



Trend Prediction and Analysis of Total Health Expenditure in Jiangsu Province Based on Grey GM (1,1)

Jiawei Xu^(✉)

Business School, Hohai University, Nanjing 213000, China
1525977285@qq.com

Abstract. With the rapid development of the social economy, people's consumption level is increasing, and more attention is paid to health security. Especially in the context of the new coronavirus epidemic sweeping the world, people's demand for a healthy environment is more urgent. The environment is people's livelihood, environmental protection is to meet people's basic health needs. Based on this, China's annual investment in public health is increasing, and the total health expenditure is an important part of local government spending, especially in the more economically developed areas, the increase in health costs is more obvious. Therefore, this paper chooses Jiangsu Province as the research object to analyze the total health expenditure of Jiangsu Province in 2015 and 2019 and its composition, using the GM (1,1) grey prediction model to analyze the fluctuation of total health expenditure and the changing trend of financing structure in Jiangsu Province in the next 6 years, to provide a reference for relevant departments in Jiangsu Province to formulate and improve health policies, and also provide scientific and powerful data support for the formulation and adjustment of macro policies, and further promote the renewal and improvement of the medical and health system in Jiangsu Province. Based on the data results obtained by the grey prediction model, it is easy to know that the total health expenditure of Jiangsu Province increased from 488.546 billion yuan to 785.104 billion yuan from 2020 to 2025. The proportion of government health expenditure and personal health expenditure in total health expenditure decreased from 21.20% and 23.30% to 19.87% and 21.20%, respectively. The proportion of social health expenditure increased from 55.50% to 58.93%. To sum up, the total health expenditure in Jiangsu Province shows a steady growth trend, but the financing structure is imbalanced. The proportion of government health expenditure is relatively low, the proportion of social health expenditure is increasing yearly, and the proportion of personal health expenditure is decreasing year by year. Therefore, in the future, relevant departments should further optimize the financing structure and increase the government's financial investment in the field of health care, to rationalize the total health expenditure and financing structure of Jiangsu Province, and constantly deepen the reform of medical and health care to ensure the sustainable development of the health care system in Jiangsu Province.

Keywords: Total health expenditure · GM (1,1) model · Grey prediction · Jiangsu Province

1 Introduction

Total health expenditure refers to the total amount of funds consumed by the whole society for health services in a certain period (usually 1 year) in a country or region [1], reflecting the expenditure of the whole society on healthcare-related which plays an important role in promoting the development of national health and reducing the economic burden of public diseases [2]. In the ‘Healthy China 2030’ planning outline, new requirements have been put forward for total health expenditure. Scientific prediction and effective intervention will not only help the health sector to accurately control the direction of development but also coordinate the proportion of government, social and personal health expenditures and reduce the medical burden of grassroots residents [3]. With the continuous advancement of China’s medical and health reform, investment in the field of health care in Jiangsu Province is increasing. However, in this process, the financing structure of total health expenditure in Jiangsu Province is unbalanced. How to effectively curb the unreasonable growth of total health expenditure, optimize the health financing structure, and reduce the burden of people’s medical treatment, has become a key livelihood issue that government departments need to solve urgently. At present, academic research on the prediction of total health expenditure mainly includes the ARIMA model method, grey GM (1,1), neural network prediction model, and so on [4]. This paper takes the total health expenditure and financing composition of Jiangsu Province from 2015 to 2019 as the research object. By constructing the grey GM (1,1) model, this paper makes a scientific and reasonable prediction and analysis of the changing trend and structural change of the total health expenditure of Jiangsu Province from 2020 to 2025, to provide a reference for the relevant departments of Jiangsu Province to formulate and improve health policies, to further promote the sustainable development of the health care system in Jiangsu Province.

2 Sources and Methods

2.1 Source of Data

The relevant data on the composition of total health expenditure and financing in Jiangsu Province is derived from the 2017–2021 ‘China Health Statistics Yearbook’. The specific data are shown in Table 1.

2.2 Empirical Method

In this paper, the grey GM (1,1) prediction model is used to predict the fluctuation trend of total health expenditure and the change of financing structure in Jiangsu Province from 2020 to 2025. In 1982, Professor Deng Julong of Huazhong University of Science and Technology published the “control problem of the grey system”, which marked the advent of the grey system theory [5]. The grey system, as the name implies, is a system between the white system and the black system, that is, a system that contains both known information and unknown information or uncertain information. After more than 40 years of development, grey system theory has been widely used in social, economic,

Table 1. Financing of total health expenditure in Jiangsu Province, 2015–2019.

