Chapter 18
Application of Improved Grey Prediction Model for Chinese Petroleum Consumption

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Abstract An improved Grey-based settlement predictor is promoted. Adopt Grey prediction as a forecasting means because of its fast calculation with a few of data inputs needed. However, our preliminary study shows that the general Grey model, GM (1,1) is inadequate to handle settlement prediction as its only adapt to the data with exponential law. In this paper, the prediction is improved significantly by adopting equal dimensionality information fill model aim at enhancing the prediction accuracy. The prediction is made on Chinese petroleum consumption in future.

Keywords Grey system theory · Improved GM (1,1) · Petroleum consumption · Prediction

18.1 Introduction

Energy is the life blood of the economy, relations with the development of the national economy and improving the People's living conditions. Energy consumption is forecast to the stable and rapid economic development, to speed up the healthy development of the energy industry, and conducive to the formulation of a sound energy planning, so energy consumption accurate forecasts that is very necessary.

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China is the world's petroleum Producing and consuming nations. In recent years, along with the rapid economic growth, domestic petroleum consumption increased substantially. How to better predict petroleum consumption, which has become an important sustainable development issues on the national economy. Many researchers developed the settlement prediction methods, 'Three Point Method' (Li et al. 1994), 'Hyperbola Method', 'Grey Theory' (Zhang et al. 1999), 'Neural Network' (Tavenas and Leroueil 1980), 'Asaokao' (Asaoka 1978) etc. Grey theory is one of the most widely used methods. Grey theory, developed originally by Deng (1982), is a truly multidisciplinary and generic theory that deals with systems that are characterized by poor information and/or for which information is lacking. The fields covered by grey theory include systems analysis, data processing, modeling, prediction, decision making and control. Grey forecasting models have been extensively used in many applications (Gao et al. 2003; Liu 2001; Meng et al. 2002; He 2002), and it was improved by many researchers.

18.2 Methodology

18.2.1 GM (1,1) Model

Deng proposed Grey theory to deal with indeterminate and incomplete systems. Unlike conventional stochastic forecasting theory, Grey theory simply needs few sample data inputs to construct a Grey model. Since the poor regularity for the tested settlement data, the AGO technique in Grey forecasting is suitable to reduce the randomization of the raw data efficiently. Generally, the procedure for GM (1,1) forecasting is explained as follows:

Step 1. Denote the original data sequence by

$$\left| X^{(0)} = \left\{ X^{(0)}(1), X^{(0)}(2), \ldots, X^{(0)}(n) \right\} \right| \tag{18.1}$$

where n is the number of data observed.

Step 2. The AGO formation of $x^{(0)}$ is defined as:

$$\left| X^{(1)} = \left\{ X^{(1)}(1), X^{(1)}(2), \ldots, X^{(1)}(n) \right\} \right| \tag{18.2}$$

where

$$X^{(1)}(1) = X^{(0)}(1)$$

$$\text{and } X^{(1)}(k) = \left\{ \sum_{i=1}^{k} X^{(0)}(i), k = 1, 2, 3, \ldots, n \right\} \tag{18.3}$$

The GM (1,1) model can be constructed by establishing a first order differential equation for $X^{(1)}(k)$ as:

$$dx^{(1)}(k)/dk + ax^{(1)}(k) = b \tag{18.4}$$

Therefore, the solution of Eq. 18.4 can be obtained by using the least square method. That is,

$$\hat{X}^{(1)}(k) = \left[X^{0}(1) - \frac{b}{a}\right]e^{-a(k-1)+}\frac{b}{a} \tag{18.5}$$

where

$$[a \quad b]^{T} = \left(B^{T}B\right)^{-1}X_{n} \tag{18.6}$$

and

$$B = \begin{bmatrix} -Z^{(1)}(2) & 1 \\ -Z^{(1)}(3) & 1 \\ \cdots & \cdots \\ -Z^{(1)}(n) & 1 \end{bmatrix} \tag{18.7}$$

where

$$\begin{aligned} Z^{(1)}(k) &= ax^{(1)}(k) + [1 - a]x^{(1)}(k) \\ X_{n} &= [x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)]^{T} \end{aligned} \tag{18.8}$$

We obtained $\hat{x}^{(1)}$ from Eq. 18.5. Let $\hat{x}^{(0)}$ be the fitted and predicted series,

$$\hat{x}^{(0)} = (x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n), \ldots \tag{18.9}$$

where $\hat{x}^{(1)}(1) = x^{(0)}(1)$

$$\hat{x}^{(0)}(k) = (1 - e^{a})\left[X^{(0)}(1) - \frac{b}{a}\right]e^{-a(k-1)} \tag{18.10}$$

where $\hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \ldots \hat{x}^{(0)}(n)$ are called the GM (1,1) fitted sequence, while $\hat{x}^{(0)}(n+1), \hat{x}^{(0)}(n+2), \ldots$ are called the GM (1,1) forecast values.

18.2.2 Improved GM (1,1) Model

Grey prediction has lot of advantages, such as less data required, regardless of distribution, regardless of trends, convenient operation, short-term forecasts of high precision, easy to test, etc., so it is widely used, and achieves satisfactory results. But there are some limitations. Many scholars encountered a number of problems of low prediction accuracy in the application of GM (1,1) model, and many researchers have proposed methods to improve prediction accuracy. There are mainly two ways to improve the forecasting model, one is to transform the original series, and the other is to transform GM (1,1) itself. GM (1,1) improved methods are generally $\hat{a}$ parameter correction method, the raw data moving average processing, and equal dimension information processing, residual treatment etc., here we took equal dimensionality information fill model.

