European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

Data Envelopment Analysis and Super Efficiency Assessment of the Healthcare Industry

Rohit Bansal[1], Palvinder Kaur Bakshi[2], Yasmeen Ansari[3]

Corresponding Author
Rohit Bansal
Accounting & Finance, Rajiv Gandhi Institute of Petroleum Technology,
Amethi: rbansal@rgipt.ac.in

ABSTRACT
This study assesses the present efficiency level of the Indian healthcare industry and suggests the areas in which it can improve operational and financial performance. The study uses panel data from 19 decision-making units (DMUs) from 31st March 2016 to 31st March 2020. These data samples have been derived from the company's income and financial statements. We employ an input-oriented DEA (Data envelopment analysis) mechanism, i.e., Cost and input minimization, instead of an output-oriented DEA emphasising profit and Production maximization. The DEA was performed through SPSS 26 version, DEA Excel Solver Pro, and R-3.4.1 software to analyze the companies' efficiency levels. The Malmquist productivity index (MPI) and Tobit regression were used to assess and compare the companies' performance during the period under consideration. Super efficiency has also been calculated using eight different prototypes based on orientation, radially, and slacks using non-parametric rank statistics, namely Mann-Whitney U-test (MW), Kolmogorov-Smirnov test (KS), and Kruskal-Wallies test (KW)**.** Overall, we find from the technical efficiency, pure technical, and scale efficiency scores that out of 19 companies, four companies are technically efficient using the CCR and the BCC model. Further results show that 12 companies are technically efficient for the period under review using the BCC model. Few known studies have used input-oriented DEA models to assess the efficiency level of Indian healthcare. According to our information, this study is unique in examining the efficiency level of the Indian healthcare sector over five years. In addition, the Tobit results show that domestic institutional investors and mutual funds significantly impact efficiency scores.

Keywords: Super efficiency, Data Envelopment Analysis, Healthcare Industry, MPI and Tobit Regression

Type: Research paper

1. Introduction

The smooth operation of the healthcare system is vital for a nation's prosperity and well-being. The outbreak of the COVID-19 pandemic underlined the criticality of the healthcare sector in an unprecedented way. Optimal allocation of capital to the industry and its prudent use lead to efficient operations, contributing to affordable care and preventing social problems that can aggravate severe instabilities and turbulence (Charnes et al. 1978; Lai et al. 2018). However, inefficiencies in the health sector continue to weaken global attempts to improve health services (Zheng et al. 2019). World Health Report 2010 exhibits that 20-40% of all health sector resources are wasted worldwide due to inefficiencies (World Health Organization 2010). Besides squeezing the resources available to be spent for the nation's well-being, such inefficiencies often inhibit the labour force involved in economic activities, limiting economic development prospects (Chaity and Islam 2022; Lokanan et al. 2019; Valdiansyah and Murwaningsari 2022; Yaya et al. 2020).

The challenge of inefficiencies is much more severe for the healthcare sector in India, suffering from low economic levels, colossal population, below-average availability of hospital beds, limited sanitation, and extreme environmental factors contributing to the incidence of disease and death (Gandhi and Sharma 2018; Kim et al. 2020; Mogha et al. 2015). While the growth of India's healthcare sector is impressive (the industry was worth 140 billion US dollars in 2016, with projections to reach 372 billion dollars by 2022 (Statista 2021)), research has extensively questioned the efficiency of the sector in meeting the needs of the masses (Gandhi and Sharma 2018; Goyal et al. 2019; Maurya et al. 2023; Mishra et al.

[1] Corresponding Author, Accounting & Finance, Rajiv Gandhi Institute of Petroleum Technology, Amethi: rbansal@rgipt.ac.in
[2] Delhi University, New Delhi India
[3] Saudi Electronic University, Saudi Arabia

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

2022, 2023; Mogha et al. 2015). The government's effort to provide healthcare services to the deprived segment and public-private collaborations contribute to closing the distance between healthcare needs and supplies. Still, the ever-growing population and the increasing incidence of the COVID-19 pandemic threaten to expand the gap further. Therefore, we conceive this paper to assess the efficiency and productivity of the Indian healthcare sector.

Assessment of efficiency and productivity has remained a cynosure in healthcare-related research (Chowdhury et al. 2014). Researchers widely use DEA as a rigorous technique to study the efficiency and productivity in the healthcare sector (Kohl et al. 2019; Kumar et al. 2017; Top et al. 2020; Verma et al. 2021; Vikas and Bansal 2019; Yaya et al. 2020; Zheng et al. 2019). We use the dataset of 19 DMUs) in India from 2016 to 2020. We rank the DMUs in the order of SE, dependent on TE calculated by the Chames, Cooper, and Rhodes (CCR) model and partial total efficiency (PTE) computed by the Banker, Chames, and Cooper (BCC) model. We employ MPI analysis to assess the efficiency of the sector. We apply super-efficiency to overcome the deficiencies in traditional DEA models (Andersen P, Petersen 1993). We use eight models, i.e., super radial, super slack-based measures (SBM), non-oriented, super (SBM) oriented, SBM orientation and SBM known orientation with the traditional BCC & CCR models. As per our knowledge, this is the first type of research that used eight different models to compare super efficiency for the Indian hospital sector to become more efficient in the competitive and cutting-edge environment.

The dual contributions of our study include theoretical and practical contributions. Theoretically, we advance the body of knowledge by suggesting a model for efficiency determination based on eight DEA models on nineteen DMUs from India. Practically, our study provides both theoretical and practical contributions. We advance the body of knowledge by proposing a model to determine efficiency based on DMUs from India. The paper highlights the inefficiencies plaguing the Indian healthcare industry and the efficiency-related problems in the Indian healthcare sector and offers managerial suggestions for improving the sector's efficiency. The remainder of the paper is structured as follows. Section 2 examines the related literature; Section 3 focuses on the data and methodology; Section 4 discusses the empirical findings; and Section 5 concludes.

2. Literature review

Efficiency can be defined as DMU's ability to increase output without increasing or decrease input without decreasing output (Broby 2022). The field of efficiency assessment is of much interest to management teams of businesses who need help identifying the areas where they need extra effort to make their businesses much more effective. Researchers globally have been working in this field (Bansal et al. 2018; Duho and Onumah 2019; Khan et al. 2020; Lokanan et al. 2019). The healthcare industry's efficiency is essential from the profit generation's perspective and society's welfare. The literature available globally on the efficiency assessment of the healthcare industry /hospitals/health centres etc., using DEA is extensive. However, we found no study analyzing the Indian healthcare industry comprising hospitals, Pharmaceutical companies, and pathology labs. Moreover, we found no analysis incorporating a DEA with peer count and eight different models of super efficiencies, namely super oriented, radial and non-oriented, MPI and Tobit regression for the entire healthcare sector in the Indian context. A summary of the published f studies on performance evaluation is presented in (see Table 1).

Table 1: Summary of relevant previous studies on performance evaluation

Studies	No. of Outlets	Country	Input variables	Output variables
(Chang et al. 2004)	578	Taiwan	Number of patient beds, number of doctors, nurses, medical support and ancillary services	The number of patient days, number Of clinic visits
(Ramanathan 2005)	20	Oman	Bed, doctors, other staff	Outpatient visits, inpatient visits, major surgeries, minor surgeries
(Butler and Li 2005)	57	USA	Total facility expenses minus payroll, total hospital beds, the total number of services offered, total employees	Total number of inpatient days at the facility, total number of inpatient and outpatient surgical operations, total number of emergency room visits, total number of outpatient visits.
(Akazili et al. 2008)	89	Africa	Total non-clinical staff and laborers, no. of clinical staff, number of beds	Number of deliveries, number of children immunized
(SHIMSHAK et al. 2009)	190	US	Registered nurses, licensed practitioners, non-nursing staff, administrative staff	Total residents, number of residents needing assistance with bathing,

				dressing, a resident needing restraint, catheter
(Sinimole 2012)	180	WHO	Per capita expenditure on health, number of nursing and midwifery personnel, number of physicians	Adult mortality rate, Infant mortality rate, neonatal mortality rate, under-five mortality rate, immunization coverage
(Asandului et al. 2014)	30	Europe	Number of hospital beds, total doctors, public health expenditure as a percentage of GDP	Life expectancy at birth, health-adjusted life expectancy, infant mortality
(Mahajan et al. 2014)	50	India	Raw material, salary, and wages, advertising, and marketing, capital usage	Net sales
(Mogha et al. 2015)	36	India	Total beds, total doctors, number of paramedical staff	Number of outdoor patients, Indoor patients, significant surgeries, and Minor Surgeries.
(Kweh, Q., Alrazi, B., Chan, Y., Wan Abdullah, W., & Mohd Azly Lee 2017)	387	Malaysia	Staff costs, debt capital, equity capital	Profit, market value
(Bahrami et al. 2018)	7	Iran	Number of physicians, nurses, active beds, equipment	Bed occupancy rates, number of discharged patients
(Gandhi and Sharma 2018)	37	India	Cost of labour, net fixed assets, current assets, other operating expenses	Total income, profit after tax
(Karahan and Dinç 2018)	9	Turkey	Total beds, Total doctors, nurses	Total patients treated, number of hospitalized
(Nurcahyo et al. 2019)	30	Indonesia	Total doctors, medical assistance personnel, Total pharmacist	Number of outpatient visits, number of babes who are immunized

Note: Details of the research paper are presented in the references

As is clear from the table, only two studies are based on the financial parameters; the rest are based on the variables related to operational performance only. Hence, the inclusion of the hospitals, pathology labs, and pharmaceutical companies and the efficiency analysis based on the financial parameters make this study unique (Bansal and Singh 2021).

