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The Dynamic Optimization Model of Industrial Structure with Energy-saving and Emission-reducing Constraint

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Abstract

In recent years, because of China's rapid economic growth, the contradiction between energy consumption, environmental pollution and economic development has become acute increasingly. Energy-saving and ejection-decreasing has become an important strategy target in China's "11th Five-Year Plan". The research on the industrial structure optimization of China, should be given full consideration to all current energy and environmental problems. The industrial structure optimization model in this paper containing energy-saving and ejection-decreasing, shows its simulation results that through optimization of the industrial structure it would be realized that meeting energy reduction demand, and also to maintain high economic growth rate.

Keywords: Optimization of industrial structure, Dynamic optimization, Energy-saving and emission-reducing

1. Introduction

China has made a tremendous achievement on economy since the reform and opening, the Gross of National Product has been growing, and the people's standard of living has been markedly improving. Optimization of the industrial structure aiming at economic growth enable the economic resources flowing from the low relatively productivity to high relatively productivity of industries, and which will also drives the total economy efficiency growing, and promotes the national economy. However, in recent years, at the same time of rapidly growing in economy, the conflict between economy growing with energy consumption and environmental pollution has been become increasingly vigorous, and therefore energy-saving and emission-reducing have been become a strategy target in China's "11th Five-Year Plan". As thus, the study up on multi-objective optimization of China's industrial structure has been with important theoretical and practical significance.

This paper constructs a dynamic optimization model of industrial structure with energy-saving and emission-reducing constraints based on "11th Five-Year Plan"; optimizes the industrial structure to resolve the current problems of China's economic development, energy and environmental issues.

2. Model Design

2.1 Objective Function

In this paper, the industrial structure optimization model continues to target for economic growth, and aims at meeting the energy-saving and emission-reducing constraints of "11th Five-Year Plan" on the binding nature of energy-saving emission reduction targets, while achieving higher levels of economic growth. So here set economic growth targets for the total GDP maximization in the planning period, that is,

$$\max \qquad f(\boldsymbol{x}_t) = \sum_{t=1}^{T} \boldsymbol{e}'(\boldsymbol{x}_t - \boldsymbol{A}_t\boldsymbol{x}_t)$$

where $\boldsymbol{x}_t = (x_{1t}, x_{2t}, \cdots, x_{nt})'$ stands for the industry's gross output vector of period t, $\boldsymbol{A}$ stands for direct consumption coefficient matrix, and $\boldsymbol{e} = (1, 1, \cdots, 1)'$ stands for unit column vector.

2.2 Constraint Conditions

2.2.1Energy Consumption Constraints

$$C_t \geq \boldsymbol{c}_t'\boldsymbol{x}_t$$

where $\boldsymbol{c}_t = (c_{1t}, c_{2t}, \cdots, c_{nt})'$ stands for energy consumption of the industry's unit gross output of period t, and C_t stands for the indices of energy consumption of period t.

2.2.2 Environment Pollution Constraints

$$W_t \geq \boldsymbol{\alpha}_t'\boldsymbol{x}_t$$

$$G_t \geq \boldsymbol{\beta}_t'\boldsymbol{x}_t$$

$$S_t \geq \boldsymbol{\gamma}_t'\boldsymbol{x}_t$$

where $\boldsymbol{\alpha}_t = (\alpha_{1t}, \alpha_{2t}, \cdots, \alpha_{nt})'$, $\boldsymbol{\beta}_t = (\beta_{1t}, \beta_{2t}, \cdots, \beta_{nt})'$, $\boldsymbol{\gamma}_t = (\gamma_{1t}, \gamma_{2t}, \cdots, \gamma_{nt})'$ stand for pollution emission of the industry's unit gross output of period t, and W_t, G_t, S_t stand for the indices of pollution emission, in wastewater, waste gas and waste solid.

