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MEASURING TECHNICAL EFFICIENCY OF HOSPITALS USING DATA ENVELOPMENT ANALYSIS: A REVIEW

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ABSTRACT

Background: Efficiency measurement has been of great interest as organizations attempt to improve their efficiency and productivity. Most worked were emphasised on efficiency measurement in hospitals. Focus were on hospitals to established and compared their relative productivity, considering the need to effectively utilize scarce resources available within them. DEA is one of measurement tool commonly used in hospital efficiency study. DEA requires some model specification when use to examine technical efficiency of the hospital. This manuscript aim was to identify the model specification of DEA commonly used in measuring the technical efficiency of hospital.

Materials and Methods: Three databases, namely PubMed, CIHAHL and ScienceDirect were used for searching articles from 2013 to 2018. The search technique will involve the use of key words, "hospital", "hospital inputs", "technical efficiency", "hospital efficiency", "hospital outputs", together with the "data envelopment analysis or DEA. Searching and screening were based on PRISAMA procedure.

Result: Twenty articles had extracted as a final result of the systematic review process. The number of DMUs was ranged between 9 and 322. Studies were varies in term on DEA model specification, and some studies were similar with other studies in regard to components of DEA model specification.

Conclusion: The DEA model specification has an ability to be customized based on researcher preferences and the objective of the study in order to measure hospital technical efficiency.

Keywords: Efficiency, hospital, data envelopment analysis, DEA

1.0 Introduction

General meaning of efficiency is about doing things in an optimal way, for example doing it the fastest or in the least expensive way. Efficiency is concerned with the optimal production and distribution or these scarce resources, and efficiency measurement is important subject to organization, it has been of great interest as organizations try to improve their productivity and efficiency (Cook & Seiford, 2009). In health sector many efficiency worked were emphasised on efficiency measurement of hospitals. Focus were on hospitals to established and compared their relative productivity, considering the need to effectively utilize scarce resources available within them (Jacobs, 2001a).

The concept of efficiency as explained by Farrell (1957) refers to the ability of a firm (hospital) to effectively generate as many outputs as possible from the supplied bundle of inputs (Farrell, 1957).

Farrell came up with three types of efficiency. They include economic efficiency (which Farrell refers to as the technical efficiency, allocative efficiency and economic efficiency (Farrell, 1957).

(i) Technical efficiency is the effectiveness with which a given set of inputs is used to produce an output. An organization is technically efficient if it is producing the maximum output from the minimum quantity of inputs, such as labour, capital and technology. Technical efficiency estimates the firm's ability (DMU) to generate as more feasible output as possible from a given set of inputs, or generate a particular amount of output by utilizing the minimum feasible set of inputs (Farrell, 1957). Moreover, technical efficiency denotes to the physical relation between resources (capital and labour) and health consequence. When the maximum potential development in outcome is gained from a set of inputs, that means a technically efficient level is reached (Palmer & Torgerson, 1999).

(ii) Allocative efficiency estimates the ability of a DMU that is technically efficient to use amounts of inputs in ratios that reduce costs of production on given input prices. This type of efficiency is calculated as the proportion of the lowest costs needed by the DMU to generate a given amount of outputs and the DMU's actual costs adjusted for technical efficiency (Farrell, 1957). Farrell called it as price efficiency, thus to calculate allocative efficiency, it requires the input prices. Nonetheless, if the inputs prices are not obtainable, the allocative efficiency could not be calculated (Badunenko, Fritsch, & Stephan, 2008).

(iii) The economic (cost efficiency) or productive efficiency occurs when the maximum number of goods and services are produced with a given amount of inputs; it is refers to the product of both allocative and technical efficiency (Farrell, 1957). Therefore, a DMU is efficient economically if it is both allocatively and technically efficient (Badunenko et al., 2008; Greene, 2008). Thus, the economic efficiency can be obtained only by the DMU consuming the minimal amount of inputs essential for production; and by combine inputs in a technique that assure the production of select quantity of output with minimum cost feasible (Blatnik, Bojnec, & Tušak, 2017; Greene, 2008).

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1.1 Approaches for Measuring Efficiency

Efficiency can be measured using two major approaches: a parametric-economic approaches and a non-parametric approach (Mitropoulos, Mitropoulos, & Sissouras, 2013).

1.1.1 Parametric-economic approaches

1.1.1.1 Stochastic Frontier Analysis

The stochastic frontier production function model was presented by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977)(Coelli, Rao, O'Donnell, & Battese, 2005, p 242). A SFA is an econometric method, which is employed to measure the relative efficiency in productive models. The assumption under SFA is that all of the entities are not efficient and subject to random noise (Ramírez-Valdivia, Maturana, Mendoza-Alonzo, & Bustos, 2015). It considers as a common method to measure efficiency under the parametric-economic approach (Lordan, 2007). SFA presume a specified functional form for the relationship between inputs and outputs (Coelli et al., 2005). Basically, SFA applies multivariate statistical techniques to examine output or cost disparity between firms and thus yield efficiency scores for the units under examination (Lordan, 2007). The SFA distinguish between random noise and inefficiency under the hypothesis of its two dissemination, which are symmetric and asymmetric (Ramírez-Valdivia et al., 2015).

