Efficiency Measurement of Hospitals in Bhubaneswar and Cuttack Cities of Odisha: A Data Envelopment Analysis Approach

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***Abstracts*-**Efficiency is always a central theme of the study of economics. Achieving Technical efficiency for any Decision Making Units (DMU) is very important to achieve productive efficiency. Data envelopment analysis (DEA) approach estimates technical efficiency of DMU in relation to their peer group having multiple input and output variable. But the challenge arises when it is the case of health sector. The objective the study is to measure technical efficiency of DMU (hospitals) in both the city of Bhubaneswar and Cuttack in Odisha state of India. The same of the study is all the 45 DMU having more than 20 beds. Simple CCR-Input oriented DEA model is used to estimates technical efficiency of hospital of all for 45 DMU. The results shows that only 13% hospitals are fully efficient and 13% are more than 75% efficient, rests all are in efficient. The DEA projection also advice how the DMU should follow their reference sets in order to reach efficiency frontier.
Keywords- DMU, efficiency, DEA, technical efficiency, mean efficiency, reference set, peer group

I. INTRODUCTION

The concept of efficiency remains always a central theme in the study of Economics. This fundamental principle of economics states deriving maximum benefits from the limited resources. This is applied in health sector too. With the use of limited health resources, we have to achieve maximum benefits to attain a complete physical, mental and social well being of the population. Efficiency will reduce when input rises keeping the output level same. Both the theoretical and practical difficulties arise when it is a case of multiple input and output case (Ballestero and Maldonadob, 2004) like health sector. Many Countries including the US, the UK the Netherlands and Australia consider efficiency is central to health system. However, discussion of efficiency in the literature is sometimes unclear, with several different definitions of efficiency in the health sector appearing in different contexts. The task for the analyst is to precisely define the production process of interest, the relevant output for that process and how the efficiency question to be addressed (Hollingsworth and Peacock, 2008).

In this context, we motivated to pursue this piece of research work in health economics especially to measure technical efficiency of hospitals situated in Bhubaneswar and Cuttack cities of Odisha because of these reasons, Firstly, research on health economics has a recent origin and potentiality to put forward it. Secondly, when we talk about economic development, we consider always the concept of quality of life. And this quality of life heavily depends on health care system. Until health care system is efficient, we cannot think about quality of life. Hence, there is a need to measure the efficiency of healthcare units for further improvement. Thirdly, literatures on measurement of technical efficiency of hospitals are scanty especially in India. Hardly, we find three pieces of work done in India on measurement of hospital efficiency: Bhat, Verma and Reuben (2001); Dash et el (2007); and Dash, Vaishnavi, and Muraleedharan (2010). Fourthly, Bhat, Verma and Reuben (2001) study focuses on analyzing the efficiency of district level government hospitals and grant-in-aid hospitals in Gujarat whereas Dash et el (2007) and Dash, Vaishnavi, and Muraleedharan (2010) measured efficiency of district level government hospitals in Tamil Nadu. In this context, the present piece of research work has been done in Bhubaneswar and Cuttack cities of Odisha due to time and cost constraint. Fifthly, when we talk about efficiency, it is the game of inputs and outputs. It is easier to identify inputs and outputs in different industries producing goods to measure efficiency. But in health care, it is a challenge to identify inputs and outputs to measure

efficiency. The main objective of this paper is to measure and analyze the technical efficiency of hospitals in Bhubaneswar and Cuttack cities thorough Data envelopment Analysis (DEA) approach.

II. DATA ENVELOPMENT ANALYSIS

Data envelopment analysis (DEA) is a non-parametric method for measuring efficiency of a set of Decision Making Units (DMUs)[1] such as firms or public sector agencies, first by Charnes, Cooper, and Rhodes (CCR) (Murillo-Zamorano, 2004; Quanling, 2001; Emrouznejad and Amin, 2009) built in the pioneering work of Farrell (Nyman et. al., 1990; Ray, 2004). In a simple term DEA is mathematical programming methods deals with efficiency measurement of DMUs with multiple inputs and outputs (Ramanathan, 2003; Acharya, D., Sahoo, B. K., & Venkatachalapathy, T. K. (2019); Barpanda, S., & Sreekumar, N. (2020)).The CRR model is limited use in the context of constant return to scale and later it extended to variable return to scale by Banker, Charnes, and Cooper (BCC) in 1981 (Emrouznejad and Amin, 2009).

DEA estimates technical efficiency of different firm units based on relative terms i.e. relative to best performing DMU (Nyman, J. A., Bricker, D. L., & Link, D. (1990); Ramanathan, 2003; Sahoo, B. K., & Mohapatra, P. K. (2001)). It does not provide activities of efficiency ranking rather it strands only the set of efficient firm unit versus the set of inefficient ones (Ballesteroa and Maldonadob, 2004). Koopmans defines a decision making unit (DMU) as technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or results in a reduction in at least one output. Thus a technically efficient DMU can produce the same output with less of at least one input, or can use the same inputs to produce more of at least one output (Sahoo, B. K., & Mohapatra, P. K. (2001)).