Year	Total health expenditure (billion yuan)	Government health expenditure		Social health expenditure		Personal health expenditure		Total health expenditure per capita (Yuan)
		Absolute number (billion yuan)	Percentage of total health expenditure (%)	Absolute number (billion yuan)	Percentage of total health expenditure (%)	Absolute number (billion yuan)	Percentage of total health expenditure (%)	
2015	2974.42	674.73	22.68	1496.00	50.30	803.69	27.02	3729.07
2016	3359.58	753.25	22.42	1754.96	52.24	851.37	25.34	4200.21
2017	3691.21	808.57	21.91	1979.83	53.64	902.81	24.46	4597.18
2018	4035.02	868.95	21.54	2209.81	54.77	956.25	23.70	5012.01
2019	4459.17	962.85	21.59	2426.12	54.41	1070.20	24.00	5525.61

and ecological research. GM (1,1) is a first-order differential equation model with one variable [6]. It has the advantages of small sample size, simple operation, and easy inspection, and is suitable for short-term and medium-term prediction.

- The original data sequence is constructed as:

$$X^{(0)} = \{X^{(0)}(1), X^{(0)}(2), \dots, X^{(0)}(n)\} \tag{1}$$

A cumulative generation process is performed on the original data, and the resulting sequence is:

$$X^{(1)} = \{X^{(1)}(1), X^{(1)}(2), \dots, X^{(1)}(n)\} \tag{2}$$

- Calculating the Adjacent Mean, $B^{(1)}(k)$ is the adjacent mean generating sequence of $X^{(1)}$:

$$B^{(1)}(k) = \frac{1}{2} [X^{(1)}(k) + X^{(1)}(k - 1)] \tag{3}$$

The differential equation of the grey GM (1,1) model is:

$$\frac{dX^{(1)}}{dt} + aX^{(1)} = \mu \tag{4}$$

In the formula, a called development grey number, μ is called endogenous control grey number.

- Using $X^{(0)}$ and $X^{(1)}$ to establish data B and data vector Y_n :

$$B = \begin{pmatrix} -\frac{1}{2}[X^{(1)}(1) + X^{(1)}(2)] & 1 \\ -\frac{1}{2}[X^{(1)}(2) + X^{(1)}(3)] & 1 \\ \vdots & \vdots \\ -\frac{1}{2}[X^{(1)}(n-1) + X^{(1)}(n)] & 1 \end{pmatrix}, Y_n = \begin{pmatrix} X^{(0)}(2) \\ X^{(0)}(3) \\ \vdots \\ X^{(0)}(n) \end{pmatrix}$$

- Using the principle of least squares calculation, solve μ and a:

$$\hat{a} = \begin{pmatrix} a \\ \mu \end{pmatrix} = (B^T B)^{-1} B^T Y_n \tag{5}$$

- Solve differential equations to derive prediction models:

$$X^{(1)}(k+1) = \left[X^{(0)}(1) - \frac{\mu}{a} \right] e^{-ak} + \frac{\mu}{a} \quad (6)$$

Calculated by matrix multiplication in order:

$$a = -0.094, \mu = 2918.682, \frac{\mu}{a} = -31049.8085, \left(X^{(0)}(1) - \frac{\mu}{a} \right) = 34024.2285$$

Therefore, the grey GM (1,1) prediction model of total health expenditure in Jiangsu Province is:

$$X^{(1)}(k+1) = 34024.2285e^{0.094k} - 31049.8085 \quad (7)$$

Similarly, the government, social, and personal health expenditure costs pass the grade ratio test. Through calculation, the prediction models of the three are:

Government health expenditure:

$$X^{(1)}(k+1) = 8739.32756e^{0.082k} - 8064.59756 \quad (8)$$

Social health expenditure:

$$X^{(1)}(k+1) = 15659.3925e^{0.107k} - 14163.3925 \quad (9)$$

Personal health expenditure:

$$X^{(1)}(k+1) = 10633.5058e^{0.076k} - 9829.81579 \quad (10)$$

- Test of Grey Prediction Model

To test the accuracy of the GM (1,1) model, the residual error, relative error, average relative error, small error probability, posterior error ratio, and accuracy should be calculated respectively. Through calculation, the average relative error of total health expenditure in Jiangsu Province is 0.00194, and the posterior error ratio is 0, indicating that the constructed prediction model has high accuracy. Similarly, the average relative errors of government health expenditure, social health expenditure, and personal health expenditure are 0.00635, 0.00543, and 0.01079 respectively, and the posterior difference ratios are 0.005, 0.002, and 0.02 respectively. This shows that the model fitting effect is ideal, and can be more accurate and reasonable prediction results.

3 Total Health Expenditure and Its Structure Prediction Results in Jiangsu Province

According to the prediction results of the above model with high precision, the grey GM (1,1) model can be used to predict the total health expenditure and its composition in Jiangsu Province in the medium and long term. Table 2 predicts that the total health expenditure and its financing structure in Jiangsu Province will continue to show an increasing trend from 2020 to 2025. With the annual increase of total health expenditure in Jiangsu Province, the government health expenditure shows an upward trend, but its annual proportion is the lowest, and it continues to show a downward trend, and the proportion of personal expenditure also shows a downward trend. Social health expenditure accounts for the largest proportion, more than half of which comes from social health expenditure, and it is increasing year by year.

Table 2. Financing projections for total health expenditure in Jiangsu Province, 2020–2025.

