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Energy Structure and Intensity Prediction During the 14th Five-Year Plan in China

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Abstract: Markov chain and nonlinear cubic exponential smoothing model are respectively used to predict China's energy structure and energy intensity during the 14th Five-Year Plan period. The results show that the proportion of coal in China during the 14th Five-year Plan period will decrease from 56.5% in 2020 to 51.7% in 2025. The share of non-fossil energy consumption will rise from 16.1% in 2020 to 19.1% in 2025. Compared with 2020, the energy intensity of the three industries will decrease by 18%, 13% and 18% respectively. Based on the prediction results, the energy structure modulating and optimization is analyzed and some suggestions are put forward.

Keywords: Energy structure; Energy intensity; Markov chain; Prediction

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1. Introduction

Energy is the basic guarantee of economic and social development, and energy structure is related to the coordinated development of economy and environment. According to China's 14th Five-year Plan, we will promote the energy revolution, build a clean, low-carbon, safe and efficient energy system, and improve energy supply and security capabilities. We will vigorously increase the scale of wind and photovoltaic power generation, and raise the share of non-fossil energy in total energy consumption to about 20%. Energy consumption and carbon dioxide emissions per unit of GDP will reduced by 13.5% and 18% respectively, which points out the direction for China's energy development in the next step.

Many scholars have studied energy structure prediction. ZHAO Liurong put forward the Logistic model of energy structure[1]. XU junwei used the gray system model GM(1,1,α) to analyze the energy structure[2]. NIU dongxiao[3] and LIU Dianhai[4] applied the markov prediction model to the energy structure prediction. However, these documents did not address the new situation during the 14th Five-year Plan period. In this paper, markov chain and nonlinear cubic exponential smoothing model are respectively used to predict China's energy structure and energy intensity during the 14th five-year Plan period. According to the prediction results, some suggestions for energy structure optimization are put forward. Prediction model theory

2. Markov prediction model

Markov prediction is a prediction model based on markov chain theory. According to the development and trend of stochastic process, the transition matrix is solved, and the future state and trend of time series are predicted by recursive equation. The basic model of Markov state transition is $S^{k+1} = S^k * P$ (1)

Where, $S^k = \left(s_1^k, s_2^k, \cdots, s_n^k\right)$ is the state vector at moment K， S^{k+1} is the state vector at moment K+1， P is Markov transfer probability matrix， $P = \lfloor p_{ij} \rfloor_{n\times n}, p_{ij} \geq 0, \sum_{j=1}^{n} p_j = 1$， p_{ij} is the probability of a transition from part i to part j. Random process $\left\{S^k, k = 1,2,\cdots\right\}$ is called a Markov chain.

Let the structure vector of the initial state of the system be:

$$S^0 = \left(s_1^0, s_2^0, \cdots, s_n^0\right) \quad (2)$$

According to Formula (1), it can be obtained from the recurrence relation

Nonlinear cubic exponential smoothing model.

The basic principle of nonlinear cubic exponential smoothing is to perform exponential smoothing again on the basis of first exponential smoothing and second exponential smoothing. The calculation formula is as follows

$$\begin{aligned} S^1 &= S^0 * P \\ S^2 &= S^1 * P = S^0 * P^2 \\ S^{k+1} &= S^k * P = S^0 * P^{k+1} \end{aligned} \quad (3)$$

$$\begin{cases} S_t' = \alpha x_t + (1-\alpha) S_{t-1}' \\ S_t'' = \alpha S_t' + (1-\alpha) S_{t-1}'' \\ S_t''' = \alpha S_t'' + (1-\alpha) S_{t-1}''' \end{cases} \quad (4)$$

S_t' is the first exponential smoothing value; S_t'' is the second exponential smoothing value; S_t''' is the third exponential smoothing value; α is smoothing coefficient.

