Forecast and Analysis Energy Structure in Seven Regions of China

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Abstract: As the world's energy consuming country, the change of China's energy structure has greatly affected the global energy emission. The prediction of its energy structure is of great significance to the energy policy guidance of the whole world and the development of the global economy. Because of China's vast territory, it is also necessary to forecast its energy structure by region. According to the characteristic that the energy consumption structure has no Markov aftereffect, this paper establishes a forecast model of the energy supply structure with planning constraints, and predicts the energy structure in the next 5 years by the model. The results show that the energy structure of different regions in China has different characteristics and will not change much in the long term.

1 INTRODUCTION

With the acceleration of industrialization, China has achieved tremendous economic development in the past few decades, and now it has become the world's second largest economy and occupies a pivotal position in the international arena. However, behind the great achievements, we have also paid a great price. The rapid development of economy brings not only the improvement of living standard, but also the excessive consumption of primary energy, great increase of carbon emissions and other environmental problems. In 2005, China was the world's second largest emitter of carbon, accounting for 18% of global emissions. In 2006, China was already the world's largest emitter of primary energy consumption. In 2018, China's carbon emissions were 27.32% of the world's total, already more than the United States and the European Union combined. Mi et al. (2017) concluded that China's carbon emissions have some time to grow and are expected to peak in 2026. China is already facing huge international pressure to conserve energy and reduce emissions. Therefore, it is extremely necessary to analyze and predict the energy structure.

This paper is divided into four parts. The second part, literature review, Part III, Data sources, the introduction of the model and a brief proof. The fourth part, the result display and analysis. The fifth part, gives the plan and the suggestion.

2 LITERATURE REVIEW

With the increasingly serious environmental problems, more and more scholars begin to pay attention to the problem of carbon emissions. Most of their research has focused on three points. First, study the decoupling relationship between carbon emissions and economic growth, the main method of this problem is Tapio decoupling mode(Tapio, 2005) .A large number of scholars have used this model to analyze the relationship between carbon emissions and economic growth in various industries. Q. Wang and Wang (2019) studied the decoupling relationship between carbon emissions from the transportation sector and economic growth in six provinces of China. Zhao, Kuang, and Huang (2016) analyzed the decoupling factors of carbon emissions in the transportation industry of Guangdong Province. Du, Zhou, Pan, Sun, and Wu (2019)[5] analyzed the decoupling factors between carbon emissions and economic growth in China's construction industry. And Another scholars Q. Wang, Su, and Li (2018) made a comparative analysis on the decoupling relationship between carbon emissions and economic growth in China and India.

The second is to study the driving factors of carbon emission and carbon emission intensity with main method LMDI model(Ang, 2003). W. Wang, Liu, Zhang, and Li (2013) explored the influence of carbon emission and carbon emission intensity driving factors in Jiangsu Province. Zhang, Song, Su, and Sun (2015) used LMDI method to analyze and

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study the influencing factors of decoupling between China's economic growth and energy consumption. In order to find an effective way to reduce China's carbon emission intensity. Other scholars have focused on the drivers of carbon emissions in various industries. Ren, Yin, and Chen (2014)[10] analyzed the influencing factors of carbon emissions in China's manufacturing industry. Some scholars also used LMDI to explore the energy structure and energy consumption. Xia and Wang (2020) analyzed the driving factors of energy consumption structure and built a hybrid prediction model.

3 DATA SOURCES AND METHODS

3.1 Data Sources

This paper selects the data of primary energy consumption and energy structure of each province in China from 1997 to 2017. All of these come from China statistical Yearbook[12] and National Bureau of Statistics[13]

3.2 Markov Model

Markov model is built on the basic principle of Markov chain. Markov chain means that in the transformation process of things, the transformation of state is only related to the previous state, so the future state of Markov chain is only related to the current state, and has nothing to do with the past state. Therefore, this model has a relatively high prediction accuracy for non-aftereffect sequences.

The markov model is established as follows:

The set of Markov processes is {S,T}, where S is a discrete set of states. $T = \{t_1, t_{2,\dots} t_n\}$ is the time set. $S = \{S_1^{1,}, S_2^1, S_3^1, \dots, S_i^t\}$. S_i^t represents the i state at time t. Let $S_i^m = i$ be the state at time m. $S_i^{m+1} = j$ be the state at time m+1, So the probability of going from state i to state j is $p_{ij} = \{P(S_i^m = i) \mid P(S_i^{m+1} = j\}$. The matrix $P = p_{ij}$ is called the one-step transfer matrix. The elements in the matrix satisfy $p_{ij} \geq 1$, and $\sum_{j=1}^{n} p_{ij} = 1$.

The state transfer equation is:

$$S^{m+1} = S^m * P \quad (1)$$

$$P = p_{ij} = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m1} & p_{m2} & \cdots & p_{mn} \end{pmatrix} \quad (2)$$

Above we have defined the one-step transfer equation p_{ij}, then we define the n-step transfer equation P_{ij}^n.