1.1.1.2 Cobb-Douglas Function

In 1928, Cobb and Douglas was introduced the particular form of production function (Gupta, 2016). It is also known as Cobb-Douglas functional form. It is the most worldwide functional form in both theoretical and empirical analysis of production growth (Kleyn, Arashi, Bekker, & Millard, 2017). The Cobb-Douglas function is suitable to work in term of factor prices and cost rather than factor inputs and outputs. The term of cost function refers to the relationship between factor prices and prices and is a twin of the principal production function (Healthfield & Wibe, 1987, p 84).

1.1.1.3 Translog Function

The term of Translog is derived from the abbreviation of Transcendental Logarithmic Function. The transcendental function consists of one functional form that combines logarithmic and non-algebraic function (Healthfield & Wibe, 1987, p 105). This function form appears to provide reasonable estimates of marginal costs when investigated close to the approximation point of the function. It also provides a second order approximation and the empirical model of its functions. It is more flexible model to work with than Cobb-Douglas form function. However, it disadvantage is that it requires that many parameters to be estimated of which this will limit the use of this model to assess efficiency that involve large changes in the inputs (Vita, 1990). And also fail to satisfy the appropriate theoretical model conditions (Diewert & Wales, 1987).

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1.1.2 Non-parametric Approaches

1.1.2.1 Data Envelopment Analysis

Data envelopment analysis (DEA) was developed in 1978. (Cook & Seiford, 2009) argue that since its advent, there have been significant improvements in theoretical growth and use of ideas in real world situations. DEA considers as non-parametric linear programming technique for estimating the relative efficiency of identical decision making units (DMUs) with multiple inputs and multiple outputs (Charnes, Cooper, & Rhodes, 1978).

Literature has shown that DEA were popular method of measuring hospital efficiency (Cantor & Poh, 2018; O'Neill, Rauner, Heidenberger, & Kraus, 2008). Several studies were used the DEA model to estimate hospitals efficiency. A study was conducted in Eastern Ethiopia by (Ali, Debela, & Bamud, 2017) to measure technical efficiency for 12 hospitals for six rounded years from 2007/08 to 2012/13. In Iran, a study was conducted by (Sheikhzadeh, Roudsari, Vahidi, Emrouznejad, & Dastgiri, 2012) to estimate technical efficiency for 11 hospitals for the year of 2004. Another study was conducted in Nigeria by (Ichoku, Fonta, Onwujekwe, & Kirigia, 2011) to examine technical efficiency for 200 hospitals for the period three months between January and March 2009. In Republic of Benin, a study was conducted by (Joses Muthuri Kirigia et al., 2010) to examine technical efficiency for 23 hospitals for the period from 2003 to 2007. The aforementioned studies shared in DEA method to measure technical efficiency for hospitals. The widespread use of DEA represents the popularity of DEA as a preferable tool in measuring efficiency.

The DEA has a penalty of strength points over the parametric approach. The DEA has its capability to cope with complicated production environments with multiple input and output (Jacobs, 2001b; Ruggiero, 2007). In contrast, the parametric approach such as SFA only able to manage multiple inputs with one input (Hamidi, 2016; Ramírez-Valdivia et al., 2015). DEA does not require the input prices to estimate technical efficiency, while the parametric approaches are required the input prices (Grosskopf & Valdmanis, 1993). Moreover, the DEA is non-parametric, thus no precise functional from is applied on the data (Grosskopf & Valdmanis, 1993). Whilst, the SFA is required a particular functional form of stochastic frontier, thus an incorrect selection of production function might affect the outcomes (Bezat, 2009). The DEA model is comparatively easy to understand, thus many researchers prefer to employ this model to assess efficiency (Blatnik et al., 2017).

This systematic review conducted with aim of identifying the model specification of DEA commonly used in measuring the technical efficiency of hospital.

2.0 Materials and Methods

This section is describing methodology used in conducting the review.

2.1 Search strategy and Selection

A systematic search was carried out, and this through three databases. These databases include PubMed, CIHAHL and ScienceDirect literature databases. The key objective will be to identify appropriate articles relevant to the research topic on measurement of technical efficiency of hospital using DEA approach. The search technique will involve the use of key words, “hospital”, “hospital inputs”, “technical efficiency”, “hospital efficiency”, “hospital outputs”, together with the “data envelopment analysis or DEA”. The range of the search will be between 2013 and 2018 to filter out all the relevant articles. Additionally, we will scan across the references of the articles identified to establish articles that could have been missing in the inclusion process. Fig 1.1 is a flow diagram that demonstrates searching and screening (PRISMA) to identify relevant articles. The articles that were selected and considered as eligible studies which only that met inclusion criteria. A study had relevant information on the use of Data Envelopment Analysis on the measurement of the hospital technical efficiency. A study provided information on hospitals inputs and outputs. A study, which used hospitals as DMUs, was relevant and was included. A study was conducted in a time range of between 2013 and 2018. The article provided full access to content in the English language.

