Scientific Research

Efficiency Evaluation of China's Medical Service

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ABSTRACT

How to improve healthcare system' efficiency has been highly concerned by Chinese government. The objectives of this paper are to establish production function of medical service and analyze returns to scale; to measure technical efficiency; and to highlight possible policy implications of the results for policy makers. Stochastic Frontier Approach (SFA) is employed in this paper based on data from 2010 China Health Statistical Yearbook. These findings suggest that increasing investment on human resource is a key factor for raising CHS' efficiency. Operation model and institution will contribute to technology efficiency of CHS.

Keywords: Medical; Service; Efficiency

1. Introduction

A key element of public policy is the promotion of good health in order to attain broad based economic growth. Base on this paradigm, many countries devote huge budgetary allocation to health. China's health reform has led a through and arduous road for decades. From 2005 to 2009, state financial input has increased by a substantial margin from 468.56 billion yuan to 155.25 billion yuan, and accounted for the proportion of total health expenses from 17.93% to 27.23%. But the problems of difficult access to and costly medical services are still outstanding. How to use scarce medical resource to play a greater efficiency is always a hot issue in the society. With the new medical reform policy introduced, basic medical and health system is established, the equity of health service has gradually increased and the medical service efficiency has been plagued by health departments.

The first systematic study of efficiency theory is a British economist Farrell of the University of Cambridge (1957)[1]. He pointed that technical efficiency reflected maximum output capacity under the established input, namely the production possibility frontier. Some researchers have carried out studies on hospital efficiency. Donald (1987) has taken a research on 166 hospitals having 23 to 1070 beds in New York in 1981[2]. In that paper economics scale of hospitals were investigated. Chirikos (1999) has taken advantage of the stochastic frontier cost functions to analyze 186 hospitals productivity efficiency in Florida from 1952 to 1993 years[3].

Peter S. Hussey, Han de Vries, *et al.* (2008) performed a systematic review for existing efficiency measures for articles published from 1990 to 2008[4]. More recently, Herve Leleu, James Moises and Vivian Valdmanis (2012) applied 'semi-parametric' approach to determining returns to scale for single and multi-output homogenous technologies. In that paper, authors have analyzed economies of scale of 235 general short term hospitals of Florida State in 2005[5].

Although in most of studies hospital efficiency are concerned, they have failed to analyze the national medical service efficiency making use of stochastic frontier approach (SFA). In this paper, we apply SFA to analyze Chinese medical service efficiency and reveal economics characteristics of medical service.

2. Material and Methods

2.1. Theoretical Framework

Efficiency is usually analyzed using a frontier model. Generally, such an exercise begins with the construction of a production or cost frontier model following either a deterministic or stochastic approach (Coelli *et al.*, 1998; Kumbhakar and Lovell, 2000; Grosskopf *et al.*, 2006; Jacobs *et al.*, 2006; Spinks and Hollingsworth, 2009; Haghiri and Simchi, 2010)[6-11]. Because deterministic models do not take into account of either the effects of random factors or of factors beyond the control of the producer. To overcome this disadvantage, this article is based on a production-based stochastic frontier model.

Production function is defined as maximum output

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under certain inputs in a given technology. The basic model is:

$$y_i = f(x_i;\beta) \cdot \exp(-\mu_i)\, i = 1,2,3,\cdots,I_\circ \qquad (1)$$

y_i stands for actual output vector of i unit, x_i stands for input vector of I unit, β stands for parameter vector for estimation, f stands for production function, μ_i stands for inefficiency of i unit, nonnegative number.

If taking Cobb-Douglas production function, we get model

$$Y = AL^\alpha K^\beta e^{-\mu} \qquad (2)$$

Taking logarithm linearization both sides, we get

$$\ln y_i = \beta_0 + \sum_{i=1}^{N} \beta_i \ln x_i - \mu_i \quad i = 1,2,\cdots,I \qquad (3)$$