Since the energy consumption structure does not fully conform to the non-after-effect characteristics, one-step transfer proof cannot be completely and accurately determined. Therefore, in order to estimate the one-step transfer matrix more accurately, the following model is established:

$$min(f(P)) = \sum_{t=0}^{T-1} ||S(t+1) - S(t) * P||^2 \quad (3)$$

$$\sum_{j=1}^{n} p_{ij} = 1 \quad (4)$$

$$p_{ij} \geq 0 \quad (5)$$

In the formula, T refers to the number of moments experienced by the system, S is the set of all states at each moment. The model is solved by nonlinear programming method.

4 RESULTS AND DISCUSSION

4.1 One-Step Transition Matrix

The one-step transfer matrix of one region is obtained from formula 4.5-4.7 and the result is as figure 1, The proportion of coal in other areas is 0.9605, 0.8964, 0.9328, 0.9986, 0.9587, 0.9779, respectively.

$$\begin{pmatrix} 0.7963 & 0 & 0 & 0.0344 & 0 & 0 & 0 & 0 & 0.1692 \\ 0.0001 & 0.1998 & 0.4724 & 0.0020 & 0.0186 & 0.3070 & 0 & 0 & 0.0001 \\ 0 & 0.0725 & 0.7964 & 0 & 0.0001 & 0.1293 & 0.0001 & 0.0013 & 0.0002 \\ 0.2235 & 0.0001 & 0.0015 & 0.7739 & 0.0005 & 0.0004 & 0.0001 & 0.0001 & 0 \\ 0 & 0.0029 & 0.0034 & 0.0012 & 0.1845 & 0.0013 & 0.7525 & 0.0094 & 0.0447 \\ 0.0005 & 0 & 0.1441 & 0.0011 & 0.0055 & 0.4102 & 0.0268 & 0.3732 & 0.0385 \\ 0.0039 & 0.0039 & 0.9380 & 0.0026 & 0.0034 & 0.0045 & 0.0401 & 0.0034 & 0.0004 \\ 0.9815 & 0.0012 & 0.0006 & 0.0001 & 0.0047 & 0.0003 & 0.0042 & 0.0035 & 0.0037 \\ 0.0012 & 0.0552 & 0.0102 & 0 & 0.0471 & 0.0026 & 0 & 0.1331 & 0.7506 \end{pmatrix}$$

South China

Figure 1: One-step transition matrix for South China.

4.2 Energy Structure Change and Forecast in Each Region

According to Formula 4.4, the one-step transfer matrix is used to predict the energy consumption of each region in the past five years, and the prediction results are shown in table 2.

Under the prediction of Markov chain, the average relative error of prediction in south China, North China, Central China, East China, northwest China, southwest China, Northeast China is 0.076, 0.075, 0.072, 0.048, 0.091, 0.082, 0.066.

The forecast results show that the proportion of various energy sources in south China is relatively healthy, the proportion of coal is relatively small, the proportion of clean energy is relatively high, and the proportion of various energy sources will not change significantly in the next few years. In North China, the proportion of coal is relatively high and rising gradually, while the proportion of clean energy and natural gas is relatively small. The proportion of coal in central China is also very low, only 0.39 in 2020, with a trend of gradual decline. The proportion of clean energy is very high and rising. The proportion of oil in east China is far higher than that in other regions, and the proportion of clean energy is relatively low. The proportion of coal is decreasing year by year, while the proportion of oil is increasing year by year, while the change of clean energy and natural gas is not obvious. The proportion of coal in northwest China is extremely high, reaching 70% in 2020 and showing an increasing trend year by year. Other sources of energy are relatively small, accounting for less than 1% of clean energy and natural gas, and will not change significantly in the next few years. The proportion of coal in southwest China will continue to decrease, while the proportion of other energy sources will increase to different degrees. The proportion of coal in northeast China will continue to decline, while the proportion of natural gas and clean energy will continue to rise.

Table 2: Energy structure forecast for each region.

