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A CRITICAL DATA ENVELOPMENT ANALYSIS OF HOSPITAL EFFICIENCY IN INDIA

Statistic

KEYWORDS : Healthcare, Socio-Economic Environment, Data Envelopment Analysis, Technical Efficiency, CCR, Reference.

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ABSTRACT

The Healthcare sector occupies a predominant role in human life all over the world. In the changing socio-economic environment, the consolidation of nation's health is primary. Today, there is high price competition in health sector. It is essential to find out the ways of resources , allocation which means to ensure the proper use. This study focuses on analysing the hospital efficiency in Andhra Pradesh with overall Indian benchmarking by using Data Envelopment Analysis. It is evaluated in terms of their efficiency which has been of interest to many researchers in countries other than India. The main aim of this paper is to study the relative efficiency of government but not that of profit. It is expected that the findings of the study would be useful to evaluate the existing policy and help policy makers to develop benchmarks in more realistic manner which enables the government to provide the grants to such hospitals for it's effective functioning.

1. Background:

India passes through a demographic and environmental transition which makes the problem on public health resources and infrastructure. In real terms, 70% of Indian population lives in the village with very limited access to private hospitals. Government hospital is the major option for their health service. It is because, the government has taken various initiatives for service oriented delivery and access to health case, these are still substantial gaps to be addressed for better health infrastructure and access.

In response to the health problems are faced, government realizes that effective health resources managements, allocation and monitoring based on gross root evidence would be reliable to cater aforesaid problems in the medical field and provide feasible and adequate quality health care services for the public. Now India Government understands the constrained on public health resources, and therefore intends to proper utilize the health resources. Therefore, it is an important to allocate resources on the basis of real world data and to regular supervising and impact assessment of the allocated resources. Evidence based health resource planning is also acknowledged under National Health Mission (NHM),by encouraging state to make 'Live' and realistic state PIPs based on surveyed data. Similar, it is an important to factor in the areas such as reach and penetration of private sector health resources, while planning for public health resources and infrastructure. Also to reach hitherto unreached segments of the population, where public health resources are constrained, potential to tie up with private sector shall be explored for better service delivery.

2. Introduction:

The main Objective of this study is to evaluate the efficiency factor of the jurisdiction of India (29 States and 6 Union Territories) with special focus on Andhra Pradesh. We now explain the efficiency in economic. The process has a single input and single output, Efficiency is defined as: $\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$, the theory of production from economics can be considered as a formal model to link inputs and outputs, this theory has several strengths. First , some formal relationship between inputs and outputs exists and a " best practice " can be identified by comparing different units transforming inputs to output where all units are assessed relative to that optimum.

The production process that can occur in hospitals seems to have the same characteristics of the above economic model in the business sector- utilization of physical and human resources as inputs to produce outputs as shown below.

Inputs → **Hospital Process** → **Outputs**

2.1 Data and variables

Different variables are defined here to conduct the analysis from the secondary data collected from the various Government hospitals in India and the Andhra Pradesh state. These variables are categorized as of two types such as input and output variables. These variables clearly are shown in Table 1.

2.1.1 Selection of variables

Once the various measures (or variables) and the measurement scales for input and output were derived from the data, the next step involved is to identify the relevant input and output variables, which contribute towards explaining the right input and output measures of the hospitals.

2.1.2 Input variables

The input variables are Number of Rural Hospitals, Number of Urban Hospitals, Number of Rural Hospital Beds, Number of Urban Hospital Beds, Number of Sub-Centres and Number of PHCs, Number of CHCs, Total Hospitals, Total Beds, Number of Doctors at PHCs, Number of Specialists at CHCs, Number of Health Assistants (Male), Number of Health Assistants (Female), Number of Health Workers (Male), Number of Health Worker (Female). The break-up of the total staff strength in terms of the number of regular doctors, number of contract doctors, are available. (Magnussen.J:1996).

2.1.3 Output variables

Hospitals provide three major output variables: Projected Population (000s), Average Population Served/Government Hospital, and Average Population Served/Government Hospital Beds. Given this homogeneity in types of services provided, the number of cases treated/handled under each category was chosen as a representative measure of the three output variables (Mersha T: 1989). In this study we choose 15 inputs and 3 outputs.

i. The 15 inputs variables considered are:

1. Number of Rural Hospitals
2. Number of Urban Hospitals.
3. Number of Rural Hospital Beds.
4. Number of Urban Hospital Beds.
5. Number of Sub-Centres.
6. Number of PHCs.
7. Number of CHCs.

