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STUDYING THE EFFICIENCY OF HOSPITALS IN THE RIYADH REGION OF SAUDI ARABIA USING DATA ENVELOPMENT ANALYSIS (DEA): A CONCEPTUAL APPROACH

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ABSTRACT

Background: Measuring efficiency is a cornerstone of the health care system in terms of evaluating individual performance of production units such as health care centre and hospital. It creates the logical frame for the allocation of resources within and between the health care entities. Despite the growing importance in assessing efficiency in the health care sector, significant ambiguity occurs about whether the approaches are appropriate be applied on health care facilities. The prime focus of this manuscript is to discuss how technical efficiency of hospitals in Saudi Arabia can be measured using the one stage DEA model.

Conceptual approach: The importance of measuring technical efficiency of hospital originates from its flexibility to compare hospitals in terms of actual utilization of inputs and outputs rather than costs or profits. Furthermore, the technical efficiency examines how well the process of production transforms inputs to outputs or its effective execution of production strategy. Thus, the DEA) is the most common method for measuring hospitals' efficiency. It is important for the researcher, student, and health care manger to deeply understand the suitable methodology for DEA when evaluating the efficiency of a health care facility.

Conclusion: The understanding of conceptual approaches towards studying the efficiency of hospitals using the DEA model could encourage and motivate the researchers, students, hospitals managers and policy makers to evaluate the technical efficiency of hospitals among Saudi Arabia and allow the determination if available resources are utilized optimally.

Keywords: Conceptual approach, technical efficiency, DEA, hospitals, Saudi Arabia.

1.0 Introduction

Efficiency can be defined as an entity which succeeds in generating the greatest possible output from a predetermined set of inputs (Farrell, 1957). In the health care industry, efficiency is measured by a known level of care or quantity by utilizing the lowest amalgamation of resources (Ozcan & Tone, 2008). Another example of how efficiency is defined in the health care industry is in the ways a health care service provider (such as a physician or hospital) is able to reduce the inputs required to generate a particular output or maximize the output from a particular set of inputs (Hussey et al., 2009). According to Farrell (1957), there are three distinct forms of efficiency, which involve technical, allocative, and economic efficiency. These types of efficiency are explained in section 2.1.

(Ozcan & Tone, 2008) indicated that measuring efficiency in the health care sector can be applied to different settings such as hospitals, physicians' practices, nursing homes, dialysis centre, community mental health centre, dental providers, radiology providers, rehabilitation providers and so forth. Moreover, measuring efficiency can be on each departmental or unit's basis in hospitals. A study conducted by (Al-shayea, 2011) aimed to evaluate the efficiency of 10 departments in King Khalid University Hospital in Saudi Arabia. Alternatively, the hospital itself can be selected for evaluation of its efficiency in general. (Abou El-Seoud ,Said, 2013) evaluated the efficiency of 20 hospitals in Saudi Arabia.

Measuring efficiency is a cornerstone of the health care system in terms of evaluating individual performance of production units such as health care centre and hospitals. It creates the logical frame for the allocation of resources within and between the health care entities (Kontodimopoulos, Nanos, & Niakas, 2006). Because the primary aim of health care entities is to boost performance and maximize health consequences, strategies to evaluate their performance and pinpoint factors in health production function should be defined clearly (Cantor & Poh, 2018).

The most common two approaches in measuring the efficiency of hospitals are the non-parametric approach recognized as data envelopment analysis (DEA) and the parametric approach of stochastic frontier analysis (SFA) (Hollingsworth, 2003). DEA and SFA are related a type of method for estimating efficiency named frontier analysis. The frontier analysis contrasts an organization's (in the case physicians practice, hospitals) usage of real inputs and outputs to efficient mixtures of several inputs and/or outputs (Hussey et al., 2009).

The DEA technique is used to empirically determine the operating entities' relative efficiency. These operating entities are also known as decision making units (DMUs), and they are considered to consume equal inputs and generating the equal outputs (Ramírez-Valdivia, Maturana, Mendoza-Alonzo, & Bustos, 2015), this is explained further in section 2.4.

The prime focus of this manuscript is to discuss how technical efficiency of hospitals in Saudi Arabia can be measured using the one stage DEA model. According to (Farrell, 1957) technical efficiency can be explained as the enlargement of the outputs for a combination and known level of inputs. Equally, technical efficiency indicates enlargement of the use of inputs for a particular level of output.