3. Research Methodology

To assess the efficiency of the Indian healthcare industry, we used three analytical techniques: DEA, MPI, and Tobit regression. The theoretical outline is projected in (see Figure 1). Firstly, DEA has been applied for calculating DMU's TE, PTE, and SE levels. Based on our review of previous studies, we created the DEA model, which includes input and output parameters. An input-oriented CCR model was used for analysis, and an input-oriented BCC model was used for comparison. The nature of the healthcare industry is the primary reason for choosing an input-oriented model. It can alter the input parameters, but the output parameters are market-controlled; hence, it would minimize the inputs to achieve the desired output level. The scale efficiency has been calculated using the CCR and BCC model scores. For 2016, 2017, 2018, 2019, and 2020, the DEA scores from CCR and the BCC model are estimated.

We apply the MPI approach for analysis. In the past (Gandhi and Sharma 2018) have also used MPI to measure efficiency over a period, but the study has been based only on private-sector hospitals in India. The MPI study parameters in the model include cost of labour, net fixed assets, current assets, other operating expenses as input parameters, total income, and profit after tax as output parameters. Further, we have also added a peer count summary. Super efficiency analysis has been calculated using eight different models with different non-parametric rank statistics tests, namely M-W, K-S, and K- W tests**.** Finally, Tobit regression analysis was used with the DEA efficiency score (CCR, output-oriented method) for 2020 as a dependent variable to test the impact of other variables, namely “promoter’s holdings,” “foreign institutional investors,” “domestic institutional investor’s,” “mutual funds holdings,” and “years since incorporation.”

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

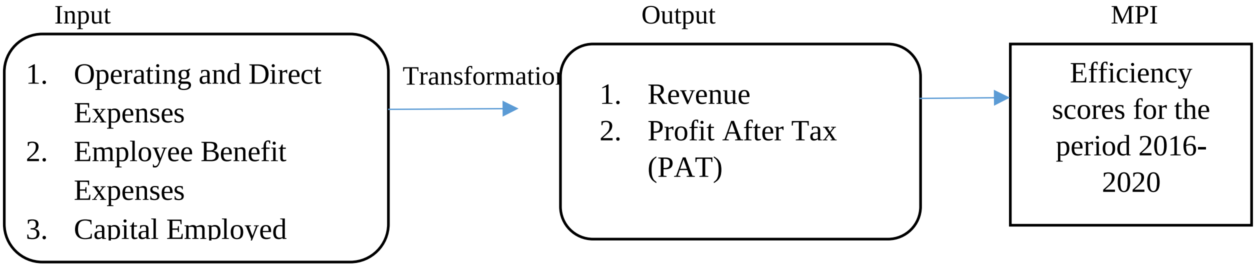

Figure 1. Conceptual framework of the research

3.1 DEA Model

The DEA was initially conceptualized by (Farrell 1957) and modified by (Charnes et al. 1978) and (Banker et al. 1984). The DEA was created to evaluate the efficiency of non-profit organisations. CCR, named after its creators CCR, and BCC, named after Banker, Charnes, and Cooper (BCC), are the two most common DEA methods, with the only difference being returns to scale.

The BCC model is expressed as:

$$\text{Min}Z_k = \emptyset k - \varepsilon\left(\sum_{i=1}^{m} S_{ik}^{+} + \sum_{j=1}^{s} S_{jk}^{-}\right)$$

Subject to:

$$\sum_{r=1}^{n} \lambda_{rk} Y_{ir} - S_{ik}^{+} = Y_{ik} \quad \forall\, i = 1, \dots \dots m,$$

$$\sum_{r=1}^{n} \lambda_{rk} X_{ij} + S_{jk}^{-} = \emptyset_k X_{jk} \quad \forall\, j = 1, \dots \dots s,$$

$$\sum_{r=1}^{n} \lambda_{rk} = 1$$

$\emptyset_k$ is unrestricted in sign, and

$\lambda_{rk}, S_{jk}^{-}, S_{ik}^{+} \geq 0 \; \forall\, r, j, i,$

$$\sum_{j=1}^{n} \lambda_j = 1$$

The presence of non-Archimedean ε specifies the model to be a two-way process. To obtain the optimal values of $\lambda_1, \lambda_2, \dots, \lambda_n, S_i^{-}, S_r^{+}$ The CCR mentioned above and BCC models have been solved as linear programming problems. The SE scores can be obtained from the CCR scores to BCC scores. A DMU is efficient if θ=1 and $S_i^{-} = S_r^{+} = 0$ for all i and r. DMU_o is weakly efficient if θ=1 and $S_i^{-} \neq 0$ and (or) $S_r^{+} \neq 0$ for some i and r.

3.2 Inputs and outputs

One model with various input and output parameters was developed based on the literature and previous studies. In the first model, the input parameters that have been selected are operating and direct expenses, Employee benefits expenses, capital employed, and book value. This model's output parameters are revenue and profit after tax. Because of the nature of the healthcare industry, this study is based on an input-oriented model. The healthcare industry's decision-making units can increase or decrease input but cannot control the output parameters. We calculated the various efficiency levels of the DMUs based on the scores obtained from both models. For 2016 to 2020, the DEA scores from CCR and BCC are computed. (Charnes et al. 1986) Presented two rules for the sample size; as per the rules stated by Cooper et al., for DEA results to be considered significant, the study's number of DMUs should be greater than or equal to the product of the input and output variables or three times the sum of the input and output variables. We used three inputs and two outputs in this study, so the minimum number of DMUs should be six for the model to have some discriminatory power; we used 19 DMUs in this study.

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

4. DEA results

The healthcare industry is related to social welfare; it is an industry catering to people's necessities. Thus, it becomes tough to work with an output maximization outlook. Hence, to become more efficient, a company has to minimize the inputs to achieve a specific output level. Considering this aspect of the industry, input-oriented DEA has been applied in this research. In this method, the inefficient firms are guided to decrease their inputs (operating and direct expenses, capital employed, employee benefit expenses, and book value in this study) for the given set of outputs. The analysis was carried out using DEA Excel Solver Pro and R software. To calculate the TE, we used the CCR model's constant returns to scale (crs) and variable returns to scale (vrs) under the BCC to calculate the PTE. SE is computed using the TE and PTE.

$$\text{Scale efficiency (SE)} = \frac{\text{TE (By CCR model)}}{\text{PTE (By BCC model)}}$$

Table 2: The summary of the variables (in INR ten million)

	Operating and direct expenses	Employee benefit expenses	Capital employed	Book value	Revenue	Profit after tax
Max	1391.68	1295.09	8721.35	8363.24	8308.7	302.76
Min	0.47	0.25	-3.1	-7.38	0.07	0.77
Average	298.89211	146.517	1287.62	1023	838.69	56.09
SD	433.38921	288.584	2367.66	1991.62	1831.44	77.81
Correlation among output and input variables						
	ODE	EBE	CE	BV	Revenue	PAT
ODE	1	0.8127	0.3923	0.249	0.7777	0.7025
EBE	0.8127	1	0.6189	0.420	0.9956	0.8241
CE	0.3923	0.6189	1	0.969	0.6019	0.6712
BV	0.2492	0.4208	0.9698	1	0.3975	0.5501
Revenue	0.7777	0.9956	0.6019	0.397	1	0.8232
PAT	0.7025	0.8241	0.6712	0.550	0.8232	1

Source: Author's calculations

The statistics for the year 2020; PAT (profit after tax), BV (book value), CE (capital employed), EBE (employee benefit expenses), ODE (operating & direct expenses)

It was found that average operating and direct expenses were 298.89, employee benefit expenses (146.51), average capital employed in the business was around (1287.62), book value (1023) with some average output, i.e., revenue (838.69) and PAT (56.09) (Table 2). Also, we have tested correlation statistics among all input and output variables. We have found less correlation (0.2492) between operating and direct expenses with book value; the remaining pairs have shown a substantial correlation.

