Original Article

Technical Efficiency of Private Hospitals in Kamrup (Metro) District, Assam: An Application of two Stage Data Envelopment Analysis model

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Abstract

Healthcare resources should not be misused as such resources can save people's life. Further, avoiding excessive resource employment can help minimize production costs. In this regard, measuring technical efficiency is essential as it helps identify the resource utilization level against the output level. The present study has estimated the relative technical efficiency scores of private hospitals in the Kamrup (Metro) district of Assam. The data for the study is collected from primary and secondary sources for the year 2019**.** Bootstrapping Data Envelopment Analysisis applied considering two outputs and six input variables. All the hospitals are technically inefficient; however, small size hospitals have shown better performance in terms of technical efficiency than big size hospitals.

The study has not distinguished the number of inpatients based on the resources consumption. In this context, there is a further scope to improve the study. However, this is the first attempt to analyse the performance of private hospitals in terms of technical efficiency in Assam. It will help the management of concerned hospitals to improve their resource utilisation strategy.

Key words: healthcare resource, technical efficiency, data envelopment analysis, performance

Introduction

India's healthcare sector has shown immense growth, which is about 22 per cent (CAGR) since 2016 and it has provided direct employment to 4.7 million people in 2022[1]. Studies revealed that demand for outpatient care in private hospital is higher than in public hospital[1, 2]. The 75th round National Sample Survey (NSS) report shows that 60 per cent of rural and 67 per cent of the urban population have used private hospitals for child delivery cases (caesarean). Consequently, the supply of private hospital services has also increased in India. However, rising healthcare cost in private hospitals is a worrisome issue for India's general public[3]. Such high expenditure in private hospitals is conspicuous since private hospitals need to improve service quality to catch up with the market share. However, it fuels rising prices of healthcare services. In this context, it is argued that hospitals

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involve in the race to purchase medical equipment and other physical facilities to improve the quality of services[4]. Undoubtedly, the quality of healthcare services is a core issue, and simultaneously, it is also vital for hospitals to examine whether the resources are appropriately used. In other words, healthcare resources should not be misused as such resources can save people's life. Further, avoiding excessive resource employment can help in minimizing cost of healthcare service production[4]. In this context, measurement of technical efficiency is essential as it helps to identify the level of resource utilization against the output level.

Researchers have found inefficient utilization of resources in private healthcare sector of India[5,6,7,8,9]. For instance, Gandhi and Sharma (2018) examined the technical efficiency of 37 private hospitals in India and found around 41 per cent hospitals are technically inefficient. Another country-level study by Chitnis and Mishra (2019) a sample of 25 private hospitals is evaluated using DEA, and in the second stage, the same sample is analysed using super-efficiency DEA for discriminating the performance of the efficient hospitals. The results show seven hospitals as the most efficient ones using DEA in the first stage. Fortis Hospital Ltd emerges as the super-efficient hospital using super-efficiency DEA analysis in the second stage. The results obtained have managerial implications. Moreover, some studies have also shown inefficiency of private hospitals in sub state level[7,8,10]

Following the idea of technical efficiency measurement, we have tried to explore the same in private hospital sector of Assam. This sector is not explored till now in terms of technical efficiency measurement. The study has concentrated only in Kamrup (Metro) district of Assam, which has the maximum number or about 24 per cent of total private hospitals in Assam. Further, the district has become an important hub for medical treatment for the people of Assam and neighbouring states[11,12]

Concept of Data Envelopment Analysis

The study has followed the non-parametric or DEA method. DEA is a linear programming method. It estimates a production unit's efficiency level by comparing the productive index of a production unit with the productive index of the best-performing unit in the given sample size[13,14]. The productive index is the ratio between the outputs and inputs of a production unit. Although the efficiency index is almost similar to the productive index, the efficiency index is a relative measure that compares one unit's performance with another best-performing unit. The estimated efficiency score lies between 0 and 1. If the efficiency score of a production unit equals 1, then the unit is considered the technically efficient or the best performer. On the contrary, if the efficiency score lies below 1, the unit will be regarded as technically inefficient[15, 14]. It has gained more popularity over the parametric method such as Stochastic Frontier Analysis (SFA) because of certain advantages like being easy to compute, support for both quantitative and qualitative forms of data and freedom from the restrictive assumptions that exist in the parametric method[14]. However, the result of the conventional DEA model may give an overestimation of efficiency scores[16]. Thus researchers have suggested bootstrapping technique to detect the error involved with efficiency scores obtained from the original DEA model. It gives a biased free efficiency score with a confidence interval[16].

