Prediction of hospital health expenditure based on GM (1.1) grey clustering model

Mengjie Luo

School of Economics and Management, Beijing Jiaotong University, Beixiaguan, Beijing, China

21120556@bjtu.edu.cn

Abstract. This paper analyzes the current situation of the development of medical and health expenditure in China, and predicts the future development trend of medical and health expenditure in China by constructing GM (1,1) grey prediction model, in order to provide decision-making reference for the government and relevant departments. According to the China Health Statistical Yearbook from 2015 to 2020, the government health expenditure, social health expenditure and individual health expenditure were selected as indicators to construct a GM (1,1) grey prediction model to predict and analyze the development trend of hospital health expenditure in China from 2020 to 2025. The accuracy of the grey prediction model established according to each index was good, the model accuracy was high and the fitting degree was good, which could be used for medium and long term extrapolation forecast. The forecast results show that from 2020 to 2025, China 's government health care expenditure, social health care expenditure and personal health care expenditure will continue to increase, among which government health expenditure will grow the fastest and other indicators will grow slowly.

Keywords: hospital health expenditure; development trend; grey prediction model

1 Introduction

Total health expenditure is the total amount of health funds raised by a country or region from the whole society for carrying out health service activities within a certain period of time[3]. It reflects the level of health expenditure burden of government, society and individual residents under certain economic development conditions. This is an important issue of concern to policy makers about a country or a region government health expenditure, social health expenditure, personal health expenditure size should be how much[2]. To this end, economists have also been trying to find the optimal size for theoretical health spending. Assuming that there is an optimal scale of government expenditure in a certain time span, if the government investment is far less than the scale, it will lead to the shrinking of the health resources of the whole society or the increase of personal health expenses, thus damaging and reducing the public health benefits[4]. On

V. Escudero et al. (Eds.): BADS 2022, AHCS 11, pp. 1164–1169, 2023.
https://doi.org/10.2991/978-94-6463-102-9_120

the contrary, if the government investment is far more than that, on the one hand, it may cause the waste of social health resources. On the other hand, it will reduce and squeeze other public inputs, thus reducing the overall efficiency of public expenditure. According to China 's basic national conditions, it is proposed that the proportion of China 's total health expenditure in GDP will reach about 5 % by the end of this century, which means that the whole society should have 5 % of economic resources invested in the medical and health field[6].

2 Sources and methods

2.1 Source of data

The data of government health expenditure, social health expenditure and personal health expenditure in China Health Statistical Yearbook from 2015 to 2020 are selected as predictors.

2.2 Research methods

Grey prediction model is a prediction method about using a small amount of incomplete information to establish mathematical model and make predictions. I use the thinking method of operational research to scientifically predict the future to solve practical problems, formulate development strategies and policies, and make decisions on major issues. Prediction is based on the past and present development rules of objective things and describes and analyzes their future development trends and conditions by means of scientific methods to form scientific assumptions and judgments. This study predicts the development trend of health expenditure in China by constructing GM (1,1) grey prediction model[1,5].

2.3 Construction of GM (1.1) Model

The first step is to set the time series to:

$$x^{(0)} = \{x^{(0)}(t_1),\ x^{(0)}(t_2),\ \ldots,\ x^{(0)}(t_n)\} \tag{1}$$

Accumulate and generate the original sequence $x^{(0)}$ by data processing

$$x_k{}^{(1)} = \sum_{i=1}^{k} x_i{}^{(0)}, k = 1,2,\ldots,n \tag{2}$$

Therefore, the corresponding differential equation of GM (1.1) model is:

$$\frac{dx^{(1)}(t)}{dt} + ax^{(1)}(t) = b \tag{3}$$

Among them, a is the development coefficient, b is the grey action quantity, a and b are the main parameters of GM (1,1) grey prediction model, a can be used to judge the prediction period : 1) when $-a < 0.3$, the model can be used for medium and long

term prediction; 2) when $0.3 < -a < 0.5$, can be used for short-term forecast ; 3) when $0.5 < -a < 1.0$, the model needs to be corrected ; 4) When $-a > 1.0$, the GM (1,1) model cannot be used for prediction.