To measure efficiency and productivity several analytical methods were developed. Beside parametric methods, e.g. stochastic frontier analysis (SFA), Data Envelopment Analysis (DEA) has become a popular benchmarking tool for evaluating the efficiency of decision-making units (Chirikos and Sear (2000)). Chirikos and Sear (2000) found differences in efficiency scores were anticipated, the reason is that the SFR model incorporates stochastic factors while the DEA model does not. Jacobs (2001) uses the same dataset to benchmark NHS hospitals in UK and compares the efficiency rankings from the cost indices with those obtained using DEA and SFA. The study concludes that the methods each have particular strengths and weaknesses and potentially measure different aspects of efficiency. The empirical results suggest that Florida hospitals by the study of Chirikos and Sear (2000) over the study period had costs that were substantially higher than the frontier level of costs. Principal Findings. DEA and SFR models yield convergent evidence about hospital efficiency at the industry level, but divergent portraits of the individual characteristics of the most and least efficient facilities.

Initially, DEA was particularly applied in the non-profit sector, since measuring efficiency there is quite difficult. Studies were conducted to identify the efficiency of schools, prisons or public transport etc. (Marschall & Flessa, 2008; Sodani and Madnani (2008)). Gradually researchers in a number of fields have quickly recognized that DEA is an excellent methodology for modeling operational processes, and its empirical orientation and minimization of a priori assumptions has resulted in its use in a number of studies involving efficient frontier estimation in the nonprofit sector with the regulated sector, and in the private sector (Cooper, Seiford and Zhu, 2011). The DEA model has several important advantages over parametric and econometric approaches. Two of the most important are, primarily the flexibility of not imposing a particular functional form on the production frontier and secondly, the ability to handle multiple-output, multiple-input technologies in a straightforward way, which is considered an important

[1] Here the Hospitals are the Decision Making Units (DMUs) for which we are going to measure efficiency.

feature when assessing efficiency in public sector activities (Tsakas, 2011). The DEA Model used in this study is..

$$Minimize$$

$$(FP_O)\theta = \frac{v_1x_{1j} + v_2x_{2j} + ... + v_mx_{mj}}{u_1y_{1j} + u_2y_{2j} + ... + u_sy_{sj}} = \frac{\sum_{i=1}^{m} v_i x_{ij}}{\sum_{r=1}^{s} u_r y_{rj}}$$

$$Subject\ to \quad \frac{v_1x_{1j} + ... + v_mx_{mj}}{u_1y_{1j} + ... + u_sy_{sj}} \geq 1 \quad (j = 1,...., n)$$

$$v_1, v_2, ..., v_m \geq 0$$

$$u_1, u_2, ..., u_S \geq 0 \qquad (1.1)$$

Where θ is ratio of virtual input to virtual output, (FP_0) θ is the fractional programming of θ, *v* and *u* are the weight assigned to input (*x*) and output (*y*) respectively, *j* is the number of hospital(s), *i* is the number of input(s), *r* is the number of output(s). x_{ij} is i_{th} input for j_{th} hospital. y_{rj} is r_{th} output for j_{th} hospital. Here, the technical efficiency is: T.E $\boldsymbol{\Omega} = \frac{1}{\theta^*}$, Where θ^* is the optimal solution of DEA FP problem of the above.

III. DEA STUDY FOR MEASURING HEALTH CARE EFFICIENCY

The study in India by Dash et al (2007) used DEA to investigate the efficiency of a set of district hospitals in the state of Tamil Nadu and found eight of the 29 hospitals (27 per cent) are efficient, the DEA score being 1.0, while the remaining 21 hospitals (72 Percent) are relatively inefficient, needing to benchmark their performance with that of their peer group. Further studies of Dash et al (2010) in Tamil Nadu State for 29 found that 52 per cent were technically efficient as they had relative efficiency score 1.00 and lie on the efficiency frontier, while the remaining 48 per cent were technically inefficient and can use some of the efficient hospitals as their peers to improve their efficiency. Further, the average scale efficiency among the inefficient hospitals was 81 per cent, which implies that the scale inefficient hospitals could reduce their size by 19 per cent without reducing their current output levels. Bhat et al (2001) used DEA methodology for analyzing the hospital efficiency of district level government hospitals and grant-in aid hospitals in Gujarat. The study got out of 21 GHs, 13 were found to be operating on the efficient frontier, and three were marginally in the 80 per cent to 100 per cent efficiency band. Three hospitals are in the 60 per cent to 80 per cent band, while one each is in the 40 per cent to 60 per cent band, and the 20 per cent to 40 per cent band. Barpanda, S., & Sreekumar, N. (2020) used DEA to Analysis performance of Hospitals in Kerala, India. They used a sample of 20 hospitals randomly selected in Kerala, and the study found that the technically efficient hospitals were performing well as far as quality measures were concerned.

Studies in Ghana has been undertaken by Osei et al (2005); Akazili et al (2008). Osei et al (2005) estimates the technical efficiency of 17 public district hospitals and 17 health centres. Eight (47%) hospitals were technically inefficient. Ten (59%) hospitals were scale inefficient. Out of the 17 health centres, 3 (18%) were technically inefficient and Eight health centres (47%) were scale inefficient. Akazili et al (2008) measure the extent of technical efficiency of public health centres in Ghana and found that Out of the 89 health centres in the analysis 31 (35%) were technically efficient whereas the remaining 58 (65%) where technically inefficient. Among the inefficient health centres 21 (24%) had a technical efficiency score of less than 50%, 24 health centres (27%) between 50 and 74%.