2.2 Screening Process

The keyword search retrieved a total of 196 articles. The search was constrained to articles that only examine the technical efficiency of hospital using DEA, hence excluding technical papers, conference papers, book chapters and editorial papers in the search results. Also, it was established that 39 articles were duplicates, and this left the screening process with 157 unique articles.

We conducted two types of screening before coming up with the final number of relevant articles. The first one was abstract screening, which used the title, keywords and abstract, but eventually had inadequate information. Also, only a few aspects from the inclusion and exclusion criteria that have been mentioned above were observed. Studies that did not measure the technical efficiency of hospital, those that focused on specialized healthcare units or heath care system together with those articles that used a different approach to measure efficiency were found and consequently excluded in full text screening. After the abstract screening, 116 studies were omitted thus left with 41 articles with the most relevant information. Bibliographic search was carried out on the remaining studies and another review for full text screening on additional 3 studies. Thus, making 44 studies as the total number reviewed in full text screening.

The full-text screening was more comprehensive than abstract screening, which demonstrated various reasons for eliminating research articles in the final analysis. The reasons for exclusion were the utilization of non-hospital DMU, and using other techniques and terms instead of DEA. Some articles’ mainly compared DEA with other approaches, and this led to their exclusion. In summary, 24 research articles were identified and omitted from this study. At this point, Only 20 articles had remained for systematic review to the end of the process. Fig. 1 shows the details on the undertaken search and screening process.

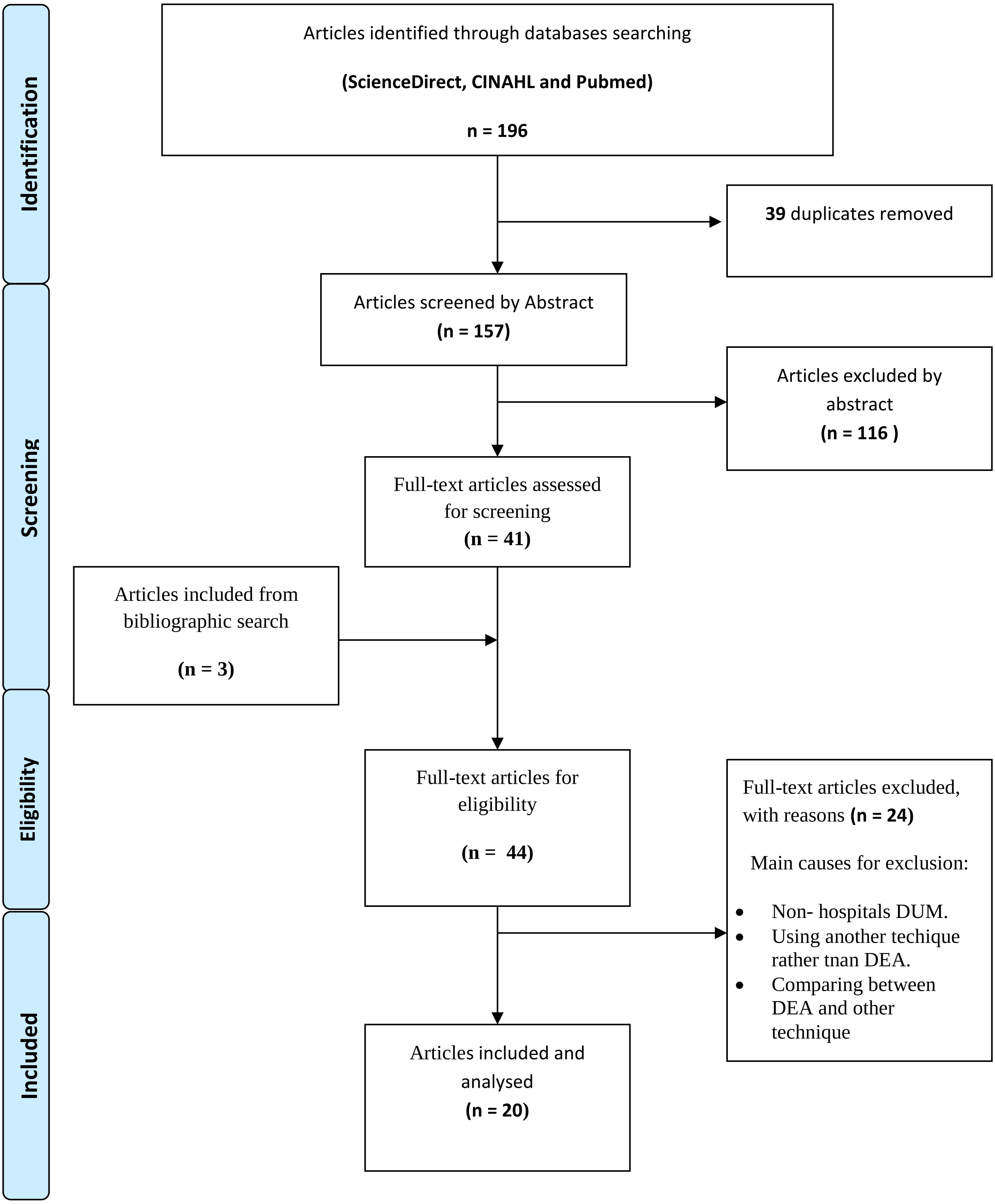

Figure 1: Flow Diagram of Searching and Screening (PRISMA), Adopted from PRISMA 2009 Flow Diagram