In addition, the economic operation is decided by inherent connection of the economic variables. The actual economic operation mechanism decides the structure of model. So the model should include the economic operation constrains as follows:

2.2.3 Dynamic Input-output Balance Constrains

$$\boldsymbol{x}_t = \boldsymbol{A}_t\boldsymbol{x}_t + \boldsymbol{B}_t(\boldsymbol{x}_{t+1} - \boldsymbol{x}_t) + \boldsymbol{y}_{1_t} + \boldsymbol{y}_{2_t}$$

where $\boldsymbol{B}_t = (b_{ij})_{n\times n}$ stands for investment coefficient matrix, b_{ij} stands for investment of the industry "i" to increase the unit output of industry "j", $\boldsymbol{B}_t(\boldsymbol{x}_{t+1} - \boldsymbol{x}_t)$ stands for capital formation vector, $\boldsymbol{y}_{1_t}$ stands for final consumption vector, and $\boldsymbol{y}_{2_t}$ stands for net export vector.

2.2.4 Capital Formation Constrains

$$(s_t + s_{f_t})\boldsymbol{e}'(\boldsymbol{x}_t - \boldsymbol{A}_t\boldsymbol{x}_t) \geq \boldsymbol{e}'\boldsymbol{B}_t(\boldsymbol{x}_{t+1} - \boldsymbol{x}_t)$$

where s_t stands for saving rate, s_{f_t} stands for the GDP proportion of foreign capital inflow. The constraints show that investment capital of next period composes of national savings and foreign capital inflow.

2.2.5 Consumer Demand Constrains

$$(1 - s_t)\boldsymbol{e}'(\boldsymbol{x}_t - \boldsymbol{A}_t\boldsymbol{x}_t) \geq \boldsymbol{e}'\boldsymbol{y}_{1_t}$$

2.2.6 Net Exports Constrains

$$s_{f_t}\boldsymbol{e}'(\boldsymbol{x}_t - \boldsymbol{A}_t\boldsymbol{x}_t) \geq -\boldsymbol{e}'\boldsymbol{y}_{2_t}$$

2.2.7 Production Capacity Constrains

$$q_1\boldsymbol{x}_{t-1} \geq \boldsymbol{x}_t \geq q_2\boldsymbol{x}_{t-1}$$

where $q_1 > 1 > q_2 > 0$. The constraints will limit the industry's rapid growth or recession. First, the short-term industry production capacity will not change too much; secondly, the excessive growth or recession of a particular industry will lead to considerable changes in industrial structure, thus cause fluctuations in economic growth.

2.2.8 Nonnegative Constraints

$$\boldsymbol{x}_t, \boldsymbol{y}_{1_t} \geq 0$$

3. Data Processing

Industry classification of this paper is consistent with the 17 sector input-output table of the National Bureau of Statistics. The data of model are from the "China Statistic Yearbook," 2005 as annual base period. According to historical data, the main parameters in model are set as follows:

$$s_t = s_0 = 0.43$$

$$s_{f_t} = s_{f_0} = 0.05$$

$$q_1 = 0.8\,,\quad q_2 = 1.2$$

According to the goal of "11th Five-Year Plan", we set C_t 4% annual increase and W_t, G_t, S_t 2% annual decline. In addition, $\boldsymbol{A}_t = \boldsymbol{A}_0$ and $\boldsymbol{B}_t = \boldsymbol{B}_0$ need to be calculated according with the relevant data.

3.1 Direct Consumption Coefficient Matrix

Direct consumption coefficient is very important in the input-output model, particularly dynamic input-output model. It reflects economic and technical relations among industries, and changes with economic environment, technical level, etc. So, direct consumption coefficient of different periods is different. In practice, because of the lag of input-output tables, the input-output analysis usually assumes that the industrial input-output relations have maintained a long period of unchanged. Clearly, it is in contradiction with actual economic changing. Therefore, Direct Consumption Coefficient matrix needs to be revised effectively.