In Italy Barbetta et al (2001) evaluated the technical efficiency of Italian hospitals for the year 1995 to1998. They adopt both parametric and non-parametric approaches to evaluate the impact of different ownership structures on the hospital technical efficiency. By applying DEA they found that the average efficiency is relatively high and growing over time, going from 74% to 81%. it is worth noting

that the most relevant change happens after 1995. They also founds that public owned hospitals are more efficient than their not-for-profit counterpart when the number of discharged patients is considered as one of the outputs. Similarly Rebba and Rizzi (2006) Showed how both the choice of specific constraints on input and output weights and the consideration of exogenous variables outside the control of hospital can affect the measurement of hospital technical efficiency using the DEA for 85 public and private hospitals in Veneto, a Northern region of Italy . Their study found that the problem of scale inefficiency, which is the first cause of the low total efficiency scores, characterizes mainly the private hospitals (about 80% of the total of private DMUs: 14 for profit and five non-profit) 15, while only 39% of the LHA public hospitals (23 DMUs) exhibit a sub-optimal size.

Rousseau and Rousseau (1997) Studied across the country level and found Austria, Germany, Ireland, the Netherlands, Sweden, Switzerland and the United Kingdom are fully efficient. Denmark scores very high. France and Italy seem to be less efficient. Switzerland's efficiency is mainly based on its high number of patents. In Germany study of Tiemann and Schreyogg (2009) evaluate the efficiency of public, private for-profit, and private non-profit hospitals. The results show that public hospitals performed significantly better than their private for-profit and non-profit counterparts. In addition, they found a significant positive association between hospital size and efficiency, and that competitive pressure had a significant negative impact on hospital efficiency. Kuntz and Scholtesy (2003) studied improvement of hospital capacity planning in Germany and found a hospital which is regarded as efficient by the model is assigned an efficiency score of 100%. If a hospital is assigned a smaller efficiency score, say 75%, then it needs to reduce its costs by 25% or increase its case load by 33% to achieve an efficiency score of 100% and their study indicates 18 out of 92 hospitals were inefficient. Another study by Steinmann et al (2004) measure and compare Hospital efficiency in Germany and Switzerland and found that Swiss distribution appears to be unimodal whereas its German counterpart seems to have a second mode around a score value of 30 percent. The group characterized by full efficiency consists of 73 observations of which 35 are German (48 percent) and 38 are Swiss hospitals (52 percent), representing 33 and 15 percent of their respective samples.

Benker et al (1986) studied a comparative application of DEA and Translog Methods to Hospital production on North Carolina Hospitals .In DEA 45 observations were estimated to be technically efficient, 37 had technically efficiency estimates between 0.9 & 1.0 and the remaining 32 were evaluated to have efficiency ratings below 0.9. The observations has been categorised into three classes on the basis of their technical efficiency .The highest efficiency rating were put into the first class, the next 37 in the second and the lowest 32 in the third class. Alexander et al (1998) used DEA to examine the extent to which managed care participation is associated with technical efficiency in outpatient substance abuse treatment (OSAT) organizations and the contributions of specific managed care practices as well as other organizational, financial, and environmental attributes to technical efficiency in these organizations in US. Based on the DEA scores, 30 of the 442 units were assigned an efficiency score of 1.00, and another 13 units were within the top 90% for efficiency. These 43 "efficient" units had scores ranging from 1.00 to 0.81, with a mean of 0.96. The remaining 399 units had scores ranging from 0.79 to 0.02

Dexter and Neill (2004) used Data Envelopment Analysis to Determine by How Much Hospitals Can Increase Elective Inpatient Surgical Workload for Each Specialty and apply it to 115 non-federal hospitals of United States (US) rural state. The case study shows that DEA may be of value to heads of anesthesia groups in recruitment decisions. The DEA may also be useful for OR managers and surgical services committees, with discretion in how Increases in operational budgets are allocated and how capital purchases are chosen. Using non-Parametric (DEA) and Parametric (SFA) applications to measure efficiency in Health Care of Europe and the USA, Hollingsworth (2003) reviewed 188 published papers on frontier efficiency measurement. The mean efficiency across the whole sample is 0.84 (excluding the within hospital studies) and the median is 0.87. Comparing efficiency across the sector, public hospitals

have the highest mean efficiency (0.95) and the highest median score (0.94), compared with not-for-profit (generally private) hospitals which have a lower mean efficiency (0.824) and a lower median score (0.874).

Liu and Mills (2005) studied the effect of performance-related pay (PRP) of hospital doctors on hospital behavior with DEA to 25 hospitals from 127 general hospitals in Shandong province China and found that bonus system change over time contributed significantly to the increase in hospital service revenue and hospital cost recovery and conclude that PRP system as designed by the sample of Chinese public hospitals was socially desirable. Pelisser et al (2011) studied health Insurance reform and efficiency of township hospitals in rural China with a sample of 24 THs, randomly selected and observed over the period 2000-2008. The technical efficiency increases from 2000 to 2002, and its average level being is quite good included in the interval [0.75; 0.85]. After 2002 up to 2008, Technical efficiency moved back from 0.85 to 0.7.