2.3 Data Synthesis

The structure form was used to synthesize and summarise the results. It displays numerous findings, which gained and categorized narratively the studies by the author, year of publication, DEA model specification which include model type, return to scale, model orientation, inputs and outputs combination, as well as the key findings of the studies.

3.0 Result

A total of 20 articles had remained as a final result of the systematic review process. Table 1 displays the summary on the study location, number of DMUs, DEA model specification used in measuring technical efficiency using DEA.

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Table 1: Summary of Systemic Review on DEA Model Specification and Types of Inputs and Outputs in Measuring Hospital Technical Efficiency Using DEA.

No.	Author (Year) Location	DEA Model Specification				Inputs	Outputs	Key findings related to Hospital Technical Efficiency (TE)
		No. of DUMs	Model Type	Return to scale	Model orientation			
1	(Ali, Debela, & Bamud, 2017), Eastern Ethiopia	12 hospitals (8 Public hospitals) And (4 private hospitals). For six rounded years from 2007/08 to 2012/13	Radial, BCC	VRS	Output-oriented.	No. of beds No. of health staff. Cost of drug supplies.	No. of outpatient visits. No. of inpatient days. No. of surgery.	Under CRS assumption; 3 (25%) of hospitals were technically efficient for the year of 2007/08 and 2008/09. 5 (41.67%) of hospitals were technically efficient for the year of 2009/10 and 2010/11. 5 (41.67%) and 4 (33.33%) of hospitals were technical efficient for the period 2011/12 and 2012/13 respectively. Under VRS assumptions: 6 (50%) and 7 (58.33%) of hospitals were technically efficient for the period 2007/08 and 2008/09 respectively. 9 (75%) of hospitals were technical efficient in the both period of 2009/10 and 2010/11. 8 (66.7%) and 9 (75%) of hospitals were technical efficient in the year of 2011/12 and 2012/13 respectively.
2	(N. Li, Wang, Ni, & Wang, 2017) Anhui, China.	12 county-level hospitals,. For the years from 2010 to 2015.	Radial, CCR	CRS	Input-oriented	No. of actual doctors. No. of actual nurses. No. of actual beds. Total expenditure.	No. of emergency visits. No. of discharged. No. of hospitalized patients.	Under CRS assumption From 2010 to 2015, there are 4, 6, 7, 7, 6, and 8 hospitals, respectively each year that were technically efficient. In the past 6 year, a total of 9 (75%) hospitals reached a TE of 1, while the other 3 (25%) hospitals never reached 1.

International Journal of Public Health and Clinical Sciences
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3	(Surat, Dalbir, & Kamlesh, 2017) Haryana, India	20 public hospitals. For the year from 2013 to 2015.	Radial, CCR and BCC	CRS and VRS	Input-oriented.	No. of doctors. No. of support staff.	No. of outpatients. No. of inpatient.	90% of hospitals were technically inefficient with a mean of technical efficiency score 32%. The efficiency results are based on mean data, which has been obtained by averaging the three years data for 2013, 2014 and 2015.
4	(Wang et al., 2017) China.	127 county public hospitals. For the years from 2012 to 2015.	Radial, CCR	CRS	Input-oriented.	No. of physicians. No. of nurses. No. of technicians. No. of actual open beds.	No. of outpatient and emergency visits. No. of inpatient days.	Under CRS assumption The average bias-corrected technical efficiency for the four-year period was 0.6094, 0.6442, 0.5785, and 0.6099 in China, Eastern, Central and Western China, respectively.
5	(Cheng et al., 2016), China.	48 hospitals. From 2008 to 2014.	Radial, CCR	CRS	Output-oriented	Total number of medical staff. Total number of other technicians. Total number of non-medical staff members. No. of beds.	No. of outpatient and emergency visits. No. of inpatient.	The average bias-corrected technical efficiency was 0.5147.
6	(Kakeman, Forushani, & Dargahi, 2016) Iran	52 hospitals with (25 public, 19 private and 10 social security) ownership. For the year 2014	Radial, BCC	VSR	Input-oriented	No. of active beds. No. of physicians. No. of nurses. No. of other medical staff.	No. of outpatient visit. No. of surgery procedures. Average of patient length of stay (ALOS). No. of hospitalization days.	Under VRS assumption: Out of 54 hospitals only 17 (30.5%) hospitals were technically efficient. 36 (67%) of hospitals were technically inefficient.

