Expenditure and Input of Chinese Community Health Service Institution: A Study Based on Grey System Theory

Bo Li\textsuperscript{1,2} and Qian LIU\textsuperscript{3,*}

\textsuperscript{1}International College of Business and Technology, Tianjin University of Technology, Tianjin 300384, China

\textsuperscript{2}Institute of Geographic Sciences and Natural Resources Research, China Academy of Science, Beijing 100101, China

\textsuperscript{3}School of Public Health, Tianjin Medical University, Tianjin 300070, China

*Corresponding author, E-mail: liuqian2010@tmu.edu.cn

Keywords: Community health service institution, Expenditure and input, Grey prediction model, Grey correlation analysis.

Abstract. Based on statistical data of expenditure and input of community health service institution in China, this paper predicts the growth of expenditure of community health service institution, and analyzes the relationship between expenditure and input of community health service institution in China, using GM(1, 1) Grey prediction model and Grey correlation analysis method. The results include: (1) the expenditure in 2020 will be three times as much as the expenditure of community health service institution in 2014; (2) in the inputs of community health service institution, the correlation between the number of health technical personnel and expenditure has the highest rank; (3) the correlations between expenditure and input factors including area of health professional houses, number of managerial personnel, number of logistics workers, number of medical beds, number of medical equipments priced 10,000 yuan and above, number of other technical personnel rank from two to seven. Based on the results, related conclusions could be drawn, including: (1) the input structure of medical personnel of community health service institution needs to be adjusted; (2) hardware inputs should be in line with the development requirement of community health service institution.

Introduction

The community health service plays a fundamental role in the national public health service system of China and is considered as an important safeguard of health for urban and rural residents. In the "Opinions on Deepening Medical and Health System Reform" by CPC Central Committee and State Council of China, it is clearly put forward that in order to strengthen the weak link in community health service system, new health care system based on community health service should be constructed and improved.

Developing community health service institutions and improving community health service capacity not only play an important role in the optimization of health resource allocation and mitigation of excessive pressure and burden on large-scale hospitals, but also play an important part in curbing the excessive growth of medical care and health service expenditure, which is conducive to easing the burden of medical expenses of both urban and rural residents.
There is a close relationship between medical health expense and expenditure of medical and health organization, thus it is of practical significance to analyze the expenditure of community health service institutions and the main influence factors of the expenditure. Although the existing literatures pay more attention to the efficiency of community health service institutions [1-4], some researchers have started to turn their attention to the excessive growth of medical care and public health expenditure and the determinants from the macroscopic perspective [5-6].

Based on the existing studies, using expenditure and investment data of Chinese community health service institutions from 2004 to 2013, this paper adopts GM(1, 1) grey prediction model to predict the growth of expenditure of Chinese community health service institutions from 2014-2020, and analyzes the correlation and relative order between the expenditure and input factors, thus providing policy references for curbing the excessive growth of expenditure of Chinese community health service institutions.

Research Method and Data

GM(1, 1) Grey Prediction Model

Grey System theory was first proposed by Deng in 1982[7]. Since then it has become a preferred method to study and model systems [8], which finds wide-range applications in biology engineering, sociology and economic science. GM(1, 1) is a well-studied prediction model based on Grey System theory. The details of the model could be described as follows.

First, through first-level accumulating generating operation on raw data sequence \( (X(0)) \), 1-AGO sequence \( (X(1)) \) could be obtained. Through mean generation with consecutive neighbors based on \( X(1) \), \( Z(1) \) sequence could be obtained. Then the basic form of GM(1, 1) model, a linear first-order differential equation of the estimation of cumulative sequence, could be established as follows:

\[
x^{(0)}(k) + az^{(1)}(k) = b
\]  

(1)

Where \( a \) represents the developing coefficient, \( b \) represents the grey input.

Based on (1), equation (2) could be established:

\[
dx^{(1)}/dt + ax^{(1)} = b
\]  

(2)

By solving equation (2), the following equation could be obtained:

\[
x^{(1)}(t) = (x^{(1)}(1) - b/a)e^{-at} + b/a
\]  

(3)

The corresponding predictive values could be obtained through least square method.

Grey Correlation Analysis

Grey correlation analysis method based on Deng’s Grey System theory was used in this study to analyze the correlation and relative order between the expenditure and input factors of Chinese community health service institutions. The details of the method could be expressed as follows.

First, through initial value treatment on raw data sequence, the dimensionless sequence could be obtained as the following equation.

\[
x' = x_i / x_i(1) = \left( x'i(1), x'i(2), ..., x'i(n) \right)
\]  

(4)

Where \( i = 0, 1, 2, ..., m \).
Second, differential sequence could be calculated as follows:
\[
\Delta_j(k) = |x_0'(k) - x_i'(k)|
\]  
(5)

Third, the grey correlation coefficient could be solved using the following equation.
\[
\gamma_{0i}(x_0(k), x_i(k)) = \frac{m + \xi M}{\Delta_i(K) + \xi M}
\]  
(6)

Where \( M \) is the maximal proximity, \( m \) is the minimal proximity, \( \gamma_{0i} \) is the grey correlation coefficient, \( \xi = 0.5 \).

