Measuring the Efficiency of Publicly Listed Indian Hospitals Through Data Envelopment Analysis – CCR Additive Model/ CCR output Model

By

Disha Jain

Dissertation submitted in partial fulfillment of the requirements of the degree

MBA Hospital and Health Management

Academic year, 2018-2020

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Internship Completion Certificate

This certificate is awarded to

Dr. Disha Jain

In recognition of having successfully completed her
Internship in the department of **Operations**
and has successfully completed her secondary research Project on

Measuring the efficiency of Publicly Listed Indian hospitals through Data Envelopment Analysis – CCR output model

Internship Date: 10th February 2020 to 31st May 2020

We wish her all the best for future endeavors.

For Burjeel Hospital, Abu Dhabi

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Acknowledgement

Few in the world can comprehend the teaching without words,
or understand the value of non-action

– Lao Tzu, Tao Te Ching, chapter 43

I am indebted to Taoist wisdom explained by Einzelganger for aiding me comprehend the art of being alive. I wish to express my gratitude to Mr. Manish Jain for recognizing the potential in me and providing me with the opportunity of employing it. I would like to take this opportunity to sincerely thank my mentor Dr. Shweta Aggarwal for her constant support and patience in completion of this study. I would like to pay my special regards to Dr. Amrtha Venugopal for being a provenance of inspiration. I would like to recognize the invaluable assistance provided by my family and friends throughout the course of life.

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Introduction

One of the common measures of the performance is productivity, which is usually computed by ratio of output/inputs. The higher the ratio the better is the performance of the entity being measured. Also, one more thing to keep in mind is that the concept of performance is a relative one, one can only said to be best if there is worst to compare it against. In terms of efficiency, places/people which use limited resources as inputs to deliver maximum possible output are termed as more efficient.

As the famous economic saying goes that resources are scarce, human wants are unlimited and means to achieve them are very limited. It becomes imperative for organizations to mindfully utilize their resources and bring the best out of what is available. Although this saying holds true in every setting, the validity of it can be multiplied with a weight factor, when applied to healthcare settings. This study aims to calculate the efficiency of the hospitals in terms of utilizing its resources in producing the revenue by the application of Data Envelopment Analysis.

Literature Review

Literature says that "there is no theoretically correct or precise measures of health exist, there is a great deal of interest in studying and understanding health-care costs, outcomes, and utilization" (Chilingerian & Sherman, 2011). "Existing literature shows a trend to examine hospital efficiency with one widely used method called the data envelopment analysis. Many studies were conducted to evaluate, how efficient hospitals are operating of for-profit, non-profit, governmental hospitals. The ultimate goals of such studies are to find whether the hospitals are producing maximum outputs with the used inputs and to figure out the determinants of the hospital performance" (Nguyen et al., 2012). A study performed in US computer industry argued that "productivity can have two dimensions: a shift of the frontier itself, and an improvement of the performance of the corporation relative to the frontier. Any recorded improvement in productivity can then be broken into two parts: improvements due to shifts of the frontier, and improved intra-period inefficiency ratings" (Thore et al., 1994). A study found that "On average, hospitals with efficient DEA scores of 1.00 had sound profitable positions, while poor performing hospitals with low DEA scores incurred net losses or earned minimal profits" (Yazar A, 1996). One of the study talks about "ownership itself and foreign management is not sufficient to bring about improvements in efficiency, interventions to improve the quality of management in hospitals could help to improve efficiency as the result of the study was about 41% to 52% of the production factors are wasted during the service delivery process in the hospitals. Using the existing amount of resources, the amount of delivered outputs can be doubled, which can significantly impact patient outcomes" (Mahate & Hamidi, 2015). A study performed in Czech and Slovak concluded that "the implementation of e-health tools contributed to the cost containment and better efficiency scores. It also stated that with the implantation of basic e-health tools smaller hospitals showed better efficiency scores in all models than larger university hospitals, which can be explained by several factors – cost-demanding diseases being treated in larger hospitals in catchment areas, higher number of patients compared to bed capacity, etc" (Sendek et al., 2015). Another study performed in Germany utilized DEA-Bootstrapping procedure with segmented hospitals to reduce the bias in the efficiency scores by controlling the variation in the size of the hospitals. The study segmented the hospitals into "hospitals

that have one internal medicine and one surgery department, none of the hospitals provides tertiary care" (Staat, 2006). The results estimated suggest "an average bias–corrected efficiency of around 80%". A study done in United Kingdom applied DEA on financial statements to overcome "one of the fundamental limitations of traditional univariate ratio analysis i.e. only two dimensions of activity, represented by numerator and denominator, can be examined in any one indicator. Yet the complexity of firms' means that inputs and outputs, both physical and financial, are multidimensional, this yields a single scalar measure of performance" (Smith, 1990). "Traditional ratios either examine only a part of the enterprise's activity, or collapse these multiple dimensions into a single unsatisfactory accounting number. It says Ratio analysis has been a tool of analysts for as long as financial statements have been prepared" (Smith, 1990). Application of DEA in healthcare industry covers a wide horizon ranging from estimating simple technical efficiency scores to complex development of financial performance index through DEA. However most of these studies have been performed in the public sector or on not for profit hospitals. There are very few studies with application of DEA in private sector which can be attributed to lack of accessible data and even lesser when it comes to using financial ratios as output variables in private sector.