7	(Kalhor et al., 2016) Iran.	54 hospitals (university, private and social security) For the year 2014	Radial, BCC.	VRS	Input-oriented	No. of medical doctors (FTE). Total number of full- No. of medical nurses (FTE). No. of supporting medical personnel. No. of beds.	No. of patient days. No. of outpatient visits. No. of patient receiving surgery. Average length of stay.	Under VRS assumption 17 (31.5%) hospitals were technical efficient. 37(68.5%) hospitals were technically inefficient. The average scores of technical efficiency for all hospitals were 81.9%.
8	(Mahate & Hamidi, 2016) United Arab Emirates	96 private and public hospitals. For year 2012.	Radial, CCR and BCC.	CRS and BCC.	Output-oriented.	No. of beds. No. of doctors. No. of dentists. No. of nurses. No. of pharmacists and allied health staff. No. of administrative.	No. of treated inpatients. No. of outpatients. Average length of stay	Third of hospitals in the UEA to be efficient. The average technical efficiency of 96 hospitals is 59% using BCC model and 48% using CCR model.
9	(Mujasi, Asbu, & Puig-Junoy, 2016) Uganda	(17) Hospitals (public and private not for profit) For financial year from July 1, 2012 to June 30, 2013	Radial, CCR, BCC.	VRS, CRS	Out-oriented	No. of medical staff. No. of hospital beds.	No. of out patient visits. No. of In-patient days.	3 hospitals (18%) were operating under CRS, implying that they were technically efficient. 10 hospitals (59%) were operating under DRS, implying that their health service outputs would increase by a smaller proportion compared to any increase in health service inputs were technically inefficient. 4 hospitals (24%)were operating under IRS, implying that their health service outputs would increase by a greater proportion compared to any increase in health service inputs were technically inefficient. Under VRS there were 8 hospitals (47%) technically efficient.

10	(Cheng et al., 2015) Henan province, China.	114 county hospitals From 2010 to 2012.	Radial, CCR and BCC.	CRS and VRS	Input-oriented	No. of physicians. No. of nurses. No. of beds.	No. of outpatient and emergency visits. No. of inpatient days.	Under CRS assumption: For the year 2010, 2011 and 2012, 2 (1.8%), 2 (1.8%) and 10 (8.8%) hospitals were technically efficient respectively. Under VRS assumption: In 2010. 2011 and 2012, 6 (5.3%), 9 (7.9%) and 18 (15.8%) hospitals, respectively, operated at the best efficiency levels.
11	(H. Li & Dong, 2015), China	14 third-grade public general hospitals. For the year 2012.	Radial, BCC.	VRS	Output-oriented.	Actual number of open beds. No. of staff.	No. of diagnostic visits. No. of discharged inpatients.	Under VRS assumption 8 (57%) hospitals out of 14 third-grade public hospital were technical efficient.
12	(Applanaidu, Samsudin, Ali, Dash, & Chik, 2014), Kedah, Malaysia	9 public hospitals. For the year from 2008 to 2010.	Radial, BCC.	VRS	Input-oriented.	No. of doctors. No. of nurses. No. of beds.	No. of outpatients. No. of inpatients. No. of surgeries. No. of deliveries.	Under VRS assumption 74% of hospitals were technically efficient for the period 2008 to 2010. The technical efficiency of inefficient hospitals ranging between 0.780 and .991.
13	(J. P. Harrison & Meyer, 2014) USA.	In 2007, 165 federal hospitals. In 2011, 157 federal hospitals.	Radial, BCC	VRS	Input-oriented.	Operating expenses. No. of hospital beds. No. of staff in full time employees. (FTEs).	No. of Inpatient days. No. of Surgical procedures. No. of outpatient visits.	Under VRS assumption In 2007, 25 (15.15%) hospitals out of 165 federal hospitals were technically efficient with the average technical efficiency scores of 0.81 In 2011, 21 (13.4%) hospitals out of 157 federal hospitals were technically efficient with the average of technical of 0.86.

