Evaluation and Ranking of Health Care Sectors Through Integrated DEA and SFA

P.S.Prema Kumar, G.Rambabu

***Abstract*: Previous research for efficiency measurement used to adopt either data envelopment analysis or stochastic frontier analysis method, but not both. Therefore, this paper is projected to measure the efficiencies of fifteen hospitals from the reports taken from the health care providers, applying both models with the three input evaluation parameters and three output evaluation parameters. The inputs selected by authors in analyzing hospital technical efficiency include number of nurses, number of physicians and number of active beds. The outputs taken are patient bed days, length of stay, outpatient visits. An Integrated DEA and SFA is adopted to rank the hospitals based on the efficiency obtained from different combinations.**

***Index Terms*: DEA, SFA, efficiency, Healthcare providers**

I. INTRODUCTION

In general, if any service sector is running effectively when the output parameters of that firm fulfilled the objectives specified to them. There are basically three main measures of efficiency. Those are allocative, technical and economic efficiencies. In case of allocative efficiency utilization inputs in an effective manner based on their technology and expenditure. Technical efficiency refers to how greatly the resources (inputs) are engaged to get the highest level of output. Whereas, total economic efficiency is the combination of technical and allocative efficiency. Hospital technical efficiency analysis how the inputs are employed to get the outputs i.e. increase in outpatient, length of stay) [1] . There was research to rank the health care providers using six dimensions in the patient's perception [2]. The Past research identified two methods to determine the efficiency; those are non-parametric methods [3] and a parametric technique [4]. Parametric methods focus on optimization of economic related things, while non-parametric techniques study technological optimization. Data envelopment analysis (DEA) is the famous estimation technique in the nonparametric approach. On the other hand DEA does not resolve the issues of a stochastic error term; Stochastic Frontier Analysis resolves the two sources of error, which are due to random noise and inefficiency. In Stochastic Frontier Analysis approach, for inefficiencies scores it is achievable to conduct statistical tests of the hypothesis the main benefit of SFA is that it is liable for the traditional random error of regression. Stochastic Frontier Analysis gives a production function of the standard regression model but with a composite interruption term which is equal to the sum of the two errors [4, 9].

When a variable is taken for efficiency analysis, it is necessary to conclude whether the variable should act as an output or an input. Some parameters can be pre-defined as outputs or inputs based on the production/service, mechanism of a DMU or the knowledge of the analyst. When it is hard to recognize the conversion mechanism, inputs and outputs should be determined accurately. When selecting variables for inclusion in a specific model, it is important to keep the model's objective in mind as well as avoid redundancy in the variables. Reducing the number of highly correlated variables (proxies) helps to increase the discriminatory power of DEA without adversely affecting the final efficiency scores. In this study, correlation analysis was used to aid in variable selection. Discretion was also used in the removal of variables, from a managerial standpoint and it may make more sense to leave certain variables in the model even if they are highly correlated. Correlation analysis is a very commonly used technique for DEA variable selection. It employs the use of the correlation coefficient (ρ) which measures how two variables vary together. The coefficient's value can range from +1, denoting a perfect positive linear relationship, to -1, denoting a perfect negative linear relationship, with 0 representing no correlation at all. Correlation analysis, in terms of variable selection, requires that the correlation coefficient be calculated for every combination of input and outputs. When there are two inputs (or outputs) that are highly correlated with one another ($|\rho|>0.95$), this suggests that the variables are too similar and convey essentially the same information. It follows that one of the two should be removed, or the two should be combined together. On the other hand, when comparing an input variable with an output variable, there should be some degree of correlation (>0.50) between the two, ensuring that they are both statistically significant. In this research correlation analysis is adopted to select the input and output.

II. DATA ENVELOPMENT ANALYSIS (DEA)

DEA methodology has made great theoretical advances, allowing for its application to a range of real-world problems including those of the healthcare sectors. DEA provides an estimation of the production function to which each individual Decision Making Unit's (DMU's) efficiency score can be compared. Furthermore, DEA offers a number of advantages over traditional parametric techniques including its ability to identify reference units for each DMU.

