The Grey System Analysis of Energy Consumption Structure Change in Xinjiang in the Context of Low-Carbon Economy

WangYue[1 2] Ke Han[2]
Xinjiang Autonomous Region Bureau of Statistics, Urumqi, Xinjiang, China 830002
Corresponding author: WangYue, **email: 398575647@qq.com**

Abstract

Combing through the research on the issue of energy consumption at home and abroad, the author finds that many scholars are using Granger Causality Test and Co-Integration Test Methods to study the long-run equilibrium relationship between energy consumption and economic growth, but not meeting the prerequisite methods and assumptions to some extent. However the conclusion is not very reliable while the method does not meet the prerequisites and assumptions. As the energy consumption structure is an overall uncertainty, the author uses the Grey Component Data System to simulate and predict changes in energy consumption structure in Xinjiang, aims to provide a new idea for the study of the structure of energy consumption.

Key words: Grey System; Component data; Energy Consumption Structure; Xinjiang

Not only is energy an important material basis for the survival and development of human society, but an important strategic material, related to the economic lifeline of a country or region. Whether energy consumption structure is reasonable or not is an important indicator to measure the economic development of a country and region. Meanwhile, it is also one of the most important indicators to judge whether the economic development of a country is of sustainability or not. Therefore, to respond to the requirements of the development of low-carbon economy and to achieve the sustainable development of the energy consumption and environmental economic development, the analysis and prediction of the changes in energy consumption structure in Xinjiang has important practical significance.

1 The Research Status Home and Abroad

On the issue of energy consumption, many scholars at home and abroad have conducted researches. It mainly includes the following research perspectives. First, the causal relationship between energy consumption and economic growth. Some foreign scholars, such as: Kraft J (1978) studied the relationship between GDP growth and energy consumption and found they had unidirectional causal relationship. Ghali (2004), Narayan (2008), Stern (1993), Stern (2000) and other scholars came to different conclusions. Domestic scholars, such as: Qiaosheng Wu (2008) and Jinwen Zhao (2007) found that China was also an unidirectional causality from GDP to energy consumption. The conclusions of many other scholars, Jian Zhou (2002), Zhiyong Han (2004), Xiaojun Ma(2004), Sheng Zeng(2009) were not the same. Second, the equilibrium relationship between energy consumption and economic growth. Zhiyong Han (2004) studied the co-integration and causality in Chinese energy consumption and economic growth during 1978-2000, and found that the long-run equilibrium relationship between China's energy consumption and economic growth existed.

Previous studies show that: first, many scholars have verified the long-run equilibrium relationship between energy consumption and economic growth, as well as the Granger causality; however, the data does not reach the inspection requirements of causality and equilibrium relationship. In addition, the choice of trend term and the constant term lag is not very scientific, but the choice of lag is quite sensitive to the test results, which will lead to the deviation of conclusion, or will result in different conclusions. Second, it is still rare to see the articles which can make predictions from the perspective of the changes in the structure of energy consumption and make recommendations based on forecast results.

2 Pressures in Front of Energy Consumption Structure Change in Xinjiang in the Context of Low-Carbon Economy

Table 1 Various Proportion of Energy Consumption in Xinjiang

The Year	Coal	Oil	Gas	Water, Wind and Power
2001	40.6	48.7	7.9	2.8
2002	38.7	48.6	9.7	3
2003	39.5	47.3	10.5	2.7
2004	41.1	46	10.2	2.7
2005	41.4	45.3	10.7	2.6
2006	37.9	42.1	17.3	2.7
2007	37.3	37.1	22.9	2.7
2008	36.7	34.7	26	2.6
2009	41.9	30.6	24.8	2.7
2010	46.5	26.5	24.1	2.9

Source: Xinjiang Statistical Yearbook (2012)

The Seventeenth Party Congress put forward a strategic task to accelerate the transformation of economic development, and stressed the need to promote economic growth from relying heavily on increased consumption of material resources to scientific and technological progress, the improvement of the quality of workers and management innovation. Compared to 2005, Carbon dioxide emissions per unit of GDP in 2020 decreased by 40% to 45%, which is a solemn commitment, also a very heavy responsibility. On the one hand, it indicates that China must change the mode of economic development, adjust the economic structure and shift to low-carbon economy; On the other hand, it marks that from government to civil society organizations, from businesses to individuals, everyone must become a member, a participant, and beneficiary of this revolution.