14	(Jehu-Appiah et al., 2014) Ghana.	128hospitals (Public, mission, quasi – government, private) For the year 2005	Radial, BCC.	VRS	Output-oriented.	Total recurrent expenditure. No. of clinical staff. No. of nonclinical staff. No. of beds.	No. of outpatient visits. No. of Inpatient days. No. of deliveries. No. of laboratory test.	Under VRS assumption 31 (24%) hospitals were technically efficient. 97 (76%) were technically inefficient.
15	(El-Seoud, 2013), Saudi Arabia	20 hospitals. For the year 2011.	Radial, CCR and BCC.	CRS and VRS.	Input-oriented and output-oriented.	No. of specialists (doctors). No. of nurses. No. of allied health. No. of beds.	No. of patients visit outpatient. No. of patients admissions. No. of laboratory tests. No. of beneficiaries of radiological imaging.	8 (40%) hospitals out of 20 hospitals were achieved general relative efficiency with the average relative efficiency is 84.6%. These findings were based on using both BBC and CCR model to measure relative efficiency in the selected sample of hospitals.
16	(Kirigia & Asbu, 2013), Eritrea	19 secondary level public community hospitals.	Radial CCR and BCC.	CRS and VRS	Output-oriented	No. of physicians (doctors). No. of nurses and midwives. No. of laboratory technicians. No. of operational beds and cost.	No. of outpatient department visits. No. of inpatient department discharges.	Under CRS assumption; 8 (42%) hospitals were technically efficient. Under VRS assumption; 13 (68%) hospitals were technically efficient.
17	(Kounetas & Papathanassopoulos, 2013) Greek.	114 public hospitals (regional, prefectural and university).	Radial, CCR and BCC.	CRS and VRS	Input-orientated	No. of beds. No. of doctors. No. of nurses.	No. of patients' days of treatment. No. of days of treatment in the outpatient departments. Total number of surgeries. No. of total medical examinations	The average efficiency for model 1 is 0.716. While the average efficiency for model 3 it is 0.713. Technical efficiency scores are significantly lower using the bootstrap methodology comparing with traditional DEA scores. Over 80 % of the examined hospitals appear to have a technical efficiency lower than .8.

18	(Jat & Sebastian, 2013), Madyah Pardesh, India	40 district hospitals in public sector. From January to December 2010	Radial, BCC	VRS	Input-oriented	No. of doctors (specialists and primary care physicians) No. of nurses. No. of beds.	No. of women with three completed antenatal checkups. No. of deliveries. No. of cesarean-section. No. of women receiving post-natal care within 48 hours of delivery. No. of medical terminations of pregnancy. No. of male and female sterilizations. No. of inpatient admissions. No. of outpatient consultations.	Under VRS, 20 (50%) district hospitals were technically efficient. 20 (50%) district hospitals were technically inefficient.
19	(Yusefzadeh, Ghaderi, Bagherzade, & Barouni, 2013) Iran.	23 teaching hospitals. For the year 2009.	Radial, BCC.	VRS	Input-oriented.	No. of active beds. No. of doctors. No. of other personnel.	No. of patients admission. Occupied day beds.	Under VRS assumption 4 (17.3%) hospitals out of 23 hospitals were technically efficient with the average technical efficiency scores of 0.548
20	(Mitropoulos et al., 2013), Greek	96 general hospitals. For the year 2005.	Radial, CCR and BCC.	CRS and VRS.	Input-oriented	No. of doctors. No. of laboratory doctors. No. of administrative staff.	No. of patient admissions in pathologic clinic. No. of patient admission in surgical clinic. No. of surgeries. No. of outpatient visits. No. of laboratory tests.	Under CRS assumption 27 hospitals were technically efficient. Under VRS assumption 36 hospitals were technically efficient

3.1 Study Location and Hospitals' Types

The studies those included those conducted in Ethiopia, China, India, Iran, United Arab Emirates, Uganda, Malaysia, the USA, Ghana, Saudi Arabia, Eritrea, and Greek. The Majority of the studies came from China with a total five studies. There were a number of hospitals types were selected as the DMUs in these studies, including the public hospitals, private hospitals, social security hospitals, university, private not for profit hospitals, quasi-government, mission hospitals, and teaching hospitals. A total of twelve studies included the public hospitals as a DMUs, two studies included combination of public and private hospitals, two studies included combination of university, private and social security hospitals, one study included public, mission, quasi-government and private hospitals, one study included public and university hospitals, one study included teaching hospitals, and only one study included public and private not for profit.

3.2 Number of DMUs (hospitals)

The analysis showed that, the number of DUMs in these studies ranged between 9 DMUs, the minimum up to 322 DMUs, the maximum.

3.2 DEA Model Specification

3.2.1 Model Type

It was found that all included studies were used the radial as a model type. The radial model consisted of the CCR (Chrance-Cooper-Rhodes) and BCC (Banker-Chrance-Cooper). Nine studies used BCC model. Eight studies used both of CCR and BCC model. Meanwhile three studies used CCR model.

3.2.2 Return to Scale Assumption

The included studies were used costant retrun to scale (CRS), variable return to scale (VRS) or both of them. Nine studies used VRS. Eight studies used both of CRS and VRS. Meanwhile three studies used CRS model.

3.2.4 Model Orientation

The model orientation was observes to be varied between studies, either the input-oriented or output-oriented or both which is in based on the objective of the study. The majority of the included studies, twelve studies used the input-orientation model. Seven studies used output-orientation model. While only study used both of input-orientation and output-orientation model.

3.3 Inputs and outputs Combination

The total combination number of inputs and outputs used among the included studies ranged between 4 (2 inputs and 2 outputs) as the lower limit and 11 (3 inputs and 8 outputs) as the upper limit.

