

Evaluation of the Medical and Health System Reform in China: Based on the Fuzz Comprehensive Evaluation Method

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Abstract: This paper aims to explore the application of the fuzzy comprehensive evaluation method in the evaluation of the medical and health system reform by establishing an evaluation index system. Index weights were determined by means of factor analysis and analytic hierarchy process (AHP), while fuzzy membership functions were used to determine the subordination grades of the evaluated objects on different indexes. Based on that, the fuzzy comprehensive evaluation results and comprehensive scores of 31 provinces, municipalities and autonomous regions in different subordination levels in China were obtained by constructing Multi-level Comprehensive Evaluation Model. The results indicated that the effect of the reform of the medical and health system was relevant to local economic development level to some extent, while both commonalities and differences exist in the results of comprehensive evaluation performance among different regions. To improve the performance of the medical and health system, practical and feasible reform measures need to be put forward based on local realities.

Keywords: Fuzzy Comprehensive Evaluation, Membership Function, AHP, Factor Analysis, Medical and Health System Reform

1. Introduction

As of 2018, the new medical reform has been in progress for nine years. China's medical reform program, aiming at addressing difficulties and high expense in medical care, has realized institutionally full coverage of the whole population by the basic medical insurance through increasing the government's input into the healthcare and adhering to the principle of "giving subsidies to both supply and demand sides", with the new rural cooperative medical system (NCMS) even integrated with the medical insurance for urban residents (MIUR) in some areas. Statistics show that the proportion of public financing in China's total health expenditure has increased from 49.1% in 2008 to 65.8% in 2013. In the suggestions about the reform of county- and city-level public hospitals announced by the General Office of the State Council, substantive actions and targets were put forward compared with the previous ones [1, 2]. With reforms of the supply and demand sides advancing continuously, the effect of the implemented reform of the

medical and health system and the fact whether the reform addresses the problems in accessing medical care for and reducing the medical burden of the masses have become key issues deserving attention.

2. Materials and Methods

2.1. Selection of Indexes

Since the new medical reform started in 2009, the World Health Organization (WHO) has designed a monitoring and evaluation framework for China's current medical and health system reform from a global perspective, which comprises a continuous progress of four stages (i.e., Input & Process-Output-Result-Effect) to evaluate the effect of the medical and health system reform [3]. Besides, some research institutions, such as the research groups from the Institute of Population Research, Peking University and Shanghai Jiao Tong University, have also evaluated the effect of China's medical and health system reform in succession [4]. However, the existing evaluation frameworks and

indexes mainly focus on the micro level but ignore the macro level, for example, such factors as the level of social and economic development in different regions as well as the economic burden of people for medical treatment are not taken into account. In this article, an index system is established based on three dimensions, i.e., social and economic conditions, medical resource conditions and residents seeking medical treatment, with which the empirical research on the implementation effect of the medical and health system reform in all regions of China is conducted.

2.2. Data Source

The samples in this paper are 31 provinces, municipalities and autonomous regions of China, while the empirical data comes from China Statistical Yearbook 2014 and China Health Statistical Yearbook 2014.

The dimensions of different indexes are greatly different and cannot be directly used for the comprehensive evaluation. Therefore, the original data of each index needs to be nondimensionalized, which is done with the Z-score function of SPSS 17.0 in this paper. Besides, the eight indexes under the dimension of residents seeking medical treatment are low-priority indexes, so the reciprocal values of their original data are used for the empirical data analysis.

2.3. Evaluation Methods and Models

2.3.1. Determination of the Evaluation Factor Set

The first layer of the evaluation factor set is the evaluation criteria layer, that is, the overall objective layer, denoted as $X = (X_1, X_2, \dots, X_N)$; the second layer is the evaluation factor layer, which is the decomposition of the overall goal, and is

denoted as $X_i = (X_{i1}, X_{i2}, \dots, X_{iN})$; and the third layer is the evaluation index layer, which is composed of statistical indexes that reflect the evaluation objectives, and is denoted as $X_{ik} = (X_{ik1}, X_{ik2}, \dots, X_{ikm})$.

