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RESEARCH ARTICLE

Performance Evaluation of Indian Private Hospitals Using DEA Approach with Sensitivity Analysis

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Abstract

Private sector hospitals in India are facing the immense pressure for cost-reduction and better treatment. In order to become efficient and competitive, these hospitals have to provide medical services of international standard at affordable prices. There is a need to develop an approach to assess the efficiency of the healthcare centres. In view of this, the study measures relative efficiency of some private sector hospitals in India. DEA based CCR and BCC models are applied to evaluate the performance of 55 private sector hospitals for the year 2009-2010. The study finds that ten hospitals can set an example of best operating practice for the remaining 45 inefficient hospitals to follow. The DEA analysis reveals that on average every hospital has to increase its output by 23.70% by maintaining the existing level of inputs. The overall performance of the hospitals is largely affected due to poor utilization of the resources. Wockhardt Hospital Ltd is found to be a benchmark in the selected hospitals. Slack analysis indicates the scope for improvement in fixed capital utilization. The sensitivity analysis depicts that the efficiency scores of the hospitals are stable even after the exclusion of the top performer.

Keywords: *DEA, Efficiency, Hospitals and Sensitivity analysis.*

Introduction

Healthcare sector is one of India's expanding sectors at rural and urban level. It is growing in terms of revenue and employment. Government of India is building a healthcare infrastructure at primary, secondary and tertiary level from last many years after independence. However, the services of the government hospitals have been shrinking. On the other hand, the private sector has grown up at much higher rate than the public sector. Inadequate infrastructure, non-availability of competent doctors and paramedical staff, poor maintenance, lack of motivation among the staff, and insufficient supply of drugs and medicines are the major problems with the public sector healthcare institutions.

Private sector healthcare services range from those provided by large corporate hospitals, small hospitals/nursing homes to clinics and dispensaries [1]. The private hospitals are increasing in numbers vastly due to a number of factors including government policies of concessional land allotment and relaxation in custom duties on import of medical equipment, rapid influx of medical technology, growing deficits of public sector hospitals, and an increasing middle-income class [1]. Private hospitals can provide the required healthcare services to India's growing population. In addition, they can be a major medical tourism destination for treating patients from other countries also.

However, the physical infrastructure is woefully inadequate to meet today's healthcare demands. Out of the 15,393 hospitals in India in 2002, about two-third were in the public sector. The number of public health facilities is also inadequate. For instance, India needs

74,150 community health centres per million populations but has less than half of that number [2]. In addition, at least 11 Indian states do not have laboratories for testing drugs, and more than half of the existing laboratories are not properly equipped or staffed. On the other hand, private hospitals provide about 60% of all outpatient care in India and as much as 40% of all inpatient care. It is estimated that nearly 70% of all hospitals and 40% of hospital beds in the country are in the private sector [2].

However, in order to become efficient and competitive, the private hospitals have to upgrade their infrastructure. They should provide cost-effective medical services of international standard at affordable prices. Thus, the growing pressure for cost-reduction and better treatment lead to a need for the development of optimization-based approaches to assess the efficiency of the healthcare institutions. Data Envelopment Analysis (DEA) determines relative efficiencies of the Decision Making Units (DMUs), such as hospitals, based on their inputs/outputs. Keeping this in view, we examine the relative performance of some private sector hospitals of India through DEA methodology. The paper attempts to estimate technical efficiency of the hospitals, set benchmark for inefficient hospitals, and suggest alternative actions that would make them relatively efficient. The paper is organized as follows: section 2 contains data and variables, section 3 models used, results and discussion are given in section 4, and section 5 contains sensitivity analysis followed by conclusion in the last.

Data and Variables Selection

Data, for the study, have been collected for 55 private sector hospitals for the year 2009-2010 from PROWESS database of Centre for Monitoring Indian Economy. The data collected are given in Table 1. The variables used in the study represent financial status of the hospitals. Attempts are made to incorporate a comprehensive list of inputs and outputs, which reflect the general and informative results. However, some considerations have been taken for the selection of number of hospitals, inputs and outputs. As the thumb rule, the number of hospitals is expected to be larger than the product of number of inputs and outputs in order to discriminate effectively between efficient and inefficient hospitals [3]. FInitially, we have considered two outputs such as operating income and net profit; and four inputs net-fixed capital, energy expenses, wages and salaries, and raw material expenses. But net profit figures for some of the hospitals are found to be negative, and DEA strictly requires value of all inputs and outputs to be positive [1]. Hence, it becomes imperative to drop net profit variable from the analysis. Most of the hospitals reported raw material zero, because the private hospitals do not provide the medicine and material required for the treatment. Generally, they prescribe the required medicine to be purchased from medical stores. Therefore, this variable is not considered for DEA analysis. Thus, finally, the input variables taken are net fixed assets, energy expenses, wages and salaries, and the output variable taken is operating income. The input and output variables are defined as follows

Net Fixed Assets (NFA)

These are the total fixed assets net of accumulated depreciation. It includes capital work in progress and revalued assets, if any.

Energy Expenses (EE)

These expenses are mainly electric charges, and also include fuel charges, if any.

Wages & Salaries (WS)

It includes total annual expenses incurred by a hospital on all employees with management. Contributions to employees' provident fund, payment of bonus and staff welfare expenses are also included under this variable.

Operating Income (OI)

It refers to the revenue generated by a hospital from its service activities during a given accounting period.

Descriptive statistics for input and output variables are shown in Table 2. Correlation analysis has been worked out to know the extent of correlation between the inputs and output. It is observed that the OI has good correlation with the input variables as shown in Table 3.