4.1 CCR model

The efficiency scores of 19 companies from 2016-2020 based on the CCR have been calculated, and It is observed that 11 out of 19 companies are operating on the frontier. The most efficient companies are Dr Lal path lab (1.00), thyrocare technologies ltd. (1.00), Shalby ltd (1.00), Kovai Medical Centre and hospital ltd (1.00), KMC speciality hospitals ltd (1.00), Fortis malar hospitals ltd (1.00), Tejnaksh healthcare ltd (1.00), NG industries ltd (1.00), Medinova diagnostic services ltd (1.00), Centennial sutures ltd (1.00), Chennai Meenakshi multispecialty hospital ltd (1.00). The average productivity score for 2016 is 0.80, with a standard deviation of 0.30. For 2017, 12 out of 19 DMUs are efficient and have a score of 1.0. The mean efficiency for the period is 0.83, and the standard deviation is 0.31. In 2018, 11 out of 19 DMUs operate on the efficient frontier. The average efficiency has, however, declined to 0.79, and the standard deviation is 0.35. In the year 2019, 13 out of 19 companies are performing efficiently. The average efficiency is 0.85, and the standard deviation is 0.30. Finally, in 2020, the no. of efficient DMUs falls to 9 out of 19. However, we must note that the average efficiency for the period is the highest, i.e., 0.92, and the standard deviation is the lowest at 0.10.

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

4.2 BCC model

The ranking of the DMUs based on the BCC model assumes that the DMUs have VRS, unlike CCR, which takes CRS and hence is a more reliable and practical approach based on real-world assumptions. As per the input-oriented BCC model, 15 of 19 DMUs performed on the efficient frontier for 2016. The average efficiency ranges from 0.90 in 2016 to 0.98 in 2020, with a standard deviation of 0.24 to 0.04. Based on the sample study through an input-oriented BCC model, which assumes a VRS for all the DMUs, we may comment that the Indian healthcare industry is performing efficiently as a whole as the average efficiency for all the periods under study has been at a very high level which depicts a healthy condition or operational efficiency of the companies of the industry.

4.3 Scale efficiency

The SE scores were computed using the TE and PTE. As a result, the SE of a DMU is the product of the TE and PTE scores (TE/PTE). Table 3 depicts the scale efficiency of the DMUs in detail.

Table 3: Scale efficiency of sample companies

S. No.	DMU	2016		2017		2018		2019		2020	
		Score	RTS	Score	RTS	Score	RTS	Score	RTS	Score	RTS
1	Apollo Hospital Enterprises	0.89	Dec	0.95	Dec	1.00	Dec	1.00	Con	1.00	Con
2	Dr Lal Path Lab	1.00	Con	1.00	Con	1.00	Con	1.00	Con	0.95	Dec
3	Fortis Health	0.78	Dec	0.90	Dec	0.89	Dec	0.91	Con	0.86	Dec
4	Aster DM Healthcare Ltd	0.99	Con	0.96	Dec	0.89	Dec	0.98	Con	0.95	Dec
5	Metropolis healthcare	0.79	Con	1.00	Con	1.00	Con	1.00	Con	1.00	Con
6	Narayana Hrudayalaya	0.67	Dec	0.68	Dec	0.79	Dec	0.90	Dec	0.87	Dec
7	Thyrocare Technologies Ltd	1.00	Con	0.94	Dec	0.91	Dec	1.00	Con	1.00	Con
8	Shalby Ltd	1.00	Con	1.00	Con	0.92	Dec	0.98	Con	0.99	Con
9	Kovai Medical Center & Hospital	1.00	Con	1.00	Con	1.00	Dec	1.00	Con	0.97	Dec
10	Indraprastha Medical Corp	0.92	Dec	0.88	Dec	0.88	Dec	0.83	Dec	0.82	Dec
11	KMC Speciality hospitals ltd	1.00	Con	1.00	Con	1.00	Dec	1.00	Con	1.00	Con
12	Fortis Malar Hospitals Ltd	1.00	Con	1.00	Con	1.00	Dec	1.00	Con	0.83	Con
13	Tejnaksh Healthcare Ltd	1.00	Con	1.00	Con	1.00	Con	1.00	Con	0.972	Inc
14	Transgene Biotek Ltd	0.42	Con	0.03	Con	1.04	Con	0	Inc	1.00	Con
15	NG Industries Ltd	1.00	Inc	1.00	Con	1.00	Inc	1.00	Con	1.00	Con
16	Medinova Diagnostic Ser Ltd	1.00	Con	1.00	Con	0.00	Inc	1.00	Con	1.00	Con
17	Centennial Sutures Ltd	1.00	Con	1.00	Con	1.00	Dec	1.00	Con	1.00	Con
18	Choksi Labs Ltd	0.93	Dec	1.00	Con	1.00	Inc	1.00	Con	0.65	Inc
19	Chennai Meenakshi Multispec	1.00	Con	1.00	Con	1.00	Con	1.00	Con	1.00	Con

Source: Author's calculations
RTS: Return to Scale, C= Constant, Con= 0, D= Decreasing, Dec = -1, I=Increasing, Inc = 1

As per Table 3, 13 out of 19 companies are operating under the CRS, i.e., scale efficient, and five are working under DRS for 2016. These companies need to reduce their business scale to become more efficient by downsizing or shutting activities in non-profit units. Similarly, one DMU, i.e., NG Industries, is operating under increasing scale, and thus, it will be more beneficial for them to expand their business, as it will improve its efficiency. For 2017, thirteen companies are operating under CRS, and six are under decreasing RTS. For 2018, 2019, and 2020, five, sixteen, and twelve companies are operating under CRS, eleven, two, and six under DRS, and three, one, and two under increasing returns to scale, respectively.

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

4.4 Benchmarking

9 of 19 DMUs are already performing efficiently and do not need any change per the benchmarking techniques. From the TE scores, we can recognize that Choksi Labs is the most inefficient operating and direct expense and needs to reduce its operating expenditure by 34.56%. Narayan Hrudayalaya also needs to cut operational and direct expenses by 22.12%.In terms of employee benefit expenses again, Choksi Lab needs to downsize its cost by 56.04%, and Fortis Healthcare also needs to reduce the employee benefit expenses by 31.17%. Regarding capital employed and Book value, Fortis Healthcare needs to change histrionically to reduce it by 86.92 % and 92.87 %. Aster DM Healthcare also needs to reduce the capital employed and the book value by 80.85% and 86.32%, respectively. The benchmarking technique gives DMUs a clear picture of what they need to do to function effectively and use their resources wisely and efficiently.

4.5 Malmquist Productivity Index (MPI)

The MPI is named after its creator, Malmquist, who established the index in 1953. This index depicts the growth of DMUs by representing total factor productivity (TFP), in which both the progress and regress of efficiency and frontier technology are evaluated across multiple layouts. The factor computes the change in productivity of a DMU over time. It was calculated as a result of catch-up and frontier shift. The catch-up (or recovery) indicator represents a DMU's progress. If the catch-up is zero, relative efficiency improved from period 1 to period 2; otherwise, it shows no change and regresses relative efficiency. The frontier shift depicts the change in frontier technology surrounding the DMU from one period to the next.

Regarding technical efficiency change, 7 out of 19 companies have regressed during 2020. Transgene Biotek has a significant relative regress in technical efficiency, i.e., 0.541. Transgene Biotek has the Lowest MPI at 0.232.8 out of 19 DMUs and has made progress and has a positive MPI for the period.