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These characteristics prove to be a very useful managerial tool as it aids in establishing potential causes and methods of improvement for the identified inefficient DMUs. Calculating the relative efficiency is one of the primary concerns in many service sectors such as in hospitals, insurances etc. DEA is a non parametric, deterministic, linear programming technique that measures the relative efficiency of a group of decision making units, which receive multiple inputs and produce multiple outputs. Linear programming is the underlying methodology that makes the DEA particularly powerful compared with alternative productivity management tools. In the usual setting, DMUs (Hospitals, Banks, schools, universities, fast food restaurants, military operations, manufacturing, benchmarking, management, baseball players and research projects) are evaluated relative to one another using a specified set of input and output factors. Different DEA models available in the literature are discussed below.

In measuring technical efficiency of a hospital, there are many methods that can be applied, and Data Envelopment Analysis is one of them. Even though Data Envelopment Analysis is widely used by the researchers, this method has its limitations. One of the limitations is that it is very model specific, and the results may be influenced by the inputs and outputs selection.

III. STOCHASTIC FRONTIER ANALYSIS (SFA)

Stochastic Frontier Analysis (SFA) of Battesse and Coelli (1992; 1995) [6, 7] and Huang and Liu (1994) [8] is the main analytical model for the parametric approach. It is a parametric device to determine the technical efficiency of a organisation A statistical software package STATA 13 is used to determine the technical efficiencies of the service sectors. Identify the input parameters and the output parameters and take different combinations with inputs as all the parametes and the output only one so that if `n' number of outputs are availble then there will be n combinations and for each such combinations efficiencis are obtained and the service sector is analysed by seeing different input and output combinations.

IV. INTEGRATED DEA AND SFA

The recent studies mentioned about how to measure the efficiency of the health care providers using SFA and the same data is taken and it is integrated to DEA. SDEA model is adopted, where the technical efficiencies measured using SFA are taken as inputs and 1 as dummy output to calculate SSDI i.e. an efficiency score. In the similar manner efficiencies measured using SFA are taken as output and 1 as dummy input to calculate SSDO i.e. an efficiency score. Finally SSDO and SSDI are combines to get the final efficiency score to give the score with equal weightage. Arithmetic mean is used to combine both SSD-I and SSDO.

A. Super efficiency with input criteria orientation (SSDI)

Super efficiency model of DEA is implemented with the above efficiencies as input criteria and dummy variable with constant value of 1 is used as output criterion. Table1 shows the SSDI model input and output parameters data

Table 1: Inputs/Output of SSDI model

HCP	Inputs(Efficiency through SFA)			Output
	Combin-ation1 (Based on LOS)	Combin-ation2 (Based on OPV)	Combin-ation3 (Based on PBD)	
HCP1	0.9702321	0.982713	0.971345	1
HCP2	0.9997945	0.98288	0.96665	1
HCP3	0.9998109	0.983021	0.97463	1
HCP4	0.9495601	0.983215	0.973054	1
HCP5	0.9481313	0.982259	0.970078	1
HCP6	0.9439996	0.983277	0.972753	1
HCP7	0.9998181	0.981706	0.978279	1
HCP8	0.7849458	0.982938	0.952431	1
HCP9	0.9397871	0.983144	0.951408	1
HCP10	0.9983123	0.983126	0.979185	1
HCP11	0.9998071	0.982317	0.977909	1
HCP12	0.9609214	0.983664	0.973348	1
HCP13	0.9390259	0.983393	0.970852	1
HCP14	0.9257195	0.985139	0.984045	1
HCP15	0.9394495	0.983515	0.962945	1

Lingo code is developed for super efficiency model of DEA. Lingo Solver 8.0 of LINDO is used to solve the super efficiency model. The efficiencies thus obtained for SSD-I model are shown table 2.

Table 2: Efficiencies of Hospitals through SSDI model

HCP	Efficiency _SSDI
HCP1	0.9984
HCP2	1.0002
HCP3	0.9988
HCP4	0.9978
HCP5	1.0049
HCP6	0.9987
HCP7	1.0009
HCP8	0.9986
HCP9	0.9999
HCP10	1.0003
HCP11	0.9988
HCP12	1.0002
HCP13	0.9978
HCP14	0.9986

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HCP15	0.9995

B. *Super efficiency with output criteria orientation (SSDO)*

Super efficiency model of DEA is implemented with the above efficiencies as output criteria and dummy variable with constant value of 1 is used as input criterion. Table 3 shows the SSDO model input and output parameters data

