the environment. Industry is the main source of energy consumption and carbon emissions. At the same time, industry is also an engine that drives the rapid development of China's economy and occupies a pivotal position in the national economy. In recent years, the share of industry in GDP has gradually declined, but is still far greater in China than in other developed countries. From the perspective of domestic development trends, in recent years, China's total energy consumption and carbon emissions in various sectors have continued to grow, and they have shown a positive relationship. The excessive proportion of industry in GDP and the imbalance in the development of the industrial structure hinder the development of low-carbon sectors in China.

In terms of theoretical research, foreign scholars began focusing on industrial structure early. Grossman and Krucger [1] found that economic development influences the environment through the industrial structure. Rostow [2] [3] thought that changes in the industrial structure have a substantial impact on economic growth and that we must attach importance to the role of leading industries in economic development**.** Natasha Xing and Yuan Che [4] used data from 27 industries in 15 countries to examine the structural change theory of endowments and to study the relationship between structural coherence and economic growth.

China's research on industrial structure started relatively late, and the work and research results mainly focus on development status and development trends. Wu et al. [5] characterize the fact that varying industrial structures and economic growth rates result in different effects on the CO2 emission of various regions. Chen et al. [6] believe that adjusting the industrial structure has a positive effect on improving carbon emission efficiency. Li et al. [7] suggest that restricting population growth and transforming industrial structures are the keys to reducing China's carbon emissions. Wu et al. [8] found that coal consumption, industrial proportion, and urbanization were positively correlated with carbon intensity. He et al. [9] base on the panel data model find that both economic growth and optimization of the industrial structure can lead to an improvement of air quality.

In this context, to realize low-carbon economic development, the important goal is to adjust the industrial structure and to control. Investment is the basis for the development of industry, and an increase in output value will, in turn, drive an increase in the amount of investment. The industrial structure depends on the investment structure, and the optimization of the investment structure will guide the development of the industrial structure. In light of the development of the industrial structure, how can the investment structure be adjusted to promote the low-carbon development of the economy? The question is very important if China is to achieve its 2020 target of developing a low-carbon industry structure and society.

The problem of structural optimization under low-carbon constraints is a complex but important issue. But, most existing research just considers the relationship between industrial structure and economic development, but few studies on the issues related to investment optimization. The industrial structure depends on the investment structure, and the optimization of the investment structure will guide the development of the industrial structure. Based on this principle, this paper analyzes industrial investment optimization under the low-carbon perspective.

Models and Data

Evaluation Model of the Low-carbonization Level of the Industrial Structure

Evaluation Content of the Industrial Structure’s Low Carbonization

Based on scientific principles, the assessment must be comparable, comprehensive, dominant, targeted and operational; thus, the assessment of the development level of the low carbonization of the industrial structure should include two aspects: an evaluation of the economic benefit and an evaluation of energy conservation and environmental protection.

Economic benefit evaluation:

Industry output growth rate. The growth rate of the output value is selected to reflect the strength and development prospects of the industry.

Investment returns. The relationship between the investment in fixed assets and the growth in output value is used to measure the utilization rate of industrial capital and the macroeconomic benefit achieved.

Energy conservation and environmental protection evaluation:

Energy intensity: Energy consumption per unit of GDP is the main indicator reflecting the level of energy consumption.

Carbon emission coefficient: The carbon emission factor is the amount of carbon dioxide emitted per unit of economic output.

Evaluation System for Industrial Structure Low Carbonization

Based on the content needed to evaluate the carbon intensity of the industrial structure, the evaluation index system should include two primary indexes: an economic efficiency evaluation index and an environmental protection evaluation index. The economic efficiency evaluation index includes two secondary indicators, industrial output growth rate and investment efficiency, and the energy-saving environmental protection evaluation index includes the two secondary indicators energy intensity and the carbon emission coefficient.

Based on the development level of each industry, calculate the status of the industrial structure development. Expressed as a formula, this would be:

Industrial structure low-carbonization level=ΣAnBn (n=1, 2, 3, 4, 5). (1)

An is the development level of the industry, and Bn is the ratio of output value.

Industrial Structure Optimization Model under a Low-carbon Background

The multi-objective decision-making method is a type of decision analysis method that has developed rapidly since the 1970s. We used a multi-objective optimization model for output value structures is used to project Chinese industry in 2020 based on low-carbon scenarios.

Decision Variables in the Industrial Structure Optimization Model

In this multi-objective optimization model, the decision variables are agricultural output (x_1), industry output (x_2), transportation output (x_3), construction output (x_4), and wholesale, retail, housing and catering output (x_5).