Barnum et al (2009) used DEA with Non-substitutable and Substitutable Inputs and Outputs to measure Hospital Efficiency of 87 US Hospital. They compared scores of the Fixed Proportion Ratio (FPR) efficiency indicator with Charnes Cooper Rhodes (CRR) measure and found the CCR scores were much higher than the FPR scores, at all of the reported efficiency levels except for the highest one. Moreover, the difference between the CCR estimate and the FPR estimate varied substantially. The R-square value of FPR and CCR was 0.83 for all 87 DMUs, but only 0.33 for the 24 DMUs with highest efficiencies.

Tsakas (2011) used DEA for management evaluation of 16 Greek public hospital units (HU). Regarding the results derived from the application of DEA for the three alternate scenarios, considering as criterion the total utilization degree of inputs, the HU 14 and 15 present the most satisfactory operation and constitute model units or report units for the rest HU of the sample. HU 14 and 15 achieve a remarkable utilization of the production resources. On the other hand, HU 5 and 4 present inefficient utilization degrees of production resources. Dimas et al (2010) evaluate the productive performance of 22 Greek public general hospitals for the period 2003–2005 and the changes that arise in efficiency and technology terms. The study observes a reduction of 4.6% averagely in the efficiency scores of the 22 hospitals during the 3 years. In fact in the year 2003, 7 hospitals appeared to be efficient and 15 inefficient while in the next year 2004 the situation changed with 9 hospitals appeared to be efficient and 13 inefficient although with lower mean efficiency score and in 2005, 7 hospitals deemed efficient and 15 inefficient.

Minh and Long (2007) studied the efficiency performance of the hospitals and medical centers in Vietnam. The data from the Economic Census for Enterprises by the General Statistics Office of Vietnam (GSO) consists of 44 observations, which include 17 hospitals and 27 medical centers in different provinces and cities in 2002. The results indicate that the average scale efficiency of the hospitals was 77.4 percent, while that of the medical centers was 58.7 percent. Further, hospitals were clearly more efficient than medical centers due to some possible factors. Locations in Hanoi and Ho Chi Minh City had no influence on either overall technical efficiency or scale efficiency. Despite differences in the results of testing the impact of net capital-labor ratio on efficiency for hospitals and medical centers, these organizations appear to operate in labor-intensive ways.

Harper et al (2001) analysed the costs and efficiency in general surgery specialties in the United Kingdom through DEA. The Non-Parametric DEA method under constant returns to scale shows that, the two input-two output model estimates average efficiency to be 88%, with one unit operating at 68% efficiency and seven units fully efficient. Estimated efficiency also increases as additional inputs are included in the model, with the four input two-output model suggesting that average efficiency amounts to 92% under variable returns to scale. In the most fully specified model, which includes four outputs, average efficiency of the sample is estimated as 96%, with 17 units lying on the frontier.

Hatam (2008) studied the efficiency of social security hospitals in Iran and found that Data Envelopment Analysis Pattern had more capacity than ratio Analysis Method. Out of total 72% (13) of the hospitals lacked scale efficiency in different levels. With respect to technical efficiency, it should be noted that 39% (seven) of the hospitals lacked technical efficiency. A comparison between technically efficiency and scale efficiency indicated that hospitals suffered more from the former than the latter. 42% of technical inefficient hospitals (eight) had problems on input and inappropriate use of beds, while another 42% were inefficient on output or patient-day viewpoint.

Kirigia et al (2010) used DEA to analyze the technical efficiency among a sample of 23 zonal hospitals in the Republic of Benin over a period of five years, i.e. 2003 to 2007. The yearly analysis revealed that 20 (87%), 20 (87%), 14 (61%), 12 (52%) and 8 (35%) of the hospitals were run inefficiently in 2003, 2004, 2005, 2006 and 2007 respectively; and they needed to either increase their outputs or reduce their inputs in order to become efficient.

Ismail (2010) used DEA to measure technical efficiency of Sudan's health institutions. Out of the 15 states, 9 (60%) were technically efficient under CRS since they had a relative technical efficiency (TE) score of 1 (100%). The efficient states were Khartoum, Gezira, Blue Nile, Red Sea, Gadaref, Kassala, South Kordofan, North Darfur, and West Darfur. The remaining 6 (40%) had a TE score of less than 1, which means that they were technically inefficient. The least inefficient state was South Darfur with TE score of 0.618, followed by Northern state (0.627), White Nile (0.639), River Nile (0.720), Northern Kordofan (0.882), and Sinnar with TE score of 0.961. These results imply that these states could potentially increase their outputs (outpatients, inpatients, and surgical operations), while leaving their inputs levels unchanged.

Sebastian and Lemma (2010) estimates the technical efficiency of a sample of health posts in rural Tigray, Ethiopia. The analysis was based on data from 60 health posts. The mean scores for technical and scale efficiency were 0.57 (SD = 0.32) and 0.95 (SD = 0.11) respectively. Out of the 60 health posts, 15 (25.0%) were found to be technically efficient constituting the best practice frontier. Thirty eight (63.3%) were operating at their most productive scale size. Marschall and Flessa (2008) applied DEA to assess the efficiency of rural health centers in Burkina Faso. The results shows according to constant returns to scale, 14 health centers were relatively efficient.