4.0 Discussion

The analysis showed that the model specification was differing in general among the included studies. This variation came as result of study objectives in each study. The number of DUMs among the included studies was different. In some studies, A study conducted in Ethiopia to measure technical efficiency for 12 public and private hospitals was employed BCC, VRS, output-oriented and the total combination number of inputs and outputs was 6 (Ali, Debela, & Bamud, 2017). Another study conducted in China to measure technical efficiency for 12 county level hospitals was used CCR, CRS, input-oriented and the total combination number of inputs and outputs was 7 (N. Li, Wang, Ni, & Wang, 2017), A study conducted in India to measure technical efficiency for 20 public hospitals was employed CCR and BCC, CRS and VRS, input-oriented and the total combination number of inputs and outputs was 4 (Surat, Dalbir, & Kamlesh, 2017).

A study conducted in China to measure technical efficiency for 127 public hospitals was employed CCR, CRS, input-orientation, and the total combination number of inputs and outputs was 6 (Wang et al., 2017). A study conducted in China to measure technical efficiency for 48 public hospitals was used CCR, CRS, output-oriented and the total combination number of inputs and outputs was 6 (Cheng et al., 2016). In Iran a study conducted to measure technical efficiency for 52 public and private hospitals was used BCC, VRS, input-oriented, and the total combination number of inputs and outputs was 8 (Kakeman, Forushani, & Dargahi, 2016).

Another study in Iran conducted to measure technical efficiency for 54 university, private, and social security was employed BCC, VRS, input-oriented, and the total combination number of inputs and outputs was 9 (Kalhor et al., 2016). A study conducted in the United Arab Emirates to measure technical efficiency for 96 public and private hospitals was used CCR and BCC, CRS and VRS, output-oriented, and the total combination number of inputs and outputs was 9 (Mahate & Hamidi, 2016). A study conducted in Uganda to measure technical efficiency for 17 public, private not for profit was used CCR and BCC, CSR and VRS, output-oriented, and the total combination number of inputs and outputs was 4 (Mujasi, Asbu, & Puig-Junoy, 2016). In China a study conducted to measure technical efficiency for 114 county hospitals was employed CCR and BCC, CRS and VRS, input-oriented, and the total combination number of inputs and outputs was 5 (Cheng et al., 2015).

Another study in China conducted to measure technical efficiency for 14 third -grade public hospitals was employed BCC, VRS, output-oriented, and the total combination number of inputs and outputs was 4 (H. Li & Dong, 2015). In Malaysia a study conducted to assess the technical efficiency for 9 public district hospitals was employed BCC, VRS, input-oriented, and the total combination number of inputs and outputs was 7 (Applanaidu, Samsudin, Ali, Dash, & Chik, 2014). In the USA a study conducted to calculate technical efficiency for 322 federal hospitals was used BCC, VRS, input-oriented, and the total combination number of inputs and outputs was 6 (J. P. Harrison & Meyer, 2014). A study conducted in Ghana to examine technical efficiency for 128 public, mission, quasi-government, and private hospitals was applied BCC, VRS, output-oriented, and the total combination number of inputs and outputs was 8 (Jehu-Appiah et al., 2014). In Saudi Arabia a study conducted to assess technical efficiency for 20 public hospitals was used CCR and BCC, CRS and VRS, Input-oriented and output-oriented, and the total combination number of inputs and outputs was 8 (El-Seoud, 2013).

A study conducted in Eritrea to measure technical efficiency for 19 secondary level public community hospitals was applied CCR and BCC, CRS and VRS, output-oriented, and the total combination number of inputs and outputs was 6 (Kirigia & Asbu, 2013). In Greek, a study conducted to examine the technical efficiency for 114 public regional, prefectural and university hospitals was used CCR and BCC, CRS and VRS, input-oriented, and the total combination number of inputs and outputs was 7 (Kounetas & Papathanassopoulos, 2013). A study conducted in India to examine the technical efficiency for 40 public district hospitals was applied BCC, VRS, input-oriented, and the total combination number of inputs and outputs was 11 (Jat & Sebastian, 2013) .

In Iran, a study conducted to measure the technical efficiency for 23 teaching hospitals was employed BCC, VRS, input-oriented, and the total combination number of inputs and outputs was 5 (Yusefzadeh, Ghaderi, Bagherzade, & Barouni, 2013). Lastly, a study conducted in Greek to examine the technical efficiency for public hospitals was used CCR and BCC, CRS and VRS, input-oriented, and the total combination number of inputs and outputs was 9 (Mitropoulos et al., 2013).

In the other hand, when the DEA model specification breaks down into model type, return to scale, model orientation, and inputs and outputs combination. There are similarities between studies. Some studies are similar in the model type BCC these study were (Ali et al., 2017), (Kakeman et al., 2016), (Kalhor et al., 2016), (Mujasi et al., 2016), (H. Li & Dong, 2015), (Applanaidu et al., 2014), (J. P. Harrison & Meyer, 2014), (Jehu-Appiah et al., 2014), (Jat & Sebastian, 2013), (Yusefzadeh, Ghaderi, Bagherzade, & Barouni, 2013). For CCR model, the studies were shared in this model type were (N. Li, Wang, Ni, & Wang, 2017), (Wang et al., 2017), (Cheng et al., 2016). For both CCR and BCC, the studies were used this model were (Surat, Dalbir, & Kamlesh, 2017), (Mahate & Hamidi, 2016), (Mujasi et al., 2016), (Cheng et al., 2015), (El-Seoud, 2013), (Kirigia & Asbu, 2013), (Kounetas & Papathanassopoulos, 2013), (Mitropoulos et al., 2013).