Year	Total health expenditure (billion yuan)	Government health expenditure (billion yuan)	Percentage of total health expenditure (%)	Social health expenditure (billion yuan)	Percentage of total health expenditure (%)	Personal health expenditure	Percentage of total health expenditure (%)
2020	4885.46	1036.01	21.20	2711.28	55.50	1138.17	23.30
2021	5369.57	1124.40	20.94	3017.08	56.19	1228.09	22.87
2022	5902.81	1220.33	20.67	3357.37	56.88	1325.11	22.45
2023	6490.28	1324.44	20.41	3736.05	57.56	1429.79	22.03
2024	7137.62	1437.44	20.14	4157.44	58.25	1542.74	21.61
2025	7851.04	1560.07	19.87	4626.35	58.93	1664.62	21.20

4 Conclusions and Discussions

The financing structure of total health expenditure in Jiangsu Province is unbalanced, and the proportion of government health expenditure is low. In terms of government health expenditure, the proportion of government health expenditure in Jiangsu Province is decreasing year by year, and it is expected that the proportion of government health expenditure may further decrease in the next six years. The problem of the low proportion of government health expenditure is not only in Jiangsu Province but also in the economically developed provinces and cities and even the whole country [7]. There is unbalanced development among regions, a large government financial gap, and serious population aging in Jiangsu Province [8], and the government financial expenditure is relatively dispersed. To better solve the contradiction between health care, to meet the basic medical and health services needs of the majority of residents, the government's financial investment has played a key role, China's new health care reform also tries to reflect this principle, but in the policy formulation and implementation process appears powerless [9]. To change this situation, our government must assume greater responsibility, adhere to serving the people wholeheartedly, and establish a long-term effective health financial investment mechanism.

In terms of social health expenditure, the proportion of social health expenditure in total health expenditure in Jiangsu Province from 2015 to 2019 was up to 54.41% and showed an increasing trend year by year. It is expected that in the next 6 years, social health expenditure will further increase, and the proportion will continue to increase. This shows that society's attention to health care is rising, and the investment in health care is also increasing. The "Implementation Opinions on Encouraging and Guiding the Accelerated Development of Social Medical Care" issued in 2015 gave social medical policy and financial support [10]. Therefore, to further increase social health expenditure, it is necessary to broaden social financing channels. Improve the existing medical system, to achieve full coverage of basic medical insurance under the premise of encouraging commercial medical insurance; at the same time, we will further expand the space for private medical institutions, implement a series of preferential tax policies, and subsidize private medical institutions to stimulate the development of private medical institutions.

In terms of personal health expenditure, the total personal health expenditure in Jiangsu Province increased year by year, and its proportion decreased steadily. The

proportion of residents' health expenditure can reflect the fairness of health expenditure financing in a country and region [11]. The "Healthy China 2030 Plan" issued and implemented by the CPC Central Committee and the State Council clearly states that the proportion of personal health expenditure is one of the main indicators for building a healthy China. According to the forecast results, personal health expenditure in Jiangsu Province in 2025 will be reduced to about 21.20%. To achieve the target value of 2030 (35%), it is necessary to further deepen the reform of medical and health care, promote the implementation of a hierarchical diagnosis and treatment system, increase the proportion of primary diagnosis, establish and improve the drug supply security system, increase the proportion of medical insurance reimbursement, and effectively reduce the cost of medical treatment.

References

1. Huang X G, Zhou L L and Wang Y 2006 *Health Economics*: p155.
2. Zhou M H and Feng Y 2019 Financing level and structure analysis of total health expenditure in Guizhou Province. *Medical and social*: p34–37.
3. Wang Y S, Li H Q and Sun H J 2020 Prediction and influencing factors of total health expenditure in China based on the grey Markov model. *Chinese Journal of Social Medicine*: p89–91.
4. Chen L 2022 Trend prediction and analysis of total health expenditure in Chongqing based on grey GM (1,1) model. *Economic Research Guide*: p108–110.
5. Cheng S Q and Hu W 2022 Based on the application of grey system theory in health test scores. *Modern business industry*: p183–184.
6. Cheng L B, Cai Z D and Zhou R 2009 *College Mathematics Experiment Course*. Beijing Institute of Technology Press, Beijing.
7. Dai S Y and Xu A J 2019 Source analysis of total health expenditure in Jiangsu Province from 2010 to 2017. *Health soft science*: p57–61.
8. Hu C Q 2019 *Research on the impact of population aging on the income and expenditure of pension insurance funds in Jiangsu Province*. Nanjing University of Posts and Telecommunications, Nanjing.
9. Wu T 2015 Government Health Expenditure Research-A Case Study of Jiangsu Province. *Health Economy Research*: p5–8.
10. Qian Z G, Wang Y C and Zhang M Q 2018 Analysis of the development status of private hospitals in Jiangsu Province and related issues. *China Research Hospital*: p9–13.
11. Ding H F, Gao K and Jiang M M 2020 Prediction of total health expenditure in Shanghai based on grey GM (1,1) model. *Medical and social*: p42–46.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