Empirical Framework

The model comprises two outputs and six inputs. The mathematical expression of the model for a hospital says ***J0*** is presented below;

$$\sum_{j=1}^{n} X_{ij}\boldsymbol{\lambda} \leq X_{iJ0}$$

$$\sum_{j=1}^{n} Y_{rj_o} - \lambda Y_{rj} \leq 0$$

$$\lambda_j = 1 .$$

$$\lambda_j \geq 0$$

J indicates the number of hospitals, where j = 1…,22. The number of inputs is indicated by ***i*** = 1,2…,6 and the number of outputs is indicated by ***r*** = 1,2. Further, Y_{rjo} it indicates hospital Jo's output vector and hospital Jo's input vector. Moreover, following the method of Simar and Wilson (2000), the bias from DEA (VRS) estimation is estimated by bootstrap as;

$$\hat{b}_i^* = \frac{1}{N}\sum_{b=1}^{N}\hat{\theta}_{in}^{*b} - \hat{\theta}_{in}$$

Where, $\hat{b}_i^*$, indicates the estimated bias score of i^{th} production unit. The confidence interval for each production unit is obtained as follows;

$$\hat{\theta}_{in}^{*(\alpha)} - 2.\hat{b}_i^*, \hat{\theta}_{in}^{*(1-\alpha)} - 2.\hat{b}_i^*$$

α, indicates a 95 per cent confidence interval.

The medical equipment index comprises 16 items (see Appendix Table B1.). The index is constructed using binary code 1 for 'Yes' and 0 for 'No'. The index represents the average of the listed items for each sampled hospital. The same weight is given to each item because all the listed items are essential for providing secondary and tertiary medical services (Clinical Establishment Act of 2010). Further, the value of the index ranges from a minimum of 0 to a maximum value of 1 where one will indicate that the hospital has all the listed medical equipment. Similarly, in the case of the physical facility index, the min-max method is used to normalise the values of indices. The index comprises a total of 15 indicators reflecting the basic facilities a hospital should have as per the Clinical Establishment Act of 2010(see, Appendix Table B2).

The government's official source confirmed that there are **64** private hospitals, including eight nursing homes. The sample size of the hospital is determined using a proportionate random stratified sampling technique. Consequently, we have considered **1/3** of the total number of hospital.

Moreover, following the earlier studies the current study has used six input variables such as operational bed, medical staff, paramedical staff, non-medical staff, physical facility index and medical equipment index. The number of available beds and physical facility index and medical equipment index represents the proxy of capital investment[18]. Similarly, the other three indicators are medical staff, paramedical staff, and non-medical staff representing labour[18, 19]. The medical staffs represent the number of physicians, the paramedical staffs represent the Nurse and midwives, and the non-medical staffs represent laboratory technicians, administrative staff. The data of the variables collected through primary survey in the year 2019 and secondary sources such as hospital's website.

Results and Discussion

Table (1) represents the basic statistics of input and output of hospitals. The average number of beds is around 119 and a very high standard deviation is observed. In case of other inputs the highest average is observed for non-medical staff and it is followed by paramedical staff and medical staff. Moreover, it is observed that hospitals have been acquiring higher number of medical equipment on average in comparison to physical facility.

Table 1: Basic Statistics of Input and Output of Private Hospitals

Variable	Mean	SD	Min.	Max.
Bed	119	94.49	20	300
Medical Staff	48.59	22	14	88
Paramedical Staff	63.77	56.43	11	213
Non-Medical Staff	145.13	71.30	52	340
Medical Equipment Index	0.85	0.19	0.46	1
Physical Facility Index	0.59	0.23	0.20	0.96
Inpatient discharged	1730.81	874.41	400	3200
Outpatient received	11325.68	6591.94	3000	24000

Source: Author's Calculation

As we mentioned earlier, the DEA (VRS) or VRSTE is a part of DEA (CRS) or CRSTE model[14] In addition, hospitals' scale efficiency (SE) will be indicated by the ratio between CRSTE and VRSTE. Moreover, the VRSTE indicates managerial efficiency or pure technical efficiency. On the contrary, CRSTE indicates the overall technical efficiency (OTE) score of hospitals[14]. Further, the study has applied the

bootstrapping technique so that the error involved with classical DEA results can be detected[20,21]. The below table (2) shows that the average efficiency score of classical DEA models is higher than that of bootstrapping DEA, which indicates that the DEA (CCR) and DEA (VRS) have overestimated the technical efficiency level of hospitals. Such a result is also reported by in a study on country-level hospitals in Shanxi province of China[21]

Table. 2: Basic Statistics of efficiency scores of Classical DEA and Bootstrapping DEA

