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A SCENARIO ANALYSIS OF ENERGY INTENSITY BASED ON INPUT-OUTPUT THROEY IN CHINA

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ABSTRACT

Energy intensity is an obligatory target in the Twelfth Five-Year Plan, which means the 16% reduction of energy consumption per GDP than the end of the Eleventh Five-Year Plan. This paper uses the input-output theory, the scenario analysis method and optimization theory, considering the minimum energy intensity as the single goal. A nonlinear optimization model is built for the evolution of energy intensity, using genetic algorithm to solve this problem. And it is the purpose to study the conditions of achieving the goals in 2010 of reducing China's energy intensity by 16%. According to the present situation of the high proportion of secondary industry in our country, and the planning guide of accelerating the development of service industry, it is urgent to develop the tertiary industry in China.

Keywords: Energy intensity, Scenario analysis method, Input-output theory, Nonlinear optimization model.

1. INTRODUCTION

In the Twelfth Five-Year Plan, the goal of doubling GDP per capita than 2010 in 2020 is a vital target. Similarly, energy intensity is an obligatory target in the Twelfth Five-Year Plan, which means the 16% reduction of energy consumption per GDP than the end of the Eleventh Five-Year Plan. It's not a vital mission during the Twelfth Five-Year, but a long-term task of the future economic development for China. The targets for saving energy and reducing pollutant emissions were set forth in the Twelfth Five-Year Plan. Nowadays, energy intensity is one of the main indicators of human development and progress for a country.

A nation's energy requirements directly determine the gap between domestic supply and demand in energy sectors, thereby having a significant impact on national energy security, which is essential to the development of a well-rounded, prosperous society. Energy intensity, the energy consumption per GDP output, can reflect the economic structure, fuel mix, and the level of technology in a country. It is one of the main indicators of human development and progress for a country [1]. Moreover, energy intensity is closely linked to the environment. It is an important means by which to reduce energy-related carbon dioxide emissions in the near future to decrease the energy intensity of activities [2]. Environmental security is also one of the most important factors in building an economically vibrant society and realizing sustainable development. Therefore, it is important to study energy requirements and energy intensity as a major aspect of the development of a society. More and more attention has been focused on energy requirements andenergy intensity in recent years. Silberglitt et al. used scenario analysis to forecast U.S. energy requirements [3].

Tiwari employed an input–output model to study the developmental trend of sectoral energy intensity in India with the data between 1983 and 1997 [4]. Perrels used an input–output model, scenario analysis, and other methods to study the lifestyle effects on energy demand and related emissions [5]. Wilting et al. applied an input–output model to study trends in Dutch energy intensities for the period 1969–1988 [6]. Yanrui Wu found that energy intensity declined substantially in China, and the main contributing factor is the improvement in energy efficiency, thus there is considerable scope to reduce energy intensity through the structural transformation of the Chinese economy in the future [7]. The Institute of Quantitative and Technology Economy of the Chinese Academy of Social Sciences had set up system dynamics and input–output models to project long-term energy requirements by applying the sectional terminal demand analysis method. Most of these studies focused either on the impact of just one factor, or on the integrated effect of all factors on energy requirements and energy intensity, though it is not possible to compare the impact of each factor explicitly from the results. Consequently, it is difficult for such results to distinguish between the starting point of adjusting and controlling energy requirements and energy intensity.

This paper uses the input-output theory, the scenario analysis method and optimization theory, considering the minimum energy intensity as the single goal. A nonlinear optimization model is built for the evolution of energy intensity, using genetic algorithm to solve this problem. And it is the purpose to study the conditions of achieving the goals in 2010 of reducing China's energy intensity by 16%.

2. MODEL

The industries are divided into 15 types. The type of the 15 industry is determined as follows:

(1) Agriculture;
(2) Extractive industries;
(3) Food manufacturing;
(4) Textile, and leather sewing products manufacturing;
(5) Other manufacturing;
(6) The electric power, heat and water production and supply industry;
(7) Coking, coal gas and petroleum processing industry;
(8) Chemical industry;
(9) Building materials and other non-metallic mineral products;
(10) Metal products manufacturing;
(11) Machinery and equipment manufacturing;
(12) Construction;
(13) Transportation posts and telecommunications industry;
(14) Wholesale and retail trade, accommodation and catering industry;
(15) Other tertiary industries.

Therefore, the primary industry contains agriculture; the secondary industry contains 2 to 12 industries; the tertiary industry contains 13, 14, 15 industries.

2.1 Variables and parameters

Here, we assume there are n industries, and $Y= [Y_1, Y_2, \dots, Y_{15}]^T$, the 15 dimension vector of final demand, as the decision variable.

Then, here follows the other main variables and parameters:

z_1, z_2, z_3 denotes the percentage value added of the primary industry, the secondary industry and the tertiary industry respectively.

$A= [a_{ij}]$ denotes the 15×15 matrix of technology matrix, also called the direct requirement matrix, where a_{ij} is the direct requirement of industry j on industry i. And the future direct requirement can be obtained by RAS method.