Models Used

Initially DEA was proposed by Charnes, Cooper and Rhodes [4]. Since early 1980s, DEA has been extensively used for efficiency analysis of healthcare organizations. Work done by Sherman [5] and Nunamker [6] are the first among those who applied DEA to measure hospitals and nursing services efficiency. Since then, DEA has been used widely in the assessment of health care organizations all over the world. Despite the availability of other efficiency measurement methods, the DEA has become the dominant approach for measuring efficiency in healthcare and many other sectors in the economy (Hollingsworth [7] and Jacobs & Smith [8]). Chilingerian and Sherman [9]

Table 1: Observed data of the sample hospitals in India (2009-2010)

Code	Inputs			Outputs	Code	Inputs			Outputs
	NFA	EE	SW	OI		NFA	EE	SW	OI
H1	840.5	36.6	118.2	681.2	H29	426.5	3.6	19.6	143.1
H2	399.5	13.9	84.9	390	H30	4951.2	130.9	648.5	1261.5
H3	1808.5	48.7	200.7	1728.4	H31	22.1	2	23.5	46.8
H4	28.5	0.4	26.8	66.6	H32	18	1.5	85.9	185.5
H5	1013.7	33.7	108.5	851.5	H33	57.5	6.5	24.6	122.2
H6	1776.8	52	205.2	1268.4	H34	996.7	47.8	160.2	1434.8
H7	1027.1	18.6	86.9	775.8	H35	14.3	0.6	7.0	18.8
H8	467.2	25	121.5	764.9	H36	408.6	10.3	32.6	372
H9	375.4	57.5	115.8	1093.8	H37	4.0	0.6	6.6	22.6
H10	115.4	5.4	31.2	106.1	H38	516.8	19	107.8	594.5
H11	35.5	1.9	9.6	57.8	H39	78	2.5	20.3	89.4
H12	44.2	1.2	9.0	35.5	H40	986.3	22.9	88.9	778.2
H13	121.6	0.4	6.8	34.2	H41	1365.4	81.3	415.5	2656.8
H14	288.8	16	198.7	889	H42	6.1	0.5	3.6	17.5
H15	937	25.4	102.4	646.6	H43	275.2	14	75.6	438.2
H16	926.4	21.5	160.3	747.9	H44	323	13	60	400.5
H17	84	6.3	40.3	145.6	H45	50.1	1.6	10.9	76.2
H18	7702.6	31.2	158.3	1102.6	H46	2456.9	44.7	138.1	529.4
H19	300.1	14.8	95.1	642.5	H47	775.8	23.8	148.3	1029.9
H20	557.8	15.1	115	619.4	H48	83.4	3.9	17.1	90.9
H21	111.5	8.0	25.5	199.8	H49	1351.2	37.1	177.1	1508.5
H22	2058.7	130.6	824.4	4364.9	H50	148	6.2	50	265.9
H23	216.1	15.8	64.9	404.3	H51	86.7	3.3	32.7	104.1
H24	441	3.7	19.4	69	H52	88.4	1.9	14.3	74.4
H25	104.3	3.2	19.9	100.2	H53	184.8	13.1	62.8	514.9
H26	969.5	51.1	115.8	1020.3	H54	301.4	7.7	18.1	106.2
H27	984.5	47.9	171.8	1320.4	H55	1574.8	138.7	581.3	5314.4
H28	644.1	29.8	113	841.4	Mean	762.4	24.6	116.1	712.1

Data Source: PROWESS database

Table 2: Descriptive statistics for inputs and outputs

Statistics	NFA	EE	WS	OI
Max	7702.6	138.70	824.40	5314.40
Min	4	0.40	3.6	17.50
Average	762.39	24.63	116.01	712.09
SD	1265.29	32.09	158.42	967.51

Table 3: Correlation matrix of input-output variables

Variables	NFA	EE	WS	OI
NFA	1			
EE	0.557	1		
WS	0.535	0.945	1	
OI	0.402	0.892	0.877	1

noted that DEA has become the researchers' choice for finding the best practices and evaluating productive inefficiency in health care institutions. The DEA models are divided into two orientations, one is input orientation and another is output orientation. The input orientated model determines by how much input quantities can be proportionally reduced without changing the output quantities produced. In contrast, the output-orientated model determines by how much output quantities can be proportionally expanded without altering the quantities of inputs. The choice of model orientation, input-oriented or output-oriented, depends on the extent to which the health institution has control on its inputs or outputs [8, 10]. The objective of the private hospitals is to maximize the operating income using existing inputs. Hence, the output oriented model is suitable for this analysis. Here we will use the output oriented CCR and BCC models for the analysis.

The Output Oriented CCR model [4]

It is given by

$$\left.\begin{aligned} & Min\, E_k = \sum_{i=1}^{m} u_{ik} x_{ik} \\ & s.t. \quad \sum_{r=1}^{s} v_{rk} y_{rk} = 1 \\ & \qquad \sum_{i=1}^{m} u_{ik} x_{ij} - \sum_{r=1}^{s} v_{rk} y_{rj} \geq 0 \qquad \forall j = 1, 2, \ldots, n, \\ & \qquad \sum_{i=1}^{m} u_{ik} x_{ij} - \sum_{r=1}^{s} v_{rk} y_{rj} \geq 0 \qquad \forall j = 1, 2, \ldots, n, \\ & \qquad u_{ik} \geq \varepsilon \qquad \forall r = 1, 2, \ldots, s, \\ & \qquad v_{rk} \geq \varepsilon \qquad \forall i = 1, 2, \ldots, m, \end{aligned}\right\} \quad (1)$$

Where

E_k is the efficiency of the kth hospital,

n is the total number of hospitals,

y_{rk} is the amount of the rth output produced by the kth hospital,

x_{ik} is the amount of the ith input used by the kth hospital,

u_{ik} is the weight given to the ith input of the kth hospital,

v_{rk} is the weight given to the rth output of the kth hospital,

ε is non-Archimedean (infinitesimal) constant.