In empirical analysis, researchers usually directly use the practical elements of the input and output of data fitting, thus average production function is obtained. It reflects relationship between average output and input factors. This is contrary to the theory of production function defined. Thus production frontier theory remerged. Three papers of Meeusen and Broeck (1977), Aigner, Lovell and Schmidt (1977), Battese and Cona (1977) first introduce SFA method. SFA model divides random disturbance into two parts, one part is the statistical error caused by random error, and another part is a technical inefficiency term. They pointed that output would be affected in production process by non-human factors such as natural disasters, random effects, climate, geography and so on. Therefore random errors should be combined with random errors (v_i). Thus the frontier production function of decision unit is random rather than certainty [12-14]. According (1), the stochastic frontier production function is

$$y_i = f(x_i;\beta) \cdot \exp\{v_i\} \exp(-\mu_i)\, , i = 1,2,3,\cdots,I_\circ \quad (4)$$

If taking Cobb-Douglas production function, we get model

$$Y = AL^\alpha K^\beta e^{v-\mu} \qquad (5)$$

Taking logarithm linearization both sides, we get

$$\ln y_i = \beta_0 + \sum_{i=1}^{N} \beta_i \ln x_i + v_i - \mu_i \quad i = 1,2,\cdots,I \qquad (6)$$

Hypothesis for V_i and μ_i: I. $v_i \sim i.i.d\ N(0,\sigma_v^2)$ II. $\mu_i \sim i.i.d\ N^+(0,\sigma_\mu^2)$ III. v_i and μ_i independent each other, uncorrelated with explanatory variables. v_i stands for random error such as measure error, statistical error and other effect factors that decision unit can't control. μ_i stands for inefficiency factors. Technical efficiency is described as:

$$TE_i = \frac{y_i}{f(x_i;\beta) \cdot \exp\{v_i\}} = \exp(-\mu_i)\, i = 1,2,\cdots,I \qquad (7)$$

$$\gamma = \frac{\sigma_\mu^2}{\sigma_\mu^2 + \sigma_v^2}\ (0 \le \gamma \le 1)$$ It represents the variance of technical inefficiency in the proportion of total variance.

When $\gamma = 0$, it means there are no technical inefficiencies. When $\gamma = 1$, it means there is no random error and all errors are caused by inefficiencies technology. SFA disperses technical inefficiencies term from residuals, thus we can estimate level of technical inefficiencies. Inefficiencies term U_i usually has four forms: half normal distribution, truncated normal distribution, Exponential distribution, and gamma distribution. Bryce and Engherg (2000) found that although there exists some difference among measure values using four distribution forms, but their ranks are essentially the same. So Bryce and Engherg drew a conclusion that when assessing the efficiency of health units, the results were essential same although different distribution forms [15]. So in this article, we choose half-normal distribution form because it has fewer parameters to deal with more simple and convenient.

2.2. Production Function of Chinese Medical Services

Usually there are two production functions to choose: Cobb - Douglas production function (C-D) or Translog function.

As we discussed before Cobb-Douglas production function is $Y = AL^\alpha K^\beta e^{v-\mu}$. Translog function is:

$$\begin{aligned}\ln Y = {}& \alpha_0 + \alpha_K \ln K + \alpha_L \ln L \\ & + \frac{1}{2}\beta_{KK} \ln^2 k + \beta_{KL} \ln K \ln L \\ & + \frac{1}{2}\beta_{LL} \ln^2 L + v - \mu \end{aligned} \qquad (8)$$

In this study involving the main variables are input indicators and output indicators. Input indicators include capital investment and labor. Capital indicator is mainly presented by medical institution Fixed Assets. Labor indicator is presented by the number of medical staffs. Because medical services in China is emphasized as public welfare, we select the quantities of medical services as output indicator rather than the business income, including numbers of outpatients and inpatients and quantities of family health services which the total number of patients that doctors have visited at home to provide medical and health care services . When we think capital and labor as input factors and use C-D function, the medical services C-D can be deserved from (6) and expressed as:

$$\ln HSO = \ln A + \alpha \ln HI + \beta \ln HS + v - \mu \qquad (9)$$

where HSO is health service output, which in this study is represented by total numbers outpatients, inpatients

and services for Family Bed. A is medical services synthesis technology efficiency. HI is capital investment to medical services which is represented by Fixed Assets. HS is medical staffs and vis error term, μis inefficiency.