2.3.2. Determination of Weight

In order to eliminate the effect of subjective factors, factor analysis and AHP are used to determine the index weights [5]. The factor analysis is used to determine the weights of the second- and third-grade indexes. First, the factor analysis is performed on the nondimensionalized indexes. Following the principle that the eigenvalue is greater than 1, the varimax orthogonal rotation method is used to rotate the factor load matrix to extract the primary factors in the three layers of social and economic conditions, medical resource conditions and residents seeking medical treatment. Then, the original indexes obtained are unitized by the load vector of each primary factor, and the weight vectors of indexes of the three grades in the index system can be obtained. Afterwards, the extracted primary factors are used as the second-grade indexes of the index system, and are unitized based on their contribution to higher-grade indexes, so as to obtain the weight vectors of second-grade indexes. The weights of the first-grade indexes are determined with AHP in the following steps:

1) Construct a pairwise comparison judgment matrix

The pairwise comparative judgment matrix of AHP reflects the relationships between factors with hierarchical structures, and gives a scale based on the importance of the measured objectives. If the importance of factor i and factor j is in the proportion of a_{ij} , the importance of factor j and factor i is in the proportion of $a_{ji} = \frac{1}{a_{ij}}$.

Table 1. Standard Table for Comparing Scores at Different Levels.

Scale	Relative importance	Notes
1	Equally important	The two have the same contribution to the goal
3	Slightly more important	One evaluation is slightly more favorable than the other one based on experience
5	Fundamentally important	One evaluation is more favorable than the other one based on experience
7	Really important	One evaluation is more favorable than the other one, which is proved
9	Absolutely important	Obvious degree of importance
2, 4, 6, 8	Indicate the median values of the adjacency determinations above	

2) Calculation Consistency Index:

The CI (Consistency Index) of the judgment matrix is:

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

The greater the value of CI, the greater the deviation of the judgment matrix from the complete consistency, while the

smaller the value of CI, the closer the judgment matrix to complete consistency.

3) RI is obtained based on the order look up table of the judgment matrix. See Table 2 for the RI (Random Index).

Table 2. RI Value Table.

Matrix order	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The relative consistency index can be calculated as: $CR = CI/RI$ (When $CR \leq 0.1$, the judgment matrix is considered to meet the conditions of consistency check)

4) By calculating the maximum eigenvalues of the judgment matrix and unitizing the corresponding

eigenvectors, the weight vectors corresponding to the first-grade indexes can be obtained.

Here, the weight vectors of the first-grade indexes are denoted as $A = (a_1, a_2, \dots, a_n)$, those of the second-grade indexes $A_i = (a_{i1}, a_{i2}, \dots, a_{in})$, and those of the third-grade indexes

$A_{ik} = (a_{ik1}, a_{ik2}, \dots, a_{ikm})$, wherein $0 < a_n, a_{iN}, a_{ikm} < 1$, and $\sum_{i=1}^n a_i = \sum_{k=1}^N a_{ik} = \sum_{j=1}^m a_{ikj} = 1$.

2.3.3. Determination of Evaluation Grades and Membership Functions

With 5 evaluation grades, the effect of the reform of the medical and health system in each region can be better compared. In this paper, the change intervals of the sample index data are divided based on the mean values of the sample index data to achieve more uniform distribution of the sample data. Given there are n sample data k_1, k_2, \dots, k_n corresponding to each third-grade index X_i , d_1, d_2, d_3, d_4, d_5 are the level values of five evaluation grades, i.e., Very Poor, Poor, Average, Good, Very Good, then: the level value of Grade Very Poor is $d_1 = \min(k_1, k_2, \dots, k_n)$; that of Grade Poor $d_2 = \frac{1}{s_{\text{num}}} \sum_{i=1}^{s_{\text{num}}} K_s$; that of Grade Average $d_3 = \frac{1}{n} \sum_{i=1}^n K_n$; that of Grade Good $d_4 = \frac{1}{l_{\text{num}}} \sum_{i=1}^{l_{\text{num}}} K_l$; that of Grade Very Good $d_5 = \max(k_1, k_2, \dots, k_n)$, wherein K_s represents the sample data below the level value of Grade Average d_3 among all sample data, with s_{num} in total; while K_l represents that above d_3 , with l_{num} in total. For convenient calculation, the membership functions $X_i^{(j)}$ corresponding to Grade V_j (Very Poor, Poor, Average, Good, Very Good) ($j = 1, 2, 3, 4, 5$) are established separately.