The CCR Envelopment Model

It is the dual problem of the model (1) and is given by:

$$\left.\begin{aligned} & Max\, Z_k = \phi_k + \varepsilon \left(\sum_{r=1}^{s} s_{rk}^{+} + \sum_{i=1}^{m} s_{ik}^{-} \right) \\ & s.t. \quad \sum_{j=1}^{n} \lambda_{jk} y_{rj} - s_{rk}^{+} = \phi_k y_{rk} \qquad \forall r = 1, \ldots, s, \\ & \qquad \sum_{j=1}^{n} \lambda_{jk} x_{ij} + s_{ik}^{-} = x_{ik} \qquad \forall i = 1, \ldots, m, \end{aligned}\right\} \quad (2)$$

ϕ_k is unrestricted is sign

$\lambda_{jk}, s_{ik}^{-}, s_{rk}^{+} \geq 0 \quad \forall i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n;\ r = 1, 2, \ldots, s,$

Where

λ_{jk} is the dual variable corresponding to the jth constraint and is known as intensity variable,

S_{rk}^{+} is the slack in the rth output of the kth hospital,

S_{ik}^{-} is the slack in the ith input of the kth hospital.

The Output-Oriented BCC Model [11]

It is given by

$$\left.\begin{aligned} & Min\, E_k = \sum_{i=1}^{n} u_{ik} x_{ik} + u_{0k} \\ & s.t. \quad \sum_{r=1}^{s} v_{rk} y_{rk} = 1 \\ & \qquad \sum_{i=1}^{m} u_{ik} x_{ij} - \sum_{r=1}^{s} v_{rk} y_{rj} + u_{0k} \geq 0, \quad \forall j = 1, 2, \ldots, n \\ & \qquad v_{rk} \geq \varepsilon \qquad \forall r = 1, 2, \ldots, s \\ & \qquad u_{ik} \geq \varepsilon \qquad \forall i = 1, 2, \ldots, m \\ & \qquad u_{0k} \text{ is unresrected in sign} \end{aligned}\right\} \quad (3)$$

The BCC Envelopment Model

It is the dual problem of the model (3) and is given by

$$\left.\begin{aligned} & Max\, Z_k = \phi_k + \varepsilon \left(\sum_{r=1}^{s} s_{rk}^{+} + \sum_{i=1}^{m} s_{ik}^{-} \right) \\ & s.t. \quad \sum_{j=1}^{n} \lambda_{jk} x_{ij} + s_{ik}^{-} = x_{ik} \qquad \forall i = 1, \ldots, m \\ & \qquad \sum_{j=1}^{n} \lambda_{jk} y_{rj} - s_{rk}^{+} = \phi_k y_{rk} \qquad \forall r = 1, \ldots, s \\ & \qquad \sum_{j=1}^{n} \lambda_{jk} = 1 \qquad \forall j = 1, 2, \ldots, n \\ & \qquad \lambda_{jk}, s_{ik}^{-}, s_{rk}^{+} \geq 0 \quad \forall i, j, r \\ & \qquad \text{and } \phi_k \text{ is unrestricted in sign} \end{aligned}\right\} \quad (4)$$

Some Definitions

Overall Technical Efficiency (OTE)

It reflects the ability of a DMU to obtain the maximum output from a given set of inputs. It is the efficiency score evaluated from CCR model.

Pure Technical Efficiency (PTE)

It refers to the proportion of technical efficiency which is attributed to the efficient conversion of inputs into output given the scale size. It is the efficiency score evaluated from BCC model.

Scale Efficiency (SE)

Scale efficiency measures the impact of scale size on the efficiency of a DMU. It is the ratio of OTE to PTE.

Efficient DMU

A DMU (Hospital) is said to be fully efficient if and only if $\phi^* = 1$ and slacks $s_j^{-*} = s_r^{+*} = 0 \, \forall j, r$ Otherwise the hospital is called inefficient.

Peer

A peer is an efficient DMU which acts as a reference point for inefficient DMUs.

Input Oriented Measure

The input oriented technical efficiency measures the input quantities which can be proportionally reduced without changing the output quantity produced.

Output Oriented Measure

The output oriented technical efficiency measures the output quantities that can be proportionally expanded without altering the input quantities used.

Returns to Scale (RTS)

It refers to the magnitude of the change in the rate of output relative to the change in scale.

Constant Returns to Scale (CRS)

The output changes in proportion to the change in inputs.

Variable Returns to Scale (VRS)

The output may increase more than the proportion increment in inputs (Increasing returns to scale) and increase less than the proportion increment in inputs (Decreasing returns to scale).

Slacks

The quantity of excess resources used and / or deficient output produced are known as input slacks and output slacks respectively by an inefficient DMU to become efficient after radial change to reach the efficiency frontier.

Results and Discussion

The efficiency scores (OTE, PTE and SE) for 55 hospitals are estimated for the year 2009-2010. The efficiency scores obtained from CCR and BCC output oriented models along with reference set, peer weights, peer counts, slacks and sensitivity analysis are discussed in this section.