8. Total Hospitals.
9. Total Beds.
10. Number of Doctors at PHCs.
11. Number of Specialists at CHCs.
12. Number of Health Assistants (Male).
13. Number of Health Assistants (Female).
14. Number of Health Workers (Male).
15. Number of Health Worker (Female).

ii. The Three Outputs variables are:

1. Projected Population (000s).
2. Average Population Served/Government Hospital.
3. Average Population Served/Government Hospital Beds.

Table - 1

Variables	Definition
Inputs	
i. Number of Rural Hospitals	Number of Rural Hospitals available in State/ UT wise.
ii. Number of Urban Hospitals	Number of Urban Hospitals available in State/UT wise.
iii. Number of Rural Hospital Beds	Number of Rural Hospital Beds available in State/UT wise.
iv. Number of Urban Hospital Beds.	Number of Urban Hospital Beds available in State/UT wise.
v. Total Hospitals	Total Number of Hospitals available (Rural & Urban) in State/UT wise.
vi. Total Beds.	Total Number of Beds available (Rural & Urban) in State/UT wise.
vii. Number of Sub centres.	Number of Sub centres available (Rural & Urban) in State/UT wise.
viii. Number of PHC's.	Number of PHCs available (Rural & Urban) in State/UT wise.
ix. Number of CHC's.	Number of CHCs available (Rural & Urban) in State/UT wise.
x. Number of Doctors at PHCs	Number of Doctors at PHCs available (Rural & Urban) in State/ UT wise.
xi. Number of Specialist at CHCs.	Number of Specialist at CHCs available (Rural & Urban) in State/ UT wise.
xii. Health Asst.Male.	Number of Health Asst. Male available (Rural & Urban) in State/ UT wise.
xiii. . Health Asst.Female.	Number of Health Asst. Female available (Rural & Urban) in State/ UT wise.
xiv. Health Workers Male.	Number of Health Workers Male available (Rural & Urban) in State/ UT wise.
xv. Health Workers Female.	Number of Health Workers Female available (Rural & Urban) in State/ UT wise.
Outputs	
i. Projected population (000's)	Total No of Population visited to Hospital (Rural & Urban) in State/ UT wise.
ii. Average population served in Government Hospitals.	Average population served in Government Hospitals (Rural & Urban) in State/UT wise.
iii. Average population served in Government Hospital Beds.	Average population served in Government Hospital Beds (Rural & Urban) in State/UT wise.

CHC: Community Health Centre **PHC**: Primary Health Centre **UT**: Union Territory

3. Methodology:

For this study, we consider the data of rural and urban hospitals across the country, which included the whole states and Union Territories with special focusing on Andhra Pradesh with the above mentioned input/output variables for the year of 2014. For this data, we employ the technique of DEA to measure the efficiency of the targeted organisation in a group relative to the best performing organisation in that group. Generally, it measures the status of efficiency of among all the states and Union Territory hospitals. (Charnes & Cooper: 1985). Data Envelopment Analysis of SSC Public Examinations 2009 -2011 of Andhra Pradesh (Raju Nellutla & VV Haragopal :2015) are used to perform TE of districts in AP. These individual hospital units are analysed and also referred to as decision-making units (DMUs) in DEA. The DMUs for which efficiency score are measured can be a whole agency such as, hospitals, banks or units within organizations which as separate wards in a hospital. To begin with , it is very essential to understand the concepts of DEA.

4. Data Envelopment Analysis:

Data Envelopment Analysis (DEA) was initially proposed by Charnes (1978) based on the concept of Technical Efficiency by Farrel (1957). Basically, it consists of two models: The Input Oriented Model and the Output Oriented Model. The Input Oriented Model is to maximise inputs for a given outputs, while the Output oriented model is to maximize outputs at given inputs. In general, the Technical Efficiency obtained from the Output oriented models differs from that acquired, from the input-oriented model unless the profit is constant return to scale.

In Recent year we have seen a greater variety of applications of DEA for use in evaluating the performances of many different kinds of entitles engaged in many different activities in many different contexts in many different countries. Presently in this paper, Data envelopment analysis (DEA) is used in an attempt to deal with the issue of measuring the relative efficiency of the participating total hospitals in India and Andhra Pradesh. This evaluation can be obtained not only at the organization level but also in sub units such as Number of Rural Hospitals, Number of Urban Hospitals, Number of Rural Hospital Beds, Number of Urban Hospital Beds, Number of Sub-Centres and Number of PHCs, Number of CHCs, Total Hospitals, Total Beds, Number of Doctors at PHCs, Number of Specialists at CHCs, Number of Health Assistants (Male), Number of Health Assistants (Female), Number of Health Workers (Male), Number of Health Worker (Female), Projected Population (000s), Average Population Served/Government Hospital, and Average Population Served/Government Hospital Beds. Hospital Efficiency in Andhra Pradesh by Data Envelopment Analysis (M. Goverdhan , VV Haragopal , 2015) was used to performing efficiency of Hospitals district wise in Andhra Pradesh.