In regard to return to scale, there were studies used VRS these studies were (Ali et al., 2017), (Kakeman et al., 2016), (Kalhor et al., 2016), (Mujasi et al., 2016), (H. Li & Dong, 2015), (Applanaidu et al., 2014), (J. P. Harrison & Meyer, 2014), (Jehu-Appiah et al., 2014), (Jat & Sebastian, 2013), (Yusefzadeh, Ghaderi, Bagherzade, & Barouni, 2013). For CRS model, the studies were shared in this model type were (N. Li, Wang, Ni, & Wang, 2017), (Wang et al., 2017), (Cheng et al., 2016). For both CRS and VRS, the studies were used this model were (Surat, Dalbir, & Kamlesh, 2017), (Mahate & Hamidi, 2016), (Kirigia & Asbu, 2013), (Cheng et al., 2015), (El-Seoud, 2013), (Kirigia & Asbu, 2013), (Kounetas & Papathanassopoulos, 2013), (Mitropoulos et al., 2013). In term of model orientation, there were some studies applied out-oriented. These studies were (Ali et al., 2017), (Cheng et al., 2016), (Mahate & Hamidi, 2016), (Mujasi et al., 2016), (H. Li & Dong, 2015), (Jehu-Appiah et al., 2014), (Kirigia & Asbu, 2013).

For input-oriented, the studies applied this orientation were (N. Li, Wang, Ni, & Wang, 2017), (Surat, Dalbir, & Kamlesh, 2017), (Wang et al., 2017), (Kakeman et al., 2016), (Kalhor et al., 2016), (Cheng et al., 2015), (Applanaidu et al., 2014), (J. P. Harrison & Meyer, 2014), (Kounetas & Papathanassopoulos, 2013), (Jat & Sebastian, 2013), (Yusefzadeh, Ghaderi,

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Bagherzade, & Barouni, 2013), (Mitropoulos et al., 2013). In regard to apply both of input-orient and output-oriented, there were only one study apply this model which was (El-Seoud, 2013).

In term of inputs and outputs combination, the analysis showed that the studies use different total combination number of inputs and outputs. In Some studies the total of combination number of inputs and outputs was 4, these studies were (Surat, Dalbir, & Kamlesh, 2017), (Mujasi et al., 2016), (H. Li & Dong, 2015). The studies with combined number of 5 inputs and outputs were (Cheng et al., 2015), (Yusefzadeh, Ghaderi, Bagherzade, & Barouni, 2013). The studies with combined number of 6 inputs and outputs were (Ali et al., 2017), (Wang et al., 2017), (Cheng et al., 2016), (J. P. Harrison & Meyer, 2014).

The studies with combined number of 7 inputs and outputs were (N. Li, Wang, Ni, & Wang, 2017), (Applanaidu et al., 2014), (Kounetas & Papathanassopoulos, 2013). Some studies with combined number of 8 inputs and outputs were (Kakeman et al., 2016), (Mahate & Hamidi, 2016), (Jehu-Appiah et al., 2014), (El-Seoud, 2013), (Kirigia & Asbu, 2013), (Mitropoulos et al., 2013). One studies used combined number of 9 inputs and outputs was (Kalhor et al., 2016). Another study used combined number of 11 inputs and outputs.

5.0 Summary:

Several important observation from these review:

(i) DEA is common measurement method used in assessing hospital efficiency.
(ii) There were variation in the number of DMUs used in DEA analysis; range from 9 to 322 DMUs.
(iii) There were variation in DEA model specification; CCR, BCC, or both and CRS,VRS, or both, Input-oriented, output-orientation or both.
(iv) There were no fixed propotion between number of inputs variables and number of outputs variable.
(v) There were variation in the total combination of inputs and outputs; range from 4 (2 inputs and 2 outputs) to 11 (3 inputs and 8 ouputs).
(vi) There were diversity in study location in term of developed country and developing country.

6.0 Conclusion

The assessment of articles showed that there was variation in the number of DMUs and the DEA model specification. This variation can be according to the study objectives. Among the commonly used DEA model specification in the measuring technical efficiency of hospital using DEA include model type in term of CCR and BCC, and return to scale in term of CCR and VRS. In regard to the input-oriented and output-oriented were commonly used separately among articles as apart of DEA model specification. However the use of both of the input-oriented and output-oriented are rarely used. Moreover, the inputs and outputs combination are differing and changeable based on the DMUs number. In general, The DEA model specification has an ability to be customized based on researcher preferences and the objective of the study in order to measure hospital technical efficiency.

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Declaration

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Authors contribution

Author 1: Information gathering, preparation and editing of manuscript.

Author 2: final reviewing of manuscript.

Author 3: final reviewing of manuscript

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