Objective Function

Maximize GDP:

In more recent years, with the advent of the new normal economic development, the Chinese economy has begun to shift from high-speed development to a more stable stage of rapid growth. Future development must first ensure economic stability. Therefore, it is necessary to ensure the maximum output value of the five major sectors. Expressed as a formula, this would be:

$$\mathrm{Max}\sum_{n=1}^{5}(x_n) \tag{2}$$

Minimize carbon emissions:

China initially established a low-carbon development policy system., The low-carbon transformation of industrial development is gradually advancing, aiming to achieve economic and social development while reducing carbon dioxide emissions. Expressed as a formula, this would be:

$$Min\frac{\sum_{n=1}^{5}(x_n an)}{\sum_{n=1}^{5}(x_n)} \tag{3}$$

The expression an is the carbon emission coefficient of each industry.

Restrictions

Product size constraint:

Fan [10] noted in the book “Research on Cost, Path and Policy of Greenhouse Gas Emissions Reduction” that for the restricted development sector, the upper limit of the average annual growth rate is set to increase the baseline growth rate of the sector by 2%, and the lower limit is the reference growth rate of the sector minus 2%. Based on China’s national conditions and drawing on Fan Ying’s research results, the five sectors discussed in this article are included in the general development industries and expressed as the following formulas:

$$\mathrm{GDP}(1+\mathrm{Cn}-2\%)\leq x_N\leq \mathrm{GDP}(1+\mathrm{Cn}+2\%)\ \ (n\in[1,5]) \tag{4}$$

GDP is the base period industry output value, and Cn is the industry benchmark growth rate.

Energy consumption constraints:

Energy consumption refers to the energy consumed by production and living. China’s energy consumption plan for 2020 calls for approximately 4.8 billion tons of standard coal. According to Liu’s [11] analysis, if the average annual growth rate of energy consumption is 1.7%, the total energy consumption in 2020 can be maintained at approximately 4.71 billion tons. However, Yan and Liu [12] have made predictions about the intensity of energy consumption. They forecast that in 2020, the energy consumption intensity of primary industry will be 0.39, that of secondary industry will be 2.25 and that of tertiary industry will be 0.44. Reflecting the above requirements, the formula is expressed as follows:

$$\frac{E_1(1+1.7\%)}{x_1} \leq 0.39 \tag{5}$$

$$\frac{E_2+\cdots+E_5(1+1.7\%)}{x_{2+\cdots+}x_5} \leq 2.25 \tag{6}$$

En (n=1, 2, 3, 4, 5) is the energy consumption of various industries in the base period
Decoupling elastic constraints:

Carbon decoupling refers to a change in the relationship between CO2 emissions and economic growth. Looking at the existing research results, during the "Twelfth Five-Year Plan" period, carbon emissions from agriculture in some regions are in a strong decoupled state (Hong and Liu [13]) (Zhou and Liu [14]), industry carbon emissions are basically in a weak decoupled state (Zhou [15]), and carbon emissions in the transportation industry are basically in a weak decoupled state (Zhang [16]). Based on the above conclusions, during the "Thirteenth Five-Year Plan" period, the carbon emission limits for some industries were set to weak decoupling, and the formula is expressed as follows (with CO2 instead of carbon emissions and GDP instead of output value):

$$\frac{\Delta CO2}{CO2} / \frac{\Delta X_n}{X_n} < 0.8 \quad (x = 1,3,4) \tag{7}$$

Non-negative constraints:

The decision variable is the output value of the industry, which is $X_n \geq 0$. (8)

The Correlation between Industrial Structure and Investment Structure

Fan et al. [26] noted that the structure deviation coefficient can reflect the proportion of the industry's output value and the proportion of its investment in fixed assets at the total data level.

$$D_i = \frac{Pi}{Wi} - 1 \text{ (i=1, 2, 3, 4, 5)} \tag{9}$$

In this formula, P_i is the proportion of the output value of industry i in the current year, and W_i is the proportion of investment in industry i in the current year. When the structure deviation coefficient is equal to zero, it indicates that the industrial structure of the industry and its corresponding investment structure have reached a state of complete adaptation at the quantitative level. The closer the structure deviation coefficient is to zero, the better the industrial structure and investment structure are.

Data Sources

The data are from the National Bureau of Statistics of the People's Republic of China, the Energy Statistics Yearbook, etc. All of these sources use industry yearbook data from 2014.

Results of Analysis

Evaluation Model of the Low-carbonization Development Level of the Industrial Structure

This paper uses SPSS software to conduct factor analysis on the data of various industries to reveal the development level of the industrial structure in the context of a low-carbon economy. Before performing a factor analysis, the KMO and Bartlett sphere tests were performed on the data collected from the five sectors. The KMO test coefficient of 0.609 is greater than 0.5, indicating that the data meet the general research criteria and is suitable for factor analysis.