The basic DEA model helps to find answers to questions such as:

(i) Which State/UT hospitals (or hospital departments) are the most efficient?

(ii) If all States/UTs hospitals are to perform according to best practice (i.e. the efficient peer hospitals), by how much could inputs/resources be reduced to produce the current output levels; or alternatively, by how much inputs be increased with the current input levels?

(iii) How much resources can be potentially saved if all States/ UTs hospitals are operating at an optimal scale?

Also, DEA makes a particular input and output targets that would make an inefficient hospital into efficient. It also ac-

knowledges resourceful peers for the hospitals, which are not efficient. "Performance of Management Schools in Secondary School Examinations of Andhra Pradesh State by Data Envelopment Analysis"(Raju Nellutla & VV Haragopal 2015). It also helps the inefficient hospitals to imitate the functional organisation of their peers so as to improve their proficiency (Grosskopf S.& Valdamanis V.1987).

4.1. The CCR Model:

In Data Envelopment Analysis(DEA) is most widely used model of CCR Model(Banker et al ., 1989; Charnes et al.,1993). A Constant Return To Scale relationship is assumed between Inputs and Outputs. It was the First Data Envelopment Analysis model to be developed CCR after Charnes, Cooper and Rhodes who introduced this model in article published in the Journal of Operational Research (1978). Given the data, we measure the efficiency of each DMU once and hence optimisations, one for each DM to be evaluated. Let the DM to be evaluated on any trial be designated as DMwhere j = 1,2,3,...n.We solve the following fractional programming problem to obtain values for the input weights (v_j) (j= 1,2...n) and output weights (w_i) (I =1,2...m) as variables.

The primal CCR model is explained as follows

Decision Making Units DMU_j: The j^{th} Decision Making Unit j= 1,2,3,...n

x_{ij}: The amount of the i^{th} input of the j^{th} DMU x_{1j}, x_{2j}, x_{3j},...,x_{mj}

y_{ij}: The amount of the j^{th} output of the j^{th} DMU y_{1j},y_{2j},y_{3j},...,y_{mj}

v_j: The weight assigned to the j^{th} input j=1,2 3,...n

wi: The weight assigned to the jth output i=1,2 3,...m

$$\text{Maximize } Z = \frac{w_1y_{1j}+w_2y_{2j}+---+w_my_{mj}}{v_1x_{1j}+v_2x_{2j}+---+v_nx_{mj}} \quad (1)$$

$$\textit{Subject to } \frac{w_1y_{1j}+w_2y_{2j}+---+w_my_{mj}}{v_1x_{1j}+v_2x_{2j}+---+v_nx_{mj}} \leq 1 \qquad j= 1,2, \ldots,n. \quad (2)$$

$$v_1,v_2,v_3,\ldots v_n \geq 0 \quad w_1,w_2,w_3,\ldots,w_m \geq 0$$

$$\text{Maximize } Z(u,v) = w_1y_{1J}+w_2y_{2J} + ---+w_my_{mJ} \quad (3)$$

$$\text{Subject to } v_1x_{1j}+v_2x_{2j} + ---+v_nx_{mj} = 1 \quad (4)$$

$$w_1y_{1j}+w_2y_{2j} + ---+w_my_{mj} \leq v_1x_{1j}+v_2x_{2j} + ---+v_nx_{mj} \quad (5)$$

$$w_1, w_2, w_3,\ldots,w_m \geq 0 \quad v_1,v_2,v_3,\ldots,v_n \geq 0$$

Optimal Solution: (v*, w*, Z*)

$$P_k = \{j: \sum_{i=1}^{m} w_m^* y_{mj} = \sum_{j=1}^{n} v_j^* x_{ij} \;\; j = 1, 2, 3, \ldots, n\} \quad (6)$$

The reference set P_k is the Primal Problem. The Primal Problem

$$\text{becomes } \textit{Maximize } Z^*(v^*, w^*) = \sum_{i=1}^{m} w_m y_{mj} \quad (7)$$

$$\textit{Subject to } \sum_{i=1}^{m} w_{ms} y_{mj} - \sum_{j=1}^{n} v_j x_{ij} \leq 0 \quad (8)$$

$$\sum_{j=1}^{n} v_j x_{mj} = 1 \quad (9)$$

$$v_j \geq 0 \quad w_i \geq 0$$

The above linear problems yield the Optimal Solution (O.S) Z*, which efficiency score is called Technical Efficiency (T.E) or CCR Efficiency for the particular DMU_j and Efficiency scores for all of them are obtained by repeating them for each DMU_j, j= 1,2,....n. The value of Z* is always less than or equal to unity. DMUs for which Z* < 1 are relatively inefficient and those for which Z* = 1 are relatively efficient, having their virtual input-output combination points on the frontier. The frontier itself consists of linear facts spanned by efficient hospitals of the data, and the resulting frontier production function has no unknown parameters.

