Analysis on Industry Structure Adjustment and Energy Consumption Based on Grey Theory

——A Case Study of Qinghai Province

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Abstract In view of the complexity and non-linearity of energy consumption system and the status quo of the development of energy in Qinghai Province, the relations between energy consumption and industrial structure is analyzed by using the quantitative analysis of grey relation degree by using the grey system theory. The relevancy degree among the primary industry, the secondary industry and the tertiary industry and living energy consumption are obtained, and then the trend of energy consumption in the following several years can be predicted. The results show that the secondary industry has the largest relevancy degree to the total energy consumption. In the end, according to the results of the research, several suggestions on how to saving energy are put forward. Firstly, the government should improve the high-tech industry and restrict the development of high-consumption and high-pollution industries. Secondly, the government should promote the low-carbon way of life; promote energy saving and control the energy consumption of the department of life. Thirdly, clean production should be actively promoted in the tertiary industry and the circular economy should be vigorously expanded.

Key words Grey relevancy analysis, Grey correlation degree, Industrial structure, Energy consumption, Qinghai Province, China

Energy is the blood for the development of economic development; the material base for sustainably developing national economy and for improving people' living condition, and the core for the nation to pursue the stable development of economy and environment. With the adjustment of industrial structure, the lifestyle and the consumption of energy have changed with it. In the study of energy, different scholars established different econometric models from various perspectives. For example, ETA-MACRO model, PILOT model, DGEM model, MEDES model and the neural network, grey theory, multivariate statistics, time series and so on were established to imitate and predict the developmental trend of Chinese future energy consumption volume[1]. LIU Jia *et al.* established a prediction model with saturation level limit model to predict the service demand of Chinese energy by adopting the ESD prediction method and aggregation model[2]. ZHONG Xiao-qing *et al.* established the prediction model by using ARIMA model to predict the energy demand, taking the time series prediction as the premise and supposing the developmental trend of energy consumption is fixed[3]. ZHANG Xiao-mei *et al.* established the Partial Least Squares Regression and optimal combing model to predict the consumption volume of primary energy sources and the emission volume caused by this[4]. On the basis of sustainable development, ZHENG Zhong-hai *et al.* studied the energy ecological footprint (EEF) from the perspective of cities, which indicates that EEF can be used as one of the evidences for evaluating energy system[5]. By using the Grey Relation Analysis, the relations between the industrial structure and energy consumption of Qinghai Province is analyzed. Besides, the energy consumption in the several years from now on is predicted and the countermeasures for developing the current industrial structure are put forward to realize the effective use of energy.

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1 Data source and research method

1.1 The general situation of study area Qinghai Province is located in 89°35′ -103°03′E, 31°4′ -39°19′N, with the area of 72.4×10^4 km^2. It is in the northeastern of Qinghai - Tibet plateau and most of the land is in the height above sea level of 3 000 m. The north mountainous area includes Qilian mountain area and Qinghai Lake basin, Xining basin, the south is Caidamu basin. The rest of the province is southern Qinghai Plateau, which takes 50% of the area of Qinghai - Tibet Plateau. Qinghai is the cradleland of Yangtze River and Yellow River, so many rivers and streams run through it and many lakes decorates the land. There are many salt lakes in Qinghai Province and the Qinghai salt lake is the biggest salt lake in China. the economic development in the area still relies on the resource exploration-based traditional industry, primary industry and capital-intensive industry and the inner structure of heavy industry is single[6]. The farming and animal husbandry are the major economy of Qinghai Province and the petroleum, natural gas, crude salt and salt-alkai chemical materials are the major industrial products. In recent years, Qinghai Province tries best to promote the recycling use of resources, the combined cycle among industries, recycling production in enterprises, which have achieved substantial progress in the Caidamu pilot zone of circular economy.

1.2 Data source The basic data of the research come from *Qinghai Statistical Yearbook*[7]. The total consumption volume of each industry from 2000 to 2009 of Qinghai Province can be

seen on Table 1.

