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Evaluation of Health Care Providers through Stochastic Frontier Analysis

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***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 healthcare 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 acre 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).

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II. STOCHASTIC FRONTIER ANALYSIS (SFA)

Stochastic frontier Analysis is a parametric tool for the essesment 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

$$Y_i = f(x_i;\beta) + \mathcal{E}_i, \qquad i = 1\ldots\ldots\ldots\ldots N$$

Where

Y_i represents output (or the log. of the output) of the i-th firm;
X_i is a kxl vector of the functions of authentic input quantities utilized by the i-th firm;
β is a vector of parameters to be measured ; and $\mathcal{E}_i$ is the composite error term which is again divided into two components well-defined as:
$\mathcal{E}_i = (v_i - u_i)$ i=1,…………..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 σ_v^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 $\mathcal{E}_i$, consists of two parts: (a) the traditional randon error v_i that determine the effect of measurement error, other statistical noise, and random shoch due to exogenous (varibles which are out of producer's control) variables (if any) ; and b) u_i, one sided compenent (as it is iid truncations (at zero) of the $N(\mu,\sigma^2)$ distribution) whch 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.

Table 1. Data on inputs and outputs of the hospitals.

HCP	Inputs			Outputs		
	NP	NN	AB	PBD	LOS	OPV
HCP1	55	118	338	152341	7.54	81308
HCP2	20	34	69	524008	16.72	10205
HCP3	330	467	530	19581	2.22	2500487
HCP4	34	98	206	281423	8.82	60384
HCP5	30	79	113	325494	10.59	24930
HCP6	37	103	226	252341	8.32	71384
HCP7	70	196	451	126878	5.99	95494
HCP8	335	532	1230	13639	1.57	2505487
HCP9	44	104	245	159571	7.94	77624
HCP10	28	50	111	424008	14.89	24045
HCP11	70	129	399	128878	7.37	87308
HCP12	25	40	105	434008	15.44	24045
HCP13	35	99	211	262344	8.5	70384
HCP14	95	217	460	104930	4.59	1400487
HCP15	30	90	196	283423	9.15	59519

NP-NO.OF PHYSICIANS; NN-NO.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

Combination	Outputs	Inputs		
1	Length of Stay	NP	NN	AB
2	Outpatient Visits	NP	NN	AB
3	Patient Bed Days	NP	NN	AB

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

$Ln(LS_i)=\beta_0+\beta_1*ln(NP_i)+\beta_2*ln(NN_i)+\beta_3*ln(AB_i)+\beta_4*ln(NM_i)+(V_i+U_i)$

Where i =1,2….15

β_0-Constant term; β_1….. β_4 (Coefficient terms);

V_i-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

Stochastic frontier normal/exponential model — Number of obs = 15; Wald χ^2 (4) 1373995.46

Log likelihood = 26.2335 — Prob > χ^2 = 0.0000

LN(LOS)	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
LN(NP)	-0.35704	0.001823	-195.91	0	-0.36062	-0.35347
LN(NN)	-0.52286	0.002513	-208.11	0	-0.52778	-0.51793
LN(AB)	-0.093317	0.001518	61.46	0	0.090341	0.096293
Constant	2.387222	0.001725	1383.7	0	2.38384	2.390603
$Ln(\sigma^2_v)$	-19.1805	5.085643	-3.77	0	-29.1482	-9.21282
$Ln(\sigma^2_u)$	-5.43236	0.365285	-14.87	0	-6.14831	-4.71642
σ_u	6.84E-05	0.000174	4.68E-07	0.009988	-	-
σ_v	0.066127	0.012078	0.046229	0.09459	-	-
σ^2	0.004373	0.001597	0.001242	0.007503	-	-
λ	966.8724	0.012075	966.8488	966.8961	-	-

In the SFA 15 observations are considered. The Wald test shows whether the variables can be considered or not. If the test value shows nonzero, one should include the variables in the model. In the results Wald χ^2 test statistic is 1373995.46 indicates that all the four variables may be considered. The log likelihood of the model is -26.2335 has no meaning in and of itself. Rather, this number can be used to help compare models. The higher the value better is the model. The value of coefficient for number of physicians is -0.35704 indicates that one percent increase in the number of physicians decrease in length of stay by 0.35704 percent. The value of coefficient for number of nurses is -0.52286, denotes that one percent increase in the number of nurses decrease the length of stay by 0.52286 percent, while coefficient value for active beds is 0.093317, indicates that one percent increase in the active beds , decrease in the length of stay by 0.093317 percent. 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 number 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