Table 4: Malmquist Productivity Index 2020

Firm	Technical Efficiency Change	Technology Change	Pure Technical Change	Scale Efficiency Change	Malmquist Index
Apollo Hospital Enterprises	1.000	1.051	1.000	1.000	1.051
Dr Lal Path Lab	0.934	1.037	0.960	0.972	0.968
Fortis Health	1.111	0.941	1.025	1.084	1.046
Aster DM Healthcare Ltd	1.080	0.986	1.067	1.012	1.065
Metropolis Healthcare	1.057	0.961	1.000	1.057	1.016
Narayana Hrudayalaya	1.013	1.049	1.008	1.006	1.063
Thyrocare Technologies Ltd	0.996	0.938	1.000	0.996	0.934
Shalby Ltd	0.946	0.932	0.930	1.017	0.881
Kovai Medical Center & Hospital Ltd	0.862	1.064	0.867	0.995	0.917
Indraprastha Medical Corp	1.000	1.017	1.000	1.000	1.017
KMC Specialty hospitals Ltd	1.000	0.984	1.000	1.000	0.984
Fortis Malar Hospitals Ltd	0.834	0.969	0.995	0.838	0.809
Tejnaksh Healthcare Ltd	0.874	0.940	1.000	0.874	0.821
Transgene Biotek Ltd	0.541	0.429	1.000	0.541	0.232
NG Industries Ltd	1.000	1.011	1.000	1.000	1.011
Centennial Sutures Ltd	1.000	1.004	1.000	1.000	1.004
Choksi Labs Ltd	0.651	0.402	1.000	0.651	0.261
Mean	0.922	0.895	0.990	0.931	0.825

Source: Author's calculations

4.6 Malmquist Index Summaries of Aannual means

In Table 5, the annual means of the MPI have been shown for 2017 to 2020. As evident from the statistics, 2019 has the highest MPI at 1.199, which shows that the technical and scale efficiency made progress during 2019 across the industry.

Table 5: Malmquist productivity index summary of annual means

Year	Technical Efficiency Change	Technology Change	Pure Technical Change	Scale Efficiency Change	Malmquist Index
2017	1.040	0.947	1.097	0.948	0.984
2018	0.961	0.940	1.040	0.925	0.904
2019	1.125	1.066	0.998	1.127	1.199
2020	0.922	0.895	0.990	0.931	0.825
Mean	1.009	0.960	1.030	0.979	0.968

Source: Author's calculation using DEAP programming

We have discussed the healthcare industry's TE, PTE, and SE for 2020. We have addressed the productivity change over the four years. Values exceeding one show progress and improvement during the period, and values less than one show productivity regress over time. Therefore, values equal to one tend to have no change in productivity. Table 5 results reflect an improvement required in the initial years, i.e., 2017, 2018, and 2019 show improvement in total factor productivity. Later, in 2020, it was reduced to 0.825 (regress and progress are required). Overall, the results demonstrate that modifications are needed to attain productivity. It is noted that the regress in the TE of 0.922 during the time is primarily due to an SE change of 0.979 and pure technical efficiency of 0.960.

MPI summary of firm means

Table 6 provides the Malmquist index (total factor productivity) summary of hospitals; it includes the average productivity scores of hospitals from 2017-20. The results imply that productivity regresses primarily due to scale efficiency and technological changes (Vikas and Bansal 2019). Inefficient DMUs should raise their scale to attain technical efficiency and factor in the rapid technological changes. Only five firms have found progress in productivity: Aster DM Healthcare Ltd exhibited the highest productivity improvement during 2017-20 with a score of 1.206, followed by Metropolis Healthcare with 1.065, Fortis Health (1.06), Apollo Hospital (1.04), and Narayana hrudayalaya (1.02). However, Transgene Biotek Ltd (0.84) has found most regress productivity changes. The deteriorating efficiency in this hospital is majorly due to scale efficiency change. Other firms, i.e., Dr Lal Path Lab (0.896), Shalby Ltd (0.888), Kovai Medical Centre and Hospital Ltd (0.901), Fortis Malar Hospitals Ltd (0.944), found regress due to scale efficiency change and technology changes. Therefore, they should invest more and open new centres in tier II and tier III cities to scale up their business.

Table 6: Malmquist index of the firm means

Firm	Technical Efficiency Change	Technology Change	Pure Technical Change	Scale Efficiency Change	Malmquist Index
Apollo Hospital Enterprises	1.027	1.019	1.000	1.027	1.046
Dr. Lal Path Lab	0.927	0.967	0.990	0.936	0.896
Fortis Health	1.112	0.954	1.047	1.061	1.060
Aster DM Healthcare Ltd	1.229	0.981	1.226	1.002	1.206
Metropolis Healthcare	1.094	0.973	1.112	0.984	1.065
Narayana Hrudayalaya	1.055	0.969	0.972	1.086	1.022
Thyrocare Technologies Ltd	1.064	0.935	1.065	0.999	0.995
Shalby Ltd	0.966	0.919	0.967	0.999	0.888
Kovai Medical Center & Hospital Ltd	0.964	0.935	0.965	0.999	0.901
Indraprastha Medical	1.000	0.971	1.000	1.000	0.971
KMC Specialty Hospitals Ltd	1.000	0.951	1.000	1.000	0.951
Fortis Malar Hospitals Ltd	0.956	0.988	0.999	0.957	0.944
Tejnaksh Healthcare Ltd	0.967	0.915	1.000	0.967	0.885
Transgene Biotek Ltd	0.927	0.908	1.220	0.760	0.841
NG Industries Ltd	1.000	0.997	1.000	1.000	0.997
Centennial Sutures Ltd	1.000	0.970	1.000	1.000	0.970
Choksi Labs Ltd	0.913	0.973	1.000	0.913	0.888
Mean	1.009	0.960	1.030	0.979	0.968

Source: Author's calculation using DEAP programming
[Note that all Malmquist index averages are geometric means]

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

It has also provided the Malmquist index (total factor productivity) summary of the healthcare industry; it includes average productivity scores from 2016-20. The results imply that productivity regresses primarily due to scale efficiency and technological changes. Inefficient DMUs should raise their scale to attain technical efficiency and factor in the rapid technological changes. Only five firms have found progress in productivity: Aster DM healthcare ltd exhibited the highest productivity improvement during 2016-19 with a score of 1.206.

The frontier shift demonstrates how the company's expertise changed from one period to the next. It exhibits the technical efficiency change result of various variables affecting the company's production and sales. The following four companies, namely Aster DM healthcare ltd, Thyrocare Technologies Ltd, Shalby Ltd, and Tejnaksh healthcare ltd, have not achieved one score during 2016-20 in frontier technology regress. On the other hand, Apollo hospital enterprises, Transgene Biotek Ltd, Choksi Labs Ltd, and Chennai Meenakshi Multispecialty have averaged. Making technological changes with a focus on healthcare is a factor of implementing new machinery and competition, living standards, and using the latest innovations, research, and development, i.e., artificial intelligence and neural networking, which attract the efficiency of companies.

The term "catch-up" (or "recovery") refers to a DMU's progress over a given period. It exhibits the catch-up summary for all the 20 DMUs over five years. The average score of the following DMUS is below 1, indicating a regress in relative efficiency from the period 2016-20, namely Dr Lal Path Lab, Shalb Ltd, Kovai Medical Centre, and Hospital Ltd, Indraprastha Medical Corporation, Fortis Malar Hospitals Ltd, Tejnaksh healthcare ltd, and Choksi labs ltd. Also, the average score of the following DMUS is above 1, indicating progress from one period to another like 2016-2020, namely Apollo Hospital Enterprises, Fortis Health, Aster DM healthcare ltd, Metropolis Healthcare, Narayana Hrudayalaya, Thyrocare technologies ltd, KMC speciality hospitals ltd, Transgene biotech ltd, NG industries ltd, Medinova diagnostic services ltd, Centennial sutures ltd, and Chennai Meenakshi multispecialty.

On analyzing the table, we understand that there is neither a change in technology in the Healthcare industry for the period under study as the frontier shift's figure remains near one for all the DMUs over the years. Moreover, the catch-up results also show that the DMUs under consideration have been performing at a constant level for the period, as the average catch-up from 2016-20 in all cases is near one except in Transgene Biotek, which suddenly surged to 1.85. Thus, a particular industry's catch-up and frontier shift.

4.7 Peer-count summary (CCR- Input-oriented model for the year 2020)

In Table 7, we have a data set for the year 2020 to count peers. Further, the study examines the out-performing units among 19 DMUs, as in the following table. Based on outcomes, Apollo Hospital Enterprises (08 times), NG Industries Ltd (07 times), and Thyrocare Technologies Ltd (05 times) Transgene Biotek Ltd (05 times), are established to be unique units with a high peer count. It reveals how these units may be used as a benchmark for an inefficient unit for further improvements.