$B= [b_{ij}]$ denotes the 15×15 matrix of total requirement index. $B= (I-A)^{-1}$, and b_{ij} is the total requirement of industry j on industry i in order to produce the unit-final demand.

$A_e= [A_{e1}, A_{e2}, \dots, A_{e15}]$ denotes the 15 dimension row vector of energy direct consumption index.

2.2 Objective function

In the Twelfth Five-Year Plan, energy intensity is planning to be 16% reduction than the end of the Eleventh Five-Year Plan. So minimizing the energy intensity of 2015 is the single object.

And we can get the objective function:

$$\min EI(Y) = \min \frac{TE+SE}{GDP} \tag{1}$$

Where EI means energy intensity, TE means the energy consumption for the production department, and SE means energy consumption for the life. And,

$$TE = A_e(I - A)^{-1}Y = A_eBY \tag{2}$$

2.3 Constraint conditions

(1)Energy constraint. Controlling the energy consumption in our country is necessary. It is one of the main purpose of reducing energy consumption per unit GDP. Therefore, energy consumption should not be higher than the planning value, which means the upper limit:

$$TE + SE \le \widehat{E} \tag{3}$$

(2)GDP constraint. In the current development stage of China, economic growth is the primacy. Therefore, the optimization results of GDP value should not be less than the planning value :

$$\sum_{i=1}^{n} Y_i \ge \widehat{GDP} \tag{4}$$

(3)Industrial structure constraint. Industrial structure constraints limit the development speed and scale of the industry. It plays a dominant constraint effect on economic growth. At present, in the industrial structure, the primary and the secondary industry have a much higher proportion, and the tertiary industry remains a strikingly low proportion. As a result, the internal structure is not reasonable, at the same time, the efficiency is low. Compared with most countries in the world, the added value of the third industry in GDP has a low proportion. It is a vital mission to accelerate the development of service industry. So, the industrial structure constraint set means the lower proportion of the primary and the secondary industry and a higher proportion of the tertiary industry.

$$\begin{cases} v_1 \le \dfrac{z_1 \sum_{j=1}^{15} b_{1j} Y_j}{\sum_{j=1}^{15} Y_j} \le w_1 \\ v_2 \le \dfrac{z_2 \sum_{i=2}^{12} \sum_{j=1}^{15} b_{ij} Y_j}{\sum_{j=1}^{15} Y_j} \le w_2 \\ v_3 \le \dfrac{z_3 \sum_{i=13}^{15} \sum_{j=1}^{15} b_{ij} Y_j}{\sum_{j=1}^{15} Y_j} \le w_3 \end{cases} \tag{5}$$

Where, v_1, w_1 denote the inferior limit and upper limit of primary industry; v_2, w_2 denote the inferior limit and upper limit of secondary industry; v_3, w_3 denote the inferior limit and upper limit of tertiary industry.

Table 1. Scenario setting

		2005	plan 1 (7%)	plan 2 (8%)	plan 3 (9%)
GDP/ 10^8 yuan		401202.1	562706.7	589497.5	617299.2
plan a	v_1-w_1	10.1%	7.1%-9.1%		
	v_2-w_2	46.7%	43.7%-44.7%		
	v_3-w_3	43.1%	43.1%-46.1%		
plan b	v_1-w_1	10.1%	6.1%-8.1%		
	v_2-w_2	46.7%	41.7%-43.7%		
	v_3-w_3	43.1%	46.1%-49.1%		

plan c	v_1-w_1	10.1%	5.1%-7.1%
	v_2-w_2	46.7%	39.7%-41.7%
	v_3-w_3	43.1%	46.1%-51.1%

3. EMPIRICAL STUDY

3.1 Data Resources

The data of 2010 are obtained from the *China statistical yearbook 2011, China statistical yearbook 2012, and China statistical yearbook 2013* respectively [8].

3.2 Scenario Setting

Three scenarios are assumed based on the standard economic development speed: plan 1 (7% increase of GDP per year), plan 2 (8% increase of GDP per year), plan 3 (9% increase of GDP per year). Under each plan there are three more scenarios based on the industrial structure in Table 1. So, there are 9 scenario projects in total.

3.3 Results

In order to solve this problem and get the results, we can use several kinds of software, such as GAMS, MATLAB and so on. Here, we choose MATLAB.

Under different scenario schemes, the optimal values of energy intensity shown in Table 2 are obviously different.

The total energy consumption in 2010 is 32.4939×10^8 tce, and GDP in 2010 is 401202×10^8 yuan. So, the energy intensity is 0.81 tce/10^4 yuan. If the energy intensity is reduced by 16%, the expected value in 2015 will be 0.68 tce/10^4 yuan. However, in Table 2, there exists a small deviation.