Stochastic frontier normal/exponential model Number of obs = 15
Wald χ^2 (4) = 9.79
Log likelihood = -22.56 Prob > χ^2 = 0.0441

LN(OPV)	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
LN(NP)	0.978529	0.517228	1.89	0.059	-0.03522	1.992277
LN(NN)	1.116022	0.780192	1.43	0.153	-0.41312	2.64517
LN(AB)	-0.12506	0.554118	-0.23	0.821	-1.21111	0.960992
Constant	1.335996	0.5209	2.56	0.01	0.315051	2.356941
Ln(σ^2_v)	-3.09082	0.371846	-8.31	0	-3.81963	-2.36202
Ln(σ^2_u)	-7.68044	18.71785	-0.41	0.682	-44.3668	29.00587
σ_u	0.213224	0.039643	0.148108	0.306969	-	-
σ_v	0.021489	0.201113	2.32E-10	1988589	-	-
σ^2	0.045926	0.017652	0.01133	0.080523	-	-
λ	0.100781	0.211394	-0.31354	0.515106	-	-

Table 5: Stochastic Frontier Analysis for Combination 3

Stochastic frontier normal/exponential model Number of obs = 15
Wald χ^2 (4) = 9.79
Log likelihood = -22.56 Prob > χ^2 = 0.0441

LN(PBD)	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
LN(NP)	-1.13029	0.14323	-7.89	0	-1.41102	-0.84957
LN(NN)	-0.03576	0.230566	-0.16	0.877	-0.48766	0.416144
LN(AB)	-0.07216	0.198139	-0.36	0.716	-0.46051	0.316186
Constant	7.44096	0.134873	55.17	0	7.176614	7.705307
Ln(σ^2_v)	-5.87497	2.259533	-2.6	0.009	-10.3036	-1.44637
Ln(σ^2_u)	-6.55073	11.94519	-0.55	0.583	-29.9629	16.86142
σ_u	0.052999	0.059876	0.005789	0.485205	-	-
σ_v	0.037803	0.225783	3.12E-07	4585.753	-	-
σ^2	0.004238	0.010912	-0.01715	0.025626	-	-
λ	0.713282	0.284767	0.155149	1.271416	-	-

The technical efficiencies so obtained for the combination 1, combination 2 and combination 3 are shown form table 6, table 7 and table 8. In case of combination 1 number of physician, number of nurses and number of active beds are taken as inputs and length of stay is taken as output

Table 6: Combination 1

HCP	HCP1	HCP2	HCP3	HCP4	HCP5
Efficiency_LOS	0.95968	0.932104	0.999803	0.932634	0.966256
HCP	HCP6	HCP7	HCP8	HCP9	HCP10
Efficiency_LOS	0.928271	0.999829	0.858261	0.933379	0.999827
HCP	HCP11	HCP12	HCP13	HCP14	HCP15
Efficiency_LOS	0.999848	0.950839	0.923149	0.954928	0.913457

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

HCP	HCP1	HCP2	HCP3	HCP4	HCP5
Efficiency_OPV	0.982713	0.98288	0.983021	0.983215	0.982259
HCP	HCP6	HCP7	HCP8	HCP9	HCP10
Efficiency_OPV	0.983277	0.981706	0.982938	0.983144	0.983126
HCP	HCP11	HCP12	HCP13	HCP14	HCP15
Efficiency_OPV	0.982317	0.983664	0.983393	0.985139	0.983515

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

HCP	HCP1	HCP2	HCP3	HCP4	HCP5
Efficiency_PBD	0.971345	0.96665	0.97463	0.973054	0.970078
HCP	HCP6	HCP7	HCP8	HCP9	HCP10
Efficiency_PBD	0.972753	0.978279	0.952431	0.951408	0.979185
HCP	HCP11	HCP12	HCP13	HCP14	HCP15
Efficiency_PBD	0.977909	0.973348	0.970852	0.984045	0.962945

V. CONCLUDING REMARKS

In this paper, stochastic frontier analysis is applied to determine the efficiency of fifteen hospitals of 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.

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