Region	Year	The energy structure								
South China		**coal**	**coke**	**Crude oil**	**gasoline**	**kerosene**	**diesel**	**Fuel oil**	**Natural gas**	**Clean energy**
	2018	0.3271	0.0348	0.2028	0.0516	0.0152	0.0638	0.0140	0.0557	0.2349
	2019	0.3271	0.0348	0.2027	0.0519	0.0152	0.0638	0.0140	0.0557	0.2347
	2020	0.3269	0.0348	0.2026	0.0523	0.0152	0.0639	0.0140	0.0558	0.2345
	2021	0.3265	0.0348	0.2025	0.0528	0.0152	0.0641	0.0140	0.0559	0.2343
	2022	0.3256	0.0349	0.2026	0.0535	0.0152	0.0644	0.0137	0.0560	0.2342
North China		**coal**	**coke**	**Crude oil**	**gasoline**	**kerosene**	**diesel**	**Fuel oil**	**Natural gas**	**Clean energy**
	2018	0.6541	0.0931	0.0498	0.0208	0.0126	0.0208	0.0031	0.0562	0.0894
	2019	0.6521	0.0948	0.0506	0.0211	0.0124	0.0220	0.0031	0.0554	0.0884
	2020	0.6503	0.0966	0.0515	0.0214	0.0122	0.0232	0.0030	0.0545	0.0872
	2021	0.6488	0.0985	0.0524	0.0217	0.0120	0.0246	0.0029	0.0533	0.0859
	2022	0.6477	0.1007	0.0531	0.0220	0.0118	0.0260	0.0029	0.0519	0.0839
Central China		**coal**	**coke**	**Crude oil**	**gasoline**	**kerosene**	**diesel**	**Fuel oil**	**Natural gas**	**Clean energy**
	2018	0.3812	0.0536	0.0521	0.0391	0.0064	0.0502	0.0055	0.0358	0.3761
	2019	0.3865	0.0545	0.0528	0.0393	0.0063	0.0495	0.0055	0.0351	0.3706
	2020	0.3929	0.0556	0.0535	0.0394	0.0061	0.0487	0.0055	0.0343	0.3640
	2021	0.4006	0.0569	0.0543	0.0394	0.0060	0.0479	0.0055	0.0333	0.3561
	2022	0.4101	0.0585	0.0549	0.0392	0.0058	0.0471	0.0055	0.0321	0.3466
East China		**coal**	**coke**	**Crude oil**	**gasoline**	**kerosene**	**diesel**	**Fuel oil**	**Natural gas**	**Clean energy**
	2018	0.4544	0.0808	0.2316	0.0513	0.0085	0.0498	0.0409	0.0607	0.0220
	2019	0.4612	0.0793	0.2293	0.0504	0.0085	0.0492	0.0411	0.0588	0.0221
	2020	0.4689	0.0775	0.2267	0.0494	0.0086	0.0486	0.0414	0.0567	0.0222
	2021	0.4780	0.0752	0.2237	0.0479	0.0086	0.0479	0.0419	0.0543	0.0225
	2022	0.4887	0.0724	0.2199	0.0459	0.0088	0.0473	0.0427	0.0515	0.0229

Northwest		coal	coke	Crude oil	gasoline	kerosene	diesel	Fuel oil	Natural gas	Clean energy
	2018	0.7176	0.0362	0.1144	0.0199	0.0021	0.0320	0.0022	0.0730	0.0026
	2019	0.7095	0.0378	0.1195	0.0201	0.0021	0.0332	0.0022	0.0727	0.0027
	2020	0.7010	0.0396	0.1249	0.0202	0.0022	0.0344	0.0023	0.0724	0.0028
	2021	0.6923	0.0415	0.1307	0.0203	0.0023	0.0357	0.0023	0.0720	0.0029
	2022	0.6832	0.0434	0.1368	0.0204	0.0023	0.0370	0.0023	0.0716	0.0030
Southwest		**coal**	**coke**	**Crude oil**	**gasoline**	**kerosene**	**diesel**	**Fuel oil**	**Natural gas**	**Clean energy**
	2018	0.4464	0.0571	0.0537	0.0892	0.0228	0.1038	0.0068	0.1215	0.0987
	2019	0.4635	0.0586	0.0510	0.0843	0.0218	0.0985	0.0065	0.1161	0.0999
	2020	0.4814	0.0602	0.0479	0.0793	0.0207	0.0935	0.0062	0.1103	0.1006
	2021	0.5003	0.0619	0.0442	0.0744	0.0197	0.0888	0.0059	0.1042	0.1006
	2022	0.5202	0.0639	0.0399	0.0695	0.0188	0.0845	0.0057	0.0978	0.0998
Northeast		**coal**	**coke**	**Crude oil**	**gasoline**	**kerosene**	**diesel**	**Fuel oil**	**Natural gas**	**Clean energy**
;	2018	0.4955	0.0594	0.2472	0.0352	0.0032	0.0347	0.0083	0.0307	0.0858
	2019	0.4996	0.0602	0.2501	0.0351	0.0032	0.0360	0.0084	0.0305	0.0772
	2020	0.5038	0.0610	0.2533	0.0349	0.0032	0.0374	0.0084	0.0301	0.0681
	2021	0.5080	0.0618	0.2567	0.0347	0.0031	0.0389	0.0086	0.0295	0.0587
	2022	0.5125	0.0626	0.2604	0.0345	0.0031	0.0405	0.0090	0.0286	0.4880

5 CONCLUSIONS AND RECOMMENDATIONS

The results show that the polarization of energy structure is very serious, and its transformation is worrying. Except for south and central China. The rest of the region's clean energy share is very small, less than 10 percent. Moreover, the transformation trend is slow, and even negative in north China, northeast China and other regions. The results of this paper also show that most of China is still coal-based, with only southern and central China out of the state. For now, China's renewable energy, clean energy growth less so for a long period of time does not change this situation. Account for this situation, the government should according to different regions to develop a different method of policy for north China, east China, should strengthen the high energy consumption, high pollution enterprise to control, reduce the one of primary energy consumption. Northwest, southwest and northeast should strengthen the research and development of performance source technology, accelerate the growth rate of new energy and clean energy through market incentive mechanism and supporting new energy enterprises, so as to increase the proportion of clean energy. For south and central China, the government should continue its investment in new energy research and development, so as to effectively increase the proportion of clean energy.

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