Fourth, the grey correlation of \( x_0 \) and \( x_i \) could be calculated as follows:
\[
\gamma_{0i} = \frac{1}{n} \sum_{k=1}^{n} \gamma_{0i}(k)
\]  
(7)

Where \( i = 0, 1, 2, \ldots, m \).

Data

The data used in this paper is obtained from “China Health Statistical Yearbook” and “China Health and Family Planning Statistical Yearbook” from 2005 to 2014. The selected expenditure and input data and indicators of Chinese community health service institutions from 2004 to 2013 include: (1) aggregate expenditure of community health service institutions \( (x_0, 10,000 \text{ yuan}) \), deflated using CPI (base year: 2004), (2) number of medical beds \( (x_1) \); (3) number of health technical personnel \( (x_2, \text{ person}) \); (4) number of other technical personnel \( (x_3, \text{ person}) \); (5) number of managerial personnel \( (x_4, \text{ person}) \); (6) number of logistics workers \( (x_5, \text{ person}) \); (7) number of medical equipments priced 10,000 yuan and above \( (x_6) \); (8) area of health professional houses \( (x_7, \text{ m}^2) \).

Results of Empirical Study

Prediction of Expenditure of Community Health Service Institutions

Based on expenditure data of Chinese community health service institutions from 2004-2013, GM(1, 1) grey prediction model can be established. Through calculation, the model parameters can be solved and model reliability is verified. The parameters of GM(1, 1) grey prediction model established in the paper are: \( a = -0.1837 \), \( b = 1395989.366 \). Meanwhile, the average relative error of prediction is 17.71%. According to relevant literature, if relative error is smaller than 0.2, it could be considered as meeting the requirements \([9]\). Therefore, the prediction results of this paper are reliable. According to the calculation of the model, predicted expenditure of Chinese community health service institutions from 2014-2020 could be obtained, as shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Expenditure</td>
<td>8948727</td>
<td>10752882</td>
<td>12920774</td>
<td>15525734</td>
<td>18655882</td>
<td>22417099</td>
<td>26936616</td>
</tr>
</tbody>
</table>

As can be observed from Table 1 that the expenditure of Chinese community health service institutions presents a rising tendency in the near future, i.e., the predicted expenditure of Chinese community health service institutions in 2020 will be more than 30 times as much as
the expenditure in 2014. If the predicted tendency is left without intervention, it is likely that Chinese urban residents will suffer relatively large medical expense burden at community health service level in the future, which will definitely cause negative effects on the public health service system of China. As a result, it is necessary to further investigate influence factors of excessive growth of expenditure of Chinese community health service institutions.

**Grey Correlation Analysis of Expenditure and Input Factors of Community Health Service Institutions**

According to the grey correlation analysis method, initial value treatment is conducted on raw data sequences to get dimensionless differential sequences. The results are shown in Table 2.

Table 2. Calculation Results of Differential sequences through Grey Correlation Analysis.

<table>
<thead>
<tr>
<th>Sequence</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>\Delta x_r - x_j</td>
<td></td>
<td>\Delta x_r - x_j</td>
<td></td>
<td>\Delta x_r - x_j</td>
<td></td>
<td>\Delta x_r - x_j</td>
<td></td>
<td>\Delta x_r - x_j</td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>0.1804</td>
<td>0.7153</td>
<td>0.1319</td>
<td>2.8977</td>
<td>3.2913</td>
<td>4.2918</td>
<td>4.3226</td>
<td>4.339</td>
<td>2.9744</td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>0.0281</td>
<td>0.1277</td>
<td>2.174</td>
<td>0.1384</td>
<td>0.7401</td>
<td>0.7748</td>
<td>1.2849</td>
<td>1.912</td>
<td>2.5354</td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>0.188</td>
<td>0.3567</td>
<td>0.9829</td>
<td>3.8795</td>
<td>4.6076</td>
<td>6.1882</td>
<td>6.6856</td>
<td>6.3796</td>
<td>6.5185</td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>0.0337</td>
<td>0.4553</td>
<td>0.351</td>
<td>3.0123</td>
<td>3.2432</td>
<td>4.1407</td>
<td>3.6063</td>
<td>2.856</td>
<td>2.093</td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>0.0269</td>
<td>0.1895</td>
<td>0.0061</td>
<td>2.6714</td>
<td>2.9068</td>
<td>4.0281</td>
<td>4.4754</td>
<td>4.0689</td>
<td>3.5981</td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>0.2247</td>
<td>0.4507</td>
<td>0.3795</td>
<td>2.2955</td>
<td>2.7166</td>
<td>4.3547</td>
<td>5.0787</td>
<td>5.5031</td>
<td>6.3737</td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>0.2386</td>
<td>0.0032</td>
<td>0.6121</td>
<td>1.4613</td>
<td>1.9215</td>
<td>2.9353</td>
<td>2.9046</td>
<td>2.3666</td>
<td>1.9746</td>
<td></td>
</tr>
</tbody>
</table>

According to the difference sequence, the maximal and minimal proximities could be solved: $M = 6.6856$, $m = 0$. Furthermore, grey correlations between expenditure (sequence $x_0$) and input factors ($x_1 \sim x_7$) of Chinese community health service institutions could be solved. The results are shown in Table 3.