Translog function is a generalization of C-D function and after its natural logarithm we can get form below:

$$\ln HSO = \beta_0 + \beta_1 \ln HI + \beta_2 \ln HS + \beta_3 (\ln HI)^2 \\ + \beta_4 (\ln HS)^2 + \beta_5 \ln HI \times \ln HS + v - \mu \quad (10)$$

β_0, β_1, β_2, β_3, β_4, β_5 are Coefficient to estimate. When $\beta_3 = \beta_4 = \beta_5 = 0$ Translog function will degenerate into C-D function. The main advantage of C-D function is concise while Translog function can express capital and labor interaction effect on output. Although Translog function has overcome the disadvantage of C-D function that elasticity of substitution is fixed at 1, it doesn't mean that Translog function is always better than C-D function. Which function we choose should be based on statistical tests according to actual situation .So we first choose Translog function, and then estimate the parameters? After that we test hypothesis of $\beta_3 = \beta_4 = \beta_5 = 0$. If hypothesis can't be refused, it means $\beta_3 = \beta_4 = \beta_5 = 0$. So we should choose C-D function .

3. Result

3.1. Estimation of C-D function

In the empirical analysis, we use data from 2010 China Health Statistical Yearbook; the data is conducted by deap 4.1 statistics software. Because we assume that μ follows half distribution, Maximum likelihood estimation (MLS) approach is applied. Estimation results on production function of Chinese medical services based on Translog function are shown in **Table 1**.

As shown in **Table 1**, β_3, β_5 are negative and it doesn't meet economics meaning. Furthermore t-value ofβ_3, β_5 are -0.0988 and -0.2676 respectively, P ＜0.05 (α＝ 0.05).Those implicate that Translog function is inappropriate. So we continue to use likelihood ratio test:

Table 1. Estimation of Chinese medical services Translog function.

parameter	Coefficient	SD	t-value
β_0	6.6255	0.5097	12.9978
β_1	0.1372	0.3095	0.4435
β_2	0.7397	1.0923	0.6772
β_3	-0.0122	0.1233	-0.0988
β_4	0.0941	0.4562	0.2063
β_5	-0.0808	0.3019	-0.2676
σ^2	0.1401	0.0680	2.0594
γ	1	0.342E-0.4	29240

H_0：$\beta_3 = \beta_4 = \beta_5 = 0$, H_1：β_3, β_4, β_5 not all zero. LR = -2{ln[L(H_0)/L(H_1)]} = 4.1267. Because $\chi^2_{0.05}(3) = 7.82$, so we can't refuse H_0, Translog function is proved inappropriate in statistic. Then we use C-D function to estimate. Results are shown below;

As shown in **Table 2**, $\gamma = 1$, according to

$$\gamma = \frac{\sigma^2_\mu}{\sigma^2_\mu + \sigma^2_\nu} \ (0 \le \gamma \le 1),$$

σ^2_μ plays a dominant role, while the effect of σ^2_ν almost ignored. So we draw a conclusion that the mode is reasonable in design and reflects the technical inefficiency very well. β1 andβ2 represent the output elasticity of capital and labor force respectively. Their value are in (0, 1) consistent with the elastic characteristics. It also implicate the mode is reasonable to some extent. According to the α and β combination condition, C-D production function has three types: 1) α + β >1, known as increasing returns to scale, it is advantageous to increase output according to the existing technology with the expansion of production scale 2) α + β <1, called diminishing returns to scale, it is the loss outweighs the gain according to the existing technology expanding the production scale to increase the output 3) α + β= 1, known as the constant return to scale, it shows that the production efficiency can't be improved with the expansion of production scale[16]. We use Wald method to test hypothesis α + β = 1. The statistic results shows F = 0.355, P ＝0.5559. Under 0.05 significant level, we can't refuse hypothesis, so we draw conclusion that economic characteristic of Chinese medical services is constant returns to scale.

3.2. TE of Chinese Medical Services

Using data of inputs and outputs based on C-D model which we concern before in this paper, we can obtain medical services TE of Chinese provinces and cities shown as below through conducting deap 4.1 statistics software.

Table 3 shows that TE score of 31 provinces in China and the average TE score is not high only 0.7672. The results confirm the existence of huge difference in efficiency among province. For example, TE score of Shanxi province is 0.4319, while Shanghai is 0.9991.