Table 7: Peer count summary

No.	DMU	Score	Peer Summary	Peer Count
1	Apollo hospital enterprises	1.00	D1, D3, D4, D6, D8, D9, D12, D18	8
2	Dr Lal's path lab	0.95	D2	1
3	Fortis health	0.86	D3	1
4	Aster DM health care ltd	0.79	D4	1
5	Metropolis Healthcare	1.00	D5, D2	2
6	Narayana hrudayalaya	0.77	D6	1
7	Thyrocare technologies ltd	1.00	D7, D2, D4, D8, D13	5
8	Shalby ltd	0.87	D8	1
9	Kovai medical centre and hospital ltd	0.97	D9	1
10	Indraprastha medical corporation	0.82	D10	1
11	KMC Speciality Hospitals Ltd	1.00	D11, D9, D18	3
12	Fortis Malar Hospitals Ltd	0.83	D12	1
13	Tejnaksh healthcare ltd	0.97	D13	1
14	Transgene biotek ltd	1.00	D14, D3, D4, D9, D13	5

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

15	NG industries ltd	1.00	D15, D2, D6, D8, D10, D12, D13	7
16	Medinova Diagnostic Services Ltd	1.00	D16, D2, D10	3
17	Centennial sutures ltd	1.00	D17, D6, D10, D12	4
18	Choksi labs ltd	0.65	D18	1
19	Chennai Meenakshi multi-hospital	1.00	D19, D6, D9, D10, D13, D18	6

Source: Author's calculation

4.8 Super efficiency analysis

Super-efficiency was initially suggested by Anderson and Peterson (1993) to overcome the deficiencies of traditional DEA models. The DMU is competitive with each other, and the most efficient units among the group will be laid down on the efficient frontier, and the rest units will find less score than the efficient. However, we cannot identify which DMUs are the most efficient among all companies, with a score of 1. Under the super efficiency, the upper bound frontier was removed to resolve this problem, and best-performing companies may be given more than one score. We have referred to (Tamatam et al., 2019) methods used to research banking efficiency. By this method, we can find out the most efficient or super-efficient healthcare unit. This paper has used eight models, i.e., Super radial, super slack-based measures (SBM), non-oriented, super (SBM) oriented and SBM orientation, and SBM known orientation traditional BCC & CCR models. As per our knowledge, this is the first type of research that used eight different models to compare super efficiency for the Indian hospital sector to become more efficient in the competitive and cutting-edge environment.

Based on super-efficiency scores (radial & SBM oriented) by the BCC model for 2020, presented in Table 8, Dr Lal Path Lab and Thyrocare Technologies Ltd were found to be efficient amongst peers, and units have been included in the sample. Thyrocare Technologies Ltd appears in the five peer count, and these five DMUs should follow this. Therefore, we can enlighten that Thyrocare is the most efficient peer count unit and sets a good benchmark. However, Apollo hospital enterprises appeared most peer count, with eight times based on the peer count, but it was very interesting to note that under super efficiency by radial and SBM oriented, it had twelve ranks. Therefore, we can say that it was efficient and set some benchmarks for these eight inefficient units. However, it was ranked in twelfth place when it competed with other efficient units under super efficiency. The other eight units cannot follow this unit. On the other hand, the following DMUs, Choksi Labs Ltd, Chennai Meenakshi Multispecialty Hospital Ltd, and Medinova Diagnostic Services Ltd, ranked 15, 14, and 13, respectively.

Table 8: Super efficiency score with BCC model

DMU	Super-Radial (SBCC-I)		Super-SBM Non-Oriented (SSBM-V-NO)		Super-SBM Oriented (SSBM-V-I)	
	Score	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Apollo Hospital Enterprises	1.000	12	2.545	2	1.000	12
Dr Lal Path Lab	*3.647	2	1.271	7	2.547	2
Fortis Health	2.125	4	1.136	8	1.369	5
Metropolis Healthcare	1.857	6	1.406	3	1.429	4
Thyrocare Technologies Ltd	2.310	3	1.379	4	1.463	3
Kovai Medical Center & Hospital	1.040	11	1.016	12	1.016	11
Indraprastha Medical Corporation	1.940	5	1.296	5	1.363	6
KMC Specialty Hospitals Ltd	1.098	10	1.041	11	1.041	10
Tejnaksh Healthcare Ltd	1.138	8	1.075	9	1.075	8
Transgene Biotek Ltd	*33.724	1	*10.132	1	*17.352	1
NG Industries Ltd	1.770	7	1.281	6	1.281	7
Medinova Diagnostic Services Ltd	1.000	13	1.000	13	1.000	13
Centennial Sutures Ltd	1.113	9	1.050	10	1.059	9
Choksi Labs Ltd	0.993	15	0.397	15	0.800	15
Chennai Meenakshi Multispecialty	1.000	14	1.000	14	1.000	14

Source: Author's calculation

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

*Infeasible score as per the thumb rule SBM: Super efficiency slack-based measure with input-oriented (input-oriented and output-oriented have given the same result, so we have only present input-oriented to avoid repeatability) SSBM-c-Super efficiency non-radial and non-oriented, SSBM-I-C: Super efficiency non-radial and input-oriented (I), & (O) output oriented.

4.9 Comparison of the DEA model with super efficiency

We have eight diverse models that give different orientations, radially and slacks-backed measures. We examine all eight models and compare the hospital's efficiency. A DMU can be an outlier if a three-score surpasses its super-efficiency. Only two units, Transgene Biotek Ltd & Dr Lal Path Lab, are outliers and infeasible by these rules. We also have tested robustness by conducting famous non-parametric rank statistics, namely the Mann-Whitney U-test, Kolmogorov-Smirnov test, and Kruskal- Wallies test**.** This exercise ascertains whether the variance between the equivalent estimates is statistically substantial or not with the null hypotheses' help.

For analysis of super-efficiency by the BCC model, we compare the results from the subsequent measures:

1. Super slack-based measure oriented (SSBM-V-I) vs super radial (SBCC-I)
2. Super slack-based measure non-oriented (SSBM-V-NO) vs Super slack-based estimation oriented (SSBM-V-I)
3. Super slack-based measure non-oriented (SSBM-V-NO) vs Super radial (SBCC-I)
4. SBM orientation and SBM non-orientation with the BCC model have given the same results, so we have not applied this rank test to these datasets.

Null Hypothesis: The distribution of scores is the same across categories of code

Table 9: Non-parametric test for super efficiency by BCC model

Formulation 1.a. Super slack-based measure oriented (SSBM-V-I) vs Super radial (SBCC-I)					
Mann-Whitney U Test		Kolmogorov-Smirnov (KS)Test		Kruskal-Wallis Test	
Mann-Whitney U stat	71	Most Extreme Diff		Test Statistic	.146[a,b]
Wilcoxon W	162	Absolute	0.34	Degree of Freedom	1
Test Statistic	71	Positive	0.34	Asymptotic Sig.(2-sided test)	0.702
Standard Error	18.314	Negative	-0.1		
Standardized Test Statistic	-0.382	Test Statistic	0.849[a]		
Asymptotic Sig.(2-sided test)	0.702[b]	Asymptotic Sig. (2-sided test)	0.467		
Exact Sig. (2-sided test)	0.728[a]				
Formulation 1.b. Super slack-based measure non-oriented (SSBM-V-NO) vs. super slack-based measure oriented (SSBM-V-I)					
		KS Test		KW Test	
Mann-Whitney U stat	72	Most Extreme Differences		Test Statistic	.108[a,b]
Wilcoxon W	150	Absolute	0.122	Degree of Freedom	1
Test Statistic	72	Positive	0.103	Asymptotic Sig.(2-sided test)	0.743*
Standard Error	18.3	Negative	-0.12		
Standardized Test Statistic	-0.33	Test Statistic	0.304*		
2-sided test	0.743*	Asymptotic Sig.(2-sided test)	0.981		
Exact Sig.(2-sided test)	0.769*				
Formulation 1.c; Super Slack-based Measure Oriented (SSBM-V-I) vs. Super Radial (SBCC-I)					
		KS Test		KW Test	
Mann-Whitney U	66.5	Most Extreme Differences		Test Statistic	.397[a,b]
Wilcoxon W	157.5	Absolute	0.34	Degree of Freedom	1
Test Statistic	66.5	Positive	0.34	Asymptotic Sig. (2-sided test)	0.52*
Standard Error	18.261	Negative	-0.07		
Standardized Test Statistic	-0.63	Test Statistic	0.849*		
Asymptotic Sig.(2-sided test)	0.529*	Asymptotic Sig.(2-sided test)	0.467*		
Exact Sig.(2-sided test)	0.538*				

Source: Author's own calculation
a. The test statistic is adjusted for t.
b. Multiple comparisons have not been performed, (*) retain the null hypothesis

Table 9 shows a statistically significant difference between these models: MW;U-test, K-S test, and K-W test. However, the high p-values indicate that no considerable transformation between the results of these formulations and consequences

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

from any further analysis will vary depending on the formulation we choose from any of the eight models. Therefore, even though the traditional CCR and BCC-oriented models cannot rank efficient healthcare companies, we use super-efficiency models to rank those efficient DMUs. Compared between the radical, non-oriented, and slack-based measures for BCC models. Thus, we choose two models, namely super slack-based action-oriented (SSBM-V-I) vs super radial (SBCC-I) and super slack-based measure-oriented (SSBM-V-I) vs super radial (SBCC-I), to process with further analysis and with the high p-values.