Based on the RAS method, we construct diagonal matrix $\boldsymbol{R}$ and $\boldsymbol{S}$ representing the fabrication and substitution effects, and set up the modification model of direct consumption coefficient matrix as follows:

$$\begin{cases} \min & \sum_{i,j} a_{ij}^{05} \log\left(\dfrac{a_{ij}^{05}}{a_{ij}^{02}}\right) \\ \text{s.t.} & \boldsymbol{A}_{05} = \boldsymbol{R}\boldsymbol{A}_{02}\boldsymbol{S} \\ & \boldsymbol{A}_{05}\boldsymbol{x}_{05} = \boldsymbol{v}_{05} \end{cases}$$

This model uses data of the gross output ($\boldsymbol{x}_{05}$) and added value ($\boldsymbol{v}_{05}$)to revise direct consumption coefficient matrix, makes a breakthrough to the continuity assumptions in changing of the relationship between input and output, and can use known data farthest.

3.2 Investment coefficient matrix

In static input-output model, the investment as a final demand is exogenous variables, which dissevers production targets and production capacity, can not accurately reflect the expand production of social product. Dynamic input-output model makes variables exogenous by introducing investment coefficient matrix, and reflects the intrinsic link between reproduction and productive investment. In the dynamic input-output analysis and application of the model, the investment coefficient matrix is the key role; the accuracy of input-output analysis depends largely on investment coefficient. We determine investment coefficient matrix as follows:

$$b_{ij_t} = \frac{\Delta s_{i_t} a_{ij_t}}{\Delta x_{j_{t+1}} \sum_{j=1}^{n} a_{ij_t}}$$

where Δs_{i_t} stands for the investment-increment of industry "i" of period t. The input-output model relates the static and dynamic input-output model, and reflects the relationship between the investment allocation and the output-increment.

4. Simulation Results

Table 1 gives the simulation results. In 2010 China's GDP will reach 29.72 trillion, in 2015 will rise to 46.64 trillion, in 2020 continued to rise to 71.85 trillion, with an average annual growth rate to reach 9-10%. Total energy consumption and pollutant emissions are scheduled to meet the binding targets, in 2020 alone than the total energy consumption in 2005 increased by 75.1%, while the GDP increased by nearly three times. The three major industrial pollutant emissions are achieved a slight decline, from 2010 to 2015 the average annual industrial waste solid discharge fell 5.6%, from 2015 to 2020 the average annual decline 6.1%, emission of pollutants has been effectively controlled.

From the changes of added value proportion of three industries, in 2010, the proportion of three industries were 19.3%, 33.7% and 47.0%, compared with 2005 the proportion of primary industry rose 6.8 percentage point decline in the proportion of secondary industry 13.8% proportion of the tertiary industry rose 7.1 percentage points. By 2015, the primary industry, the proportion of secondary industry continues to decline, respectively, 10.4%, 29.8%, while the tertiary industry rose to 59.8. 2020, the proportion of primary industry dropped to 3.0%, the secondary industry accounted for by small pick-up , To 32.8%, the proportion of the tertiary industry continued to rise to 64.2%, the three-industry structure is close to the level of developed countries.

Table 2 gives the simulation results of added value structure of 17 sectors. In 17 sectors, increased proportion of larger industries are Textile, Sewing, Leather and Furs Products; Construction; Transportation, Postal and Telecommunication Services; Real Estate, Leasing and Business Services; Other Services. And the remaining nine sectors largely decline in the proportion. We can see that the 10 sectors, only Textile, Sewing, Leather and Furs Products increased proportion, and 3 sectors have increased the proportion in the tertiary industry, and the increase in larger, industrial structure softening trend is very clear.

This trend of industrial structure indicates that China's industrial structure in recent decades through the development and adjustment, the overall already in the middle stage of industrialization, economic growth too dependent on the input of capital and resources, high-value, low-power the tertiary industry development has been slow and the increasingly serious environmental pollution, the development of sustainable capacity is not strong. In China's industrialization process, the main driving force behind economic growth in the industry are mainly from the secondary industry, while the secondary industry is the largest energy consuming industries, but also has brought more emissions. Therefore, the energy of the emission reduction targets to achieve, is bound to accelerate the development of the tertiary industry, in general, the tertiary industry in achieving rapid development, we do not need too many resources into, is in need of more human capital and technical input . Although the reform and opening up, the Chinese Government has been vigorously develop the tertiary industry, tertiary industry in the proportion of the national economy has maintained an upward trend, from 1978's 24.2% rise in 2005 to 39.9%; However, from this model to optimize results, The goal of reducing emissions and energy requirements, and the tertiary industry in the national economy as the proportion is still low.