The second step is to construct data matrix B and data vector Y respectively:

$$B = \begin{pmatrix} -\frac{1}{2}\left[x^{(1)}(1) + x^{(1)}(2)\right] & \cdots & 1 \\ -\frac{1}{2}\left[x^{(1)}(2) + x^{(1)}(3)\right] & \cdots & 1 \\ \vdots & \ddots & \vdots \\ \frac{1}{2}\left[x^{(1)}(n-1) + x^{(1)}(n)\right] & \cdots & 1 \end{pmatrix} \tag{4}$$

$$Y = \begin{pmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{pmatrix} \tag{5}$$

Assuming that a $\hat{a}$ is the number of parameters to be estimated, then $\hat{a} = \binom{a}{u}$., it can be obtained by the least square method:

$$\hat{a} = (B^T B)^{-1} B^T Y \tag{6}$$

A prediction model can be obtained by establishing a model and solving the generated and restored values:

$$\hat{x}^{(1)}(k+1) = \left[x^{(1)}(1) - \frac{\hat{u}}{\hat{a}}\right] e^{-\hat{a}k} + \frac{\hat{u}}{\hat{a}} \tag{7}$$

The reduction value can be obtained from the accumulation:

$$\hat{X}^{(0)} = [\hat{X}^{(0)}(1),\ \hat{X}^{(0)}(2),\ n,\ \hat{X}^{(0)}(n)] \tag{8}$$

The third step is to test the model by posterior difference ratio:

$$C = \frac{S_2}{S_1} \tag{9}$$

where S_1 represents the variance of residuals and S_2 represents the variance of $x^{(0)}$. The model accuracy levels are shown in Table 1.

Table 1. Criterion of model accuracy [Owner-draw]

prediction precision grade	C
Level 1 (best)	C≤0.35
Level 2 (qualified)	0.35<C≤0.5
Level 3 (barely)	0.5<C≤0.65
Level 4 (unqualified)	0.65<C

China 's total health expenditure, government health expenditure, social health expenditure and personal health expenditure reached 7217.5 billion yuan, 21941.9 billion yuan, 30273.67 billion yuan and 19959.43 billion yuan respectively, accounting for

30.4 %, 41.94 %, 27.65 % and 7.1 % of the national total respectively by the end of 2020. Compared to 2015, the average annual growth rate of private hospitals were: 14.0 %, 20.8 %, 10.4 %, 17.1 %, 14.2 % from 2015 to 2020.

China 's government health expenditure, social health expenditure, personal health expenditure are rising trend from 2015 to 2020. In terms of total amount: social health expenditure is the largest, individual and social health expenditure is relatively small. In terms of growth rate; government health care expenditure growth is relatively large, social health expenditure is relatively slow and slightly downward trend, personal health care expenditure showed a steady upward trend. Thus, although spending on social health care has increased dramatically, even exceeding government spending, there is a downward trend after 2019 from 2015 to 2020

3 Establishment of health expenditure forecasting model in China

The first is the forecasting model of government health expenditure, which builds a time series according to Equation (1), and According to formula (2), the column is generated by accumulating constructions: (12475.28, 26385.59, 41591.46, 57990.59, 76007.54, 97949.44)

According to the formula (4) (5), the data matrix B and data vector Y are constructed. Let $\hat{a}$ be the number of parameters to be estimated, $\hat{a} = \binom{a}{u}$, using the least squares method to obtain $\hat{a} = (B^T B)^{-1} B^T Y$, a $= -0.113731944$, $= 11244.74423$, $\frac{u}{a} = -98870.58852$, then the prediction model of government health expenditure is:

$$\hat{x}^{(1)}(k+1) = (111345.8685)e^{0.113731944k} - 98870.58852 \tag{10}$$

According to the formula (9) and table 1, the posterior difference ratio C is 0.197544748, which is far less than 0.35 indicating that the accuracy of the model is very high. Therefore, the established prediction model can be used for medium- and long-term extrapolation prediction. Similarly available: individual health expenditures and social health expenditures can be predicted as shown in tables 3

3.1 Test of grey prediction model

To test the accuracy of GM (1.1) model, the average relative error and posteriori error ratio should be calculated respectively. The average relative errors of government health care expenditure are 0.035837, 0.011745, 0.026722, 0.047093 and 0.036647, respectively. The average relative errors of social health care expenditure are 0.04371, 0.002566, 0.031965, 0.040329 and 0.034622, respectively. The average relative errors of personal health expenditure are 0.022939, 0.004704, 0.016766, 0.016952 and 0.015356, respectively. The posterior difference ratios C of government health expenditure, social health expenditure and personal health expenditure were 0.197545,0.174436 and 0.096958 (less than 0.35). It shows that the high accuracy of

the constructed prediction model confirms that the fitting effect is ideal, and more accurate and reasonable prediction results can be obtained.