Technical Efficiency

DEA evaluates the set of hospitals that construct the production frontier. The hospitals having values of the OTE score equal to one, form the efficient frontier and those having the values less than one are inefficient. Technical Efficiency scores are calculated through CCR model. Table 4 evinces that out of 55 hospitals 10 hospitals are relatively technical efficient (OTE = 1) and thus form the efficient frontier. The remaining 45 hospitals are inefficient as they have efficiency scores less than one. The 10 efficient hospitals are H4, H7, H9, H13, H14, H32, H36, H37, H45 and H55. These hospitals are on the efficient frontier and thus forms the "reference set", i.e., these hospitals can set an example of the best operating practice for the remaining 45 inefficient hospitals to follow. Mandke Foundation (H30) is the most technical inefficient hospital since it scores only 23.0% efficiency. Among the inefficient hospitals, 18 hospitals have the efficiency scores above the average efficiency score (0.763). This reveals that on average hospital have to increase its outputs by 23.70% by maintaining the existing level of inputs. We also use the frequency of efficient hospitals in the reference set (i.e., peer count) to discriminate

Table 4: Resulting efficiency scores of hospitals by CCR model

Code	OTE	Ref. Set	Peer Weight	Peer Count	Code	OTE	Ref. Set	Peer Weight	Peer Count
H1	0.566	H36,H9,H55	1.59,0.15,0.09	0	H29	0.894	H13,H7	0.56,0.18	0
H2	0.620	H45,H7,H55	6.24,0.05,0.02	0	H30	0.230	H7,H55,H45	3.62,0.27,	0
H3	0.906	H7,H36,H55	1.09,1.25,0.11	0	H31	0.473	H55,H37,H32	0.01,0.28,0.18	0
H4	1	H4	1	7	H32	1	H32	1	2
H5	0.734	H36,H9,H55	2.23,0.07,0.05	0	H33	0.611	H55,H37	0.04,0.66	0
H6	0.634	H7,H36,H55	0.79,1.87,0.13	0	H34	0.898	36,9,55	1.72,0.18,0.14	0
H7	1	H7	1	18	H35	0.567	H4,H45,H14	0.03,0.13,0.03	0
H8	0.750	H7,H55,H45	0.08,0.13,3.83	0	H36	1	H36	1	14
H9	1	H9	1	7	H37	1	H37	1	2
H10	0.452	H45,H55,H14	1.65,0.02,0.01	0	H38	0.715	H45,H7,H55	6.47,0.12,0.05	0
H11	0.735	H45,H7,H55	0.39,0.002,0.01	0	H39	0.715	H4,H45,H14	0.10,1.15,0.01	0
H12	0.600	H13,H45,H4	0.06,0.73,0.03	0	H40	0.880	H7,H36,H55	0.5,1.09,0.02	0
H13	1	H13	1	7	H41	0.792	H45,H55,H14	13.38,0.42,0.14	0
H14	1	H14	1	12	H42	0.802	H32,H14,H55	0.013,0.004,0.003	0
H15	0.655	H7,H36,H55	0.51,0.81,0.06	0	H43	0.738	H45,H55,H14	3.59,0.06,0.01	0
H16	0.701	H13,H45,H4	2.29,0.17	0	H44	0.765	H7,H55,H45	0.18,0.06,0.94	0
H17	0.538	H45,H55,H14	0.04,0.03,0.10	0	H45	1	H45	1	25
H18	0.819	H7,H13	1.62,2.54	0	H46	0.336	H36	4.24	0
H19	0.975	H45,H55,H14	3.69,0.05,0.13	0	H47	0.945	H45,H7,H55	11.19,0.18,0.02	0
H20	0.828	H13,H45,H4	0.73,9.16,0.38	0	H48	0.592	H7,H55,H45	0.05,0.02,0.09	0
H21	0.819	H36,H9,H55	0.12,0.05,0.03	0	H49	0.986	H7,H55,H45	1.02,0.09,2.97	0
H22	0.771	H45,H55,H14	12.29,0.60,1.71	0	H50	0.885	H45,H55,H14	2.04,0.01,0.12	0
H23	0.671	H7,H36,H55	0,0.13.0.11	0	H51	0.602	H4,H45,H14	0.10,1.18,0.09	0
H24	0.426	H7,H13	0.19.0.43	0	H52	0.783	H13,H45,H4	0.26,1.12,0.01	0
H25	0.684	H45,H7,H55	1.49,0.03,0.01	0	H53	0.981	H45,H55,H14	1.04,0.08,0.03	0
H26	0.837	H9,H36	0.45,1.96	0	H54	0.514	H36	0.56	0
H27	0.780	H36,H9,H55	1.60,0.09,0.79	0	H55	1	H55	1	32
H28	0.757	H36,H9,H55	1.05,0.01,0.13	0	Mean	0.763	-	-	-

among them. The higher peer count represents the extent of robustness of that hospital compared with other efficient hospitals. In other words, a hospital with higher peer count is likely to be a hospital, which is efficient with respect to a large number of factors and is probably a good example of a "global leader" or a hospital with high robustness. Efficient hospitals that appear seldom in the reference set are likely to possess a very uncommon input/output mix so when the peer count is low, one can safely conclude that the hospitals is somewhat of an odd unit and cannot be treated as a good example to be followed. Based on robustness of efficiency scores, the hospitals on the frontier are classified as

High Robustness

Wockhardt Hospital Ltd.,(H55, peer count =32) is considered as high robust hospital as it has maximum peer count, so it can be considered as global leader in terms of technical efficiency.

Middle Robustness

Banashankari Medical & Oncology Research Centre Pvt. Ltd., (H7, peer count = 18), Dr. Agarwal's Eye Hospital Ltd. (H14, peer count =12), Noida Medicare Centre Ltd. (H36, peer count =14) and Sada Sharada Tumour & Research Institute. (H45, peer count =25) are classified in the middle robust group.

