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The Prediction of Energy Consumption Based on GM(1,1) Model in Hebei Province

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Abstract: According to the raw data of 1990-2009 total energy consumption in Hebei province, This article build a Grey Prediction System GM (1,1). Research indicates that the total energy consumption in Hebei province have increased in exponential way. The fitting accuracy of this predicting model is 92.30%, development coefficient reaches 0.04.So the predicting model GM (1,1) is suitable for the prediction model for long-term economic forecast. During period of "the Twelfth Five-year Plan", The total energy consumption in Hebei province is expected to increase with 8.97% rate, and it will reach 43601.16 10000 tons of SCE by 2015.

Keywords: grey forecasting, Energy consumption, GM (1, 1)

1 Introduction

The low efficiency of energy utilization in Hebei province gets more and more attention. In order to improve the energy efficiency in Hebei province, "the Twelfth Five-year Plan" of China puts forward: Continuing to give priority to the development of Saving, based on domestic and diversified development, protecting the environment, to strengthen international cooperation and mutual benefit, adjustment optimizes the energy structure, constructing the safety, stability and economic, clean modern energy industry system. And the total energy consumption of Hebei province is very large. The total energy consumption is 25418.79 10000 tons of SCE in Hebei province in 2009, while national total energy consumption is 306647 10000 tons of SCE. The total energy consumption in Hebei province amounting to 8.29%.It should take accountability of energy conservation and emissions reduction. So it would play great role to China's economic development that the predictive accuracy of the total energy consumption in Hebei province.

The study objects of Grey prediction system GM(1,1) model is an Uncertainty System, the information for this model is insufficient .GM(1,1) means that a system which part of information is known, and part of information is unknown. In recent years, gray forecast is more widely used and advantages of less sample data, computing convenient, short time forecast of high accuracy, and detected-ability owned by GM(1,1) have also been widely recognized in the academic circles. So according to the grey theory, through the generating method, the irregular data of system can become regular sequences that it can identify the uncertainties of system and predict the parameters of it.

2 Theory of GM(1, 1) model

The basic principle of grey forecasting is to make accumulation generation through the original series of discrete random data and get accumulation generation sequence with high index regularity. Then after parameter estimation, we can get the prediction through gradually minus the calculation. So a grey forecasting model GM(1,1)) was established. It has four steps: generating grey sequences, index rule inspection, model parameter estimation and model error inspection.

3 Forecasting model of the total energy consumption in Hebei

According to the theory of GM (1, 1) model and analysis steps, with the raw data of 1990-2009 total energy consumption in Hebei province from HEBEI ECONOMIC YEAR BOOK, This article established a forecasting model (Tab.1)

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Table 1: Table1 Primary Energy Consumption in Hebei Province

Year	**Total Energy consumption (10000 tons of SCE)**	**Year**	**Total Energy consumption (10000 tons of SCE)**
1990	6124.22	2000	11195.71
1991	6471.93	2001	12114.29
1992	6866.29	2002	13404.53
1993	7861.92	2003	15297.89
1994	8168.62	2004	17347.79
1995	8892.41	2005	19835.99
1996	8938.47	2006	21794.09
1997	9033.01	2007	23585.13
1998	9151.12	2008	24321.87
1999	9379.27	2009	25418.79

Step 1:Assume $x^{(0)}$as original discrete time variable

$$x^{(0)} = (x^{(0)}(1), x^{(0)}(2), ...x^{(0)}(19), x^{(0)}(20) = (6124.22, 6471.93, ...24321.87, 25418.79)$$

Calculate the accumulate sequence$x^{(0)}$**:**

$$x^{(1)} = (x^{(1)}(1), x^{(1)}(2), ...x^{(1)}(19), x^{(1)}(20)) = (6124.22, 12596.15, ...239784.6, 265203.3)$$

Step 2:Index rule inspection

First of all, set $X^{(0)}$ to authentic smoothness inspection:

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

$$\rho(4) = 0.403953461 < 0.5, \rho(5) = 0.298950094 < 0.5, ...$$

Therefore, when $k > 4$,the quasi smooth condition is satisfied.