According to the general criteria that the eigenvalue is greater than 1, a total of two principal factors are extracted, denoted by F1 and F2, respectively, and their degree of interpretation of the total variance is 63.466% and 26.349%, the cumulative interpretation reached 89.815%, able to better represent most of the information of the original variables

According to the characteristics of the variables explained by various factors (Table 1), factor 1 is designated the energy-saving and emission reduction factor, denoted as F1; factor 2 is designated the cost-effective factor, denoted as F2. The overall level of low-carbon development in the industrial structure is denoted as F, which is the final calculation for the development level of the industrial structure. The results of the calculations are shown in Table 2.

Table 1, Rotated analysis matrix

	Factor	
	1	2
Investment returns	-.899	
Energy intensity	.889	
Carbon emission coefficient	.849	
Industry output growth rate		-.964

Table 2, Score sheet

Industry	F1	F2	overall ratings
Agriculture	-0.50103	0.1596	-0.27
Industry	1.17431	0.56846	0.96
Construction industry	-1.3142	0.77676	-0.58
Transportation industry	0.78815	0.22631	0.59
Wholesale, retail, housing and catering	-0.14723	-1.73113	-0.7
Industrial structure			0.33

Solution to the Industrial Structure Optimization Model

This paper selects Lingo 11 software to solve the industrial structure optimization model. The optimization results(Billions RMB) are as follows.

x_1=84163.64 , x_2=302389.3, x_3=71740.78, x_4=42681.49, x_5=132498.89.

Summary

Judging from the results of the evaluation model for the low-carbonization level of the industrial structure, the degree of low carbonization in the current industrial structure is not high.

Combined with the comprehensive scores and industrial structure analysis, first, according to previous annual data, industry accounts for more than 50% of the industrial structure, which is far higher than other sectors, but the overall score of industry is not high. It can be concluded that promoting China’s industrial structure requires controlling the scale of industrial development and adjusting the investment structure in the industrial sector. Second, the wholesale, retail, housing and catering sector has the lowest comprehensive scores, and the overall level of development of this sector is not high. This indicates a need to increase investment in fixed assets in this sector, promote its technological progress and industrial upgrading and improve its low-carbon economic development level. Combined with the results of industrial structure optimization, the proportion of output value after optimization in various industries can be calculated (Table 3).

Table 3, The proportion of optimized output value

Industry	Optimized output value (%)
Agriculture	13.29
Industry	47.74
Construction	11.32
Transportation	6.74
Wholesale, retail, housing and catering	20.92

Table 4, Current industry investment (%)

Sector / Time	Agriculture	Industry	Construction	Transportation	Wholesale, retail, housing and catering
2016	7.41	67.96	1.38	16.06	7.20
2015	7.02	73.62	1.65	16.42	8.50
2014	5.71	70.40	1.42	14.88	7.59
2013	5.29	71.46	1.44	14.45	7.37
2012	5.10	71.65	1.73	14.58	6.94

In analyzing the current industry investment situation (Table 4) and the industrial structure optimization goals (Table 3), we find that the proportion of China’s investment in industry has gradually improved in the past five years, but there are still some problems that require the government to regulate the economy at a macroeconomic level. Based on t he results of the industrial structure optimization, the following investment optimization proposals are made to gradually increase the degree of adaptation of the industrial and investment structures.

From the perspective of the data, in recent years, the proportion of investment in agriculture has gradually increased, but compared to 13.67% of the output value in 2020, the investment in fixed assets needs further improvement. Given the important position of industry in China’s economy, industrial investment accounts for a large share. Due to its high energy consumption and high pollution status, the proportion of industrial investment has experienced a downward trend. In 2016, it gradually declined from approximately 70% to approximately 60%. The decline rate is relatively pronounced, but compared to the projected 47.74% share in 2020, investment in industry still needs to be adjusted and controlled. From the data of the past five years, the proportion of investment in the construction industry is relatively stable, but in comparison with the output value, the amount of investment in the construction industry needs to be increased. The proportion of investment in transportation has slightly increased. Compared to its share of output value, investment in the transportation industry needs to be controlled. The proportion of investment in the wholesale, retail, housing and catering industries has gradually increased, but there is still a considerable gap compared to its 20.92% of the output value share. Going forward, it will be necessary to increase investment in this sector.

Promoting industrial low-carbon development is the only way to solve environmental problems and resource constraints. At present, China's low-carbon development is progressing steadily, but there are still challenges. Solving these challenges starts with restructuring the industrial structure, optimizing the investment scale in various industries, guiding industry to achieve low-carbon development, and achieving a win-win situation for economic development, energy saving and emissions reduction. These measures will enable China to realize the long-term sustainable development of its economy and society.

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