1.1 Approaches of Measuring Technical Efficiency

There are two approaches to measuring technical efficiency which are the input-oriented approach and output-oriented approach.

1.1.1 Input-oriented Approach

Based on Farrell's views which suggested that firms use two inputs ($x1$ and $x2$) to produce a single output (q), under the assumption of constant returns to scale (CRS) (Coelli, Rao, O'Donnell, & Battese, 2005) understanding of the unit isoquant of a fully efficient organization which is denoted by SS' in figure 1.1 allows the evaluation of technical efficiency. If a known organization utilizes amounts of inputs, expressed by the dot P, to generate a unit of output, the technical inefficiency of that organization might be signified by the interval between QP that is the quantity by which all inputs might be proportionately diminished in the absence of a diminution in output (Coelli et al., 2005). This is mostly stated in proportion by the ratio QP/0P that denote the proportion that all inputs require to be minimized to reach production in light of technical efficiency. Thus, the technical efficiency of an organization is mostly calculated by the ratio as below (Coelli et al., 2005):

$$TE = 0Q/0P$$

That is equivalent to 1 minus QP/0P. It represents in a score between 0 and 1, which illustrates the technical efficiency score of the organization. The score of 1 means that the organization is full technically efficient. For instance, the dot of Q is technically efficient due to its location on the efficient isoquant (Coelli et al., 2005).

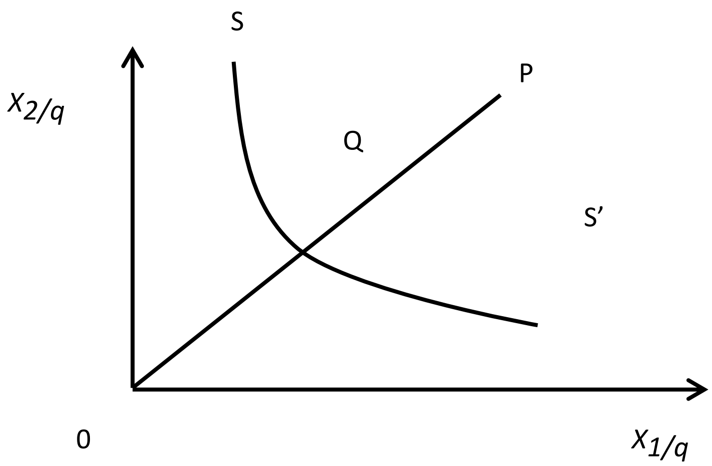

Figure 1.1: Technical Efficiency from Input Orientation (Coelli et al., 2005)

1.1.2 Output-oriented Approach

The output-oriented technical efficiency refers to the output amounts that can be proportionally enlarged without alerting the input amounts employed (Coelli et al., 2005).. This results in output-oriented measures as contrasting to the input-oriented measures. The output-oriented measure can be demonstrated where production includes two outputs ($q1$ *and* $q2$) and a sole input (x) if there is assumption of constant return to scale. This can be seen in figure 1.2 which shows the curve ZZ' as a curve of the unit production probability. The dot A relates to an inefficient organization. The inefficient organization at dot A is located beneath the curve, since ZZ' denotes the higher limit of production probabilities. The interval AB indicates technical inefficiency, which is the quantity when outputs might be enlarged in the absence of demanding additional input. Thus, a measurement of technical efficiency in light of output-oriented can be donated as the expressed below (Coelli et al., 2005):

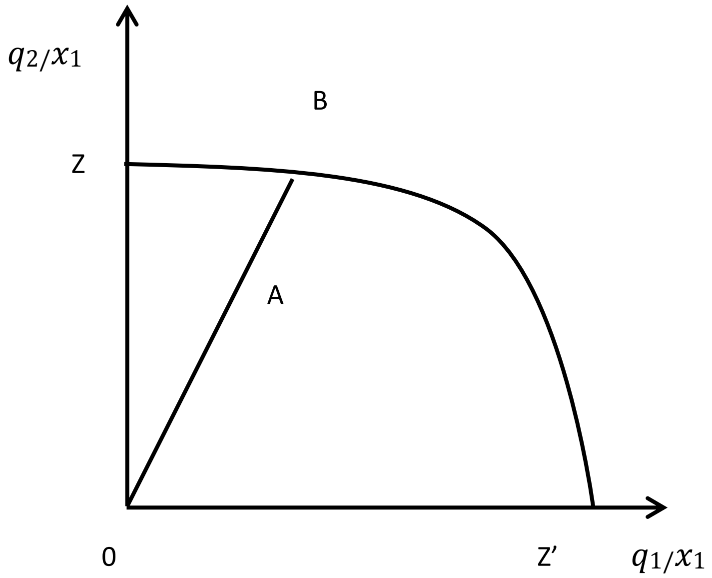

Figure 1.2: Technical Efficiency from Output Orientation (Coelli et al., 2005)