At present, the economy of Xinjiang is in a stage of rapid growth; a huge demand for energy will be met because of some socio-economic development trends, such as large-scale infrastructure development, industrialization, urbanization, and the anticipation that people may live a well-off life. Xinjiang riches in coal resources, and coal consumption is dominant in the energy consumption structure. How to change disadvantages to advantages in the low-carbon economy in the process of a new round of global challenges， and how to shift energy consumption in Xinjiang from "high-carbon" to "low-carbon" on the basis of keeping rapid economic growth are the predicaments faced by the energy consumption structure change in Xinjiang. From the perspective of energy structure in Xinjiang, fossil energy accounts for more than 95%

of the overall energy structure (as shown in Table 1), coal accounts for the proportion of total energy consumption increased by 60.4% in 2001 to 65.8% in 2010. The proportion of coal is increasingly high, so economy in Xinjiang is still driven by the high-carbon energy in the development process of industrialization. From the angle of economic structure in Xinjiang, the economic entity is the second industry, which determines that the main sector of energy consumption is industry. And the high-carbon consumption characteristics of industrial production technology increase the tendency of high carbon economy of Xinjiang. In order to ensure the rapid economic development in Xinjiang, and to reduce carbon emissions to meet the constraints and requirements of the low-carbon economy, we must make efforts in energy saving, comprehensive utilization of resources and significantly reduce environmental pollution. Xinjiang can get out the passive situation of dilemma only when the energy consumption structure is adjusted and the economic growth mode conversion is solved.

3 The Grey System Analysis of Energy Consumption Structure Change in Xinjiang

The Grey Theory proposed by Professor Ju-long Deng in 1982, is a new method to study a small amount of data and the problem of information uncertainty. From the perspective of objects and methods, the Grey Theory is based on the characteristics of a small amount of data available after Grey Model processing, which obtains a satisfactory and credible conclusion. By processing the raw data to find the variation of the system, to generate a strong regular sequence of data, and then to create a corresponding differential equation model. Since the structure of energy consumption data is a component of the data, taking into account the advantages of the Grey System Analysis, the author made the Grey System Analysis on the basis of logarithmic transformation of energy consumption structure data .

The proportion of all kinds of energy consumption accounted for total energy consumption is a kind of special data, their range (0,1),and the sum is equal to 1, which is also known as the component data. Collinearity must exist between composition variables, which has brought a lot of difficulties to the traditional statistical analysis. So, the author has to process the data of all energy consumption proportion in Xinjiang by nonlinear dimensionality reduction, then establish GM (1,1) model by using data after dimensionality reduction and predict future values of the composition data.

3.1 Grey System GM (1,1) Model

Used GM (n, 1) model is GM model with only one variable, and the data should reflect and predict the object sequence of the combined effect. However, due to the larger n makes calculation more complex, but the accuracy is not necessarily high; n is generally less than 3, and under the most circumstances $n = 1$, while the calculation is relatively simple. Widespread applicability, denoted as GM (1,1).

In accordance with the relation $X^{(1)}(K)=\sum_{i=1}^{k} x^{(0)}(i)$ seeking original series 1 - AGO sequence. Namely: establish the original sequence, recorded as: $X^{(0)} = \{X^{(0)}(1), X^{(0)}(2), \ldots, X^{(0)}(n)\}$

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Note：$X^{(1)}(t)=X^{(0)}(1)+X^{(0)}(2)+\ldots+X^{(0)}(t)$

Calculate the data matrix

$$B=\begin{bmatrix} -\frac{1}{2}\left(x^{(1)}(1)+x^{(1)}(2)\right) & 1 \\ -\frac{1}{2}\left(x^{(1)}(2)+x^{(1)}(3)\right) & 1 \\ \vdots & \vdots \\ -\frac{1}{2}\left(x^{(1)}(n)+x^{(1)}(n-1)\right) & 1 \end{bmatrix}$$