Low Robustness

Apollo Health & Lifestyle Ltd (H4, peer count = 7), Breach Candy Hospital Trust (H9, peer count = 7), Dolphin Medical Services Ltd. (H13, peer count = 7), Max Neeman Medical Intl. Ltd. (H32, peer count = 2), and Onnu Kurae Ayiram Yogam Mission Hospital Ltd. (H37, peer count = 2) are graded in the low robust group in terms of overall technical efficiency.

Pure Technical Efficiency

Since CCR model works on the basis of CRS in which scale-size of the DMU is not considered, so it is relevant to assess technical efficiency. Therefore, in order to know whether inefficiency in any hospital is due to inefficient production operation or due to unfavourable conditions displayed by the size of hospital, BCC model is also applied [12]. Table 5 shows DEA results calculated by this model. It is evident from Table 5 that out of 55 hospitals only 10 are overall technical efficient (OTE=1), and 12 hospitals are pure are technical efficient (PTE = 1), i.e., none of these has scope to further augment outputs (maintaining the same input level) while remaining 43 hospitals are relatively inefficient (score < 1). PTE measures that how efficiently inputs are converted in to outputs irrespective of the size of the hospital. The average of PTE comes out to be 0.788; this means that given the scale of operation, on average a hospital can increase its outputs by 21.20% of its observed level without reducing its inputs level.

Table 5: OTE, PTE, SE and RTS of 55 hospitals in India in 2009-2010

Code	OTE	PTE	SE	RTS	Code	OTE	PTE	SE	RTS
H1	0.566	0.596	0.95	DRS	H29	0.894	0.895	0.999	IRS
H2	0.620	0.647	0.959	DRS	H30	0.230	0.251	0.918	DRS
H3	0.906	0.925	0.98	DRS	H31	0.473	0.485	0.975	IRS
H4	1	1	1	-	H32	1	1	1	-
H5	0.734	0.807	0.91	DRS	H33	0.611	0.618	0.989	IRS
H6	0.634	0.658	0.964	DRS	H34	0.898	0.943	0.952	DRS
H7	1	1	1	-	H35	0.567	0.644	0.881	IRS
H8	0.750	0.761	0.986	DRS	H36	1	1	1	-
H9	1	1	1	-	H37	1	1	1	-
H10	0.452	0.458	0.986	DRS	H38	0.715	0.739	0.967	DRS
H11	0.735	0.787	0.934	IRS	H39	0.715	0.727	0.983	DRS
H12	0.600	0.616	0.974	IRS	H40	0.88	0.897	0.982	DRS
H13	1	1	1	-	H41	0.792	0.819	0.967	DRS
H14	1	1	1	-	H42	0.802	1	0.802	IRS
H15	0.655	0.662	0.990	DRS	H43	0.738	0.754	0.978	DRS
H16	0.701	0.753	0.931	DRS	H44	0.765	0.767	0.998	DRS
H17	0.538	0.544	0.988	IRS	H45	1	1	1	-
H18	0.819	0.853	0.96	DRS	H46	0.336	0.4	0.839	DRS
H19	0.975	0.996	0.979	DRS	H47	0.945	0.991	0.954	DRS
H20	0.828	0.876	0.945	DRS	H48	0.592	0.609	0.972	IRS
H21	0.819	0.858	0.954	IRS	H49	0.986	1	0.986	DRS
H22	0.771	0.869	0.887	Drs	H50	0.885	0.902	0.981	DRS
H23	0.671	0.683	0.982	IRS	H51	0.602	0.606	0.993	DRS
H24	0.426	0.427	0.998	IRS	H52	0.783	0.797	0.982	DRS
H25	0.684	0.696	0.983	DRS	H53	0.981	0.982	0.999	DRS
H26	0.837	0.910	0.92	DRS	H54	0.514	0.545	0.943	IRS
H27	0.780	0.812	0.961	DRS	H55	1	1	1	-
H28	0.757	0.768	0.986	DRS	Mean	0.763	0.788	0.966	

PTE is concerned with the efficiency in converting inputs to outputs for the given scale size of the hospitals as we observe that H42 and H49 are CCR technically inefficient while they are pure technically efficient. Inefficiency in these hospitals is due to scale-size. If we check their returns to scale, H42 shows IRS and H49 DRS. However, the inefficiency is much higher in H42 compared to H49. It suggests that if effect of scale-size neutralized, H42 can become efficient by increasing the investment in the hospital.

Scale Efficiency

Scale efficiency (SE) is the ratio of the OTE and PTE scores. If the value of the SE score is one, then the hospital is apparently operating at optimal scale size. If the value is less than one, then the hospital appears either small or big relative to its optimum scale size [13]. From Table 5, we see that out of 55 hospitals, 10 hospitals are scale efficient, while the remaining 45 hospitals are scale inefficient. The average scale efficiency is 0.966 which indicates that on average a hospital may have to increase its scale by 3.40% beyond its best practice average targets under VRS, if it were to operate at CRS. RTS analysis indicates that the 13 hospitals are operating on IRS, 10 hospitals on CRS and remaining 32 inefficient hospitals on DRS. It shows that more than 50% hospitals are operating on DRS, indicating the under utilization of the existing scale-size.

