Application of Gray Metabolic Model in the Prediction of the Cotton Output in China

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Abstract In order to forecast the cotton output of China in the year 2011, Gray Metabolic Forecast Model is established based on both the Gray Forecast Model and the Metabolic Theory. According to the actual situation, forecast results of conventional GM (1, 1) Model and Metabolism GM (1, 1) Model are analyzed, showing that Metabolism Forecast Model has higher precision than the conventional forecast model. Therefore, Metabolism GM (1, 1) Model is used to forecast the cotton output of China in the year 2011, which is 614 968.3 thousand tons.

Key words Gray system, GM (1, 1) Model, Cotton output, China

The situation is complicated in the cotton market in the year 2010. Price of cotton shows great fluctuation. The purchase price of new cotton reaches 9.6 – 10.2 yuan per kilogram in September 24th in Xinjiang region, which produces one third of the cotton in China. In some cotton regions, the purchase price is as high as 11 yuan per kilogram, increasing by 50% – 70% compared with the price of the last year. Cotton is a major farm produce, as well as one of the major cash crops during the agricultural production in China. It is also the main raw material of textile enterprises, the necessity of people’s life, and an important industrial raw material and military supply. Improving the production of cotton can help to adjust the structure of agricultural production and is of great important practical significance and has far-reaching strategic significance. Therefore, cotton output must be effectively forecasted in order to improve the cotton production and to adjust the structure of agricultural production. Metabolic Forecast Model is established based on both the Gray Forecast Model and the Metabolic Theory, so as to forecast the cotton output in the year 2011 and to provide references for the reasonable decision-making of cotton production in China.

1 Research method and data source

Gray System is a method put forward by professor Deng Julong in the year 1982, which can effectively deal with the problems of small sample and poor information. Gray Forecast is a forecast method based on Gray System Theory. Its basic idea is to turn the ruleless historical data with randomness and uncertainty into a series of numbers with exponential law of growth through accumulation. Thus, Gray Differential Equation and Forecast Model are established. Gray Forecast Model is a forecast model with relatively high precision of prediction and can establish modeling containing less than 4 data, which are just suitable for the forecast model of cotton yield with many uncertainties. The old data should be eliminated and new data should be adopted during modeling, considering that the cotton output fluctuates greatly, the information content of old data declines over time, and the new data have greater impact on the forecast result. Thus, Gray Metabolism GM (1, 1) Model is established. The modeling step of conventional GM (1, 1) Model is put forward, as well as the modeling method of Gray Metabolism GM (1, 1) Model.

1.1 The modeling step of conventional GM (1, 1) Model

Assuming that the historical data of cotton yield is \( X(0) = [x(0)(1), x(0)(2), \cdots, x(0)(n)]^T \),

(1) Accumulated generating. Accumulation of series \( X(0) \) is carried out:
\[
X(1) = [x(1)(1), x(1)(2), \cdots, x(1)(n)]^T
\]
where \( x(1)(k) = \sum x(0)(i), k=1, 2, \cdots, n \).

(2) Determining the parameter list \([a, b]^T\). Parameter list to be identified is \([a, b]^T = (B^T)^{-1}B^TY_x\), where
\[
B = \begin{bmatrix} -z(1)(2) & 1 \\ -z(1)(3) & 1 \\ \vdots & \vdots \\ -z(1)(n) & 1 \end{bmatrix}, Y_x = \begin{bmatrix} x(0)(2) \\ x(0)(3) \\ \vdots \\ x(0)(n) \end{bmatrix}, z(1)(k) = \frac{1}{2}(x(1)(k-1) + x(1)(k)), k=2, 3, \cdots, n.
\]

(3) Establishing GM(1,1) Forecast Model. Let \( x(1)(0) = x(0)(0) \), the time response equation of Gray GM(1,1) Model is:
\[
\begin{align*}
x(1)(k+1) &= x(0)(k) - \frac{b}{a} x(0)(k) + \frac{b}{a}, \quad (k=1, 2, \cdots, n) \\
\hat{x}(0)(k+1) &= \hat{x}(0)(k+1) - \hat{x}(1)(k) = (1 - e^z) [x(0)(1) - \frac{b}{a} e^{-ak}], \quad (k=1, 2, \cdots, n)
\end{align*}
\]

(4) Accuracy test. The calculation equation of Mean Relative Error is
\[
\Delta = \frac{1}{n} \sum_{k=1}^{n} \left| \frac{\hat{x}(0)(k) - \hat{x}(0)(k)}{\hat{x}(0)(k)} \right|, \quad k=1, 2, \cdots, n.
\]
Smaller relative error indicates higher accuracy of the model.

