Evaluation of Health Care Providers Through Stochastic Frontier Analysis

P.S. Prema Kumar, G. Ramababu

Abstract: The relationship between efficiency and quality in the health care sectors is reflected by various aspects. The aim of this paper is to determine the efficiency of the health care providers during the years 2018 and 2019 and to study the connotation between efficiency and its input and output parameters (measuring factors). This paper is intended to measure the efficiencies of fifteen hospitals. Where stochastic frontier analysis method is adopted to determine the efficiency. There are three input parameters and three output parameters. The inputs that were considered by researchers in analyzing hospital technical efficiency include number of physicians, number of nurses and number of active beds. The outputs considered are length of stay, outpatient visits and patient bed days. In three different combinations the results are analyzed. Each combination includes all the three input parameters and one output parameter. The data was collected from the fifteen health care sectors of AP, India.

Index Terms: Health care providers, SFA, efficiency.

I. INTRODUCTION

Regardless of the weightage of measurement of efficiency in healthcare providers, statistical programming frontier techniques have been applied to health care sectors, banks, and other service sectors [1]. Patient satisfaction and service quality are very important factors in evaluation of health care sector [2]. This paper helps the stakeholder to select the healthcare providers where the technical efficiencies are determined. Efficiency is nothing but how an organization effectively make use of its inputs resources to yield outputs, that is the best services or goods out of the available resources [3]. Stochastic frontier analysis (SFA) sets a credible benchmark in evaluating the service quality of the healthcare sectors [4]. Realizing the factors effecting the productivity is a very important aspect in determining the efficiency. Inpatient active beds, average length of stay are important indicators to determine the efficiency of the health sectors [5]. The health care provider is a unique area of application of the parametric and non-parametric methods to determine its productivity [6]. Most researches of health care productivity use the production-function model, where health care results are termed as the output of a health care production function [7]. It is required to test the efficiency of the health care sector if one is keen to satisfy the needs of both inpatient and the outpatient [8]. There is evidence from the literature that inefficiencies in health care spending are high [9] and because of these inefficiencies, many nations could accomplish the same level of health care output with a lower level of spending [10]. Therefore, from the past research SFA method is adopted to determine the technical efficiency of health care providers by taking the three input parameters and three output parameters of the decision-making unit (DMU).

II. STOCHASTIC FRONTIER ANALYSIS (SFA)

Stochastic frontier Analysis is a parametric tool for the essecment of technical efficiency of any organization. Anner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977) nearly at the point of time proposed this model. They gave a stochastic production function as

\[ Y_i = f(x_i; \beta) + \xi_i, \quad i = 1, \ldots, N \]

Where \( Y_i \) represents output (or the log. of the output) of the \( i \)-th firm; \( X_i \) is a \( k \times 1 \) vector of the functions of authentic input quantities utilized by the \( i \)-th firm; \( \beta \) is a vector of parameters to be measured; and \( \xi_i \) is the composite error term which is again divided into two components well-defined as:

\[ \xi_i = (v_i - u_i), \quad i = 1, \ldots, N. \]

Here \( v_i \)'s are expected to be independently and identically distributed (iid) random errors, whicha are having normal distribution with mean zero and unknown variance \( \sigma^2 \). independent of the random variable \( u_i \) which are assumed to include for technical efficiency in production and are generally assumed to be iid truncations (at zero) of the \( N(\mu, \sigma^2) \) distribution. Here, \( v_i \) account for random variation of production outside the control of the individual firm or producer. The error \( \xi_i \) consists of two parts: (a) the traditional random error \( v_i \) that determine the effect of measurement error, other statistical noise, and random shock due to exogenous (variables which are out of producer’s control) variables (if any); and (b) \( u_i \) one sided component (as it is iid truncations (at zero) of the \( N(\mu, \sigma^2) \) distribution) which determine the effect of inefficiency.

III. CASE STUDY

In this case study, efficiency of the fifteen hospitals in AP, India are evaluated and using proposed SFA. This research considered three inputs and three outputs. The inputs are Number of Physicians (NP), Number of Nurses (NN) and Number of Active Beds (AB). The outputs considered are Length of Stay (LOS), Outpatient Visits (OPV) and Patient Bed Days (PBD). Table 1 show the input and output data.

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The technical inefficiency model were used to analyze the data. The stochastic frontier Cobb-Douglas cost function was specified as follows:

\[ \ln(LS_i) = \beta_0 + \beta_1 \ln (NP_i) + \beta_2 \ln (NN_i) + \beta_3 \ln (AB_i) + \beta_4 \ln (PBD_i) + (V_{i0}, U_{i}) \]

Where \( i = 1, 2, \ldots, 15 \)

\( \beta_0 \)-Constant term; \( \beta_1, \ldots, \beta_4 \) (Coefficient terms); \( V_{i0} \)-random error outside the control of the hospitals; \( U_{i} \)-Technical inefficiency due to characteristics of the hospital such as location, years of existence, size of the hospital etc.

Estimation of the stochastic frontier analysis according to a Cobb-Douglas production function is done using STATA 13.0 – A Statistical software and the results are presented in table 3.3. Then, using STATA 13.0, the parameters of the model are obtained, and the overall model of the FCF is obtained using appropriate cost function (Cobb-Douglas function). Goodness of fit is met using Z statistic for each independent variables. Table 3 shows the output of software.