Table 3: Inputs/Output of SSDO model

HCP	Input	Output (Efficiency through SFA)		
		Combin-ation1 (Based on LOS)	Combin-ation2 (Based on OPV)	Combin-ation3 (Based on PBD)
HCP1	1	0.9702321	0.982713	0.971345
HCP2	1	0.9997945	0.98288	0.96665
HCP3	1	0.9998109	0.983021	0.97463
HCP4	1	0.9495601	0.983215	0.973054
HCP5	1	0.9481313	0.982259	0.970078
HCP6	1	0.9439996	0.983277	0.972753
HCP7	1	0.9998181	0.981706	0.978279
HCP8	1	0.7849458	0.982938	0.952431
HCP9	1	0.9397871	0.983144	0.951408
HCP10	1	0.9983123	0.983126	0.979185
HCP11	1	0.9998071	0.982317	0.977909
HCP12	1	0.9609214	0.983664	0.973348
HCP13	1	0.9390259	0.983393	0.970852
HCP14	1	0.9257195	0.985139	0.984045
HCP15	1	0.9394495	0.983515	0.962945

Lingo Solver 8.0 of LINDO is used to solve the super efficiency model. The efficiencies thus obtained for SSD-O model are shown table 4.

Table 4: Efficiencies of Hospitals through SSD-O model

HCP	Efficiency _SSDO
HCP1	1.0011
HCP2	0.9994
HCP3	0.9993
HCP4	0.9998
HCP5	0.9969
HCP6	0.9488
HCP7	0.9986
HCP8	0.9987
HCP9	0.9994
HCP10	0.9989
HCP11	0.9989
HCP12	1.0005
HCP13	1.1793
HCP14	0.9987
HCP15	0.9983

C. *Aggregated Efficiency Score (SSD)*

SSDO and SSDI values are combined using arithmetic mean to get a combined efficiency score for each bank. This efficiency score is called as SSD score. SSD scores are used to rank the hospitals in descending order of magnitude. SSD scores and ranking of the hospitals is shown in table 4.

Table 4: Ranking of Hospitals through SFA-DEA

HCP	Efficiency _SSDI	Efficiency _SSDO	Efficiency _SSD	Rank
HCP1	0.9984	1.0011	0.99975	5
HCP2	1.0002	0.9994	0.9998	4
HCP3	0.9988	0.9993	0.99905	9
HCP4	0.9978	0.9998	0.9988	12
HCP5	1.0049	0.9969	1.0009	2
HCP6	0.9987	0.9488	0.97375	15
HCP7	1.0009	0.9986	0.99975	6
HCP8	0.9986	0.9987	0.99865	14
HCP9	0.9999	0.9994	0.99965	7
HCP10	1.0003	0.9989	0.9996	8
HCP11	0.9988	0.9989	0.99885	11
HCP12	1.0002	1.0005	1.00035	3
HCP13	0.9978	1.1793	1.08855	1
HCP14	0.9986	0.9987	0.99865	13
HCP15	0.9995	0.9983	0.9989	10

From the results, it is observed that HCP 14 is ranked as first with relative SSD score of 1.03104 followed by HCP13 with SSD value of 1.08855. HCP4 is ranked least efficient with relative SSD score of 0.97375. Although data under study consisted of multiple outputs, the proposed approach is able to compute efficiency scores in SFA framework without aggregating the outputs or without using distance functions which are of very complex. The proposed model acknowledges the stochastic nature of the data by decomposing the error term into two parts: (a) the traditional random error that captures the effect of measurement error, other statistical noise which captures the effect of inefficiency.

V. CONCLUDING REMARKS

This paper proposed integrated method of DEA-SFA for ranking of fifteen public sector hospitals of India. The results indicated that number of physicians, number of nurses, active beds, length of stay, outpatient visits and patient bed days are most important variables in the efficiency evaluation of the health care sectors. The integrated approach overcomes some of the shortcomings of the direct methods, to make the best use of their individual strengths. The integrated method made SFA simple, when there are multiple outputs and also multiple inputs, in the computation of technical efficiency for each DMU. The proposed method, overcomes the problem of infeasibility. Stakeholders can observe position of hospitals by using efficiency results. Moreover, health care providers can improve their overall performance by taking decision based on efficiency results.

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