Research question

How efficient are publicly listed Hospitals of India?

Objective

- To measure and compare the efficiencies of the publicly listed hospitals
- To make projection on required output level to reach the efficiency frontier

Abbreviations used in this study

1. DMU: Decision Making Units
2. DEA: Data Envelopment Analysis
3. PAT: Profit After Tax
4. ROCE: Return on capital employed
5. CCR-O: Charnes, Cooper, and Roades output orientation
6. CCR-I: Charnes, Cooper, and Roades input orientation
7. BCC-O: Banker, Charnes and Cooper output orientation
8. BCC-I: Banker, Charnes and Cooper input orientation
9. NSE: National Stock Exchange
10. BSE: Bombay Stock Exchange

Research methodology

DEA Concept:

Productivity and efficiency are majorly measured by four methods which are, total factor productivity (TFP) indices, least-squares econometric production models, stochastic frontiers and data envelopment analysis (DEA). The first two methods are frequently applied

to aggregate time-series type of data set; these two methods presume that all entities being measured are technically efficient. The next two methods are frequently applied to data of entities at one point of time. It usually computes the relative efficiency among those firms. The above methods, basing on the involvement of econometric estimation of parametric functions, can be grouped as parametric and non-parametric methods.

Data Envelopment Analysis utilizes linear programming methods to create a non-parametric piecewise surface or frontier over the given data. The term Data Envelopment Analysis, emanates from this characteristic since in mathematical dialect, such a surface or frontier is said to "envelop" these data points. Measures of efficiency are then determined relative to this surface or frontier. The data points lying on this frontier are deemed as efficient and underneath or over that as inefficient. Likewise these methods can deal with large quantities of constraints/relations and variables which loosen ups the prerequisites that are frequently experienced when one is constrained to selecting only a few inputs variables and outputs variables. The ***DEA*** models with input orientation think about the conceivable reductions in input levels while keeping up the present output levels where as for ***DEA*** models with output orientation it is vice versa i.e. conceivable output augmentations while keeping the present input levels. When a graph is plotted in DEA, Efficiency frontier for the output oriented model is concave to origin and for input oriented model is convex to the origin.

There is a Key contrast between the data envelopment analysis and regression analysis. In regression analysis, the regression line in the graph goes through the “middle” of the data points. The performance of data points above this line is considered as superior or excellent while for the data points below it, is considered as sub-par or inferior. The degree of inferiority or excellence of these data points can be measured by their extent of the deviance from regression line. Contrarily, the frontier line assigns the performance of the best unit and evaluates the performance of other units by deviances from the best unit. Therefore regression analysis measures the average or central tendency behaviour while the Data envelopment analysis measures the relative best performance and calculates all performances by the deviations from the frontier line.

Other advantages of DEA models are, it does not necessitate the study performer to prescribe any weights to input and output variable, as in the other methods of productivity or efficiency measurement neither does it require setting the functional forms that are required in approaches with statistical regression nor it requires stating the form of the relation between these output and input variables. DEA methodology uses variable weights, directly derived from the data, which avoids the hassle of assigning fixed weights with prior assumptions and computations, to the inputs and outputs. Also these weights are assigned in a way that the resulting ratio value, for each of the DMU’s being measured, is maximized to all other hospitals when these weights were assigned to their inputs and outputs. Therefore DEA methodology was used for measuring the efficiency of the hospitals

Methodology:

DEA has more than 50 models of measuring the efficiency, basing on the input and output orientation, basing on measurement of allocative efficiency or technical efficiency, basing on the constraints given of like profit maximization, basing on different version named

developed by their authors like CCR or BCC model. The model used in for this study is CCR-additvie model, as this was the first developed model which got major recognition in the literature. Chosen input variables for measuring efficiency are Total number of doctors and total number of hospital beds. Chosen output variables for measuring efficiency are ARPOB, PAT, and ROCE.