Table 1 Total energy consumption of each industry in Qinghai Province from 2000 to 2009 $\times 10^4$ tce

Year	Total energy consumption x_0	Primary industry x_1	Secondary industry x_2	Tertiary industry x_3	Domestic energy consumption x_4
2000	874.53	12.95	660.93	75.03	125.62
2001	935.19	14.67	668.66	66.45	185.41
2002	973.65	12.94	653.35	108.03	199.33
2003	1 065.52	11.22	726.83	124.41	203.06
2004	1 323.60	11.93	950.42	142.48	218.77
2005	1 643.48	10.50	1 206.13	190.13	236.72
2006	1 883.59	10.54	1 445.12	194.62	233.31
2007	2 062.90	10.50	1 619.52	226.53	206.35
2008	2 182.34	10.89	1 729.46	232.91	209.08
2009	2 355.99	9.67	1 839.10	263.73	243.49

1.3 Research method Grey relation analysis is a systematic analysis method which belongs to grey system theory[8]; it uses the order of grey relation to describe the correlation degree among factors and emphasis the order of the correlation degree among factors. In dealing these data, most the data can be solved by using probability theory and mathematical statistics, and the problem of uncertainty can be solved by using vague mathematics. However, there is another problem about uncertainty Grey system theory is the theory for solving the problems of less data and uncertainty[9]. The grey relation analysis method can make up for the defect caused by the system analysis of mathematical statistics. Through the analysis of correlation degree, the principal factors that affect the changes of key values can be found out.

The correlation degree analysis is to quantitatively compare the developmental momentum of a developing system and the quantitative comparison of developmental momentum is the comparison of the geometrical relationship of each time series[10]. According to the mathematic foundation of space theory, the grey system theory has established the correlation coefficients between reference sequence and x_0 and several number sequence x_i. Collecting the dispersed information of correlation coefficients and then averaging them, then the correlation degree of comparison sequence x_i to reference sequence x_0 can be obtained. The specific steps are as follows:

In the first step: determining correlation coefficient. Taking the aggregate volume ($\times 10^4$ tce) of energy consumption of Qinghai Province from 2000 to 2009 as reference sequence x_0, and taking the energy use of the primary industry, the secondary industry and the tertiary industry and energy use in daily life as comparison sequence x_i.

In the second step: initializing the data. Using all the data in the same number sequence to divided the first data, and then a group of speed series of fixed base, the dimension of various factors can be eliminated, thus, the closeness and comparability of various factors can be strengthened. $x_i = INIT\omega_i, i=0,1,2,3,4$.

In the third place: calculating the absolute value of each comparison number sequence and reference sequence.

$$\Delta_{ij}(k) = |x_i(k) - x_j(k)|, k=1,2,\cdots,10 \quad (1)$$

In the fourth place: using the formula of difference sequence (1), and supposing $\Delta(\max) = \max_i \max_k \Delta_{0i}(k)$, $\Delta(\min) = \min_i \min_k \Delta_{0i}(k)$, then the maximum value and minimum value of the series can be obtained by using the following formula. In the formula, ζ is resolution ratio, $\zeta \in [0,1]$, the smaller the ζ, the bigger the resolution ratio. Generally, according to the minimum information theory, $\zeta = 0.5$.

$$\gamma(x_0(k), x_i(k)) = \frac{x(\min) + \zeta x(\max)}{\Delta_{0i}(k) + \zeta x(\max)} \quad (2)$$

In the fifth place: $\gamma(x_0, x_i) = \frac{1}{n}\sum_{k=1}^{n}\gamma(x_0(k), x_i(k))$ (3)

In the formula, $\gamma(x_0, x_i)$ is the correlation degree of the i number series and reference number series.

2 Results and analysis

The energy consumption of Qinghai Province is composed by the following four aspects: the energy consumption of the primary industry, the energy consumption of the secondary industry, the energy consumption of the tertiary industry and the energy consumption of the daily life. The changed of the above mentioned energy consumption will directly affect the energy consumption situation of the whole energy consumption situation. Therefore, analyzing the close relations among the four factors and energy consumption, calculating the correlation degree of four energy consumption factors and energy consumption are the major direction of the research.

According to the data in Table1 and formulas(1) and (2), the grey correlation coefficient can be calculated, the results can be seen on Table 2.