Variable	Mean	SD	Min.	Max
DEA (CRS)	0.89	0.18	0.46	1
DEA (VRS)	0.93	0.13	0.56	1
Scale Efficiency	0.94	0.09	0.65	1
Bootstrapping DEA (CRS)	0.80	0.18	0.41	0.98
Bootstrapping DEA (VRS)	0.84	0.15	0.49	0.99
Bootstrapping Scale efficiency	0.90	0.09	0.59	0.99

Source: Author's Calculation

Further, table (2) shows the average VRSTE or managerial efficiency level of hospital is 0.93, which is more than the average CRSTE. However, after detecting the errors from the efficiency scores, the average managerial efficiency level comes down to 0.84, which indicates that hospitals need to improve the managerial performance to improve input's function on average by 16 per cent. Additionally, the observed difference between CRSTE and VRSTE is caused by the inefficient size of the operation of hospitals, which can be indicated through scale efficiency. However, the average bootstrapping scale efficiency (SE) of hospitals is greater than the average VRSTE score, indicating the dominance of managerial inefficiency over the hospital's overall technical inefficiency level.

The below table (3) shows that small size hospitals have performed better than the big-size hospitals. For example, hospital-like Pratiksha (H13) is relatively small and shares less than 1% of the total hospital bed. However, the hospital has achieved the highest efficiency score. Similarly, Central Nursing Home (H19), a small hospital, has achieved the second-highest efficiency score. On the contrary, big-size hospitals like Ayursundra (H15), Agile (H22) have shown very poor performance in terms of technical efficiency. These big size hospitals have huge scope to expand output levels to around 59 and 57 per cent without changing the input level. The Ayursundra hospital covers around 11 percent of the total hospital bed. Further, the hospital has shared 9% of the entire medical staff. A similar scenario is observed in the case of non-medical staff. Moreover, the index value of physical facilities is equal to one, which implies that the hospital has been providing a wide range of facilities. Despite having all these resources, the hospital has recorded around 1% of total inpatients and 3% of total outpatients. Similarly, the Agile hospital has achieved the second lowest efficiency score. The hospital is also prominent in size and has a relatively high range of physical facilities. For example, the hospital has shared around 6 per cent of the total hospital bed and 5 per cent of the entire medical staff. However, the hospital has recorded around 1% of total inpatients and 2% of total outpatients only.

On the contrary, Pratiksha hospital (H13) is relatively tiny and shares less than 1% of the total hospital bed has recorded around 4 per cent of total inpatients and 8 per cent of total outpatients.

Table. 3: Technical Efficiency Scores of Private Hospitals in Kamrup (Metro) District

Hospitals	DEA (CRS)	Bootstrapping DEA (CRS)	Lower Bound	Upper Bound	DEA (VRS)	Bootstrapping DEA (VRS)	Lower Bound	Upper Bound	Bootstrapping SE
Swagata (H1)	1	0.89	0.8012	0.9950	1	0.93	0.7104	0.9942	0.97
Apollo(H2)	0.95	0.90	0.8821	0.9447	1	0.98	0.8242	0.9953	0.93
Aruna (H3)	1	0.87	0.7132	0.9948	1	0.91	0.8247	0.9963	0.90
Health City (H4)	1	0.88	0.7645	0.9953	1	0.9	0.7192	0.9953	0.92
Sanjivani (H5)	1	0.93	0.8912	0.9953	1	0.92	0.7509	0.9952	0.94
Exellcare (H6)	0.94	0.82	0.7123	0.9249	0.98	0.86	0.8127	0.9796	0.91
Downtown (H7)	0.97	0.91	0.6854	0.9644	1	0.97	0.8921	0.9947	0.96
Hayat (H8)	0.97	0.87	0.6712	0.9458	1	0.9	0.8127	0.9952	0.94
Arya (H9)	1	0.89	0.6012	0.9955	1	0.95	0.6426	0.9945	0.96
Critical Care (H10)	0.56	0.48	0.3523	0.5545	0.86	0.56	0.3738	0.8307	0.59
Dispur Hospital (H11)	1	0.92	0.8123	0.9954	1	0.94	0.7412	0.9921	0.96
Namecare (H12)	0.87	0.86	0.7123	0.8634	0.94	0.88	0.5962	0.9381	0.89
Pratiksha (H13)	1	0.98	0.8213	0.9910	1	0.99	0.9145	0.9944	0.99
Gate (H14)	0.87	0.68	0.5123	0.8612	0.89	0.73	0.6213	0.8845	0.89
Ayursundra (H15)	0.46	0.41	0.3123	0.4535	0.56	0.49	0.3156	0.5499	0.74
SatribariCristian Hospital (H16)	0.58	0.51	0.4521	0.5787	0.68	0.54	0.4523	0.6614	0.83
Saint John (H17)	1	0.85	0.8021	0.9989	1	0.84	0.7123	0.9944	0.88
Kumar Nursing Home (H18)	1	0.93	0.8326	0.9956	1	0.96	0.8123	0.9978	0.98
Central Nursing Home (H19)	1	0.97	0.7826	0.9956	1	0.97	0.7896	0.9931	0.99
E.G Nursing Home (H20)	1	0.92	0.8123	0.9971	1	0.9	0.8223	0.9903	0.96
GNRC (H21)	1	0.9	0.7123	0.9942	1	0.93	0.7236	0.9958	0.93
Agile (H22)	0.48	0.43	0.3124	0.4720	0.61	0.59	0.4863	0.6036	0.85