4.2. Potential Improvement: An efficient study not only provides an efficiency score per each unit but also indicates by how much and in what areas is incompetent unit need to improve in order for the best. This information can enable goals to be set which could be help incompetent hospitals for better results.

4.3. Peer Group: Data Envelopment Analysis (DEA) identified for each inefficient unit a set of excellent units, called a Peer Group, which includes those units that are efficient if evaluated with the Optimal System of Weights of an inefficient unit.

4.4. Reference comparison: The information mentioned can be utilised as a base for framing goals for the units, when the result of hospitals as incompetent is felt to be vindicated. As part of the first step is concerned for framing goals, the incompetent hospitals can be compared with the hospitals in its reference set.

5. Empirical Study:

Hospitals data were collected for the year of 2014 includes, India , Union Territories and Andhra Pradesh State (Andhra Pradesh& Telangana) respectively to analysis the efficiency of hospitals i.e., Number of Rural Hospitals, Number of Urban Hospitals, Number of Rural Hospital Beds, Number of Urban Hospital Beds, Number of Sub-Centres and Number of PHCs, Number of CHCs, Total Hospitals, Total Beds, Number of Doctors at PHCs, Number of Specialists at CHCs, Number of Health Assistants (Male), Number of Health Assistants (Female), Number of Health Workers (Male),Number of Health Worker (Female), Projected Population (000s), Average Population Served/Government Hospital, and Average Population Served/Government Hospital Beds were taken into consideration for this empirical investigation

The Results of Data Envelopment Analysis (DEA) for the Hospital data are presented below:

Technical Efficiency Table :

Table- 2

S. No	State/UT	Score (%)	Technical Efficient (CCR)	Reference	Peers	Number of the peers
1	Andhra Pradesh	100.00%	1.0000	4	0	Andhra Pradesh
2	Arunachal Pradesh	100.00%	1.0000	1	0	Arunachal Pradesh
3	Assam	100.00%	1.0000	1	0	Assam
4	Bihar	100.00%	1.0000	15	0	Bihar
5	Chhattisgarh	58.44%	0.5844	0	4	Daman &Diu, Delhi, Haryana, Uttar Pradesh.
6	Goa	87.05	0.8705	0	5	Bihar,Chandigarh,Daman&Diu,Delhi,Utter Pradesh.
7	Gujarat	100.00%	1.0000	2	0	Gujarat
8	Haryana	100.00%	1.0000	5	0	Haryana
9	Himachal Pradesh	51.26%	0.5126	0	6	Bihar,D& N Haveli, Delhi, Haryana, TamilaNadu
10	Jammu & Kashmir	42.04%	0.4204	0	3	Bihar,Chandigarh,Utter Pradesh
11	Jharkhand	100.00%	1.0000	4	0	Jharkhand
12	Karnataka	54.77%	0.5477	0	5	Andhra Pradesh, Bihar, Chandigarh, Delhi, UtterPradesh
13	Kerala	100.00%	1.0000	1	0	Kerala.
14	MadhyaPradesh	88.55%	0.8855	0	5	Bihar,Chandigarh,D& N Haveli, Delhi, Utter Prdesh
15	Maharashtra	91.94%	0.9194	0	5	Andhra Pradesh, Bihar, Chandigarh, Delhi, UtterPradesh
16	Manipur	93.31%	0.9331	0	5	Bihar, D& N Haveli, Daman& Diu Haryana, Tamila Nadu
17	Meghalaya	63.38%	0.6338	0	5	Bihar, D& N Haveli, Delhi, Gujarath, Haryana
18	Mizoram	41.27%	0.4127	0	5	Bihar, D& N Haveli, Daman &Diu, Jharkhand, UtterPradesh
19	Nagaland	100.00%	1.0000	3	0	Nagaland
20	Odisha	100.00%	1.0000	1	0	Odisha
21	Punjab	70.19%	0.7019	0	4	Andhra Pradesh, Chandigarh, Delhi, Utter Pradesh.
22	Rajasthan	65.08%	0.6508	0	4	Bihar, Chandigarh, Jharkhand, Utter Pradesh.
23	Sikkim	56.33%	0.5633	0	3	Bihar, D& N Haveli, Delhi.
24	Tamila Nadu	100.00%	1.0000	4	0	Tamila Nadu
25	Tripura	92.65%	0.9265	0	5	Bihar, D & N Haveli ,Daman& Diu, Delhi, Tamila Nadu
26	Utter Pradesh	100.00%	1.0000	10	0	Utter Pradesh.
27	Uttarakhand	89.79%	0.8979	0	4	Bihar,Chadigarh,Delhi,Nagaland
28	West Bengal	100.00%	1.0000	1	0	West Bengal
29	Chandigarh	100.00%	1.0000	10	0	Chandigarh
30	A & N Islands	78.28%	0.7828	0	3	Bihar, D & N Haveli,Jharkhandu
31	D & N Haveli	100.00%	1.0000	10	0	D& N Haveli.
32	Daman&Diu	100.00%	1.0000	1	0	Daman & Diu.
33	Delhi	100.00%	1.0000	13	0	Delhi.
34	Lakshadweep	100.00%	1.0000	1	0	Lakshadweep
35	Puducherry	82.21%	0.8221	0	4	Chandigarh, D&N Haveli, Delhi, Nagaland