Inclusion criteria: Hospitals listed on National stock exchange (NSE) and Bombay stock exchange (BSE)

Exclusion criteria: Hospitals which have not disclosed their information in public domain of the selected input and output variables

Time period: Past one financial year data (2019)

Data sources: Fiscal and annual reports of the publically listed hospitals

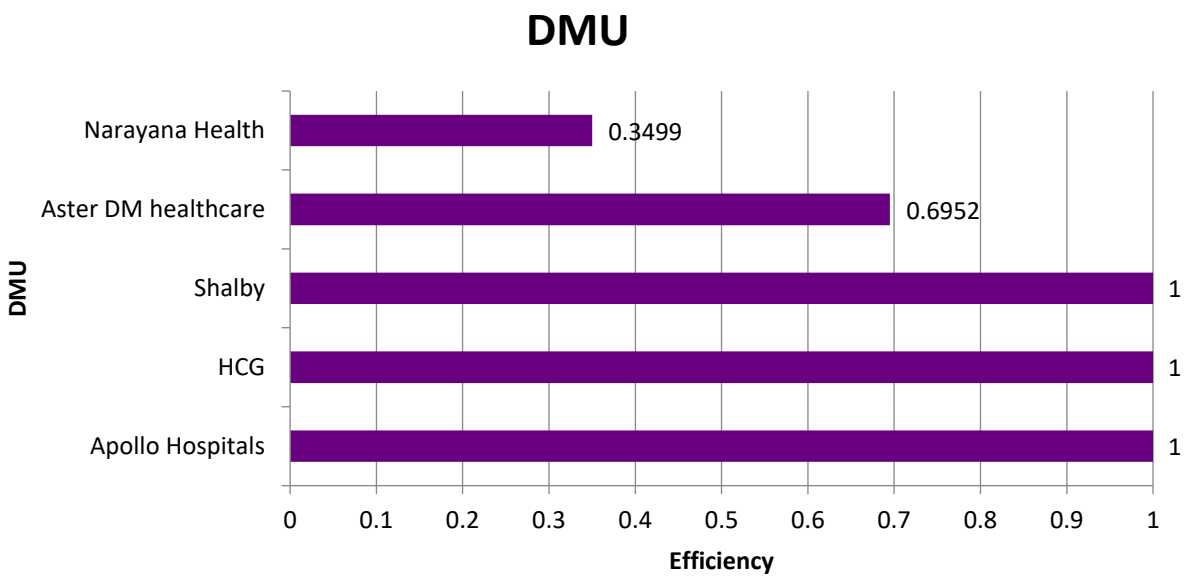
Software and tools: Microsoft excel with DEA solver plugin

Data:

S.No.	DMU	(O)PAT in Crore	(O)ROCE	(O)ARPOB	(I)Beds	(I)Doctors
1	Apollo Hospitals	302.76	10.74	34226	10167	10000
2	Aster DM healthcare	48.07	1.91	60000	5441	2756
3	HCG	7.25	5.82	31423	1872	205
4	Narayana Health	50.08	6.66	24155	7155	3644
5	Shalby	32.1	6.69	31235	2012	500

Results:

Based on the measured inputs and outputs, from the results, it is evident that 3 out of 5 hospitals are efficient and 2 out of 5 hospitals are inefficient. It is observed that a majority of the weight are assigned to output of PAT followed by ARPOB in DEA CCR-O model when seen in totality. In inputs majority of the weight have been assigned to the bed, expect for shalby hospital where the weights are given to the doctors. For the inefficient DMU's to reach the efficiency frontier i.e. achieving best possible outputs from the current input levels, they have to reach the projection mentioned in the projection table, which states a difference of 185% with the current outputs in the both PAT and ROCE for Narayana health. Also major slack is seen in doctors amongst the inputs and in ARPOB amongst the outputs, in the inefficient DMUs'



Weighted Data:

Input

No.	DMU	Score	Rank	v(1)*Beds	v(2)*Doctors
1	Apollo Hospitals	1	1	1	0
2	Narayana Health	0.3499	5	2.85809	0
3	Aster DM healthcare	0.6952	4	1.43853	0
4	HCG	1	1	1	0
5	Shalby	1	1	0	1