Source: Author's Calculation

Similarly, Central nursing home has achieved the second-highest efficiency score. The hospital has acquired only 1% of the total beds and less than 1% of the medical staff.

Further, the above table (2) suggests existence of variance among efficiency scores (CRSTE). Hence, the bootstrapping overall efficiency scores of hospitals have been classified based on quartile values. The results of quartile values suggest that 7 (32%) hospitals such as Sanjivani, Downtown, Dispur hospital, Pratksha, Kumar Nursing Home, Central Nursing Home, and E.G Nursing Home have the highest potential to become technically efficient. These hospitals can improve their efficiency score by slightly increasing output levels at a given amount of resources.

Table: 4 Classification of Efficiency Scores (CRSTE) based on Quartile Values

Lowest Score (< Q1)	Below Average (between Q1 &Q2)	Above Average (between Q2&Q3)	Highest Score (≥ Q3)
Critical Care, Gate, Ayursundra, Satribari Christian, Agile	Excell care, Saint John, Aruna, Hayat, Namecare	Swagata, Health City, Arya, GNRC, Apollo	Sanjivani, Downtown, Dispur Hospital, Pratiksha, Kumar Nursing Home, Central nursing home, E.G nursing home.
Note; Q1 = 0.82, Q2= 88, Q3=91 Source: Author's Calculation			

On the contrary, the above table (4) shows five hospitals namely hospitals such as Critical Care, Gate hospital, Ayursundra, Satribari Christian hospital, Agile hospital have achieved the lowest efficiency score. These hospitals are big in size and have the maximum scope to increase output level with the available resources.

Conclusion

From the above discussion it is revealed that classical DEA model has overestimated the efficiency scores of hospitals and it has been refined by the bootstrapping technique. The result of bootstrapping DEA model shows that all the sample hospitals are technically inefficient. The result also suggests that managerial inefficiency is the major cause of overall inefficiency level. However, 7 (32%) hospitals namely Sanjivani, Downtown, Dispur hospital, Pratksha, Kumar Nursing Home, Central Nursing Home, and E.G Nursing Home can become technically efficient with a little afford. On the contrary, five or about 23 per cent hospitals namely Critical Care, Gate hospital, Ayursundra, Satribari Christian hospital, Agile, which are relatively large in size has large scope to improve their efficiency scores. Thus, the maximum number of relatively large hospitals has not shown better performance. Instead, small, size (below average) hospitals have achieved better performance.

The current study is not free from limitations. The study has not distinguished the number of inpatients based on the resources consumption, generally a serious patients needs more resource than a normal patients. In this context, there is a further scope to improve the study. However, this is the first attempt to analyse the performance of private hospitals in terms of technical efficiency in Assam.It will help the management of concerned hospitals to improve their resource utilisation strategy.

Conflict of Interest: No

Source of Funding: Self

Ethical Clearance: The study is based on both primary and secondary data (hospitals websites). Primary data are collected by questionnaire method.

Appendix. B1: Medical Equipment Indicators

Indicator	**Indicator**
Patient monitoring machine	Colposcopy
Anaesthesia machine	Endoscope
Defibrillator	Audiometry
Stretcher	Suction machine
Sterilizers	Oxygen cylinder
Electro surgical unit	X ray machine
Electrocardiogram	Mobile operating light
Fluid warmers	MRI machine

Appendix B2: Physical facility Indicators

Indicators	**Indicators**
Number of Ambulance	Total boundary space (in sq.meter)
Number of Blood Bank	Number of waiting room
Number of Ward	Number of Washing Machine
Number of Operation theatre	Number of CCTV camera
Number of Pharmacy	Number of T.V
Number of OPD clinic	Number of Purified water machine
Number of ICU	Number of A.C room
Number of Pick Up Van	

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