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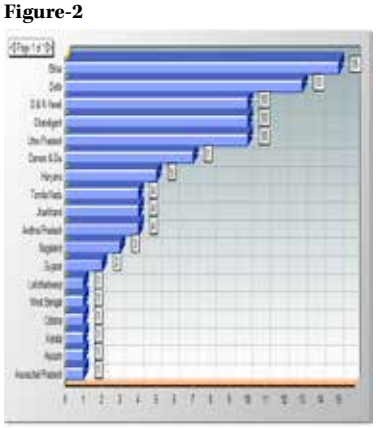
The technical efficiency variation is compared for India and Andhra Pradesh have the following bounds $0.4127 \leq \lambda \leq 1.000$. Out of 35 (29 States and 6 Union Territories), only Eighteen States including Union Territories have been emerged as efficient namely Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Haryana, Jharkand, Kerala, Nagaland, Odisha, Tamilnadu, Utter Pradesh, West Bengal, Chandigarh, D&N Haveli, Daman & Diu, Delhi and Lakshadweep and the remaining states and Union Territories input losses due to Technical efficiency. The Distribution of Scores graph of hospitals in India is presented below:

Distribution Scores Graph
Figure-1

The Reference graph of Hospitals in India is presented below:
Reference graph:
Figure-2



5. Conclusion: The findings of Technical Efficiency is indicating a wide variation in the State/UT hospitals as indicated by the authorized the Number of Rural Hospitals, Number of Urban Hospitals, Number of Rural Hospital Beds, Number of Urban Hospital Beds, Number of Sub-Centres and Number of PHCs, Number of CHCs, Total Hospitals, Total Beds, Number of Doctors at PHCs, Number of Specialists at CHCs, Number of Health Assistants (Male), Number of Health Assistants (Female), Number of Health Workers (Male), Number of Health Worker (Female).

On the basis of Technical efficiency , which highlighted the year 2014, considered that the fifteen State hospitals and one UT hospital were revealed that there is some of the hospitals efficiency scores are extremely low.

Efficiency ranging from 0.4127 to 1.000. The low level performance states and Union Territories such as Chattisgarh, Goa, Himachal Pradesh, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Punjab, Rajasthan, Sikkim, Tripura, Uttarakhand, A&N Islands and Puducherry are showed. With DEA, in which the Technical Efficiency of all hospitals are measured is defined by those hospitals in the group with a Technical Efficiency score of 100%. These hospitals are giving the good performance.

The results of this study indicate that many of the state and UT hospitals operate at Technical Efficiency Level well below. This study further reveal that the dominant scale inefficiency is increasing return to scale in the presence of increasing return to scale, increasing the level outputs require an increasing in the Number of Rural Hospitals, Number of Urban Hospitals, Number of Rural Hospital Beds, Number of Urban Hospital Beds, Number of Sub-Centres and Number of PHCs, Number of CHCs, Total Hospitals, Total Beds, Number of Doctors at PHCs, Number of Specialists at CHCs, Number of Health Assistants (Male), Number of Health Assistants (Female), Number of Health Workers (Male), Number of Health Worker (Female) in the inefficient state and UTs in order to improve their performance.

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