Establish a data column $Y_n=\left(x^{(0)}(2), x^{(0)}(3),\ldots, x^{(0)}(n)\right)^T$ (1)

Calculate parameter column by the method of least squares $\hat{a}$ $\hat{a}=\begin{pmatrix} a \\ b \end{pmatrix}=\left(B^T B\right)^{-1} B^T Y_n$ (2)

The function of time as follows: $\hat{x}^{(1)}(k+1)=\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-ak}+\frac{b}{a}$ (3)

Derivate restore: $\hat{x}^{(0)}(k+1)=-a\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-ak}$ (4)

Calculate the absolute and relative error between $x^{(0)}(t)$ and $\hat{x}^{(0)}(t)$

Recorded as $e^{(o)}(t)=x^{(o)}(t)-\hat{x}^{(0)}(t)$, $q(t)=\frac{e^{(0)}(t)}{x^{(0)}(t)}\times 100\ \%$ (5)

Finally, we need to test the accuracy of the model, also need to modify the model to predict if it does not meet the accuracy requirements. Formula (5) is the basic one of GM (1,1) model of Grey prediction accuracy.

3.2 The Composition Data

J. Aitchison proposed the theory of logic normal distribution and the method of logarithmic transformation in 1986. Based on addition logic normal distribution theory, J.Aitchison proposed the calculating method of eliminating the component data redundancy dimension by logarithmic transformation. As follows: to sequence a group of component data collected in chronological order: $P(t)=(P_0(t), P_1(t), \ldots, P_n(t))\in R^{n+1}$, note, $\sum P_j(t)=1$, $0<P_j(t)<1$, $t=1,2,\ldots,T$, apparently; $q_i(t)=\ln[P_i(t)/P_0(t)]$, $i,t=1,2,\ldots,n$; (6)

Aitchison selected $q_i(t)=\ln[P(t)/P_0(t)]$ as analysis variables, which was very convenient in some situations.First, in the conversion of the formula (6), the component data is reduced from the original (n +1)-dimensional space to the n-dimensional; the original variable linearly related to the n+1th is converted into n independent variables; thus the redundancy dimensions of original composition data is eliminated. Second, $q_i(t)$ values $(-\infty, +\infty)$, it is very convenient to choose the function of the model. Third, according to the adder logic normal distribution, qi (t) obey the n-dimensional normal distribution. Then, establish the n GM (1,1) model according to the data $Q(t)=(Q_1(t), Q_2(t),\ldots,Q_n(t))$, $t=1,2,\ldots,T$ $\hat{q}_i^{(0)}(t)=\hat{q}_i^{(1)}(t+1)-\hat{q}_i^{(1)}(t)$ $i=1,2,\ldots,n$ (7)

According to the formula (7), the value of Q for the t +1th moment can be predicted. $\hat{q}_i^{(0)}(T+1)=\hat{q}_i^{(1)}(T+1+1)-\hat{q}_i^{(1)}(T+1)$ $i=1, 2,\cdots, n$ (8)

Finally, calculate the value of P for the moment T +1th by formula (9) and (10)

$P_i(t+1)=\dfrac{1}{1+\sum_{j=1}^{n} e^{\hat{q}_j(T+1)}}$, i=0 (9) $P_i(t+1)=\dfrac{e^{\hat{q}_i(T+1)}}{1+\sum_{j=1}^{n} e^{\hat{q}_j(T+1)}}$, $i=1,2,\ldots n$ (10)

3.3 Results

Analyze the rules of energy consumption structure change and forecast the arbitrariness which may help to overcome the macro decision-making and industrial policies formulating. Next, analyze the rules of change by using the data of the energy consumption structure 2006-2010 in Xinjiang (Table 1) and by adopting Grey Component Data Modeling Methods.

Adopt gray prediction method for component data, write MATLAB program and calculate the simulation value in the proportion of a variety of energy consumption in Xinjiang between 2001 and 2007. Meanwhile, compare the analog values and the actual value to calculate the relative error (Table 2). The average relative errors of wide variety of energy sources are: coal 3.94%, oil 4.78%, natural gas7.6%, water wind power 5.14%. According to experience, if the mean relative error value is within 10%, the predicted value substantially meet the requirements, and then the prediction can be made.