Super efficiency score with CCR model

Based on super-efficiency scores (radial & SBM oriented) by the CCR model for the year 2020, presented in Table 10, NG Industries Ltd and Apollo hospital enterprises found to be efficient amongst peers and units have been included in the sample. Apollo Hospital Enterprises (08 times) and NG Industries Ltd (07 times) appear in the top slot in the peer count. Therefore, the remaining DMUs should follow these two companies to achieve efficiency. Consequently, we can enlighten that NG industries are the most efficient and peer-count units and set a good benchmark for others. However, Apollo Hospital enterprises appeared in most peer counts eight times, but very infesting to note that radial and SBM were oriented under super efficiency; it had twelve ranks based on the peer count. On the other hand, the following DMUs, Chennai Meenakshi Multispecialty Hospital Ltd and Medinova Diagnostic Services Ltd, are found on the bottom, respectively.

Table 10: Super efficiency scores with the CCR model

Super Efficiency analysis (CCR-I)	Super-Radial (SCCR-I)		Super-SBM Non-Orient (SSBM-C-NO)		Super-SBM Oriented (SSBM-C-I)	
DMU	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Apollo Hospital Enterprises	1.496	3	1.196	3	1.223	2
Metropolis Healthcare	1.307	4	1.134	5	1.1348	5
Thyrocare Technologies Ltd	1.248	5	1.145	4	1.145	4
KMC Specialty Hospitals Ltd	1.059	7	1.032	7	1.033	7
Transgene Biotek Ltd	*34.499	1	1.943	1	*16.032	1
NG Industries Ltd	1.560	2	1.218	2	1.222	3
Medinova Diagnostic Ser Ltd	1.000	8	1.000	8	1.000	8
Centennial Sutures Ltd	1.096	6	1.045	6	1.057	6
Chennai Meenakshi Multispecialty Hospital Ltd	0.888	9	0.578	9	0.734	9

Source: Author's calculation

*Infeasible score as per the thumb rule SBM: Super efficiency slack-based measure with input-oriented (have given the same result, so we have only present input-oriented to avoid repeatability) SSBM-c- Super efficiency non-radial and non-oriented, SSBM-I-C: Super efficiency non-radial and input-oriented (I), & (O) output oriented.

1. Super slack-based measure oriented (SSBM-C-I) vs Super Radial (SCCR-I)
2. Super slack-based measure non-oriented (SSBM-C-NO) vs super slack-based measure oriented (SSBM-C-I)
3. Super slack-based measure non-oriented (SSBM-C-NO) vs super radial (SCCR-I)
4. Slack-based measure (SBM-C-I) vs traditional CCR- I, the input model

Hypothesis Test: Null Hypothesis: The distribution of scores is the same across categories of code

Table 11: Non-parametric test for super efficiency by CCR model

Formulation 2.a. Super slack-based measure oriented (SSBM-C-I) vs super radial (SCCR-I)					
		KS Test		**KW Test**	
Mann-Whitney U stat	34.5	Most Extreme Diff		Test Statistic	1.636[a, b]
Wilcoxon W	62.5	Absolute	0.57	Degree of Freedom	1
Test Statistic	34.5	Positive	0.57	Asymptotic Sig. (2-sided test)	0.201*
Standard Error	7.818	Negative	0		
Standardized Test Statistic	1.279	Test Statistic	1.07*		
Asymptotic Sig.(2-sided test)	0.201*		0.20*		

Exact Sig.(2-sided test)	0.209*	Asymptotic Sig.(2-sided test)			
Formulation 2.b. Super slack-based measure non-oriented (SSBM-C-NO) vs. super slack-based measure Oriented (SSBM-C-I)					
		KS Test		**KW Test**	
Mann-Whitney U	27.5	Most Extreme Differences		Test Statistic	.003[a,b]
Wilcoxon W	55.5	Absolute	0.161	Degree of Freedom	1
Test Statistic	27.5	Positive	0.161	Asymptotic Sig.(2-sided test)	0.95*
Standard Error	8.618	Negative	-0.13		
Standardized Test Statistic	-0.06	Test Statistic	0.31*		
Asymptotic Sig.(2-sided test)	0.954*	Asymptotic Sig.(2-sided test)	1.0*		
Exact Sig.(2-sided test)	0.955*				
Formulation 2.c. Super slack-based measure Non-oriented (SSBM-C-NO) vs. Super radial (SCCR-I)					
		KS Test		**KW Test**	
Mann-Whitney U	34.5	Most Extreme Differences		Test Statistic	.567[a,b]
Wilcoxon W	62.5	Absolute	0.446	Degree of Freedom	1
Test Statistic	34.5	Positive	0.446	Asymptotic Sig.(2-sided test)	0.452*
Standard Error	8.633	Negative	-0.12		
Standardized Test Statistic	0.753	Test Statistic	0.863*		
Asymptotic Sig.(2-sided test)	0.452*	Asymptotic Sig.(2-sided test)	0.446*		
Exact Sig.(2-sided test)	0.463*				

Source: Author's calculation
a. The test statistic is adjusted for the t-test.
b. Multiple comparisons have not been performed ;(*) retain the null hypothesis

Based on Table 11, we have tested three different models under CCR related to orientation, radiality, and slacks-based measurements. The results of the difference between the three tests are exhibited in the table. However, we choose out of any of the three models. Compared the radial measures, non-oriented models, slack-based measures and constant return to scale (CRS); thus, we choose the model super slack-based measure non-oriented (SSBM-C-NO) vs Super Radial (SCCR-I) to process with further analysis and with the high p-values.

4.10 Determinants of efficiency of the Indian healthcare industry

After evaluating efficiency, the next important step is to understand and identify the determinants of efficiency. To the extent possible, the management needs to know about the factors that impact the DMU's control of internal and external factors.

Theoretical model and hypothesis development

The Decision-making process in an entity has a significant impact on the productivity of a unit. Productivity and output translate into better financial performance. We have identified some factors that influence a DMU's decision-making process. Hypotheses are developed based on these factors, and then run some statistical tests to test these hypotheses. The percentage of a Promoter's holding in a business decides the concentration of the decision-making power. Entities with a higher promoter's holding can implement the promoter's decisions as the majority lies with them. Moreover, as the promoters have a long-term vested interest in the company, they are interested in the unit's long-term welfare. Hence, a higher percentage of the promoter's holding impacts the unit's efficiency.

H1: A higher percentage of the promoter's holding has a crucial impact on the efficiency of the Indian healthcare industry

The percentage of foreign institutional investment in a business unit might mean the unit is lucrative in return on investment. FII is tough to attract, but it is also called "hot money" as these kinds of investors may withdraw their money at any time as per their interest. FIIs may not be a crucial factor affecting the unit's efficiency.

H2: The percentage of foreign institutional investment does not have a crucial impact on the efficiency of the Indian healthcare industry.

Domestic institutional investment is the investment made by the country's financial institutions based on the nit. The DII is based not only on profit generation or return on investment but also on many other factors like a country's social, economic, and political situations. DIIs invest in sick units to revive them because of the country's economic and social

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

welfare. Percentage of Domestic Institution Investment in the shareholding of a healthcare unit, thus positively impacts the unit's efficiency.

H3: The percentage of domestic institutional investment has a crucial impact on the efficiency of the Indian healthcare industry.

The percentage of mutual fund holdings in the shareholding pattern also impacts the unit's efficiency. Like DII, mutual funds are generally a long-term investment interested in the long-term wellness of the venture. Mutual funds are not direct investments; these are consolidated investments of several small individual investors invested through an investment company and managed by a fund manager. Such investment gives the board the freedom to improve efficiency to provide a better return on investment.

H4: The percentage of mutual fund holdings has a crucial impact on the efficiency of the Indian healthcare industry.

The age difference of the unit understudy from the year 2020 has been identified as another variable that can have an impact on the efficiency of the unit.

H5: The age of the unit has an impact on the efficiency of the Indian healthcare industry.