Androutsou et al (2011) use malmquist Productivity Index and its decompositions in DEA to assess performance in seven homogenous specialty clinics across all National Health System (NHS) hospitals in the Regional Health Authority of Thessaly (RHAT), over the period 2002–2006. The found Homogeneity in assessing hospitals' performance provides evidence on the efficiency and productivity gains among clinics and suggests improvements in those which appear inefficient. The difficult economic situation Greece is facing nowadays makes the assessment of NHS hospitals' performance a priority in the decision-making

Applanaidu et. al. (2014) use DEA to measure Technical and Scale Efficiency of Public District Hospitals in Kedah, Malaysia. Data were obtained from nine public hospitals in Kedah for three years from 2008 to 2010 for 27 DMUs with input data comprised the number of doctors, nurses and beds while the number of outpatients, inpatients, surgeries and deliveries performed represented the outputs. Of these 27 DMUs, 74 per cent were technically efficient which lied on the best-practice frontier. The technical efficiency (TE) score of technical-inefficient hospitals ranged between 0.780 and 0.991 with the average of 0.935 while the score of scale-inefficient hospitals was between 0.832 and 0.992. The average score of 16 scale-inefficient DMUs was 0.938 which implies that, on average, these DMUs were able to reduce 6.25 per cent of their resources while maintaining the same number of output. Average score of 16 scale-inefficient DMUs was 0.938 which implies that, on average, these DMUs were able to reduce 6.25 per cent of their resources while maintaining the same number of output.

Almeida et. al. (2015)studied Hospital efficiency in Portuguese for 37 NHS Hospitals in 2009 and found that outside of the frontier adjusting for quality does have an impact in efficiency scores. We conclude that the empirical evidence is not sufficient to identify a clear trade-off between efficiency and quality in the hospitals under review, implying the possibility that efficiency gains may be achieved without a significant sacrifice of service quality. Nevertheless, there is enough evidence to conclude that analyzing hospital efficiency without consideration of differences in quality of service will generate biased results. When perceived quality is brought to the analysis, the gap between efficient and inefficient units tends to widen.

Rezapour, A., Azar, F. E., Zadeh, N. Y., Roumiani, Y., & Faradonbeh, S. B. (2015) studied Technical efficiency and resources allocation in university hospitals in Tehran, between 2009-2012 using DEA. They found the average of technical; management (pure) and scale efficiency of the studied hospitals during the study period were calculated 0.87, 0.971, and 0.907, respectively. by using DEA, amount of technical, management and scale efficiency, and also the degrees of inefficiency, excess or deficiency of inputs and the amount of optimized resources for producing the specified level of products in the inefficient hospitals. According to the results, it was found that in hospitals which do not operate efficiently, capacity of increasing the technical efficiency exists through the removal of surplus factors without changes in the level of outputs.

Bahrami, M. A., Rafiei, S., Abedi, M., & Askari, R. (2018) used Data Envelopment Analysis for Estimating Efficiency of Intensive Care Units of seven training hospitals affiliated by YUMS in Iran. The study found that study findings indicated average scores of technical, managerial and scale efficiency to be relatively 0.883, 0.89 and 0.913. The mean score of technical efficiency in ICUs was 0.883 depicting the potential of study units to save about 12% of their input resources toward achieving maximum performance.

Pirani, N., Zahiri, M., Engali, K. A., & Torabipour, A. (2018) used DEA to study a panel data to measure efficiency before and After Health Sector Evolution Plan in Southwest of Iran. This study, panel data of 17 public hospitals affiliated with Ahvaz University of Medical Sciences, in southwest of Iran were studied during 2012-2016. The mean of technical efficiency, managerial efficiency, and scale efficiency of the hospitals during 2012-2016 were 0.230, 0.272 and 0.732, respectively. Assessment of return to scale results over 5 years showed that 65% (11 cases) of hospitals had a decreasing return to scale, 24% (4 cases) had a constant return to scale, and 12% (2 cases) had an increasing return to scale. Also, mean of technical managerial, and scale efficiency in specialized hospitals were higher than other hospitals (0.331, 0.353, and 0.873). The results showed that efficiency of selected public hospitals was the poor. Technical efficiency and managerial efficiency were lower than scale efficiency rate

Jing, R., Xu, T., Lai, X., Mahmoudi, E., & Fang, H. (2020) measured technical efficiency of Public and Private Hospitals in Beijing, China by using DEA and they found The technical efficiency, pure technical efficiency and scale efficiency of public hospitals were higher than those of private hospitals during 2012–2017.In 2013, the pure technical efficiency of private hospitals (0.606) was higher than that of public hospitals (0.576). The technical efficiency, pure technical efficiency, and scale efficiency of public hospitals had a downward trend, with technical efficiency decreasing from 0.589 in 2012 to 0.473 in 2017, pure technical efficiency from 0.612 to 0.518, and scale efficiency from 0.952 to 0.925. At the same time, technical efficiency and pure technical efficiency in private hospitals also declined from 0.452 and 0.606 in 2012 to 0.315 and 0.376 in 2017, respectively, but scale efficiency of private hospitals has risen from 0.782 in 2012 to 0.841 in 2017.