Table 2 The Error Value of Various Energy Consumption Proportion in Xinjiang %

Years	The actual value of coal	Analog value	Absolute error	relative error	The actual value of natural gas	Analog value	Absolute error	relative error
2006	37.9	37.3	0.6	1.6	17.3	18.9	1.6	9.2
2007	37.3	37.0	0.3	0.8	22.9	26.0	3.1	13.5
2008	36.7	38.7	2.0	5.4	26.0	25.0	1.0	3.8
2009	41.9	43.2	1.3	3.1	24.8	23.7	1.1	4.4
2010	46.5	50.6	4.1	8.8	24.1	22.4	1.7	7.1
Years	The actual value of petroleum	Analog value	Absolute error	relative error	The actual value of Water，Wind and Power	Analog value	Absolute error	relative error
2006	42.1	41.1	1.0	2.4	2.7	2.7	0.0	0.0
2007	37.1	34.4	2.7	7.3	2.7	2.6	0.1	3.7
2008	34.7	33.6	1.1	3.2	2.6	2.8	0.2	7.7
2009	30.6	30.1	0.5	1.6	2.7	2.9	0.2	7.4
2010	26.5	24.0	2.5	9.4	2.9	3.1	0.2	6.9

The predictive value of the energy 2011-2015 (see Table 3) can be calculated based on the reduction equation.

3.4 The Result Analysis

According to the predicted results, the structure of energy consumption in Xinjiang in the next five years will further change. The proportion of coal consumption will continue to increase; the proportion of oil consumption is falling significantly; the proportion of natural gas consumption is decreased; the proportion of the water wind and power consumption is incremental trend. That the rise of the proportion of coal consumption and oil and the downward trend of natural gas consumption is closely related to the characteristics of energy consumption structure during the "Eleventh Five-Year" period. Classic studies show that, the Grey System Analysis is not suitable for large sample forecast, because that would cause a rise in an exponential trend of prediction error. So I use the data for the past five years in this forecast, and the forecast value can reflect the changes in the structure of energy consumption in the next five years.

Table 3 Predictive Value of The Proportion of Energy Consumption %

The Year	Coal	Oil	Gas	Water, Wind and Power
2011	54.7	21.3	20.9	3.2
2012	58.5	18.8	19.5	3.2
2013	62.1	16.7	18.0	3.3
2014	65.3	14.8	16.6	3.3
2015	68.3	13.2	15.2	3.3

Of the world energy consumption structure in 2008, crude oil accounted for 34.8%; natural gas accounted for 24.4%; coal 29.2%; hydropower accounted for 6.4%; and nuclear power 5.5%. Compared with the world average, by 2015, the coal consumption proportion in Xinjiang is far higher than the world average in 2008, while the consumption of natural gas and water wind power is far below the world average, which is bound to increase the pressure of economic and environmental coordination development.

4 Main Conclusions And Inspiration

First, the author adopts Grey Compositional Data Analysis to predict the energy consumption structure in Xinjiang. Compared with the traditional ideas, the prediction of the total energy consumption first and the structure second is more simple, feasible, and of high accuracy, which provides a new way for the study of energy consumption structure change.

Second, from the study finding, the proportion of coal consumption in Xinjiang within the next five years shows an upward trend, while natural gas has been gradually declining, which is not commensurate with the strategic position of abundant natural gas resources in Xinjiang; the proportion of water wind power and other renewable energy rises slowly, which can't agree with the ideas of actively developing renewable energy in the 18th CPC National Congress.

Third, adhering to the principle of environmental priorities, the scientific planning should be made in energy industrial layout, extension of industrial chain to achieve the development and utilization with a high starting point, high standard, high efficiency. To further strengthen the advantages of solar and wind energy resources in Xinjiang, accelerate the development of the national large-scale solar photovoltaic power generation, wind power and other strategic emerging energy industry, and make full use of Gobi, beaches to develop wind, solar and other clean energy. To introduce advanced technology and capital home and abroad; to integrate the utilization and development of wind energy resource; to strengthen the research,development and application of the combination of solar energy utilization and heat pump technology; find solutions to power generation, heating, reducing costs, expanding markets, promoting industrial development comprehensively.

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