1.2 Modeling principle of Metabolism GM (1, 1) Model

Metabolic Model mainly pays attention to the continuous supplementation of new information and the removal of old informa-
tation, which can better reveal the trend of system development, obtain higher precision of prediction. The modeling process of Metabolism GM (1, 1) Model is as follows:

(1) Conventional GM (1, 1) Model is applied in the original series \( X^{(0)} = \{ x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n) \} \). Its forecast value is \( \hat{x}^{(0)}(n+1) \).

(2) According to the new series \( NX = \{ x^{(0)}(2), x^{(0)}(2), \ldots, x^{(0)}(n), \hat{x}^{(0)}(n+1) \} \), Metabolism GM (1, 1) Model is obtained by using the Conventional GM (1, 1) Model.

### 1.3 Data source

The measured values of cotton output in China in the year 2001–2009 are from the 2010 China Statistical Yearbook (Table 1) [3].

### 2 Result and analysis

In order to better plan the cotton planting area in China after the year 2010 and to effectively regulate the cotton price and cotton yield in China, it is necessary to establish a forecast model of cotton yield in China. Considering the great fluctuation and randomness of cotton output, the forecast model of cotton output in China is put forward based on the Metabolism GM (1, 1) Model. Table 1 reports the results calculated by conventional GM (1, 1) Model and Metabolism GM (1, 1) Model.

Conventional GM (1, 1) Model is applied in the modeling of the measured values of cotton output in China, which are 632.4, 571.4, 753.3, 762.4, 749.2, and 637.7. Considering the great randomness of data, weakening of the raw data is usually carried out in order to improve the precision of prediction, and to eliminate the interference on data. A first-order weakening operator commonly used is \( x^{(0)}(k) \) \[ d = \frac{1}{n-k+1} \left\{ x^{(0)}(k) + x^{(0)}(k+1) + \cdots + x^{(0)}(n) \right\}. \]

\[ \text{Table 1 Cotton output in China from the year 2004 to 2009} \times 10^4 \text{ t} \]

<table>
<thead>
<tr>
<th>Year</th>
<th>Conventional GM model</th>
<th>Metabolism GM model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measured value</td>
<td>Weakening</td>
</tr>
<tr>
<td>2004</td>
<td>632.4</td>
<td>692.072 2</td>
</tr>
<tr>
<td>2005</td>
<td>571.4</td>
<td>693.606 7</td>
</tr>
<tr>
<td>2006</td>
<td>753.3</td>
<td>693.308 3</td>
</tr>
<tr>
<td>2007</td>
<td>762.4</td>
<td>682.527 8</td>
</tr>
<tr>
<td>2008</td>
<td>749.2</td>
<td>665.575 0</td>
</tr>
<tr>
<td>2009</td>
<td>637.7</td>
<td>637.700 0</td>
</tr>
<tr>
<td>2010</td>
<td>634.030 8</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>665.575 0</td>
<td></td>
</tr>
</tbody>
</table>

The second-order weakening operator is \( D^2 \), \( x^{(0)} D^2 = \left( x^{(0)}(n) + \ldots + x^{(0)}(2) \right) \right\}, \] where \( x^{(0)}(k) \) \[ = \frac{1}{n-k+1} \left\{ x^{(0)}(k) + x^{(0)}(k+1) + \cdots + x^{(0)}(n) \right\}. \]

Thus, the measured value of cotton output after the second –order weakening is:

\( X^{(2)} = \{ 692.072 2, 693.606 7, 693.308 3, 682.527 8, 665.575 0, 637.700 0 \} \)

Through calculation, the forecast model of data after the second –order weakening is

\[ \hat{x}^{(2)}(k+1) = (692.072 2 - 723.867 8) e^{-0.020 5 k} + \frac{723.867 8}{0.020 5} - 34623 e^{-0.024 7 k} + 35315 \]

This model is used to carry out forecast and the fitted value is obtained:

\( \hat{x}^{(2)} = \{ 692.077 2, 702.458 0, 688.205 9, 674.242 9, 660.563 2, 647.161 1 \} \)

The average relative error is calculated

\[ \Delta = \frac{1}{6} \sum_{k=1}^{6} | \hat{x}^{(2)}(k) - x^{(2)}(k) | = 0.054 6. \]

Mode (4) is used to forecast the cotton output in the year 2010, and the forecast value is 6 340 308 tons. Forecast values of grain yield in China in 2010 are selected as the new modeling data. Then, data in the year 2004 are eliminated during modeling. We have the following forecast model:

\[ \hat{x}^{(1)}(k+1) = (693.606 7 - 721.395 8) e^{-0.024 7 k} + \frac{721.395 8}{0.024 7} - 28557 e^{-0.024 7 k} + 29251 \]

\[ \hat{x}^{(1)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(2)}(k) \]