IV. DATABASE AND METHODOLOGY

The study has used secondary data from government of Odisha publications and primary data from Bhubaneswar and Cuttack cities of Odisha to substantiate objectives respectively. The study was conducted in Bhubaneswar and Cuttack cities of Odisha because of (i) convenience, (ii) availability of large number of hospitals, and (iii) state's major cities. The study is based on population survey. The universe of the study contained all the hospitals / nursing homes in Bhubaneswar and Cuttack cities having at least twenty beds irrespective of public and private ownerships. The population size is 50. But we have collected data from 45 (Bhubaneswar – 19, and Cuttack 26) hospitals. We could not collect data from five hospitals because of their non-cooperation. A structured schedule / questionnaire was prepared and administered to collect primary data. The data was collected from the hospital administrator / manager / superintendent(s) by direct interview method.

After careful review of literature mentioned in the study of hospital efficiency measurement, we have used the Number of Doctors, Total number of Beds and total number of Paramedical staffs as input variables. Similarly Average number of Outpatient, inpatients, Surgery cases (including delivery surgery) and average number of laboratory cases per day as output variables to measure the technical efficiency of hospitals. To measure the technical efficiency of hospitals, the study used Charnes, Cooper and Rhodes (CCR) model of DEA. Generally, output oriented DEA model is used in service sector like Hospital (Ray and Chen, 2010). As the present study is measuring the technical efficiency of hospitals, we should also follow the same. But in our study most of the hospitals (88 percent) are belonged to private sector in which they have more control over inputs than output. Therefore, we used the input oriented DEA model to minimize the inputs.

We chose to employ DEA approach to estimate technical efficiency of individual hospitals and health centers because it can handle multiple input and multiple output models/scenarios typical of hospitals and health centers, It does not require an assumption of a functional form relating inputs to output(as regression methods do), health facilities are directly compared against a peer or combination of peers, inputs and outputs can be very different units and it does not require information on prices of inputs and outputs. On the other hand even though we chose to use DEA, we were fully aware that it has two main limitations. Firstly, it attributes any deviation from the "best practice frontier" to inefficiency, while some could be due to statistical noise, e.g. epidemics or measurement errors. Secondly, given that DEA is deterministic/nonparametric technique, it is difficult to conduct statistical tests of hypotheses concerning the inefficiency and the structure of the production function.

V. ANALYSIS AND RESULTS

The study measure the relative technical efficiency of the hospitals in Bhubaneswar and Cuttack cities of Odisha state by eliminating hospital having no bed strength. The table no. 1 shows that there are 398 hospitals in both Bhubaneswar (148) and Cuttack (250) city. Out of these 52% are no bed hospitals, remain 48% hospitals range beds from 5 to 100 and more. Only 14% and 8% hospitals are having more than 50 beds in Bhubaneswar and Cuttack respectively. The density of less bed hospital is more in both cities as compared to more than 50 beded hospitals, but still this is less than the no beded hospitals. Again out of total sample hospitals only five hospitals are (11%) public hospitals, but all are having more than 100 beds. Other forty (89%) are private health service provider i.e. Hospitals.

TABLE 1
HOSPITALS WITH BED STRENGTH

Number of Beds	Total Hospital	%	Hospital in Bhubaneswar	Percentage	Hospital in Cuttack	%
No Bed Hospital	206	52.78	72	48.64	134	53.6
less than 5 Bed	5	1.036	4	2.70	1	0.4
5 to 10 Bed	65	17.95	32	21.62	33	13.2
10 to 15 Bed	55	13.64	16	10.81	39	15.6
15 to 20 Bed	22	5.26	5	3.37	17	6.8
20 to 30 Bed	16	3.31	3	2.03	13	5.2
30 to 50 Bed	7	1.45	2	1.35	5	2
50 to 100 Bed	9	1.86	5	3.38	4	1.6
more than 100 Bed	13	2.69	9	6.08	4	1.6
Total no of Hospitals	398	100	148	100	250	100

Source: Department of health and family welfare Government of Odisha.

The scatter diagram of efficiency score of all the sample hospital of the study has been shown in the figure no. 1. Those hospital touches the line horizontal with score 1 are designated as fully efficient hospital as they earned the maximum score. Out of the 45 hospital undertaken in the study, only six hospitals are 100% efficient relative to the other hospitals (DMU 8, 15, 23, 36, 37 and 40). DMU 19, 35 and 42 has scored more than 0.9. 42% hospital are having score more than 0.5 and rest 57% hospitals having less score than 0.5. The mean efficiency score is 0.59 with standard deviation 0.24. Out of 45 hospitals 26 hospitals (57.8%) have less than and 19 hospitals (42.2%) have more than the mean efficiency score. Further the analysis has been classified in to three bases i.e. Efficiency according to city, to ownership and strength of bed (See Table No.2). In this regard the DMU 39 to DMU 43 is government hospitals and rests are the private hospitals.