Table 6: Slacks in Inputs and Outputs by CCR model

Code	Inputs			Output	Code	Inputs			Output
	NFA	EE	SW	OI		NFA	EE	SW	OI
H1	0	0	0	0	H29	171.59	0	0	0
H2	0	0	0	0	H30	0	0	0	0
H3	0	0	0	0	H31	0	0	0	0
H4	0	0	0	0	H32	0	0	0	0
H5	0	0	0	0	H33	0	1.27	0	0
H6	0	0	0	0	H34	0	0	0	0
H7	0	0	0	0	H35	0	0	0	0
H8	0	0	0	0	H36	0	0	0	0
H9	0	0	0	0	H37	0	0	0	0
H10	0	0	0	0	H38	0	0	0	0
H11	0	0	0	0	H39	0	0	0	0
H12	0	0	0	0	H40	0	0	0	0
H13	0	0	0	0	H41	0	0	0	0
H14	0	0	0	0	H42	0	0	0	0
H15	0	0	0	0	H43	0	0	0	0
H16	0	0	0	0	H44	0	0	0	0
H17	0	0	0	0	H45	0	0	0	0
H18	5726.82	0	0	0	H46	725.99	1.07	0	0
H19	0	0	0	0	H47	0	0	0	0
H20	0	0	0	0	H48	0	0	0	0
H21	0	0	0	0	H49	0	0	0	0
H22	0	0	0	0	H50	0	0	0	0
H23	0	0	0	0	H51	0	0	0	0
H24	194.04	0	0	0	H52	0	0	0	0
H25	0	0	0	0	H53	0	0	0	0
H26	0	5.15	0	0	H54	74.54	1.98	0	0
H27	0	0	0	0	H55	0	0	0	0
H28	0	0	0	0	Mean	125.33	0.17	0	0

Input-Output Targets for Inefficient Hospitals

DEA allows setting the input and output targets for inefficient hospitals [14], so that they improve their performance and each of the hospitals become efficient. According to the CCR model the targets for the inefficient hospitals are as follows:

For outputs:

$$\overline{y_{rk}} = \phi_k^* \, y_{rk} + S_{rk}^{+*} = \sum_{j=1}^{n} \lambda_{jk}^* y_{rj}$$

For inputs:

$$\overline{x_{rk}} = x_{ik} - S_{ik}^{-*} = \sum_{j=1}^{n} \lambda_{jk}^* x_{ij}$$

where $\overline{y_{rk}}$ (r= 1) and $\overline{x_{ik}}$ (i= 1,2,3,) are the output and input targets respectively for the k^th^ hospital; y_{rk} and x_{ik} are the actual output and inputs respectively of the k^th^ hospital; ϕ_k^* is the optimal efficiency score of the k^th^ hospital; s_{ik}^{-*} and s_{rk}^{+*} are the optimal input and output slacks of the k^th^ hospital for (i=1,2,3,) and (r=1). The optimal input and output slacks for inefficient hospitals are given in Table 6:

The target values for all inputs and outputs of inefficient hospitals along with percent age-reduction in inputs and augmentation in outputs are given in Table 7. It shows that on average hospitals has significant scope to reduce inputs and augment outputs relative to the best performing hospital. On average 44.27 % of OI should be augmented along with 18.12 % reduction in NFA, and 0.85% in EE, if all the inefficient hospitals operate at the efficient level.

Table 7: Target values of input and output variables under CCR output oriented model

	Inputs			Output		Inputs			Output
Code	NFA	EE	SW	OI	Code	NFA	EE	SW	OI
H1	840.5(0)	36.6(0)	118.2(0)	1203.82(76.72)	H29	254.91 (40.23)	3.6(0)	19.6(0)	160.03(11.83)
H2	399.5(0)	13.9(0)	84.9(0)	628.84(61.24)					
H3	1808.5(0)	48.7(0)	200.7(0)	1906.72(10.32)	H30	4951.2(0)	130.9(0)	648.5(0)	5483.67(334.69)
H5	1013.7(0)	33.7(0)	108.5(0)	1159.67(36.19)	H31	22.1(0)	2(0)	23.5(0)	99.02(111.57)
H6	1776.8(0)	52(0)	205.2(0)	1999.65(57.65)	H33	57.5(0)	5.23(19.54)	24.6(0)	200.04(63.70)
H8	467.2(0)	25(0)	121.5(0)	1019.63(33.30)	H34	996.7(0)	47.8(0)	160.2(0)	1598.19(11.39)
H10	115.4(0)	5.4(0)	31.2(0)	234.95(121.44)	H35	14.3(0)	0.60(0)	7(0)	33.14(76.29)
H11	35.5(0)	1.9(0)	9.6(0)	78.68(36.12)	H38	516.8(0)	19(00	107.8(0)	831.67(39.89)
H12	44.2(0)	1.2(0)	9(0)	59.19(66.72)	H39	78(0)	2.5(0)	20.3(0)	125.07(39.89)
H15	937(0)	25.4(0)	102.4(0)	986.73(52.60)	H40	968.3(0)	22.9(0)	88.9(0)	884.23(13.62)
H16	926.4(0)	21.5(0)	160.3(0)	1067.55(42.74)	H41	1365.4(0)	81.3(0)	415.5(0)	3353.43(26.22)
H17	84(0)	6.3(0)	40.3(0)	270.77(85.97)	H42	6.1(0)	0.50(0)	3.6(0)	21.82(24.71)
H18	1975.78 (74.35)	31.2(0)	158.3(0)	1345.86(22.06)	H43	275.2(0)	14(0)	75.6(0)	593.83(35.51)
					H44	323(0)	13(0)	60(0)	523.29(30.66)
H19	300.1(0)	14.8(0)	95.1(0)	658.90(2.55)	H46	1730.91 (29.55)	43.63 (2.39)	138.1(0)	1575.87(197.67)
H20	557.8(0)	15.1(0)	115(0)	748.23(20.80)					
H21	111.5(0)	8(0)	25.5(0)	244.05(22.15)	H47	775.8(0)	23.8(0)	148.3(0)	1090.04(5.84)
H22	2058.7(0)	130.6(0)	824.4(0)	5659.76(29.67)	H48	83.4(0)	3.9(0)	17.1(0)	153.51(68.88)
H23	216.1(0)	15.8(0)	64.9(0)	602.58(49.04)	H49	1351.2(0)	37.1(0)	177.1(0)	1530.36(1.45)
H24	246.92 (44.01)	3.7(0)	19.4(0)	161.83(134.54)	H50	148(0)	6.2(0)	50(0)	300.32(12.95)
					H51	86.7(0)	3.3(0)	32.7(0)	173.02(66.21)
H25	104.3(0)	3.2(0)	19.9(0)	146.43(46.14)	H52	88.4(0)	1.9(00	14.3(0)	95.04(27.74)
H26	969.5(0)	45.95 (10.08)	115.8(0)	1219.47(19.52)	H53	184.8(0)	13.1(0)	62.8(0)	524.83(1.93)
					H54	226.86 (24.73)	5.72 (25.71)	18.1(0)	206.54(94.48)
H27	984.5(0)	47.9(0)	171.8(0)	1692.52(28.18)					
H28	644.1(0)	29.8(0)	113(0)	1111.25(32.07)	Mean	692.04 (18.12)	24.44 (0.85)	116.19 (0)	972.53(44.27)

