Grey Prediction Analysis on Forestry Industrial Structure of China

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Abstract The grey relevance analysis is applied to study the 1996 – 2009 output value structure of China forestry system. Based on GM(1,1) model, information model is established to predict the forestry industrial structure of China in the next 10 years. Result shows that grey correlations between the three forestry industries and the forestry output value are 0.849 1, 0.731 1 and 0.821 3, respectively, with its order being secondary industry < tertiary industry < primary industry. Prediction result shows that forestry industry of China is in the middle stage of industrialization; and both secondary and tertiary industries will develop rapidly and become the leading industries.

Key words Forestry industrial structure, Grey correlation, Grey prediction, GM(1,1) model, China

After years of rapid development since the founding of China, China forestry has formed a comprehensive industrial system. As a basic industry of national economy, forestry industry shows rapid economic growth, playing an important role in promoting economic development, expanding employment, and ensuring the ecological safety[1]. Grey Correlation Model is used to analyze the structures of forestry three industries in China in the years 1996 – 2009, and to forecast the variation tendency of forestry industrial structure in the next 10 years, in order to provide an important theoretical basis for the appropriate policy making of forestry industrial structure.

1 Research method and data source

1.1 Research method Grey system theory is a new systematic subject established by Professor Deng Ju-long in the 1980s. And grey correlation degree model analysis is the most widely applied in this system theory. Grey correlation analysis is to find out the correlation, the principal contradiction, the main characteristics and main influencing factors among random factor sequences by certain data processing under the situation of incomplete information[2]. Grey correlation degree analysis uses the degree of correlation to describe the relative changes in factors during the system development based on grey system, that is the correlation of change size, direction and speed indices[3]. Its essence is to judge the correlation by the similarity of curve geometry of comparative sequence. During the system development, similar geometrical shape indicates close variation tendency of sequences and greater correlation[4].

1.1.1 Analysis steps of grey correlation.

(1) Determine the reference sequence and comparison sequence. Sequence composed by the annual forestry GDP is taken as the reference sequence X_0; and the comparison sequences of forestry three sequences are X_1, X_2 and X_3.

$$X_0 = \{X_0(K), K=1,2,3\cdots\}, X_1 = \{X_i(K), K=1,2,3\cdots\}$$

Dimensionless treatment on both reference sequence and comparison sequence is carried out, so as to obtain a group of fixed base development speed sequences.

(2) Calculate the difference sequence. After calculating the absolute difference $\Delta_{oi} = |X_o(K) - X_i(K)|$, we obtain an absolute difference sequence. Then, the maximum value Δ_{max} and minimum value Δ_{min} are found out in the absolute difference sequence.

(3) Calculate the correlation coefficients. Correlation coefficient $\varepsilon_i(K)$ reflects the correlation degree, the calculation equation of which is $\varepsilon_i(K) = \dfrac{\Delta_{min} + \rho \times \Delta_{max}}{\Delta_i(K) + \rho \times \Delta_{max}}$, where ρ is resolution coefficient with its value range being 0.1 – 0.5. In this research, we let $\rho = 0.5$.

(4) Calculate the correlation degree. Correlation degree γ_i is obtained according to the arithmetic mean value of $\varepsilon_i(K)$.

1.1.2 Calculation method of GM(1,1) model.

(1) Calculate the accumulation sequence and nearest neighbor sequence. If the original sequence is $X^{(0)} = [X^{(0)}(1), X^{(0)}(2), \cdots X^{(0)}(n)]$, its generation sequence 1 – AGO is:

$$X^{(1)} = [X^{(1)}(1), X^{(1)}(2), \cdots X^{(1)}(n)]$$

where, $X^{(1)}(K) = \sum_{i}^{K} X^{(0)}(i); K=1,2,\cdots n.$

$Z^{(1)}$ is the generation sequence of mean neighbor sequence of $X^{(1)}$:

$$Z^{(1)} = [Z^{(1)}(2), Z^{(1)}(3), \cdots Z^{(1)}(n)]$$

where $Z^{(1)}(K) = \dfrac{1}{2}[X^{(1)}(K) + X^{(1)}(K-1)]; K=2,3,\cdots n.$

(2) Estimate the parameter. Use $X^{(1)}(K)$ to establish the winterization equation of GM(1,1) grey differential equation:

$$\frac{d_{x^{(1)}}}{d_t} + \alpha X^{(1)} = b$$

where α and b are undetermined parameters, which are called the development grey number and the endogenous control grey