This manuscript discusses the conceptual approaches towards studying the efficiency of hospitals study using data envelopment analysis (DEA) among hospitals in Saudi Arabia. It consists of four sections. The first section describes the problem and clarifies the research question then specifies the aim of the manuscript. In the second section, theoretical aspects which elucidate the concept of efficiency, hospital production function, hospital technical efficiency, data envelopment analysis and review literature are introduced. The third section defines the methodology which consists of study design, orientation model, homogeneity of hospitals, DEA inputs and outputs, DMUs sample size, study instrument, data analysis, interpretation of technical efficiency scores from DEA model, and expected outcome. A conclusion is provided in the final section.

1.2 Problem Statement

Despite the growing importance in assessing efficiency in the health care sector, significant ambiguity occurs about whether the approaches are appropriate be applied on health care facilities (Milstein & Lee, 2007). According to (O'Kane et al., 2008) there is an uncertainty in terms of efficiency expressions which are used by diverse participants to denote various concepts. Additionally, there is little recognition about the scope of approaches that are available to evaluate efficiency and in what way existing efficiency metrics take into account the areas of interest. In Saudi Arabia, more investigations on the performance of hospitals in terms of efficiency is required to provide complete information whether hospitals resources are distributed and utilized optimally (Helal & Elimam, 2017).

1.3 Research Question of Study

This manuscript aims to answer the question on how to employ data envelopment analysis (DEA) to measure technical efficiency of hospitals in Saudi Arabia.

1.4 Objective of Study

The objective of this manuscript is to elucidate a convenient way to employ data envelopment analysis (DEA) to measure technical efficiency of hospitals in Saudi Arabia.

2.0 Theoretical Aspects

This section discusses the theoretical aspects which give the reader a good understanding about concept of efficiency, hospital production function, hospital technical efficiency, data envelopment analysis and literature review.

2.1 Concepts of Efficiency

The efficiency measurement showed in Koopmans's (1951) who was captivated in the analysis of production and in Debreu (1951) who was established the coefficient of resources utilization. In 1957, Farrell defined efficiency as an entity successful generating the greatest possible output from a predetermined set of inputs (Farrell, 1957).

According to Farrell (1957), there are three distinct forms of efficiency, which involve technical, allocative, and economic efficiency. Technical efficiency is where an entity is able to produce greatest output from a predetermined set of inputs. The allocative efficiency refers to the ability of technical efficient firms to use inputs in ratio that reduce production costs for set input prices. Meanwhile, the combination of allocative efficiency and technical efficiency indicates the economic efficiency. Thus, when a firm is technically and allocatively efficient, it is considered as economically efficient. Economic efficiency is calculated as the ratio of the lowest possible costs and the actual identified costs for a firm (Farrell, 1957). Efficiency is expressed as follows (Farrell, 1957):

$$Efficiency = \frac{weighted\ sum\ of\ output}{weighted\ sum\ of\ input}$$

2.2 Hospital Production Function

The principle of the economic theory of production is straightforward: production includes the usage of assorted kinds services and goods to produce output. These services and goods refer to inputs that are converted to output in a production operation (Hollingsworth & Peacock, 2008). According to Hollingsworth and Peacock, the economists differentiated between three kinds of inputs which are known as production factors, labour, capital and land. Where labour refers to inputs from human effort, capital refers to buildings, machines and plants. Land donates inputs from natural resources which make production feasible (Hollingsworth & Peacock, 2008).