Fig. in braces are the percentage reduction in the corresponding inputs and percentage addition in corresponding outputs to make the hospital efficient.

Sensitivity Analysis

To investigate the robustness of the efficiency score, Sensitivity Analysis has also been conducted [2]. For sensitivity analysis efficient hospitals removed one by one peer count wise. For this firstly we remove H55 (peer count 32), from the reference set. By this operation we observe that 10 hospitals are CCR efficient with TE is 0.771 and 17 are BCC efficient with PTE 0.810. H53 is the efficient one after removing hospital H55. This indicates that inefficiency of H53 is due to H55, thus the hospital H53 has the structure similar to H55. If we remove H45 (peer count 25), then 9 hospitals are CCR efficient with TE 0.767 and 11 are BCC efficient with PTE 0.789. If we remove H7 (peer count 18), then 10 hospitals become CCR efficient with TE 0.759 and 11 hospitals are BCC efficient 0.785. If we remove H36 (peer count 14), then 9 hospitals becomes CCR efficient with TE 0.775 and 11 hospitals are BCC efficient with PTE with PTE 0.796. If we remove H14 (peer count 12), then 9 hospitals are efficient with TE 0.759, and 13 hospitals are pure technically efficient with PTE 0.787. All the efficient CCR or BCC hospitals are given in Table 8 with their respective mean efficiencies.

Table 8: Efficiency scores during Sensitivity Analysis

Efficient hospital to be removed	Mean TE	New efficient hospitals (CCR Model)	Mean pure TE	New efficient hospitals (BCC Model)
Initial Efficiency Values	76.30% (initial)	H4,7,9,13,14,32,36,37, 45,55, (initial)	78.80% (initial)	H4,7,9,13,14,32,36,37,42, 45,49,55, (initial)
H55 (PC=32)	77.10%	H4,7,9,13,14,32,36,37, 45,53	81.0%	H3,4,7,9,13,14,19,22,32, 34,36,37,41,42,45,49,53
H45 (PC=25)	76.70%	H4,7,9,13,14,32,36,37, 55	78.90%	H4,7,9,13,14,32,36,37,42, 49,55

H7 (PC=18)	75.90%	H4,9,13,14,19,32,36,37,45,55	78.50%	H4,9,13,14,32,36,37,42,45,49,55
H36 (PC=14)	77.50%	H4,7,9,13,14,32,37,45,55	79.60%	H4,7,9,13,14,32,37,42,45,49,55
H14 (PC=12)	75.90%	H4,7,9,13,32,36,37,45,55	78.70%	H4,7,9,13,19,32,36,37,42,45,4749,55

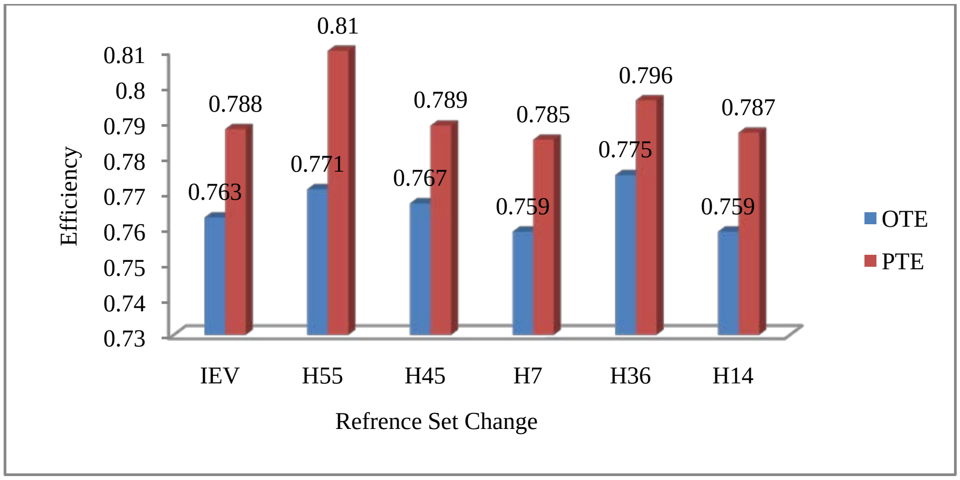

Fig. 1: Graph between deleted most peercount hospitals with their efficiencies

Conclusion

In this paper, we have measure technical and scale efficiencies of some private sector hospitals in India by using DEA. The study finds that out of 55 hospitals 10 hospitals (18.18 %) have maximum degree of efficiency. The mean OTE of hospitals is 76.30%, indicating that on average 23.70% of the technical potential of hospitals is not in use. This implies that these hospitals have the scope of producing the 23.70 % more output with the same level of inputs. H4, H7, H9, H13, H14, H32, H36, H37, H45 and H55 have scored the technical efficiency score of unity and thus they form the efficiency frontier. Among the efficient hospitals, Wockhardt Despite the fact the DEA results in this paper give an indication on the degree of hospital's efficiency in the process of transforming inputs in to outputs, the conclusion on the efficiency of hospitals need to be taken with some carefulness. The results of this study are dependent upon the choice of the inputs and outputs.