Output

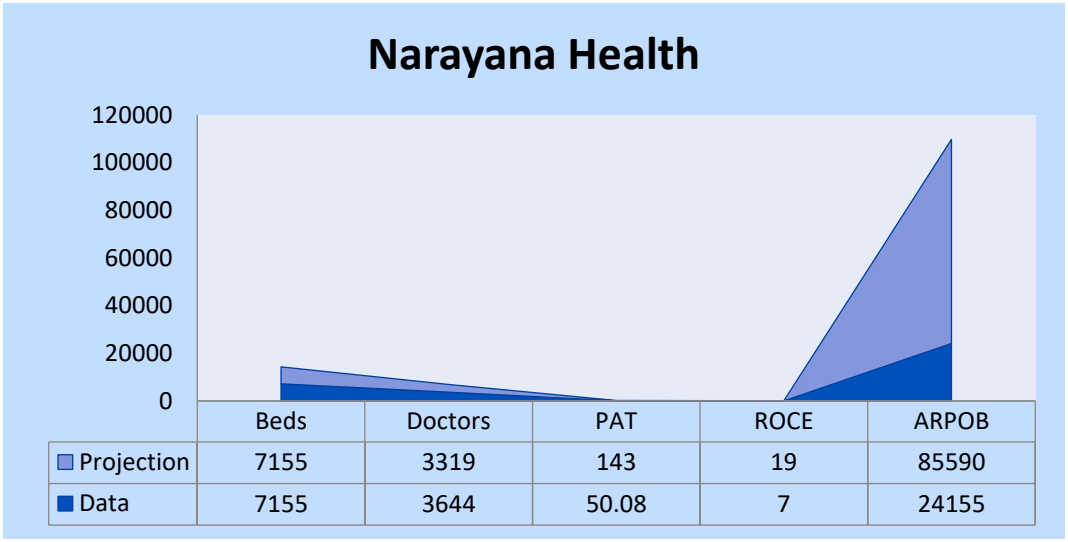
No.	DMU	Score	Rank	u(1)*PAT in Crore	u(2)*ROCE	u(3)*ARPOB
1	Apollo Hospitals	1	1	0.82226	0.17774	0
2	Narayana Health	0.3499	5	0.55237	0.44763	0
3	Aster DM healthcare	0.6952	4	0.07719	0	0.92281
4	HCG	1	1	0.02352	0	0.97648
5	Shalby	1	1	1	0	0

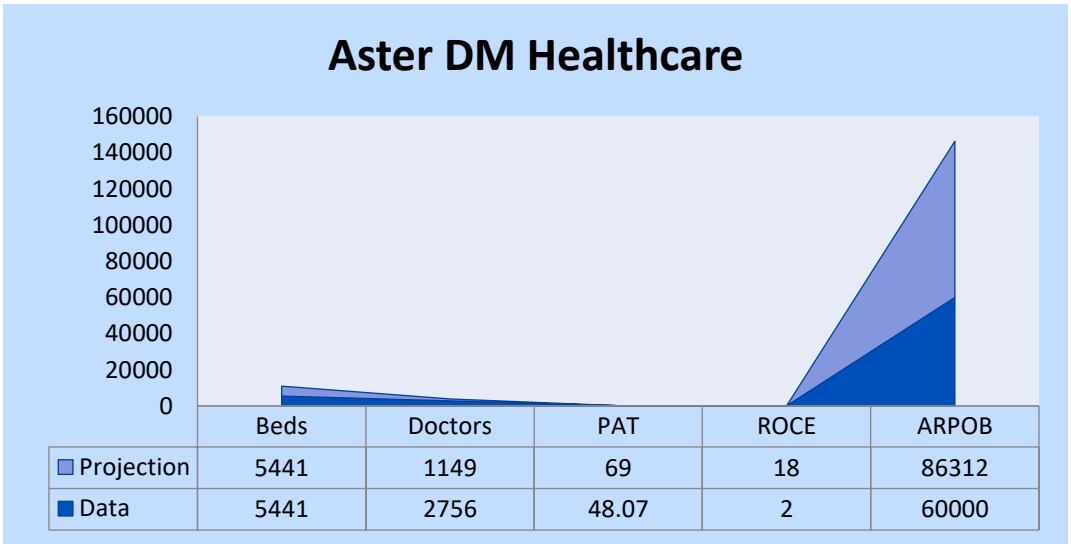
Slack:

				Slack	Slack	Slack	Slack	Slack
No.	DMU	Score	Rank	Beds	Doctors	PAT in Crore	Return on capital employed	ARPOB
1	Apollo Hospitals	1	1	0	0	0	0	0
2	Narayana Health	0.3499	5	0	324.998	0	0	16552.8
3	Aster DM healthcare	0.6952	4	0	1607.02	0	15.028	0
4	HCG	1	1	0	0	0	0	0
5	Shalby	1	1	0	0	0	0	0

Projections:

Projected input and output levels to reach Efficiency Frontier





		Narayana Health	Aster DM healthcare
S.No.	Inputs and Outputs	Diff. (%)	Diff. (%)
1	Beds	0	0
2	Doctors	-9	-58.31
3	PAT	186	43.853
4	ROCE	186	830.67
5	ARPOB	254	43.853

Interpretation:

It is ironical to see that the hospital which market's itself as working towards being efficient and having optimum resource utilization is the least efficient amongst the 5 hospitals under this study, when seen under the purview of financial ratios as outputs. This could be attributed to the fact that the ARPOB of the Narayana Health was the least amongst the five hospitals. In spite of the aster DM healthcare generating the highest ARPOB amongst the four hospitals it still not on the efficient frontier which could be because of its least performing output i.e. ROCE. For the inefficient DMUs' to improve, their emphasis should be more on number of beds being used either increasing their utilization rate or decreasing the number of beds.

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