Table 3. Grey correlations of expenditure and input factors of community health service institutions.

<table>
<thead>
<tr>
<th>Factors</th>
<th>$\gamma_{01}$</th>
<th>$\gamma_{02}$</th>
<th>$\gamma_{03}$</th>
<th>$\gamma_{04}$</th>
<th>$\gamma_{05}$</th>
<th>$\gamma_{06}$</th>
<th>$\gamma_{07}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation</td>
<td>0.661</td>
<td>0.8079</td>
<td>0.5873</td>
<td>0.6891</td>
<td>0.6641</td>
<td>0.6414</td>
<td>0.739</td>
</tr>
<tr>
<td>Order</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>2</td>
</tr>
</tbody>
</table>

According to the correlation results in Table 3, among the input factors that have influences on expenditure of Chinese community health service institutions, the degree of correlation between expenditure and number of health technical personnel is the highest among all the correlations. Area of health professional houses, number of managerial personnel, number of logistics workers, number of medical beds, number of medical equipments priced 10,000 yuan and above, and number of other technical personnel take the second place to seventh place in the correlation degree with expenditure of Chinese community health service institutions.

**The Personnel Input Structure Should be Adjusted**

From the research results of the paper, it is clear that among various input factors, the number of health technical personnel is the most closely correlated factor with expenditure of Chinese community health service institutions, whereas the number of managerial personnel, the number of logistics workers, and the number of other technical personnel take the third, fourth, and seventh places in the correlation degree with expenditure. The results indicate that there
exists unbalance problem in the personnel input structure of current Chinese community health service institutions.

On one hand, it is necessary to appropriately use more input on health technical personnel in order to attract more talents and retain them. Only in doing so, highly skilled community health service staff could be establish and maintained to guarantee the successful construction and smooth operation of multi-level medical care and health service system and two-way referral system.

On the other hand, it is necessary to control the preferential input on health technical personnel within an appropriate limit, so that effective performance incentive could obtained, excessive disparity of inputs on different categories of staff could be avoided, and a stable Chinese community health service team could be maintained.

The Hardware Input Should Meet the Development Requirement

As can be seen through further analysis of the empirical results of this paper, area of health professional houses, number of medical beds, and number of medical equipments priced 10,000 yuan and above take the second, fifth, and sixth places in the correlation degree with expenditure. The results indicate that in the input of current Chinese community health service institutions, the enlargement of area of health professional houses are more effective than the effects of increase in number of medical beds and number of equipments.

In a multilevel classified medical care and health service system, the main orientation for community health service institutions is the rehabilitation and minor disease therapy, which fundamentally requires relatively large area of health professional houses. Therefore, it is necessary to spend relatively more input on spatial enlargement of Chinese community health service. However it should be noticed that the input in beds and medical equipments should not be ignored. Furthermore, the growth of buildings should be effectively controlled within a reasonable limit, so that the balance between house input and medical equipment input could be maintained.

On one hand, improvement of medical skill level in community health service institutions requires both highly skilled health professional staff and advanced medical equipments. Only the coordination of both factors could facilitate sustainable development of Chinese community health institutions.

On the other hand, the spatial enlargement should be coupled with corresponding level of medical facilities such as equipments and beds, so as to give full play of Chinese community health service institutions in the national medical care and health service system of China.

Conclusions

Based on statistical data for expenditure and input of community health service institution in China from 2004 to 2013, using GM(1, 1) grey prediction model and grey correlation analysis method, this paper predicts the growth of expenditure of community health service institution, and analyzes the relationship between expenditure and input of community health service institution in China. The empirical results show that first, the expenditure in 2020 will be three times as much as the expenditure of community health service institution in 2014; second, in the considered inputs of community health service institution, the correlation between the number of health technical personnel and expenditure has the highest rank; third, the correlations
between expenditure and input factors including area of health professional houses, number of managerial personnel, number of logistics workers, number of medical beds, number of medical equipments priced 10,000 yuan and above, number of other technical personnel have the ranks from two to seven. Therefore, the input structure of medical personnel of community health service institution needs to be adjusted, and the hardware inputs should be in line with the development requirement of community health service institution.

**Acknowledgement**

This research was financially supported by the Project of Humanities and Social Science Research Foundation of China Ministry of Education (No. 16YJCZ040).

**References**