Table 2 Grey correlation coefficient of the total energy consumption of each industry in Qinghai Province from 2000 to 2009

Year	$\gamma(x_0(k), x_1(k))$	$\gamma(x_0(k), x_2(k))$	$\gamma(x_0(k), x_3(k))$	$\gamma(x_0(k), x_4(k))$
2000	1.000 0	1.000 0	1.000 0	1.000 0
2001	0.938 8	0.944 1	0.841 3	0.705 4
2002	0.895 1	0.886 4	0.748 9	0.672 8
2003	0.734 5	0.891 3	0.688 9	0.709 8
2004	0.621 8	0.928 0	0.716 4	0.810 2
2005	0.476 8	0.947 1	0.597 9	0.994 7
2006	0.420 8	0.967 5	0.688 7	0.766 5
2007	0.386 1	0.914 1	0.595 9	0.576 2
2008	0.370 5	0.889 2	0.615 3	0.539 5
2009	0.333 3	0.916 6	0.542 5	0.563 0

According to the date in Table 3, the grey correlation of the

three industries and the daily energy consumption to energy consumption can be calculated by using formula(3). The grey correlations are 0.617 8, 0.928 4, 0.703 6 and 0.738 8 respectively. The grey correlation degree can directly reflect the advantages and disadvantages of each comparison sequence and reference sequence. The bigger the correlation degree, the bigger the influence of comparison sequence on reference sequence. The descending order of correlation degree is $r(x_0, x_2) > r(x_0, x_4) > r(x_0, x_3) > r(x_0, x_1)$, that is to say, the order of the industries are the secondary industry > daily energy use > the tertiary industry > the primary industry.

3 Conclusions and suggestions

3.1 Conclusions From the perspective of the above grey correlation series, in the four factors, the secondary industry has the closet relation with the energy consumption, followed by the daily energy use, the tertiary industry and the primary industry. As the main factor, the secondary industry has relatively larger influence on the development of system, so optimizing the secondary industry is the precondition for realizing energy saving.

From the perspective of the volume of energy consumption, the energy consumption of the secondary industry has occupied the dominant role, followed by the daily energy consumption. Combining the changing trend of energy consumption and correlation coefficient, we can forecast that, in short period, the increase of energy consumption in Qinghai Province will not so strong and the increase momentum of energy consumption will decrease gradually.

The statistics and calculating results reflect that the secondary industry is the competitive industry in the area, but its proportion is relatively low, but the developmental tempo of the tertiary industry has increased and its proportion has improved relatively.

3.2 Suggestions Through the above analysis, it is obtained that in order to control the total energy consumption, the energy consumption of the secondary industry and daily consumption should be started from. So the paper puts forward the following suggestions for the development of industries in Qinghai Province, so as to realize the energy saving.

3.2.1 In the secondary industry, the government should greatly improve the high technological industry and restrict the development of high-energy consumption and high pollution industry. The government should insist the equal importance to energy exploitation and energy saving, and put energy saving as the priority. The government should optimize industrial structure; develop and promote the technology of energy saving; as well as intensify the construction of energy system an d supervise the implementation of energy saving.

3.2.2 The government should promote low-carbon way of life style; greatly promote energy saving and reasonably control the volume of energy consumption of life department. The government should deepen the awareness of energy saving and form the energy saving idea in the nation wide; the citizens should form the habit of saving energy and establish the awareness of social crisis; and form the energy-saving and healthy consumption model.

3.2.3 The government should vigorously promote the cleaning production and develop circular economy. By doing this, the consumption of energy can be reduced, as well as the production and emission of wastes.

4 Summary

By using the grey theory to analyze the relation between industrial structure adjustment and energy consumption, it demands a small number of original data and the calculation process is simple, and the correlation degree can reflect the closeness degree of each factor. Therefore, as one of the factors that affects the energy consumption system, the grey theory system is of great practical value. However, besides the four factors that affect the energy consumption, the consumption of energy is also affected by economical circle, national policy, natural disaster and some other uncertain factors. So various factors should be analyzed comprehensively; new data should be introduced into and the relevant parameters should be remedied to ensure the reliability of the evaluation.

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