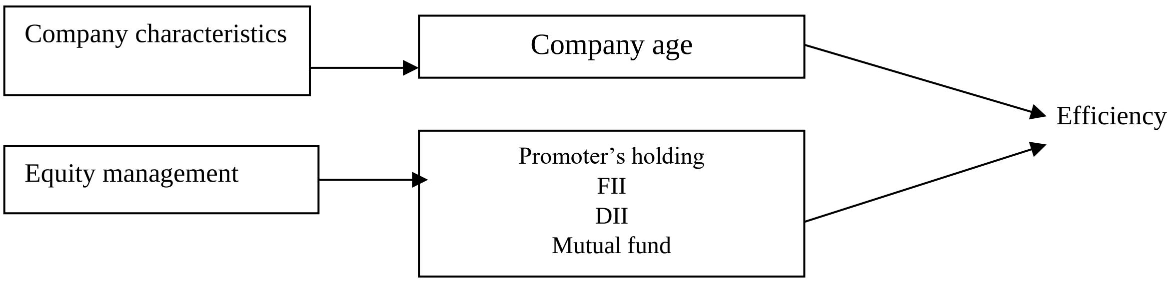

Figure 2: Theoretical model for determinants of efficiency

Table 12 shows a Tobit regression model used to investigate the factors with the highest efficiency by regressing the CCR 2020 scores against the following explanatory variables: beta value, promoter's holdings, non-holding promoter's FII, DII, MF, and age difference. The Tobit regression was chosen because of the truncation of the effectiveness scores between 0 and 1. The results of Tobit regression were reported in this study using the Eview-11 edition. The equation is given below:

DEA S = C(1) + C(2)*AD_2020 + C(3)*DII + C(4)*FII + C(5)*MF + C(6)*PH

Where PH = proportion of the promoter's ownership in the respective DMU
AD= firm's age difference since its incorporation in 2020
DEAS = DEA CCR input-oriented 2020 score

Table 12: Tobit model with the dependent variable: CCR 2020 scores

Dependent Variable: DEA Score				
Included observations: 20				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.556488	0.940300	0.591820	0.5540
DII	-0.075752	0.032000	-2.367231	0.0179*
FII	-0.006676	0.017990	-0.371114	0.7106
MF	0.142641	0.060677	2.350809	0.0187*
PROMOTERS	-0.006721	0.009939	-0.676233	0.4989
AGE_DIFF_2020	0.024708	0.023074	1.070797	0.2843
Mean dependent var	0.500000	S.D. dependent var		0.512989
SE of regression	0.386380	Log-likelihood		-14.81717
Sum squared resid	2.090055	Avg. log-likelihood		-0.740858

Source: Author's calculation

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
https://doi.org/10.52783/eel.v13i5.830
http://eelet.org.uk

In the last part of this study, analysis reveals that productivity scores are significantly affected by domestic institutional investors and mutual funds. The Tobit regression model demonstrates that the Indian healthcare industry is derived from mutual fund holdings and domestic institutional investors. Understandably, as the domestic mutual funds' holdings grow, they gain more control over the company's management, which positively affects its financial performance. Hence, our hypotheses H_3 and H_4 stand accepted.

Other variables, namely FII, promoter's holdings, and age difference have not significantly impacted healthcare companies' efficiency scores. The company's age has no bearing on its productivity, and both operate efficiently, whether old or new. Promoters and foreign institutions do not play any crucial role in the Indian healthcare sector, efficiency, and profitability. Hence, our hypotheses related to FII H_2 stand accepted as the FII does not significantly impact the healthcare Industry's efficiency. However, H_1 and H_5 related to the promoter's holding and age of the unit stand rejected.

5. Conclusion

An efficient healthcare sector ensures a nation's prosperity and well-being, especially in a developing economy. To evaluate the industry's efficiency in Indian economy, this study ranked 19 DMUs in India based on SE, TE, CCR, PTE, and BCC models using the data from 2016 to 2020. To assess the sector's efficiency, we carry out the super-efficiency analysis suggested by (Andersen and Petersen 1993), followed by the MMPI analysis.

Based on the TE of the DMUs evaluated through the CCR model, we find nine DMUs performing efficiently. In comparison, the evaluation based on VRS and PTE through the BCC model finds fifteen 19 DMUs to be efficient performers. Adopting a rigorous approach, we have calculated the scale efficiency used to assess whether a unit functions at the proper operation scale. Scale efficiency shows that only five companies are exhibiting increasing returns to scale between 2016-20. Out of the remaining companies, twelve DMUs operated at increasing returns to scale for one year, while two DMUs operated at an increasing rate for two years. Our findings indicate that these companies may increase their inputs and expand their business for scale efficiency. These DMUs may also consider cutting down or shutting down the non-profit-making units.

Per benchmarking in cost reduction, ten DMUs need to cut down their expenses, i.e., operating and direct payment, employee benefit expenses, capital employed, and book value, to perform at the efficient frontier. Our findings concerning the MPI analysis highlight that eight DMUs have made progress over the period. As per the peer count summary, Apollo Hospital Enterprises, NG Industries, Thyrocare Technologies, and Transgene Biotek Limited have the highest peer count, becoming the most effective units. We use eight models to assess the super efficiency with various non-parametric rank statistics, i.e., MW-U-test, KS test, and KW test. In addition, our study incorporates statistical tests to check the multiple units' robustness level and produce a more robust result. We choose two models (super slack-based measure oriented (SSBM-V-I) v/s super radial (SBCC-I) and super slack-based measure oriented (SSBM-V-I) v/s super radial (SBCC-I)) to process with further analysis under BCC assumptions. Also, we choose super slack-based action non-oriented (SSBM-C-NO) v/s super radial (SCCR-I) models to process with further research under CCR assumptions. The Tobit results show that DII and MF significantly impact efficiency scores.

6. Managerial implications

Efficiency assessment is an essential tool for any management to assess business performance. The benchmarking, scale efficiency, and super efficiency assessment give an edge to our study as they provide a clear picture for self-assessment. This study will help DMUs decide on how to operate at an optimal level. DMUs can decide at which stage or period they should cut down their expenditure, which will help recognize the different heads of expenses where too much focus is necessary. From this study, DMUs can determine the factors that affect the efficiency score and can be utilized for forecasting.

The management must carefully consider the factors contributing to the inefficiencies. Companies can reap large-scale benefits if these issues are adequately addressed. Future scholarship can compare the Indian healthcare sector's efficiency with other countries' healthcare sectors. The selected companies' efficiency may be evaluated to check the performance compared to the peers and changes in the efficiency levels. Further research may use various variables as input and output. Future scholarship may replicate our methods and procedures in other industrial sectors, such as FMCG, the financial industry, and the energy sector, to assess their operational efficiency.

Note: Data available from the authors upon reasonable request: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

References

Akazili, J., Adjuik, M., Jehu-Appiah, C., & Zere, E. (2008). Using data envelopment analysis to measure the extent of technical efficiency of public health centres in Ghana. BMC International Health and Human Rights, 8(1), 11. https://doi.org/10.1186/1472-698X-8-11

Andersen P, Petersen, N. (1993). A Procedure for Ranking Efficient Units in Data Envelopment Analysis. Management Science, 39(10), 1261–1264. http://deazone.com/en/andersen-p-and-nc-petersen-1993-a-procedure-for-ranking-efficient-units-in-data-envelopment-analysis-management-science-3910-1261-1264

Andersen, P., & Petersen, N. C. (1993). A Procedure for Ranking Efficient Units in Data Envelopment Analysis. Management Science, 39(10), 1261–1264. https://doi.org/10.1287/mnsc.39.10.1261

Asandului, L., Roman, M., & Fatulescu, P. (2014). The Efficiency of Healthcare Systems in Europe: A Data Envelopment Analysis Approach. Procedia Economics and Finance, 10, 261–268. https://doi.org/10.1016/S2212-5671(14)00301-3

Bahrami, M. A., Rafiei, S., Abedi, M., & Askari, R. (2018). Data envelopment analysis for estimating efficiency of intensive care units: a case study in Iran. International Journal of Health Care Quality Assurance, 31(4), 276–282. https://doi.org/10.1108/IJHCQA-12-2016-0181

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. Management Science, 30(9), 1078–1092. https://doi.org/10.1287/mnsc.30.9.1078

Bansal, R., Singh, A., Kumar, S., & Gupta, R. (2018). Evaluating factors of profitability for Indian banking sector: a panel regression. Asian Journal of Accounting Research, 3(2), 236–254. https://doi.org/10.1108/AJAR-08-2018-0026

Bansal, R., & Singh, D. (2021). Efficiency drivers of insurers in GCC: an analysis incorporating company-specific and external environmental variables. Cogent Economics & Finance, 9(1). https://doi.org/10.1080/23322039.2021.1922179

Broby, D. (2022). The use of predictive analytics in finance. The Journal of Finance and Data Science, 8, 145–161. https://doi.org/10.1016/j.jfds.2022.05.003

Butler, T. W., & Li, L. (2005). The utility of returns to scale in DEA programming: An analysis of Michigan rural hospitals. European Journal of Operational Research, 161(2), 469–477. https://doi.org/10.1016/j.ejor.2003.09.019