(1) The index X_i is the member of the membership function for low grade level.

$$X_i^{(1)} = \begin{cases} 1 & x = d_1 \\ \frac{d_2 - x}{d_2 - d_1} & d_1 < x < d_2 \\ 0 & \text{Others} \end{cases}$$

(2) The index X_i is the member of the membership function for lower grade level.

$$X_i^{(2)} = \begin{cases} 0 & \text{Others} \\ \frac{d_3 - x}{d_3 - d_2} & d_2 < x < d_3 \\ \frac{x - d_1}{d_2 - d_1} & d_1 < x < d_2 \\ 1 & x = d_2 \end{cases}$$

(3) The index X_i is the member of the membership function for average grade level.

$$X_i^{(3)} = \begin{cases} 0 & \text{Others} \\ \frac{d_4 - x}{d_4 - d_3} & d_3 < x < d_4 \\ \frac{x - d_2}{d_3 - d_2} & d_2 < x < d_3 \\ 1 & x = d_3 \end{cases}$$

(4) The index X_i is the member of the membership function for higher grade level.

$$X_i^{(4)} = \begin{cases} 0 & \text{Others} \\ \frac{d_5 - x}{d_5 - d_4} & d_4 < x < d_5 \\ \frac{x - d_3}{d_4 - d_3} & d_3 < x < d_4 \\ 1 & x = d_4 \end{cases}$$

(5) The index X_i is the member of the membership function for high grade level.

$$X_i^{(5)} = \begin{cases} 1 & x = d_5 \\ \frac{x - d_4}{d_5 - d_4} & d_4 < x < d_5 \\ 0 & \text{Others} \end{cases}$$

The fuzzy set that maps the object to be evaluated to V_j ($j = 1, 2, 3, 4, 5$) by means of the membership function on each evaluation index is denoted as $(r_{ikj1}, r_{ikj2}, \dots, r_{ikjp})$, so the evaluation matrix of the second-grade index can be expressed as $R_{ik} = \begin{pmatrix} r_{ik11} & r_{ik12} & \dots & r_{ik1p} \\ \vdots & \vdots & \ddots & \vdots \\ r_{ikj1} & r_{ikj2} & \dots & r_{ikjp} \end{pmatrix}$.

2.3.4. Multi-level Comprehensive Evaluation Model

The preliminary comprehensive evaluation is the comprehensive evaluation of m factors of each $X_{ik} = (X_{ik1}, X_{ik2}, \dots, X_{ikm})$ based on initial models, which obtains the membership grade vector $B_{ik} = A_{ik} \circ R_{ik} = (b_{ik1} \ b_{ik2} \ b_{ik3} \ b_{ik4} \ b_{ik5})$ of X_{ik} . Then a second-grade evaluation is performed on $X_i = (X_{i1}, X_{i2}, \dots, X_{iN})$ using the membership grade vector B_{ik} of each second-grade index X_{ik} , so as to obtain the membership grade vector $B_i = A_i \circ R_i = (b_{i1} \ b_{i2} \ b_{i3} \ b_{i4} \ b_{i5})$ of the first-grade index X_i . Finally, the total goal membership degree

vector $B = A \circ R = A \circ \begin{pmatrix} B_1 \\ B_2 \\ \vdots \\ B_N \end{pmatrix} = (b_1 \ b_2 \ b_3 \ b_4 \ b_5)$ of

the total goal $X = (X_1, X_2, \dots, X_N)$ is obtained.

In order to highlight the differences between grades, the scores of the Grades I, II, III, IV, and V are set as 1, 4, 9, 16 and 25. Let $\gamma = (1 \ 4 \ 9 \ 16 \ 25)$, then the total evaluation score of the medical and health system reform in different regions can be obtained: $\text{Score} = B \cdot \gamma^T$.

3. Empirical Results

The following results are obtained according to the fuzzy comprehensive evaluations of the effect of the medical and health system reform in 31 provinces, autonomous regions and municipalities in China.

3.1. Index System and Weights

With the index system hierarchicalized and index weights determined, the index system obtained is shown in the following table:

Table 3. The Evaluation Index System and Weights of the Medical and Health System Reform.