Hospital Ltd. (H55) is found to be the most efficient hospital. On the contrary, Mandke Foundation is found to be the most inefficient hospital. The Mandke Foundation hospital (H30) has to increase its output by 334.69% with the same level of inputs.

The results of BCC model shows that out of 55 hospitals, 12 hospitals (21.82%) are pure technical efficient. It is also observed that out of 12 BCC efficient hospitals 10 have CRS, one have DRS and one have IRS. Out of remaining 43 inefficient hospitals, most of the hospitals are showing DRS. The model suggested that on average, inefficient hospitals may be able to augment its output by 21.20% relative to the best performing hospital.

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Appendix – A:

S.No.	Hospital name	Location	Incorporate year
H1	Aditya Birla Health Services Ltd.	Maharashtra	2001
H2	Alps Hospital Pvt. Ltd.	New Delhi	1989
H3	Apollo Gleneagles Hospitals Ltd.	West Bengal	1988
H4	Apollo Health & Lifestyle Ltd.	Tamil Nadu	2001
H5	Apollo Hospitals Intl. Ltd.	Tamil Nadu	1997
H6	Artemis Medicare Services Pvt. Ltd.	New Delhi	2005
H7	Banashankari Medical & Oncology Research Centre Pvt. Ltd.	Karnataka	1986
H8	Billroth Hospitals Ltd.	Tamil Nadu	1994
H9	Breach Candy Hospital Trust	Maharashtra	1946
H10	Chennai Meenakshi Multispecialty Hospital Ltd.	Tamil Nadu	1990
H11	Crescent Medical Centre Ltd.	Kerala	1993
H12	Dhanvantri Jeevan Rekha Ltd.	UP	1993
H13	Dolphin Medical Services Ltd.	AP	1992
H14	Dr.Agarwal's Eye Hospital Ltd.	Tamil Nadu	1994
H15	Escorts Heart & Super Speciality Hospital Ltd.	New Delhi	2003
H16	Escorts Hospital & Research Centre Ltd.	New Delhi	1997
H17	Fortis Clinical Research Ltd.	New Delhi	2005
H18	Fortis Hospitals Ltd.	Haryana	2009
H19	Fortis Malar Hospitals Ltd.	Tamil Nadu	1989
H20	G N R C Ltd.	Assam	1985
H21	Ganga Care Hospital Ltd.	Maharashtra	2005
H22	Indraprastha Medical Corpn. Ltd.	New Delhi	1988
H23	Jaya Diagnostic & Research Centre Ltd.	AP	1987
H24	Jubilant First Trust Healthcare Ltd.	UP	2006
H25	K M C Speciality Hospitals (India) Ltd.	Tamil Nadu	1982
H26	Kims Health Care Mgmt. Ltd.	Kerala	1995
H27	Kovai Medical Center& Hospital Ltd.	Tamil Nadu	1985
H28	Lakeshore Hospital & Research Centre Ltd.	Kerala	1996
H29	Lotus Eye Care Hospital Ltd.	Tamil Nadu	1997
H30	Mandke Foundation	Maharashtra	1998
H31	Mangal Anand Health Care Ltd.	Maharashtra	1992
H32	Max Neeman Medical Intl. Ltd.	New Delhi	1999
H33	Medinova Diagnostic Services Ltd.	AP	1993
H34	Miot Hospitals Ltd.	Tamil Nadu	1994
H35	NagarjunaAyurvedic Centre Ltd.	Kerala	1996
H36	Noida Medicare Centre Ltd.	New Delhi	1988
H37	Onnu Kurae AyiramYogam Mission Hospital Ltd.	Kerala	1992
H38	Peerless Hospitex Hospital & Research Center Ltd.	West Bengal	1989
H39	Prerana Hospital Ltd.	Maharashtra	1996
H40	Pulikkal Medical Foundation	Kerala	1976
H41	Quality Care India Ltd.	AP	1992
H42	Rajasthan Cancer Cure Hospital Ltd.	Rajasthan	1995
H43	Ramkrishna Care Medical Sciences Pvt. Ltd.	MP	1998
H44	Regency Hospital Ltd.	UP	1987
H45	SadaSharada Tumour & Research Institute.	Karnataka	1989
H46	Sahara India Medical Institute Ltd.	Maharashtra	1997
H47	Sahyadri Hospitals Ltd.	Maharashtra	1996
H48	Sharma East India Hospitals & Medical Research Ltd.	Rajasthan	1989
H49	Sterling Addlife India Ltd.	Gujrat	2000
H50	Sushruta Medical Aid & Research Hospital Ltd.	AP	1985
H51	Trichur Heart Hospital Ltd.	Kerala	1985
H52	Valluvanad Hospital Complex Ltd.	Kerala	1985
H53	Visakha Hospitals & Diagnostics Ltd.	AP	1998
H54	Westfort Hi-Tech Hospital Ltd.	Kerala	1989
H55	Wockhardt Hospital Ltd.	Maharashtra	1991