However, the trend can still be found from the results. Plan c can always get a smaller energy intensity value. In plan c, there are smaller v_1, v_2 and larger w_3. According to the present situation of the high proportion of secondary industry in our country, and the planning guide of accelerating the development of service industry, plan c is more adaptive to the current situation. On the other hand, it is urgent to develop the tertiary industry in China.

Obviously, in the tertiary industry, energy intensity is small, the unit of energy can create large added value, and the tertiary industry occupies a larger proportion in the national economy. So its development cannot significantly increase GDP, but reduce energy consumption in large quantities. So, in the three industries, it will be priority to developing the tertiary industry. The secondary industry, whose energy intensity is much bigger, makes more contribution to the national economy development. The model can be adjusted to change industry structure inside the secondary industry, which can promote the development of low energy consumption industry and limit the growth of energy-intensive industry. Then GDP increases and energy consumption tends to decline.

For another, the speed of the GDP developing is another factor on the energy intensity. If the GDP develops faster, the energy intensity will decrease more to some extent.

As a result, the industrial structure and the GDP development affect the energy intensity jointly. The single improvement of each factor is unilateral. They should be analyzed synthetically.

From the results, it can be fingered out that more constraints can be added to refine the model.

Table 2. Results

EI (tce/10^4 yuan)	plan 1	plan 2	plan 3
plan a	0.7938	0.7952	0.7544
plan b	0.7938	0.7745	0.7537
plan c	0.7935	0.7177	0.6928

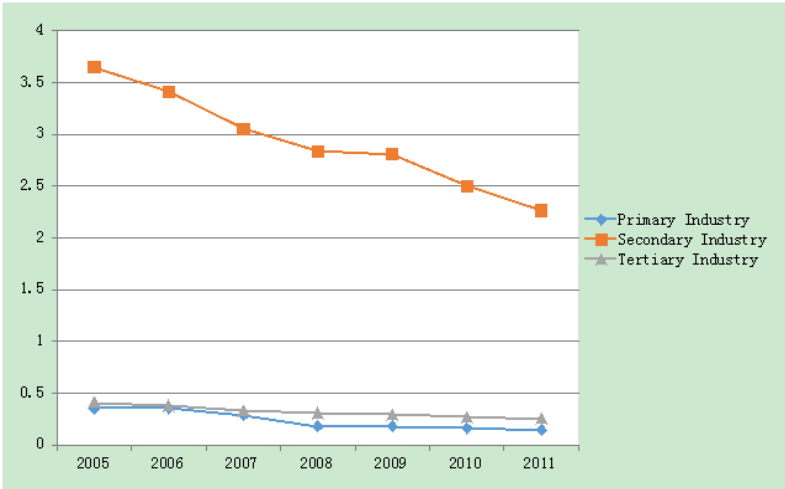

Figure 1. The energy intensity of different industries from 2005 to 2011

4. CONCLUSIONS

This paper uses the input-output theory, the scenario analysis method and optimization theory, considering the minimum energy intensity as the single goal. A nonlinear optimization model is built for the evolution of energy intensity, using genetic algorithm to solve this problem. And it is the purpose to study the conditions of achieving the goals in 2010 of reducing China's energy intensity by 16%.

According to the present situation of the high proportion of secondary industry in our country, and the planning guide of accelerating the development of service industry, it is urgent to develop the tertiary industry in China.

REFERENCES

1. J. W. Sun, The Decrease in the Difference of Energy Intensities Between OECD Countries from 1971 to 1998, *Energy Policy*, pp. 631–635, 2002. DOI: 10.1016/S0301-4215(02)00026-5.
2. J. C. M. Farla, K. Blok, The Use of Physical Indicators for the Monitoring of Energy Intensity Developments in the Netherlands 1980–1995, *Energy*, pp. 609–638, 2000. DOI: 10.1016/S0360-5442(00)00006-2.
3. R. Silberglitt, A. Hove, P. Shulman, Analysis of US Energy Scenarios: Meta-Scenarios, Pathways, and Policy Implications, *Technol. Forecast. Soc. Change*, pp. 297–315, 2003. DOI: 10.1016/S0040-1625(02)00254-8.
4. P. Tiwari, An Analysis of Sectoral Energy Intensity in India, *Energy Policy*, pp. 771–778, 2000. DOI: 10.1016/S0301-4215(00)00051-3.
5. C. Weber, A. Perrels, Modelling Lifestyle Effects on Energy Demand and Related Emissions, *Energy Policy*, pp. 549–566, 2000. DOI: 10.1016/S0301-4215(00)00040-9.
6. H. C. Wilting, W. Biesiot, H. C. Moll, Trends in Dutch Energy Intensities for the Period 1969–1988, *Energy*, pp. 815–822, 1998. DOI: 10.1016/S0360-5442(98)00035-8.
7. Wu Y., Energy Intensity and its Determinants in China's Regional Economies, *Energy Policy*, pp. 703-711, 2012. DOI: 10.1016/j.enpol.2011.11.034.
8. National Bureau of Statistics of China (NBSC), China Statistical Yearbook, Beijing: China Statistics Press; 2013.