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number, respectively. If the vector of undetermined parameter is $\partial = [a, b]^T$, we have $Y = \begin{bmatrix} X^{(0)}(2) \\ X^{(0)}(3) \\ \vdots \\ X^{(0)}(n) \end{bmatrix}, B = \begin{bmatrix} -Z^{(1)}(2) & 1 \\ -Z^{(1)}(3) & 1 \\ -Z^{(1)}(2) & 1 \\ \vdots & \\ -Z^{(1)}(n) & 1 \end{bmatrix}$ according to the least square method. Thus, we have

$$\partial = (B^T B)^{-1} B^T Y$$

(3) Establish GM (1,1) prediction model. The time response sequence of GM (1,1) model $X^{(1)}(K) + \alpha Z^{(1)}(K) = b$ is

$$\hat{X}^{(1)}(K+1) = [X^{(0)}(1) - \frac{b}{a}]l^{-ak} + \frac{b}{a}, K=1,2,\cdots n$$

(4) Restore the predicted value. The following sequence is used to carry out the accumulative reduction of predicted value:

$$\hat{X}^{(1)}(K+1) = \hat{X}^{(0)}(K+1) - \hat{X}^{(1)}(K), K=1,2,\cdots n$$

(5) Carry out posterior error test. When the small error probability $P > 0.95$ and the posterior error ratio $C < 0.35$, the model belongs to first-order model. When the mean residual ratio is less than 5%, its predicted value meets the requirements of precision.

(6) Establish GM (1,1) Model group. Theoretically, GM (1,1) Model can forecast the indefinite future when it is time continuous function. However, in fact, during the development of a grey system, there will be some random perturbations or driving factors, which reduce the accuracy of system development and weaken the significance of prediction. This research conducts modeling in different time periods, selects the optimal data, and brings a new data into the model at anytime, so as to establish new information model to carry out dynamic prediction.

1.2 Data sources and description Data in this research are from the 1996 – 2009 *China Forestry Statistical Yearbook*[5]. Since the year 2003, the category of the output value of wood and bamboo logging industry has been transferred from the secondary industry into the primary industry. And the output value of forestry service industry is calculated into the primary industry in the years 2003 – 2007 and is then changed into tertiary industry in the years 2008 and 2009. Therefore, data after the year 2003 need to be adjusted. In other words, the output value of wood and bamboo logging industry should be deducted from the forestry primary industry and added into the secondary industry; while the output value of forestry service industry in the years 2003 – 2007 should be eliminated from the primary industry and calculated into the tertiary industry (Table 1).

2 Result and analysis

2.1 Analysis of correlation degree According to the calculation steps in "**1.1.1**", sequence of the correlation coefficient between the forestry three industries and the forestry output value is obtained (Table 2).

According to the calculation result in Table 1, arithmetic mean of the grey correlation coefficients between the forestry three industries and the forestry output value is calculated in the years 1996 – 2009. Thus, the grey correlation degrees of forestry three industries and the forestry output value are $\gamma_1 = 0.849\,1$, $\gamma_2 = 0.731\,1$ and $\gamma_3 = 0.821\,3$, that is $\gamma_2 < \gamma_3 < \gamma_1$.

Table 1 Constitution of the three industries and forestry GDP in China in the years 1996 – 2009 $\times 10^8$ yuan

Year	Total output value	Primary industry	Secondary industry	Tertiary industry
1996	1 707.76	1 186.08	427.39	94.29
1997	1 918.24	1 376.96	444.12	97.16
1998	2 727.84	1 903.09	716.23	108.52
1999	3 187.73	2 134.82	930.88	122.03
2000	3 555.47	2 389.30	1 034.60	131.57
2001	4 090.48	2 703.70	1 241.62	145.16
2002	4 634.24	2 911.72	1 485.69	236.83
2003	5 860.33	3 084.21	2 412.42	363.70
2004	6 892.21	3 416.29	2 995.70	480.22
2005	8 458.74	3 820.55	3 974.97	663.22
2006	10 652.21	4 019.59	5 821.16	811.46
2007	12 533.42	4 757.54	6 744.81	1 031.07
2008	14 406.41	5 544.46	7 652.61	1 209.34
2009	17 493.73	6 461.55	9 481.62	1 550.56

Table 2 Grey correlation coefficients between the forestry output value and the three industries in the years 1996 – 2009

Year	Primary industry	Secondary industry	Tertiary industry
1996	1	1	1
1997	0.993 7	0.986 1	0.984 7
1998	0.998 8	0.987 0	0.930 4
1999	0.988 9	0.950 4	0.912 5
2000	0.988 8	0.946 3	0.896 9
2001	0.981 0	0.921 3	0.874 6
2002	0.958 5	0.886 7	0.967 3
2003	0.877 8	0.729 6	0.933 5
2004	0.837 9	0.667 5	0.849 6
2005	0.775 1	0.578 7	0.741 6
2006	0.677 0	0.447 1	0.716 0
2007	0.642 1	0.414 3	0.624 1
2008	0.631 5	0.386 7	0.576 3
2009	0.554 6	0.333 3	0.490 5