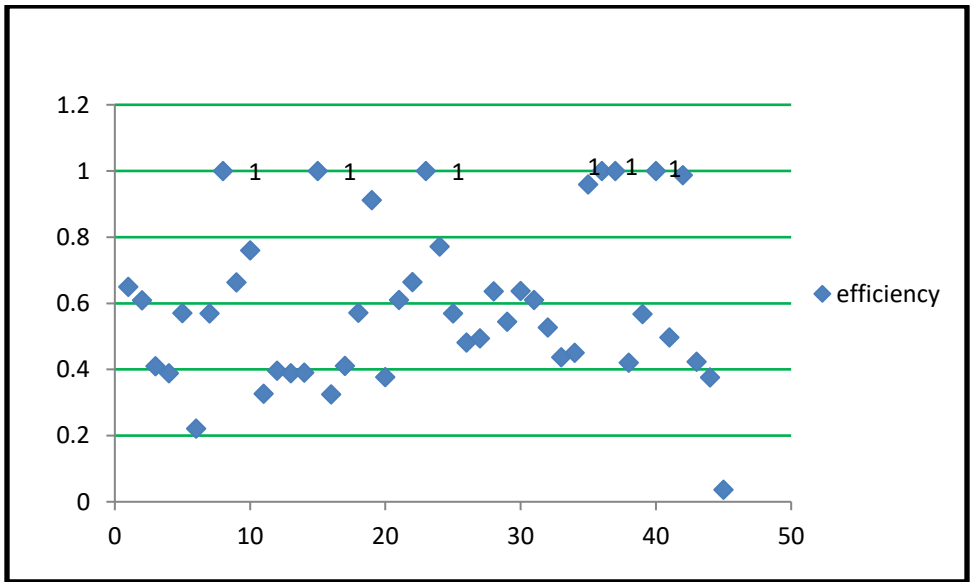

Fig.1. Efficiency Score Plots of DMUs, Source: Compiled by Author from primary study

TABLE 2
EFFICIENCY ANALYSIS

Classification Base		Overall Mean Efficiency Score	Hospitals		No. of Efficient Hospital
			Above Mean Efficiency	Below Mean Efficiency	
City	Bhubaneswar		10 (52.6%)	9 (47.4)	3
	Cuttack		16 (61.5%)	10 (38.5%)	3
Ownership	Private		23 (57.5%)	17 (42.5%)	5
	Public	**0.59**	3 (60%)	2 (40%)	1
Beds	>100		8 (61.5%)	5 (38.5%)	2
	50-100		6 (66.7%)	3 (33.3%)	1
	30-50		6 (85.7%)	1(14.3)	0
	20-30		6 (37.5%)	10(62.5%)	3
Both Cuttack and Bhubaneswar			26 (57.8%)	19 (42.2%)	6

Source: Compiled by Author from primary study

In both Bhubaneswar and Cuttack three hospitals are efficient equally. The mean efficiency of all hospitals is 0.56. In Bhubaneswar there are 10 hospitals lies above and 9 hospitals lies below the mean efficiency score. Similarly, 16 hospitals are above and 10 hospitals are lies below the mean efficiency score in the case of Cuttack. It can be observed that more hospitals are above the mean efficiency score in Cuttack than Bhubaneswar. When we compare the case of ownership, the study shows that numbers of private hospitals (5) are more sufficient than the public hospital (1). But comparatively 60% hospitals are lies above the mean efficiency score in case of public hospital, which is 57.5% in the case of private hospitals. There are 42.5% and 40% hospitals are lies below than the mean efficiency score in case of private and public respectively. According to strength of bed the study illustrate hospitals having less beds are more efficient than more beded hospitals. Two hospitals are efficient among the hospitals having more than 100 beds are efficient, one hospitals is efficient among the hospitals having 50 to 100 beds are and three hospitals are efficient among the 20 to30 beded hospitals. Eight hospitals lies above and five hospitals lies below the mean efficiency score in case of hospital having more than 100 beds. Six hospitals lie above the mean efficiency score in case of hospitals having 20 to 30, 30 to 50 and 50 to 100 beds. For the same range 10, 1 and 3 hospitals lying below the mean efficiency score.

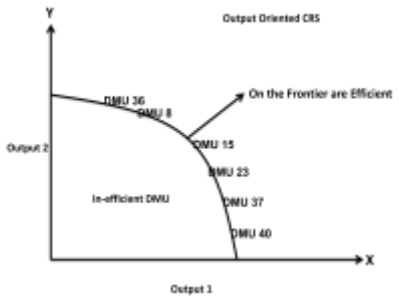

Fig.2. Efficient DMUs on Output Oriented Frontier

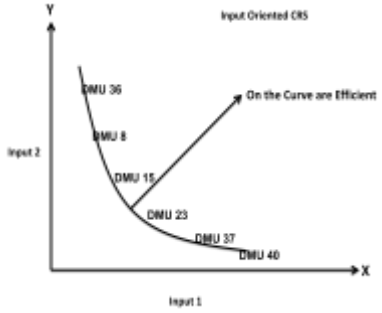

Fig.3. Efficient DMUs on Input Oriented Frontier

The above two diagram shows the frontier analysis of the efficient DMUs. The figure 2 and 3 shows the DMUs which are on the frontier are efficient one in both Output and input oriented frontier respectively.

VI. DEA PROJECTION

The main objective of this study was to measure the technical efficiency of hospitals situated in Bhubaneswar and Cuttack in relative terms. This will ultimately help to analyze the result for the improvement of health output in the cities. From the analysis, it is found that there are lots of scopes for improvement of health output from the existing level of inputs or same health output can be produced by reduction in health inputs. The DEA projection suggests that all the hospitals should reduce their strength of bed with reduction of some doctors also. At the same time 73% hospital should increased their outpatient level on an average basis. Similarly 30% hospitals have to raise number of inpatients minimally. Also 24% and 15% hospitals have to raise the output level for surgery and laboratory cases respectively.