Table 3: Stochastic Frontier Analysis for Combination 1

NP-NUMBER OF PHYSICIANS; NN-NUMBER OF NURSES; AB-ACTIVE BEDS; PBD-PATIENT BED DAYS; LOS-LENGTH OF STAY; OPV-OUTPATIENT VISITS

IV. RESULTS AND DISCUSSION

Evaluation of efficiency of fifteen hospitals is carried out by adopting SFA method. Various combinations of health care parameters for each output parameter with all inputs and efficiencies of all the combination are determined through SFA. STATA 13 – A Statistical software package is used to implement SFA to determine the efficiencies of the hospitals. The input output combinations for evaluation of efficiencies of hospitals are shown in the below table 2.

Table 2: The input output combinations for SFA

<table>
<thead>
<tr>
<th>Combination</th>
<th>Outputs</th>
<th>Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Length of Stay</td>
<td>NP, NN, AB</td>
</tr>
<tr>
<td>2</td>
<td>Outpatient Visits</td>
<td>NP, NN, AB</td>
</tr>
<tr>
<td>3</td>
<td>Patient Bed Days</td>
<td>NP, NN, AB</td>
</tr>
</tbody>
</table>

For all these combinations technical efficiencies of all the hospitals are determined though SFA. In this, thesis stochastic frontier model having the functional form of the Cobb Douglas stochastic frontier cost model is adopted for length of stay, as there is decrease in length of stay with increase in inputs. In case of patient bed days as there is decrease in PBD with increase in inputs. In case of number of outpatient visits, Cobb Douglas stochastic frontier production model is adopted for as there is increase in number of outpatient visits with increase in inputs. Stochastic frontier Cobb-Douglas cost function and the
The standard error of the coefficient is used to measure the precision of the estimate of the coefficient. The smaller the standard error, the more precise is the estimate. The standard errors of numbers of physicians, number of nursing staff, number of active beds and constant term are 0.001823, 0.002513, 0.001518 and 0.001725 respectively. The model was able to estimate the coefficient for the three variables with greater precision since the value of the constant term is low when compared to the other variables. Similarly, for table 4 and table 5 gives the combination 2 and combination 3

Table 4: Stochastic Frontier Analysis for Combination 2

<table>
<thead>
<tr>
<th>Stochastic frontier normal/exponential model</th>
<th>Number of obs = 15</th>
<th>Wald $\chi^2 (4) = 9.79$</th>
<th>Log likelihood = -22.56</th>
<th>Prob &gt; $\chi^2 = 0.0441$</th>
</tr>
</thead>
<tbody>
<tr>
<td>LN(NP)</td>
<td>Coef.</td>
<td>Std. Err.</td>
<td>z</td>
<td>P&gt;</td>
</tr>
<tr>
<td>LN(NN)</td>
<td>0.978529</td>
<td>0.517228</td>
<td>1.88</td>
<td>0.069</td>
</tr>
<tr>
<td>LN(AL)</td>
<td>0.123506</td>
<td>0.554118</td>
<td>-0.23</td>
<td>0.821</td>
</tr>
<tr>
<td>Constant</td>
<td>1.335996</td>
<td>0.5250</td>
<td>2.56</td>
<td>0.01</td>
</tr>
</tbody>
</table>

In case of combination 2 number of physician, number of nurses and number of active beds are taken as inputs and outpatient visit is taken as output.

Table 7: Combination 2

<table>
<thead>
<tr>
<th>HCP</th>
<th>HCP1</th>
<th>HCP2</th>
<th>HCP3</th>
<th>HCP4</th>
<th>HCP5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency_ LOS</td>
<td>0.999848</td>
<td>0.950839</td>
<td>0.923149</td>
<td>0.954928</td>
<td>0.913457</td>
</tr>
<tr>
<td>Efficiency_ OPV</td>
<td>0.982713</td>
<td>0.98288</td>
<td>0.983021</td>
<td>0.983215</td>
<td>0.982259</td>
</tr>
<tr>
<td>Efficiency_ PBD</td>
<td>0.983277</td>
<td>0.981706</td>
<td>0.982938</td>
<td>0.983144</td>
<td>0.983126</td>
</tr>
</tbody>
</table>

In case of combination 3 number of physician, number of nurses and number of active beds are taken as inputs and inpatient bed days are taken as output.

Table 8: Combination 3

<table>
<thead>
<tr>
<th>HCP</th>
<th>HCP1</th>
<th>HCP2</th>
<th>HCP3</th>
<th>HCP4</th>
<th>HCP5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency_ LOS</td>
<td>0.997909</td>
<td>0.973348</td>
<td>0.970852</td>
<td>0.984045</td>
<td>0.962945</td>
</tr>
<tr>
<td>Efficiency_ OPV</td>
<td>0.971345</td>
<td>0.96665</td>
<td>0.97463</td>
<td>0.973054</td>
<td>0.970078</td>
</tr>
<tr>
<td>Efficiency_ PBD</td>
<td>0.972573</td>
<td>0.978279</td>
<td>0.952431</td>
<td>0.951408</td>
<td>0.979185</td>
</tr>
</tbody>
</table>

V. CONCLUDING REMARKS

In this paper, stochastic frontier analysis is applied to determine the efficiency of fifteen hospitals in India. Where number of physicians, number of nurses and number of active beds are taken as inputs. Length of stay, outpatient visits and patient bed days are taken as outputs. Three different combinations are taken with all the three inputs as common and one output each time. Using the Statistical software, technical efficiency of healthcare providers is determined for all the three combinations. Service sectors can improve their overall performance by taking decision based on these efficiency results.

REFERENCES


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