Rank of the correlation degree shows that in the years 1996 – 2009, forestry output value in China has the strongest correlation with primary industry, and the weakest correlation with secondary industry. This indicates that forestry primary industry has hug impact on the development of forestry industry in China. Starting from the angle of the dynamic development of grey theory, forestry three industries in China in different stages are compared. It is concluded that the forestry primary industry in China shows a downward trend of correlation degree; and the secondary and tertiary industry show a stable upward trend. Development tendency of forestry industry structure will be gradually transferred from " primary, secondary, tertiary" into " tertiary, secondary, primary". This is because with the increasingly serious environmental problems and the protection policies of forestry resources, the scale of wood production in primary industry will be smaller. In the secondary industry, single operation and low-level processing of raw materials will gradually be changed into diversified management and comprehensive utilization, so as to improve the value added of forest products and to enlarge the scale of secondary industry. Tertiary industry, which is mainly the forest tourism and forest service, will be developed rapidly with the development of economy.

2.2 Development forecast of the output value of forestry industry in China According to the related principles and formulas in " **1. 1. 2** ", accumulation sequence (Table 3) and neighbour sequence (Table 4) are obtained.

Table 3 Piecewise model groups of the output values of forestry three industries in the years 1996 – 2009

Industry	Code of model	Period of years	Prediction model	Posterior error ratio C	Small error probability P	Average residual error rate // %
Primary industry	A_1	1996 – 2009	$13\ 385.98l^{-0.11\ 226\ k} - 12\ 199.9$	0.123 7	1	5.48
	A_1	1997 – 2009	$15\ 342.78l^{-0.110\ 196k} - 14\ 138.7$	0.125 7	1	4.34
Secondary industry	B_1	1996 – 2009	$2\ 621.51l^{-0.233\ 233k} - 2\ 194.12$	0.174 2	0.923	23.72
	B_2	1997 – 2009	$3234.17l^{-0.231\ 674k} - 2\ 806.78$	0.148 3	1	17.70
	B_3	1998 – 2009	$33\ 798.28l^{-0.230\ 695k} - 3.3370.85$	0.144 0	1	16.56
	B_4	1999 – 2009	$4\ 657.46l^{-0.229\ 567k} - 4\ 230.07$	0.144 4	1	16.33
	B_5	2000 – 2009	$5\ 987.01l^{-0.226\ 561\ k} - 5\ 559.62$	0.145 8	1	14.44
	B_6	2001 – 2009	$7\ 782.97l^{-0.22\ 118k} - 7\ 355.58$	0.149 7	1	11.79
	B_7	2002 – 2009	$10\ 622.74l^{-0.210\ 956k} - 1\ 015.35$	0.141 4	1	7.75
	B_8	2003 – 2009	$13\ 386.62l^{-0.203\ 671k} - 12\ 959.23$	0.141 4	1	7.06
	B_9	2004 – 2009	$188\ 883.76l^{-0.188\ 547k} - 18\ 456.37$	0.148 6	1	5.21
	B_{10}	2005 – 2009	$28\ 556.69l^{-0.163\ 302k} - 28\ 129.3$	0.089 5	1	1.97
Tertiary industry	C_1	1996 – 2009	$334.1l^{-0.245\ 232k} - 239.81$	0.134 7	1	18.84
	C_2	1997 – 2009	$425.83l^{-0.245\ 383k} - 331.54$	0.137 8	1	19.05
	C_3	1998 – 2009	$531.96l^{-0.244\ 867k} - 437.67$	33 0.129 1	1	19.05
	C_4	1999 – 2009	$669.03l^{-0.243\ 278k} - 574.74$	0.116 5	1	18.95
	C_5	2000 – 2009	$863.01l^{-0.239\ 457k} - 768.72$	0.105 0	1	14.49
	C_6	2001 – 2009	$1\ 150.91l^{-0.231\ 728k} - 1\ 056.62$	0.085 9	1	7.75
	C_7	2002 – 2009	$1\ 471.73l^{-0.22\ 382k} - 1\ 377.44$	0.070 5	1	4.29

Taking the output values of forestry three industries in Table 1 as the original series, different time segments are selected in the years 1996 – 2009 in order to generate module and to establish GM(1,1) model group (Table 3). Among the models selected, A_1 of primary industry, B_{12} of secondary industry, and C_7 of tertiary industry meet the requirements of posterior variance test, which is first-order model and has the highest prediction accuracy. Thus, models A_1, B_{12} and C_7 are selected.