Fitting value forecasted by this model is

\[ N\hat{x}^{(2)}(k) = (693.606 7, 695.675 8, 678.728 4, 662.194 0, 646.062 3, 630.323 6) \]

The average relative error is calculated

\[ \Delta = \frac{1}{6} \sum_{k=1}^{6} | \hat{x}^{(2)}(k) - N\hat{x}^{(2)}(k) | = 0.033 0. \]

Through comparison, it can be concluded that the prediction precision of the model with upgraded data is higher than the conventional forecast model. Thus, the Metabolism GM (1, 1) Model can improve the precision of prediction effectively. Moreover, according to the analysis on the average relative error, Metabolism GM (1, 1) Model has a precision of 3.3%, which is relatively high and can be used as the forecast model of cotton output in China. Thus, the five-dimensional gray metabolism model of cotton yield in China is obtained:

\[ \hat{x}^{(1)}(k+1) = -28557 e^{-0.024 7 k} + 29251 \]

\[ \hat{x}^{(1)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(2)}(k) \]

Based on this, the cotton output in the year 2011 is 6 149 683 tons.

### 3 Conclusion

China is a big agricultural country, and cotton is one of the major agricultural products. Thus, cotton is an important factor affects the income of farmers. Affected by the continuous rainy during boll opening and split boll stages in August 2010 in the Huanghe valley, some cotton areas were suffered from serious flood disasters, which was bad for the growth of cotton. And the unit yield of cotton declined, which greatly affected the output.
2.2 Perfecting the construction of rural infrastructure, establishing brand and widening the channels for collecting funds  
In the first place, the primary agricultural industrial cluster should perfect the construction of rural infrastructure and create favorable conditions for developing the cluster. For example, continuously perfecting the conditions of road and other infrastructure demanded by the other infrastructure, such as electric power and wells and so on. The value of social brand is bigger and bigger and the cluster should try to create its brand, so as to improve the competitiveness of cluster by relying on the power of brand. As the same time, the government should try to help farmers and processing enterprises to collect funds through many ways and approaches to solve the shortage of capital.

2.3 Greatly developing the related industries and pillar industries  
The related industries and pillar industries of the primary agricultural industrial cluster are scanty greatly, which greatly affects the competitiveness of cluster. The government should develop the related industries and pillar industries; improve the standardization, systemization of transaction; develop united logistics, especially, develop the development of cold chain logistics, so as to reduce the sections of circulation, lower the costs of circulation and transaction and some other costs to improve the competitiveness of cluster and promote the development of cluster. The government should try to solve the problems of shortage of capital encountered by the related industries to promote the rapid development of them. Meanwhile, the agricultural cluster should provide good equipments so as to strengthen the development of cluster.

2.4 The government should perfect the land transfer system, improve the organizational degree and cultivate the pillar industries  
The government should accelerate the system reform of land transfer; promote the appropriate scale operation of land; satisfy the intensive degree of agriculture; improve the organizational degree; reduce the problems bought by over-dispersed operation and lift the competitiveness of cluster. The processing enterprises of agro-products are the core of agricultural industrial cluster, so the cluster should be further developed. The development of pillar enterprises in particular can improve the competitiveness of cluster. So the pillar industries must be cultivated to promote the growth of cluster.

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of cotton in China, and led to the price rise of cotton. Therefore, government made a series of corresponding control policies. In August 10th, national reserve cotton was sold in order to control the price of cotton. And it will gradually return to normal levels when cotton is all picked. Based on the Gray Metabolic Forecast Model, forecast model of cotton yield in China is established; and the cotton output in the year 2011 is forecasted. Since there is great increase in the cotton price at present, farmers might plant more cotton in the year 2011 and the cotton output might increase greatly. Thus, government

2.5 The government should strengthen its support on cluster  
The government plays a major role in developing cluster and the public goods ( roads, brands) should be supplied by the government. For one thing, the government should try to construct the service system of developing cluster; increase the input on the infrastructure construction of cluster and create the brand of the cluster by the way of exhibition; for another thing, the government should create favorable environment for the development of cluster. The government can promote the benign competition of the cluster by using the related laws and regulations. Besides, the government can improve the overall competitiveness of the clusters by encouraging them to cooperate.

References


should strengthen the regulation, control the planting area of cotton, open up more sales channels for cotton, and effectively ensure the interests of cotton farmers.

References