Table 2. China 's health expenditure forecast model level accuracy tes [Owner-draw]

index	forecasting model	posterior difference ratio	model accuracy
government health expenditure	$\hat{x}^{(1)}(k+1) = (111345.8685)e^{0.113731944k} - 98870.58852$	0.198	C≤0.35
social health expenditure	$\hat{x}^{(1)}(k+1) = (166598.746954922)e^{0.1130046129294k} - 150092.03695$	0.174	C≤0.35
personal health expenditure	$\hat{x}^{(1)}(k+1) = (131228.376822657)e^{0.098913041751584k} - 119235.726822657$	0.097	C≤0.35

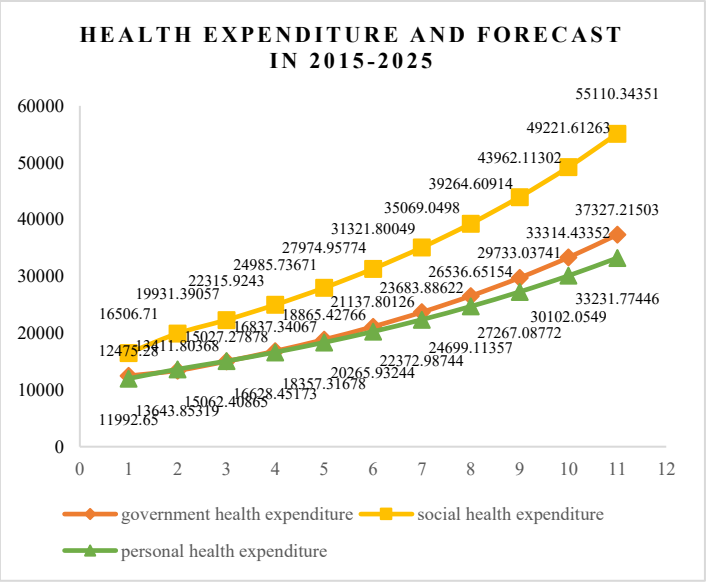

Fig. 1. Health Care Expenditure and Projected Trends 2015 – 2025[Owner-draw based on the model]

4 Conclusion

From the results of high-precision model test, the model can be used to forecast the health expenditure in the medium and long term. The total health expenditure and its composition will continue to rise from 2015 to 2025, and the total health expenditure will increase by 2 times (from 126.534 billion yuan to 394.296 billion yuan). The proportion of government health expenditure to total health expenditure will maintain a

slow and steady growth rate, and social health expenditure will increase the most, from 40.29 % to 43.85 %. On the contrary, the proportion of government health expenditure in total health expenditure decreased from 30.45 % to 29.70 %, and the proportion of personal health expenditure in total health expenditure decreased from 29.27 % to 26.44 %. The proportion of social health expenditure and the proportion of government and personal health expenditure showed a relationship of shift and change, which showed that the society invested more and more in medical and health care, the level of financing was higher and higher, and the financing structure was more equitable. It can be seen that the burden of medical expenditure of individuals and governments has gradually eased, and the level of health will continue to improve.

References

1. Chen Lu. Trend prediction and analysis of total health expenditure in Chongqing based on grey GM (1,1) model [J]. Economic Research Guide, 2022 (13): 108-110.
2. Liu Minquan, Li Xiaofei, Yu Jiantuo. Government health expenditure and its equity in China [J]. Journal of Nanjing University (Philosophy). Humanities. Social Science Edition), 2007 (03): 23-33.
3. Liu Junmin. Research on government health expenditure and management mechanism under public finance [J]. Economic Research Reference, 2005 (94): 2-20 + 37.
4. Dai Yingzi. Public Health Expenditure: Size and Allocation [J]. Fiscal Research, 2004 (06): 30-32.
5. Jiang Zhihua, Zhu Guobao. Grey prediction model GM (1,1) and its application in traffic volume prediction [J]. Journal of Wuhan University of Technology (Traffic Science and Engineering), 2004 (02): 305-307.
6. Zhao Yuxin, Wan Quan, Tao Sihai, Huang Jieping, Wang Li. Results and analysis of China 's total health expenditure in 2002 [J]. China Health Economy, 2004 (03): 5-10.
7. Mu Yong. Direct Modeling Method of Unbiased Grey GM (1,1) Model [J]. Systems Engineering and Electronic Technology, 2003 (09): 1094-1095 + 1107.