According to the methods mentioned above, optimal model (Table 4) are selected so as to calculate the predictive values of forestry three industries in the years 2015 and 2020 (Table 5).

Table 4 The optimal forecasting model for forestry three industries

Industry	Prediction year	Period of years	Prediction model	Posterior error ratio C	Small error probability P	Average residual error rate // %
Primary industry	2015	2002 – 2014	$24\ 514.5l^{-111507K} - 23\ 328.42$	0.066 0	1	1.92
	2020	2007 – 2019	$43\ 892.29l^{-0.109\ 27k} - 42\ 706.21$	0.027 3	1	1.02
Secondary industry	2015	2009 – 2014	$54\ 374.73l^{-0.15914k} - 53\ 947.34$	0.012 8	1	0.27
	2020	2014 – 2019	$126\ 952.6l^{-0.152\ 428k} - 126\ 52.5.2$	0.006 0	1	0.26
Tertiary industry	2015	2006 – 2014	$3\ 547.6l^{-0.213\ 306k} - 3\ 454.31$	0.021 7	1	1.33
	2020	2011 – 2019	$10\ 953.24l^{-0.204\ 226k} - 10\ 858.95$	0.012 7	1	0.68

Table 5 Prediction result of forestry three industries

Prediction year	Total output value $\times 10^8$ yuan	Primary industry		Secondary industry		Tertiary industry	
		Output value $\times 10^8$ yuan	Annual average growth rate // %	Output value $\times 10^8$ yuan	Annual average growth rate // %	Output value $\times 10^8$ yuan	Annual average growth rate // %
2010	19 666.46	6 782.27	12.33	10 944.14	24.13	1 940.05	22.34
2015	41 631.63	11 798.57	12.17	24 246.56	22.37	5 586.50	22.64
2020	87 698.72	20 336.16	12.04	51 946.88	21.17	15 415.68	22.61

Table 5 shows that during the development of China forestry in the next 10 years, secondary industry will take a leading role in both output value and development speed. At the same time, tertiary industry which is at a disadvantage stage will obtain rapid development, which verifies the calculation result of grey correlation. Although forestry output value increases each year, the overall efficiency of forestry industry is low in China, which is manifested mainly in the aspects of low science and technology content of forestry products, the extensive economic growth pattern of forestry, and the low science and technology contribution rate of forestry industry. These problems should be solved during the future development of forestry industry, in order to realize the rational development of forestry industry.

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est rate, the short term of loan, the complex procedure, the limited payment ability of peasant households and the lack of loan knowledge, peasant households only get limited financial support, which has restricted the concurrent-business behavior of peasant households and its sustainable development. Therefore, government should establish a financial system suitable for the development of rural areas, improve the service quality and level of agriculture-related financial institutions, and provide more financial support for the concurrent business of peasant households.

3.3 Establishing information base for rural labor force; providing more information and channel for the concurrent business of peasant households There are few channels and little information for the peasant households to get concurrent business. Therefore, government should provide more information and channels for concurrent business, and encourage peasant household to run concurrent business. At the same time, government should establish information base for rural labor force, find out the status of the rural labor force, enhance the dynamic management of labor resources, and solve the problem of asymmetric information in the concurrent business of peasant households.

3.4 Enhancing the cultivation of farmers' market awareness; improving their ability to adapt to market economy In Karst mountainous area, farmers' market awareness is lacked due to the backward economic development and the traditional agricultural production mode. Therefore, government should propagate the knowledge of market economy through newspaper, magazine, brochure and other means, promote the cultivation of farmers' market awareness, enhance the enthusiasm of peasant households in participating in concurrent business, and improve the ability of peasant households to adapt to market economy.

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The rapid development of forestry tertiary industry will accelerate the development of forestry industry in future, which should be paid attention to during the industrial structure adjustment of forestry industry.

3 Conclusion and suggestion

3.1 Conclusion Forecast analysis on the forestry industrial structure in China by grey correlation degree shows that during the development of forestry over the past decade, industrial structure is improved; but the secondary industry, which will play a leading role in the future industrial development, now still relies on the traditional manufacture, not the growth of new industries. Forestry tertiary industry will exceed the primary industry and become the second largest power for the development of forestry industry in future.

3.2 Suggestion In the development of forestry industry in future, it is necessary to develop forest foods, forest tourism, wildlife breeding and utilization and other new industries based on the sustainable development of traditional industries. Thus, a new development pattern can be established to accelerate the development of forestry industry by commercial forest, to promote the development of resources cultivation industry by forest product industry, to speed up the forest service industry by forest tourism, to solve the problem of single wood operation of forestry industry in China and to realize the rationalization of forest industry structure.

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