Generally modeling must be based on the latest data as a reference point. According to the different choice of data, new information model and equal dimension new information model are commonly used in GM (1,1) model. New information model will add the new information into the original series when coming up with new information and modeling after adding the new information (full-line modeling), also known as metabolic models. It's mechanism close to the general theory of forgetting factor modeling ideas.

18.3 Empirical Analysis

In 1993, China became a petroleum importing country. With the rapid development of the national economy, petroleum demand was in the rapid growth, the petroleum supply situation will be even more severe in the future. No matter From the goal of economic development, or the goal of environmental protection, adjusting and improving the energy structure, promoting the diversification of energy use are the only way for China's sustainable energy strategy. Table 18.1 shows China's petroleum consumption in recent years.

The raw data $x^{(0)}(k)$ are tested by Quasi-smooth conditions. Then Test whether $x^{(1)}$ have the quasi-exponential law. Raw data, for example:

$$\rho(k) = \frac{x^{(0)}(k)}{x^{(1)}(k-1)} \tag{18.11}$$

Table 18.1 Petroleum consumption of China

Years	The proportion of total energy consumption (%)				Petroleum (million tons of standard coal)
	Coal	Petroleum	Nature gas	Hydroelectric, nuclear, wind power	
2002	66.3	23.4	2.6	7.7	35520
2003	68.4	22.2	2.6	6.8	38847
2004	68.0	22.3	2.6	7.1	45319
2005	69.1	21.0	2.8	7.1	47414
2006	71.1	19.3	2.9	6.7	49924
2007	71.1	18.8	3.3	6.8	52735
2008	70.3	18.3	3.7	7.7	53334
2009	70.4	17.9	3.9	7.8	54889
2010	68.0	19.0	4.4	8.6	61738
2011	69.7	18.2	4.6	7.4	63278

when $k > 3, \rho(k) < 0.5$, Quasi-smooth conditions are met.

Given

$$\text{Given } \delta^{(1)}(k) = \frac{x^{(1)}(k)}{x^{(1)}(k-1)} \tag{18.12}$$

when $k > 3, \delta^{(1)}(k) \in [1, 1.5]$, then Quasi exponential law are met.

First doing the quasi-smooth test, the results are as follow:

$$\begin{aligned}
&\rho(3) = 0.55, \rho(4) = 0.36 < 0.5,\\
&\rho(5) = 0.28 < 0.5, \rho(6) = 0.24 < 0.5,\\
&\rho(7) = 0.23 < 0.5, \rho(8) = 0.19 < 0.5,\\
&\rho(9) = 0.17 < 0.5, \rho(10) = 0.12 < 0.5
\end{aligned}$$

So when k > 3, the quasi-smooth conditions is met.

Similarly quasi-exponentially test, when k > 3, meet the exponential law.

To illustrate the superiority of improved GM (1,1) model in predicting. For the purpose of fitting the existing data and predicting future demand, we selected petroleum consumption data and using MATLAB software for data processing. The result of relative error of calculated values and actual values are as follows in Table 18.2 by using gray theory method.

Using Gray theory to fit the original data, the model has a higher fitting accuracy. Because of uncertainty of the future factors, using traditional gray theoretical model to predict may cause the results are untrue. Sometimes the higher the reliability of the data closing to the true value and the longer time interval, the data reliability is easier to change. Therefore using equal dimensionality information fill model to predict China's future petroleum consumption will be better, we used MATLAB software predicted the results shown in Table 18.3.

Table 18.2 Chinese petroleum consumption fitting value (million tons of standard coal)

Years	Petroleum	Traditional GM(1,1) model			Error test
		Predicted value	Residual	Relative error (%)	
2002	35520	35520	0	0.00	C = 0.02
2003	38847	39746	−899	−2.31	P = 1
2004	45319	42840	2479	5.47	
2005	47414	46776	638	1.35	
2006	49924	49770	154	0.31	
2007	52735	53645	−910	−1.73	
2008	53334	54987	−1653	−3.10	
2009	54889	56765	−1876	−3.42	
2010	61738	62876	−1138	−1.84	
2011	63278	63786	−508	−0.80	

Table 18.3 The forecast value china's petroleum consumption (million tons of standard coal)

Years	Petroleum	Years	Petroleum	Years	Petroleum
2012	67646	2018	97180	2024	139911
2013	72690	2019	104769	2025	150558
2014	74876	2020	112466	2026	161961
2015	77925	2021	120915	2027	174083
2016	83413	2022	130027	2028	187124
2017	90110	2023	139911	2029	201156

18.4 Conclusion

Through the forecast shows that China's petroleum consumption in the year of 2029 will increase of 13.351 billion tons standard coal compared to the year of 1998. A big shortfall of petroleum demand will lead a tough situation of the petroleum security. In the year of 2029, China will basically realize industrialization and modern agriculture, the rapid growth in demand of petroleum will restrict China's economic growth, if we do not take some practical countermeasures for the security of petroleum.

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