TABLE 3
DEA PROJECTION OF DMUS WITH RESPECT TO NEAREST EFFICIENT DMUS

DMU	Score	Rank	Reference	DMU	Score	Rank	Reference	DMU	Score	Rank	Reference
DMU 1	0.65	15	DMU 8	DMU 16	0.33	43	DMU 23	DMU 31	0.61	18	DMU 23
DMU 2	0.61	19	DMU 40	DMU 17	0.41	34	DMU 8	DMU 32	0.53	26	DMU 8
DMU 3	0.41	35	DMU 8	DMU 18	0.57	20	DMU 15	DMU 33	0.44	31	DMU 8
DMU 4	0.39	38	DMU 15	DMU 19	0.91	9	DMU 15	DMU 34	0.45	30	DMU 8
DMU 5	0.57	21	DMU 8	DMU 20	0.38	40	DMU 15	DMU 35	0.96	8	DMU 36
DMU 6	0.22	44	DMU 23	DMU 21	0.75	12	DMU 8	DMU 36	1	1	DMU 36
DMU 7	0.57	22	DMU 8	DMU 22	0.66	13	DMU 8	DMU 37	1	1	DMU 37
DMU 8	1	1	DMU 8	DMU 23	1	1	DMU 23	DMU 38	0.42	33	DMU 8
DMU 9	0.66	14	DMU 23	DMU 24	0.77	10	DMU 8	DMU 39	0.57	24	DMU 36
DMU 10	0.76	11	DMU 15	DMU 25	0.57	23	DMU 15	DMU 40	1	1	DMU 40
DMU 11	0.33	42	DMU 8	DMU 26	0.48	29	DMU 8	DMU 41	0.5	27	DMU 37
DMU 12	0.4	36	DMU 15	DMU 27	0.49	28	DMU 8	DMU 42	0.99	7	DMU 40
DMU 13	0.39	39	DMU 15	DMU 28	0.64	17	DMU 8	DMU 43	0.42	32	DMU 15
DMU 14	0.39	37	DMU 8	DMU 29	0.54	25	DMU 8	DMU 44	0.38	41	DMU 8
DMU 15	1	1	DMU 15	DMU 30	0.64	16	DMU 8	DMU 45	0.04	45	DMU 15

Source: Compiled by Author from primary study

Application of DEA-CCR model found that six hospitals are efficient out of the 45 hospitals under the study. Majority of the so called corporate and tertiary sectors hospitals are found inefficient in Bhubaneswar and Cuttack, both in government and private sector, for example, DMU 12 (0.39), DMU 1(0.65), DMU 41 (0.49) and many more. DEA also projected some approach to few hospitals to follow up their asymptotical peer hospital (reference set) in order to reach to efficiency frontier. Few of these are DMU 42 (0.99) should follow DMU 40 (1), DMU 35 (0.96) should follow DMU 36 (1). Similarly 44% DMU has to follow DMU 8 as their reference set, 22% DMU has to follow DMU 15 as their reference set and 11% DMU has to follow DMU 23 as their reference set in order to reach gradually towards the efficiency frontier.

VII. CONCLUSION

After careful analysis the hospital input and output data through DEA model we can see various problems are associated with hospital for which they become relatively inefficient in comparison of other hospitals. The main issue in the study is highlighted here is that how DMU are efficient in relation to each other with same kind of variable. This does not imply that if a DMU (hospital) is inefficient means it is not giving good service rather that for providing good service it is running as technically inefficient in relation to other DMU. In some cases even the health infrastructure is not so good but the health output is better and somewhere even if there is good health infrastructure the health output is very low. Therefore in this section the study is suggesting some policy implications to improve the health infrastructure and output and simultaneously how they become an efficient hospital also.

According to rising of health hazard day by day all most all hospitals are over ambitious and raised their beds, but with this also they may not able to get patients with accordance therefore they need to reduce their bed in order to become efficient. Three hospitals i.e. DMU 42 (0.99), DMU 35 (0.96) and DMU 19 (0.91) are nearby the efficiency score, therefore the need to fine tune in their input and output so they become efficient. DMU 10, DMU 21 and DMU 24 are 75% efficient so they need to adjust 25% more in their input and output in order to become efficient which is not a difficult task for them. Again if we see the efficiency score 15% hospitals are having 60% efficient. They have to also raise more the inputs and outputs to become efficient.

In the case of Government Hospitals, what we observe that the infrastructure is not as attractive as the private hospitals. Even though patient's visits are too high to these hospitals than the private hospitals. For example, DMU 41 is the biggest one and patient's visits are very high, but the numbers of surgery cases are very less. This may be due to the surgeon's advice to go to private hospitals where they take part-time work. This is applicable to all Government Hospitals. So they need to raise number of surgeries, inpatients and Laboratory Cases.

In the case of private hospitals, the treatment fees are very high. It is not affordable by the BPL and also just APL category patients. Private hospitals are inefficient, mostly, due to less number of outpatients. This have to increase their outpatients and this can be done by reduction in their fees. Again, they may also provide some not-for-profit scheme to low income people to raise their outpatients.

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