Expected future value of T period x_{t+T} , the calculation formula is

$$x_{t+T} = A_T + B_T T + C_T T^2 \qquad (5)$$

Where

$$A_T = 3S_t' - 3S_t'' + S_t'''$$
$$B_T = \frac{\alpha}{2(1-\alpha)^2}\left[(6-5\alpha)S_t' - (10-8\alpha)S_t'' + (4-3\alpha)S_t'''\right] \qquad (6)$$
$$C_T = \frac{\alpha}{2(1-\alpha)^2}\left(S_t' - 2S_t'' + S_t'''\right)$$

Energy structure prediction

Markov prediction model has the characteristics of no aftereffect, and the future development and change of variables are only determined by the recent state, and have nothing to do with the past state. This prediction model has been widely used in energy structure prediction and other fields, achieving high prediction accuracy.

In this section, markov prediction model is used to forecast China's energy structure in 2020-2025. In markov prediction model, the determination of probability transition matrix is the most critical issue, which is generally difficult to obtain directly, but it can determine the state data of energy structure in various periods. The energy structure of China from 2015 to 2019 is shown in Table 1.

Table 1 Energy structure from 2015 to 2019 in China

Indicators	2015	2016	2017	2018	2019
Proportion of coal consumption(%)	63.8	62.2	60.6	59	57.7
Proportion of oil consumption(%)	18.4	18.7	18.9	18.9	18.9
Proportion of gas consumption(%)	5.8	6.1	6.9	7.6	8.1
Proportion of non-fossil energy consumption(%)	12	13	13.6	14.5	15.3

Using the theory of goal programming, the optimal probability transition matrix is solved by minimizing the error rate between the actual value and the predicted value of energy structure as the objective function, and a quadratic programming problem is formed. This probability transfer matrix solution method comprehensively considers the transfer error rate of four periods from 2015 to 2016, 2016 to 2017, 2017 to 2018 and 2018 to 2019. By fitting these four transfer processes, the transfer error rate of four periods is minimized. It fully reflects the law of development and change of China's energy structure from 2015 to 2019.

The state vector composition matrix A of energy structure in 2015, 2016, 2017 and 2018 is

$$A = \begin{bmatrix} 63.8 & 62.2 & 60.6 & 59 \\ 18.4 & 18.7 & 18.9 & 18.9 \\ 5.8 & 6.1 & 6.9 & 7.6 \\ 12 & 13 & 13.6 & 14.5 \end{bmatrix} \qquad (7)$$

Suppose that the Markov transfer matrix P is

$$P = \begin{bmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ p_{21} & p_{22} & p_{23} & p_{24} \\ p_{31} & p_{32} & p_{33} & p_{34} \\ p_{41} & p_{42} & p_{43} & p_{44} \end{bmatrix} \qquad (8)$$

According to the recursive form (3) of Markov prediction model, the predicted values of state vector of energy structure in 2016, 2017, 2018 and 2019 constitute matrix B:

$$B = A * P \qquad (9)$$

The actual value of state vector of energy structure in 2016, 2017, 2018 and 2019 constitutes matrix C:

$$C = \begin{bmatrix} 62.2 & 60.6 & 59 & 57.7 \\ 18.7 & 18.9 & 18.9 & 18.9 \\ 6.1 & 6.9 & 7.6 & 8.1 \\ 13 & 13.6 & 14.5 & 15.3 \end{bmatrix} \qquad (10)$$

In fact, due to changes in the objective environment, the theoretically calculated predicted state B is not completely consistent with the actual state C, and there is a certain degree of error. Taking the sum of squares of error as the objective function, the following quadratic programming model is established:

$$\min \quad f(p) = \|B - C\|^2$$
$$s.t.\begin{cases} \sum_{j=1}^{n} p_j = 1, & i = 1,\cdots,4 \\ p_j \geq 0, & j = 1,\cdots,4 \end{cases} \qquad (11)$$

According to the definition of one-step transition probability matrix, the sum of the proportion of all kinds of energy consumption is 1 and cannot be negative, so as to construct the constraint condition. The optimization model is a quadratic programming problem with 16 variables. The transition probability matrix P is obtained by solving it through Matlab software.