Chaity, N. S., & Islam, K. M. Z. (2022). Bank efficiency and practice of earnings management: a study on listed commercial banks of Bangladesh. Asian Journal of Accounting Research, 7(2), 114–128. https://doi.org/10.1108/AJAR-09-2020-0080

Chang, H., Chang, W.-J., Das, S., & Li, S.-H. (2004). Health care regulation and the operating efficiency of hospitals: Evidence from Taiwan. Journal of Accounting and Public Policy, 23(6), 483–510. https://doi.org/10.1016/j.jaccpubpol.2004.10.004

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. European Journal of Operational Research, 2(6), 429–444. https://doi.org/10.1016/0377-2217(78)90138-8

Charnes, A., Cooper, W. W., & Thrall, R. M. (1986). Classifying and characterizing efficiencies and inefficiencies in data development analysis. Operations Research Letters, 5(3), 105–110. https://doi.org/10.1016/0167-6377(86)90082-9

Chowdhury, H., Zelenyuk, V., Laporte, A., & Wodchis, W. P. (2014). Analysis of productivity, efficiency and technological changes in hospital services in Ontario: How does case-mix matter? International Journal of Production Economics. https://doi.org/10.1016/j.ijpe.2013.12.003

Duho, K. C. T., & Onumah, J. M. (2019). Bank diversification strategy and intellectual capital in Ghana: an empirical analysis. Asian Journal of Accounting Research, 4(2), 246–259. https://doi.org/10.1108/AJAR-04-2019-0026

Farrell, M. J. (1957). The Measurement of Productive Efficiency. Journal of the Royal Statistical Society. Series A (General), 120(3), 253. https://doi.org/10.2307/2343100

Gandhi, A. V., & Sharma, D. (2018). Technical efficiency of private sector hospitals in India using data envelopment analysis. Benchmarking: An International Journal, 25(9), 3570–3591. https://doi.org/10.1108/BIJ-06-2017-0135

Goyal, J., Singh, M., Singh, R., & Aggarwal, A. (2019). Efficiency and technology gaps in Indian banking sector: Application of meta-frontier directional distance function DEA approach. The Journal of Finance and Data Science, 5(3), 156–172. https://doi.org/10.1016/j.jfds.2018.08.002

Karahan, M., & Dinç, H. (2018). Evaluation of Hospital Performance with Data Envelopment Analysis. European Journal of Multidisciplinary Studies, 7(2), 53. https://doi.org/10.26417/ejms.v7i2.p53-59

Khan, M. A., Siddique, A., & Sarwar, Z. (2020). Determinants of non-performing loans in the banking sector in developing state. Asian Journal of Accounting Research, 5(1), 135–145. https://doi.org/10.1108/AJAR-10-2019-0080

Kim, Y. C., Park, M. J., & Atukeren, E. (2020). Healthcare and welfare policy efficiency in 34 developing countries in Asia. International Journal of Environmental Research and Public Health, 17(13), 1–21. https://doi.org/10.3390/ijerph17134617

Kohl, S., Schoenfelder, J., Fügener, A., & Brunner, J. O. (2019). The use of Data Envelopment Analysis (DEA) in healthcare with a focus on hospitals. Health Care Management Science, 22(2), 245–286. https://doi.org/10.1007/s10729-018-9436-8

Kumar, D., Kumar, S., Bansal, R., & Singla, P. (2017). A Survey to Nature Inspired Soft Computing. International Journal of Information System Modeling and Design, 8(2), 112–133. https://doi.org/10.4018/IJISMD.2017040107

Kweh, Q., Alrazi, B., Chan, Y., Wan Abdullah, W., & Mohd Azly Lee, R. (2017). Environmental, Social and Governance and the Efficiency of Government-linked Companies in MalaysiaNo Title. Institutions And Economies, 9(2), 55–74. https://ijie.um.edu.my/article/view/4904

Lai, K. K., Cheung, M. T., & Fu, Y. (2018). Resource Allocation in Public Healthcare: A Team-DEA Model. Journal of Systems Science and Complexity. https://doi.org/10.1007/s11424-017-6124-6

Lokanan, M., Tran, V., & Vuong, N. H. (2019). Detecting anomalies in financial statements using machine learning algorithm. Asian Journal of Accounting Research, 4(2), 181–201. https://doi.org/10.1108/AJAR-09-2018-0032

Mahajan, V., Nauriyal, D. K., & Singh, S. P. (2014). Technical efficiency analysis of the Indian drug and pharmaceutical industry. Benchmarking: An International Journal, 21(5), 734–755. https://doi.org/10.1108/BIJ-10-2012-0070

Maurya, P. K., Bansal, R., & Mishra, A. K. (2023). Russia–Ukraine conflict and its impact on global inflation: an event study-based approach. Journal of Economic Studies. https://doi.org/10.1108/JES-01-2023-0003

Mishra, A. K., Bansal, R., & Maurya, P. K. (2023). Investing for a better tomorrow: Values-driven antecedents of investment in socially responsible equity funds by Indian retail investors. Journal of Cleaner Production, 420, 138441. https://doi.org/10.1016/j.jclepro.2023.138441

Mishra, A. K., Bansal, R., Maurya, P. K., Kar, S. K., & Bakshi, P. K. (2022). Predicting the antecedents of consumers' intention toward purchase of mutual funds: A hybrid PLS-SEM-neural network approach. International Journal of Consumer Studies. https://doi.org/10.1111/IJCS.12850

Mogha, S. K., Yadav, S. P., & Singh, S. P. (2015). Slack based measure of efficiencies of public sector hospitals in Uttarakhand (India). Benchmarking: An International Journal, 22(7), 1229–1246. https://doi.org/10.1108/BIJ-12-2013-0122

Nurcahyo, R., Kristiningrum, E., & Sumaedi, S. (2019). ISO 9001-certified public healthcare center's efficiency and re-certification. International Journal of Productivity and Performance Management, 69(4), 794–812. https://doi.org/10.1108/IJPPM-11-2018-0406

Ramanathan, R. (2005). Operations assessment of hospitals in the Sultanate of Oman. International Journal of Operations & Production Management, 25(1), 39–54. https://doi.org/10.1108/01443570510572231

SHIMSHAK, D., LENARD, M., & KLIMBERG, R. (2009). Incorporating quality into data envelopment analysis of nursing home performance: A case study☆. Omega, 37(3), 672–685. https://doi.org/10.1016/j.omega.2008.05.004

Sinimole, K. R. (2012). Evaluation of the efficiency of national health systems of the members of World Health Organization. Leadership in Health Services, 25(2), 139–150. https://doi.org/10.1108/17511871211221055

Statista. (2021). Size of the healthcare sector in India 2008-2022 Published by Statista Research Department, Nov 30, 2020 India's healthcare sector was worth over 140 billion U.S. dollars as of 2016, with projections to reach up to 372 billion dollars by 2022. The country. Statista.

Top, M., Konca, M., & Sapaz, B. (2020). Technical efficiency of healthcare systems in African countries: An application based on data envelopment analysis. Health Policy and Technology, 9(1), 62–68. https://doi.org/10.1016/j.hlpt.2019.11.010

Valdiansyah, R. H., & Murwaningsari, E. (2022). Earnings quality determinants in pre-corona crisis: another insight from bank core capital categories. Asian Journal of Accounting Research, 7(3), 279–294. https://doi.org/10.1108/AJAR-08-2021-0134

Verma, R. K., Kumar, A., & Bansal, R. (2021). Impact of COVID-19 on Different Sectors of the Economy Using Event Study Method: An Indian Perspective. Journal of Asia-Pacific Business, 22(2), 109–120. https://doi.org/10.1080/10599231.2021.1905492

Vikas, V., & Bansal, R. (2019). Efficiency evaluation of Indian oil and gas sector: data envelopment analysis. International Journal of Emerging Markets, 14(2), 362–378. https://doi.org/10.1108/IJoEM-01-2018-0016

World Health Organization. (2010). Health topics about efficiency.

Yaya, S., Xi, C., Xiaoyang, Z., & Meixia, Z. (2020). Evaluating the efficiency of China's healthcare service: A weighted DEA-game theory in a competitive environment. Journal of Cleaner Production, 270, 122431. https://doi.org/10.1016/j.jclepro.2020.122431

Zheng, D., Gong, J., & Zhang, C. (2019). Efficiency of medical service systems in the rural areas of Mainland China: a comparative study from 2013 to 2017. Public Health, 171, 139–147. https://doi.org/10.1016/j.puhe.2019.04.003