Again, set $x^{(1)}$ for authentic index rule inspection.

$$\sigma^{(1)}(k) = \frac{x^{(1)}(k)}{x^{(1)}(k-1)}$$

Gain

$$\sigma^{(1)}(4) = 1.4039535 < 1.5, \sigma^{(1)}(5) = 1.2989501 < 1.5, ...$$

Therefore, when $k > 3$, quasi index rule satisfied. So it can be established for GM (1, 1) model.

Step 3: Columns $\hat{a} = [a, b]^T$ are parameters of the least-square estimation

$$\hat{a} = (B^T B)^{-1} B^T Y = \begin{bmatrix} \text{- } 0.085909989 \\ 4785.935951 \end{bmatrix}$$

Therefore, reflecting $\hat{x}^{(1)}$ and $\hat{x}^{(0)}$'s tendency of the development coefficient $-a$is -0.085909989, From the historical data of grey background value unearths the action b is 4785.935951

Step 4: make sure energy consumption forecasting model and the time response type

$$\begin{cases} \hat{x}^{(1)}(k) = \left[x^{(0)}(1) - \frac{b}{a}\right] e^{-a(k-1)} + \frac{b}{a} = 56742.66\text{exp}(0.08591\text{k}) - 55708.725 \\ \hat{x}^{(0)}(k) = \hat{x}^{(1)}(k) - \hat{x}^{(1)}(k-1) = 4671.236\text{exp}(0.08591\text{k}) \end{cases}$$

Above is the total energy consumption for GM (1, 1) of mathematical expressions.k is one time variable. Using the prediction model of Hebei province in 1990-2009 energy consumption of historical data fitting results see Fig.1.

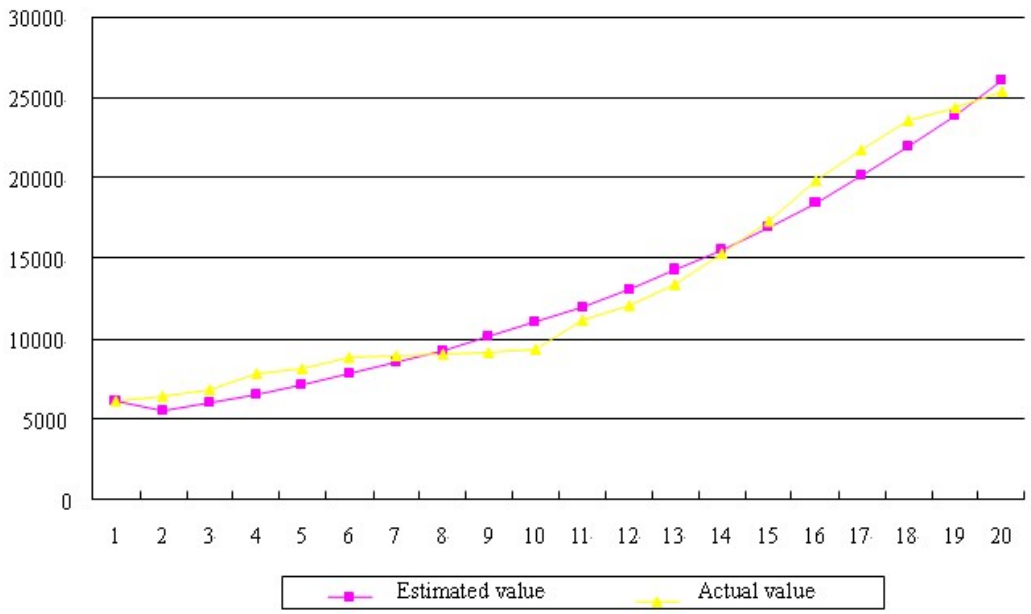

Figure 1: Hebei energy consumption forecasting model fitting effect

Step 5: model error inspection With the prediction model calculation simulation data, the absolute error and relative error see table 2. Respectively calculate original sequence and variance of residual sequence s_1 ands_2. Use this to calculate than mean variance$c$:

$$c = \frac{s_2}{s_1} = \frac{992.5926287}{6488.214857} = 0.152983933 < 0.35$$

Therefore, based on the error inspection standard, than mean variance is n small error probability level 1 of:

$$0.6745\text{s}1 = 4376.301$$

$$|\varepsilon(1) - \bar{\varepsilon}| = 230.0468795, |\varepsilon(2) - \bar{\varepsilon}| = 694.9578466, \ldots\ldots |\varepsilon(20) - \bar{\varepsilon}| = 850.9952363,$$

It were less than 4376.301

Therefore, cause$P = 100\% > 95\%$, based on the error inspection standards, small error probability for level 1, so the model can forecast it.

Step 6: Use the energy consumption forecasting model constructed in the forth step, predict Hebei energy consumption during"12th five-year" plan

$$\hat{x}^{(0)} = (\hat{x}^{(0)}(21), \hat{x}^{(0)}(22), \hat{x}^{(0)}(23), \hat{x}^{(0)}(24), \hat{x}^{(0)}(25), \hat{x}^{(0)}(26)) =$$
(28375.72,30921.25,33695.15,36717.88,40011.77,43601.16)

Therefore, during"12th five-year" plan Hebei province energy consumption is expected to increase from 30921.25 tons standard coal in 2011 to 43601.16 tons standard coal in 2015, 5 years average growth rate is 8.97%

4 Conclusions

4.1 The rule of the total energy consumption in Hebei

According to the raw data of 1990-2009 total energy consumption in Hebei province, Research indicates that the total energy consumption in Hebei province have increased in exponential way.

Table 2: Table2 Energy consumption forecasting model simulation result checkout

Serial number	year	Actual data	Estimated data	Absolute error	Relative error
1	1990	6124.22	6124.22	0	0.00%
2	1991	6471.93	5546.925	925.004726	14.29%
3	1992	6866.29	6044.53	821.759766	11.97%
4	1993	7861.92	6586.774	1275.145536	16.22%
5	1994	8168.62	7177.662	990.9575244	12.13%
6	1995	8892.41	7821.558	1070.851984	12.04%
7	1996	8938.47	8523.216	415.2537005	4.65%
8	1997	9033.01	9287.819	-254.809119	-2.82%
9	1998	9151.12	10121.01	-969.89312	-10.60%
10	1999	9379.27	11028.95	-1649.6815	-17.59%
11	2000	11195.71	12018.34	-822.629437	-7.35%
12	2001	12114.29	13096.48	-982.193637	-8.11%
13	2002	13404.53	14271.35	-866.816268	-6.47%
14	2003	15297.89	15551.6	-253.713769	-1.66%
15	2004	17347.79	16946.71	401.0790703	2.31%
16	2005	19835.99	18466.97	1369.019287	6.90%
17	2006	21794.09	20123.61	1670.479659	7.66%
18	2007	23585.13	21928.86	1656.265788	7.02%
19	2008	24321.87	23896.06	425.8057523	1.75%
20	2009	25418.79	26039.74	-620.948357	-2.44%

4.2 The forecasting model of total energy consumption in Hebei

$$x^{(0)}(n) = 4671.236\exp(0.08591(n - 1990))$$

$$n = 2011, 2012, 1013, 2014, ...$$

4.3 The development trend of energy consumption in Hebei

Using energy consumption forecasting model GM (1, 1), fitting value on the actual value of the fitting precision is 92.30%, Residual inspection, prediction effect very good, can objectively reflect the hebei province energy consumption growth trend.

4.4 The Prediction of the total energy consumption During period of "the Twelfth Five-year Plan"in Hebei

The GM (1, 1) model conforms to long-term forecast standards. During period of "the Twelfth Five-year Plan", The total energy consumption in Hebei province is expected to increase with 8.97% rate, and it will reach 43601.16 10000 tons of SCE by 2015.

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