$$P = \begin{bmatrix} 0.9598 & 0.0402 & 0.0000 & 0.0000 \\ 0.0000 & 0.8661 & 0.0000 & 0.1339 \\ 0.0000 & 0.0000 & 0.6635 & 0.3365 \\ 0.0708 & 0.0122 & 0.2112 & 0.7058 \end{bmatrix} \qquad (12)$$

According to Markov recursive equation, the energy structure in 2020-2025 can be predicted. The results are shown in Table 2

Table 2 Predicted results of energy structure for 2020-2025

Year	Proportion of coal consumption(%)	Proportion of oil consumption(%)	Proportion of gas consumption(%)	Proportion of non-fossil energy consumption(%)
2020	56.4649	18.8826	8.5870	16.0655
2021	55.3324	18.8201	9.0905	16.7570
2022	54.2945	18.7289	9.5706	17.4060
2023	53.3442	18.6161	10.0263	18.0134
2024	52.4751	18.4876	10.4569	18.5804
2025	51.6811	18.3483	10.8623	19.1083

According to Table 2, according to the recursion of the development and change law of China's energy structure from 2015 to 2019, during the 14th Five-Year Plan period, the proportion of coal consumption in China will decrease significantly from 56.5% in 2020 to 51.7% in 2025, and the proportion of oil consumption will decrease from 18.9% in 2020 to 18.3% in 2025. The share of natural gas consumption will increase from 8.59% in 2020 to 10.9% in 2025, while the share of non-fossil energy consumption will increase from 16.1% in 2020 to 19.1% in 2025.The proportion of non-fossil energy consumption has not reached the 20% set out in the 14th Five-Year Plan.

3. Energy intensity prediction

This section collects the added value and energy consumption of each industry from 2000 to 2019. The added value of each industry takes 2000 as the base year, and the added value index of each industry is used to subtract, and then the energy intensity of each industry is calculated. Energy intensity is the energy consumption per unit of GDP, that is, the ratio of industrial energy consumption to industrial added value. The data are from China Statistical Yearbook and China Energy Statistical Yearbook. Nonlinear cubic exponential smoothing model is used to predict the energy intensity of each industry from 2020 to 2025. The results are shown in Table 3.

Table 3 Predicted results of industry energy intensity for 2020-2025

Year	The first industry	The second industry	The third industry
2020	0.2851	1.2304	0.6121
2021	0.2770	1.1882	0.5924
2022	0.2678	1.1516	0.5716
2023	0.2576	1.1206	0.5498
2024	0.2463	1.0951	0.5270
2025	0.2341	1.0753	0.5033

As can be seen from Table 3, the energy intensity of the first industry decreases from 0.2851 in 2020 to 0.2341 in 2025, decreasing by 18%. The energy intensity of the secondary industry decreased from 1.2304 in 2020 to 1.0753 in 2025, decreasing by 13%; Energy intensity of tertiary industry decreased from 0.6121 in 2020 to 0.5033 in 2025, decreasing by 18%; It can be seen that the energy intensity of the secondary industry decreases at a relatively slow rate, failing to meet the 13.5% requirement of the 14th Five-Year Plan.

4. Conclusion

Optimization of energy structure and reduction of energy intensity can reduce carbon emissions per unit GDP and achieve low-carbon economic growth pattern. During the 14th five-year period, we need to further increase the rate at which clean energy replaces fossil energy. We will vigorously develop clean energy such as wind and solar energy and gradually reduce consumption of fossil energy. We will accelerate the establishment of a national carbon emission trading market and give full play to the role of market mechanisms in energy conservation and emission reduction. Using the “invisible hand” of the market to form a reasonable and effective carbon price can raise the cost of fossil energy to curb its consumption, while improving the competitiveness of clean energy and contributing to China’s commitment to “carbon peak by 2030 and carbon neutral by 2060”.

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