First-grade indexes	Weights of first-grade indexes	Second-grade indexes	Weights of second-grade indexes	Third-grade indexes	Weights of third-grade indexes
Social and economic conditions X_1	0.105	Economic level X_{11}	0.613	Local fiscal revenue (in 100 million yuan) X_{111}	0.119
				General budget revenue (in 100 million yuan) X_{112}	0.117
				Per capita fiscal revenue (yuan) X_{113}	0.156
				Per capita GDP (yuan) X_{114}	0.156
				Per capita disposable income of urban residents (yuan) X_{115}	0.157
		Social Security X_{12}	0.387	Per capita net income of rural residents (yuan) X_{116}	0.158
				Per capita funding of NCMS (yuan) X_{117}	0.137
				Number of rural residents participating in NCMS (10,000) X_{121}	0.271
				Number of urban residents participating in MIUR (10,000) X_{122}	0.216
				Number of urban workers participating in MIUR (10,000) X_{123}	0.216
Medical resource level X_2	0.258	Financial investment in medical and health services X_{21}	0.701	Total population at the end of year (10,000) X_{124}	0.297
				Proportion of medical & health expenditure in public finance expenditure (%) X_{211}	0.489
				Proportion of financial subsidy in total revenue of medical and health institutions (%) X_{212}	0.511
				The proportion of medical service providers' investment in fiscal expenditure in the medical and health system (%) X_{221}	0.241
		Provision of medical services X_{22}	0.295	Number of medical workers per 1,000 people X_{222}	0.260
				Number of licensed (assistant) physicians per 1,000 people X_{223}	0.258
				Number of general practitioners per 10,000 people X_{224}	0.241
				Number of outpatient/emergency admissions per 100 people X_{311}	0.318
				Hospitalization rate of residents (%) X_{312}	0.427
				Average length of stay X_{313}	0.255
Residents seeking medical treatment X_3	0.637	Hospitalization X_{31}	0.428	Average hospital visits of residents X_{321}	0.304
				Average outpatient medical expenses per person/time (yuan) X_{322}	0.348
				Per capita medical expenses of inpatients (yuan) X_{323}	0.348
				Proportion of urban residents' health care expenditure (%) X_{3311}	0.508
		Medical expenses X_{32}	0.292	Proportion of rural residents' health care expenditure (%) X_{332}	0.492
		Medical burden X_{33}	0.280		

3.2. Results of Fuzzy Comprehensive Evaluation

The membership degree vectors of the total goals obtained in each region at the five evaluation grades are shown in Table 4, and the comprehensive score and ranking of each region are calculated based on the scores 1, 4, 9, 16 and 25 of the five grades.

Table 4. The Membership Degree Vectors at Five Evaluation Grades and Comprehensive Score of Each Region.

	b_1	b_2	b_3	b_4	b_5	Comprehensive Score	Ranking
Beijing	[0.273	0.139	0.288	0.104	0.195]	9.976	6
Tianjin	[0.178	0.382	0.126	0.202	0.092]	8.542	17
Hebei	[0.098	0.344	0.335	0.150	0.071]	8.691	16
Shanxi	[0.052	0.343	0.377	0.181	0.046]	8.861	14
Inner Mongolia	[0.065	0.393	0.274	0.262	0.006]	8.449	18
Liaoning	[0.222	0.366	0.309	0.102	0.000]	6.114	30
Jilin	[0.168	0.266	0.347	0.202	0.016]	7.994	22
Heilongjiang	[0.177	0.455	0.275	0.036	0.057]	6.467	28
Shanghai	[0.228	0.226	0.173	0.123	0.249]	10.879	4
Jiangsu	[0.079	0.310	0.414	0.174	0.023]	8.396	19
Zhejiang	[0.061	0.245	0.286	0.364	0.042]	10.504	5
Anhui	[0.060	0.412	0.238	0.231	0.059]	9.009	13