Table 2. Estimation of Chinese medical services C-D function.

parameter	Coefficient	SD	t-value
β_0	6.4890	0.4194	15.471
β_1	0.1953	0.2707	0.7215
β_2	0.8367	0.2842	2.944
σ^2	0.1442	0.0298	4.835
γ	1	0.2605	3878

Shanghai is a metropolis and has a rich medical resource. This leads to many patients come to Shanghai from other the relatively disadvantaged and predominantly rural province.

According to 2010 China Health Statistical Yearbook, China is geographically divided into three areas, the Eastern area, Central area and Western area. The Eastern area includes 11 provinces such as Beijing, Tianjin et al. The Central area includes 8 provinces such as Shanxi, Jilin et al and Western area includes 12 provinces such as Inner Mongolia, Guizhou, et al. **Table 4** present mean TE scores of districts according three areas of China. Average TE of eastern area is 0.83 higher than while central and western areas. This is primarily because China has always taken eastern area development as the priority strategy since the reform and opening 1978. This leads to eastern economic is better than others areas and eastern medical resources are more high quality than others. For instance, medical talents are more willing to work in eastern area because of good work condition and high income.

Table 3. TE of Chinese 31 provinces.

Eastern area	TE	Central area	TE	West area	TE
Beijing	0.9138	Shanxi	0.4319	Inner Mongolia	0.5155
Tianjin	0.7374	Jilin	0.5336	Guizhou	0.5975
Hebei	0.9002	Heilongjiang	0.4664	Sichuan	0.9781
Liaoning	0.5059	Anhui	0.7876	Yunnan	0.8562
Shanghai	0.9991	Jiangxi	0.8649	Tibet	0.6752
Jiangsu	0.8667	Henan	0.9262	Shanxi	0.8643
Zhejiang	0.9277	Hubei	0.7284	Gansu	0.7046
Fujian	0.7342	Hunan	0.6066	Qinghai	0.9907
Shandong	0.8608			Ningxia	0.7446
Guangdong	0.9686			Xinjiang	0.5233
Hainan	0.7162			Chongqing	0.9402
				Guangxi	0.9069
Mean TE	**0.7672**				

Table 4. Area 's TE distribution in China.

Area	Number of districts with TE			TE score efficiency(%)	
	Less than 70%	70%-89%	90% or more	Mean	Minimum
Eastern area	1	5	5	0.8301	0.5059
Central area	4	3	1	0.6682	0.4319
Western area	4	4	4	0.7748	0.5155
Total	9	12	10	0.7577	0.4319

4. Discussion

4.1. Labor and Capital's Effect on Chinese Medical Services

According to C-D production function estimation results, the coefficient of lnHS is 0.8367 representing output on labor supply elasticity, that is to say, input increase one percent, the output will increase about by 0.8367%, under the capital investment remaining constant. Similarly, if the labor input remains unchanged, capital inputs increase one percent, the output will increase on about by 0.1953%. This is mainly because of the medical health services is a kind of labor-intensive service and professional knowledge is critical. Therefore, how to improve investment medical human resource is a key factor for CHS output. One way is the supplement of "fresh blood" to increase the training students' number from medical school, especial the shortage areas such as general practitioners**,** rehabilitation physicians, community nurses and so on. Another way is to improve the medical staff skills through on-the-job training.

4.2. Returns to Scale of CHS

According the paper' results show that the sum of two elastic coefficients (α+β) in production function of CHS is 1; it reflects that CHS is constant returning to scale. This is to say that if labor input and capital input enlarged 1 time, then the output is also enlarged 1 time. The efficiency of CHC will not increase through scale expanding except for improving the TE. In order to improve the Efficiency of Chinese medical service, health administration department should enhance medical health interior management level, such as constructing effect mechanism and appropriate operation model.

4.3. Chinese Medical Services Development Uneven

As shown in **Table 3**, the provinces that TE exceeds 0.8 are only account for about 48%, and seven provinces TE is less than 0.6. Figure has also shown that there is a big room for China to improve medical service TE. The results explain there are significant differences among eastern area, west area and central area in China. TE of eastern area is highest while the central area is lowest. The difference suggests Chinese health administration should spread eastern area health development experience to promote central area health development.

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