5. Conclusion

To change China's current economic development in the high energy consumption, high emission problem, we should start from industrial structure optimization, optimize the industrial structure by reasonable policies and measures, the realization of China's economic growth mode from the side of the extensive growth resources to the partial knowledge Technology-intensive growth change. China's industrial structure optimization of the overall trend should be "softening", that is, in the industry in the development of tangible products and resources and other production factors reduce the growing role and knowledge, technology, services and information such as the role of soft factors of production increasing, In various industries in the rapidly increasing input. High-tech industries and the continuous development of the tertiary industry, especially the rapid development of information industry, China's economy should become the future development trend. China's industrial structure optimization, to control the growth, speed up and eliminate backward production capacity, improve the promotion of industrial restructuring policies and measures to actively promote energy restructuring. On the one hand we must vigorously develop the tertiary industry, to improve the professional division of labor and social efficiency, with the focus on positive developments in the production of services; meet people's needs and to facilitate the life of the masses as the center and enhance the development of life and services; On the other hand we must vigorously Development of high-tech industry, adhering to a new road to industrialization and promoting the upgrading of traditional industries, improving high-tech industries in the proportion of industries.

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Table 1. Industrial Structure and the Main Macroeconomic Indicators (100 million Yuan, %)

	2005	2010	2015	2020
Gross Output	496791	665584	888193	1255387
GDP	183868	297150	466433	718471
Proportion of Primary Industry	12.5%	19.3%	10.4%	3.0%
Proportion of Secondary Industry	47.5%	33.7%	29.8%	32.8%
Proportion of Tertiary Industry	39.9%	47.0%	59.8%	64.2%
Growth Rate of Gross Output		6.0%	5.9%	7.2%
Growth Rate of GDP		10.1%	9.4%	9.0%
Energy Consumption	199926	243240	295939	350440
Industrial Wastewater Discharge	145344	131379	118757	107347
Industrial Waste Gas Discharge	265203	239723	216690	195871
Industrial Waste Solid Discharge	1490	1347	1007	734

Table 2. Changes of Industrial Added Value and the Proportion of 17 Sectors (100 million Yuan)

	2005		2010		2015		2020	
	Added value	%	Added value	%	Added value	%	Added value	%
Agriculture	23070	12.5	57407	19.3	48322	10.4	21839	3.0
Mining and Quarrying	10318	5.6	9133	3.1	4563	1.0	1495	0.2
Foodstuff	7499	4.1	9012	3.0	6037	1.3	1978	0.3
Textile, Sewing, Leather and Furs Products	5887	3.2	14649	4.9	35548	7.6	51637	7.2
Other Manufacturing	3693	2.0	1221	0.4	400	0.1	131	0.0
Production and Supply of Electric Power, Heat Power and Water	2082	1.1	682	0.2	335	0.1	834	0.1
Coking, Gas and Petroleum Refining	8692	4.7	5842	2.0	1943	0.4	637	0.1
Chemical Industry	2950	1.6	967	0.3	317	0.1	104	0.0
Building Materials and Non-metal Mineral Products	9874	5.4	15740	5.3	21428	4.6	20636	2.9
Metal Products	19442	10.6	12335	4.2	4170	0.9	1366	0.2
Machinery and Equipment	6795	3.7	5272	1.8	1727	0.4	566	0.1
Construction	10134	5.5	25216	8.5	62746	13.5	156132	21.7
Transportation, Postal and Telecommunication Services	10836	5.9	25352	8.5	32279	6.9	30681	4.3
Wholesale and Retail Trades, Hotels and Catering Services	17728	9.6	9630	3.2	3156	0.7	1034	0.1
Real Estate, Leasing and Business Services	11156	6.1	27760	9.3	69077	14.8	171885	23.9
Banking and Insurance	6307	3.4	8738	2.9	7034	1.5	2305	0.3
Other Services	27406	14.9	68194	22.9	167353	35.9	255211	35.5