	b₁	b₂	b₃	b₄	b₅	Comprehensive Score	Ranking
Fujian	[0.004	0.156	0.474	0.257	0.107]	11.707	2
Jiangxi	[0.109	0.279	0.230	0.370	0.011]	9.493	10
Shandong	[0.072	0.360	0.367	0.182	0.018]	8.184	21
Henan	[0.138	0.371	0.259	0.111	0.120]	8.739	15
Hubei	[0.109	0.456	0.345	0.088	0.000]	6.464	29
Hunan	[0.197	0.344	0.227	0.212	0.019]	7.492	25
Guangdong	[0.080	0.132	0.383	0.287	0.098]	11.338	3
Guangxi	[0.086	0.339	0.300	0.177	0.097]	9.406	11
Hainan	[0.044	0.197	0.464	0.282	0.010]	9.804	8
Chongqing	[0.090	0.476	0.415	0.016	0.003]	6.052	31
Sichuan	[0.081	0.432	0.265	0.196	0.025]	7.961	23
Guizhou	[0.266	0.152	0.239	0.186	0.156]	9.905	7
Yunnan	[0.037	0.330	0.331	0.253	0.047]	9.583	9
Tibet	[0.223	0.106	0.053	0.124	0.493]	15.458	1
Shanxi	[0.137	0.304	0.412	0.141	0.006]	7.457	26
Gansu	[0.168	0.239	0.267	0.258	0.067]	9.350	12
Qinghai	[0.140	0.446	0.191	0.202	0.020]	7.381	27
Ningxia	[0.074	0.391	0.335	0.198	0.001]	7.845	24
Xinjiang	[0.209	0.347	0.126	0.273	0.044]	8.203	20

4. Discussion

According to the results of the comprehensive evaluation, we can find that the effect of the medical and health system reform is related to the level of local economic development to some extent, while Tibet is an exception. Tibet is sparsely populated, and the access to medical services is affected by traffic, geographical environment and low per capita income, so the medical and health care services are provided by the government. In economically developed regions such as Beijing, Shanghai and Guangdong, the medical resources are rich in terms of both financial investment in medical and health care and the provision of medical services. The higher comprehensive scores of these regions mainly come from higher-grade social and economic conditions and medical resources as well as lower grade for residents seeking medical treatment. However, it should be pointed out that as a large number of tertiary, Grade A hospitals gather in the economically developed regions, there is a “siphonic effect” on patients in surrounding areas [6-8], which in turn improves the low priority indexes of per capita hospital visits and per capita medical expense of local residents to some extent. So the evaluation results in these regions are suspected to be underrated. The evaluation results of economically underdeveloped regions such as Shanxi, Qinghai and Ningxia are ranked lower mainly due to the low membership grades of the social and economic conditions, those of Liaoning and Hubei the low level of medical resources, and those of Heilongjiang and Chongqing low membership grades in all the three dimensions. Therefore, both commonalities and differences exist in the results of comprehensive evaluation performance among different regions. However, as current status of medical services varies, the performance of medical services should be improved based on local conditions. In this paper, the following three suggestions are put forward:

First, more of the government's financial investment

should be put into the remote areas where medical resources are not abundant and transportation is inconvenient, so as to provide basic and accessible medical services to the masses through giving subsidies to both supply and demand sides [9]. At the same time, promoting the reform of medical and health administration and supervision system, especially promoting the de-administration of public hospitals [10, 11], is the key to solve this problem.

Second, as for the areas in shortage of medical resources, it is advised to attract and retain talented individuals by supporting the construction of hospital departments and improving the medical technologies of medical personnel, and encouraging investment of social capital into provision of medical services to create a competitive market environment, as only competition can improve the enthusiasm of medical staff and promote the improvement of the medical technologies, which will ultimately prevent local patients from outflowing and attract patients from the surrounding areas [12]. For regions with abundant medical resources, it is advised to reasonably reduce per capita medical expenses through controlling expenses by means of medical insurance, so as to reduce the economic burden of the masses.

Finally, reconstruct the medical insurance system. At present, the medical insurance fund does not have the nature of market players. The collection of medical insurance funds is carried out in accordance with administrative divisions and unified by the specialized agencies of the government departments. The administrative agencies that finance and pay for medical expenses have not play the role of the market players [13]. To a certain extent, the current medical system is not conducive to fairness and lack of efficiency. Reconstructing medical insurance system, grasping the quintessence of social insurance mode and controlling of medical expenses is the way out for solving the problem of seeing a doctor [14-15]; this is the right choice for the reform of the health care system.

5. Conclusion

In summary, these results suggested that the effect of the medical and health system reform was related to the level of local economic development to some extent. In economically developed regions, the medical resources were rich in terms of both financial investments in medical care and the provision of medical services. However, in economically underdeveloped regions, neither medical resources nor financial subsidies were inadequate. This may aggravate the inequities of the use of health service. The reform of medical and health system should promote the flow of high-quality medical resources based on local actual conditions, so as to better meet people's needs for medical services.

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