It is essential to understand how much output can be created from various mixtures of inputs. The function of production explains the probabilities, which is expressed by mathematically identifying the span of technically feasible mixtures of inputs in the operation of producing output (Hollingsworth & Peacock, 2008).The single-output model considers a sole identical output, y. The technical association among inputs and outputs is symbolized by production function:

$$y = f(x_1, \ldots, x_n) \qquad (2.1)$$

Where $(x_1, \ldots., x_n)$ represent the n factor inputs in the operation of production, and the technology which generators face is represented by $f(\bullet)$. The function of production displays the greatest feasible production level that can be reached, assuming the level of technology, for various amounts and types of inputs. Hence, for all producers, the technology is supposed to be constant, identified and accessible. Equation 2.1 thus explains a simply technical association, outlining the technical restraints on producers and the operation of production (Hollingsworth & Peacock, 2008). The production function can be represented graphically in figure 2.1, where the horizontal axis depicts diverse quantities of all inputs. The technical possibility happens when all points are at the right or on the production function (PF). For instance, output y^0 can be generated utilizing the variant mixtures of inputs represented by *A* and *B*, where *B* utilizes more inputs than *A* (Hollingsworth & Peacock, 2008).

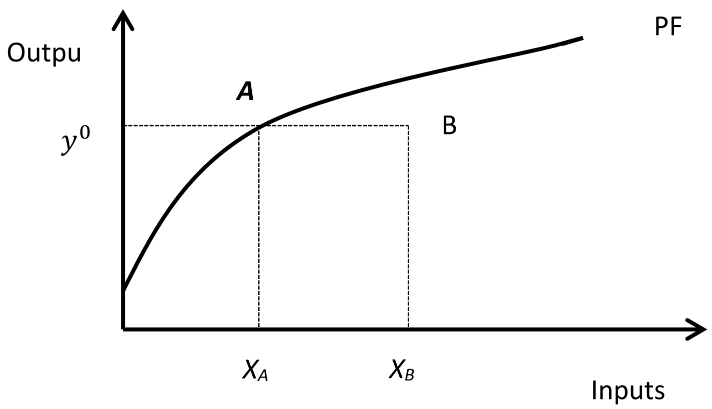

Figure 2.1: The Production Function (Hollingsworth & Peacock, 2008)

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A suitable technique of imagining the function of production is by composing isoquants. The term of isoquant consists of iso that signifies equality and quant for quantity. The isoquant depicts all mixture of inputs that would generate a known amount of output in efficient technical approach. The isoquant for output y^0 expressed by:

$$y^0 = f(x_1, \ldots, x_n)$$

Figure 2.2 illustrates the isoquant 1^0 *and* 1^1 for output amount y^0 *and* y^1 while there are two factor inputs x_1,..., x_2. The x_1 and x_2 represent the labour and capital respectively. The y^0 be produced from any mixture of labour and capital on the bend 1^0. Mixture *A* utilizes extra labour and fewer capital than *B*, indicating *A* is more labour intensive than *B*, while *B* is more capital intensive than *A*. To expand output away than y^0 extra labour and or capital is required. There is no intersection between isoquants due to its convexity to the origin. The convexity refers to the returns to an input decline as a larger quantity of that input is utilized in operation of production (Hollingsworth & Peacock, 2008).

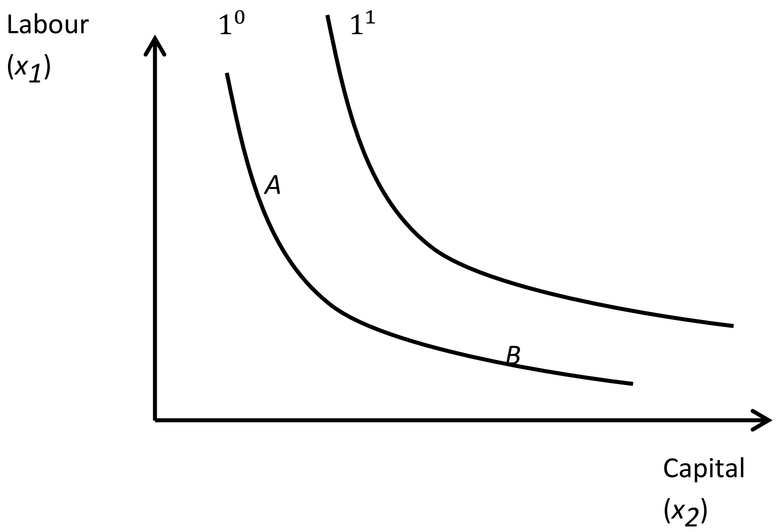

Figure 2.2: The isoquant

2.3 Hospital Technical Efficiency

According to (Farrell, 1957) the hospital is defined as efficient when it is capable to select an optimum level of inputs to create the greatest output from a predetermined level of inputs. This view is echoed by (Hussey et al., 2009).

To estimate hospital efficiency, the outputs of the hospital must be determined. There are many feasible measurements of hospital outcomes for instance, number of cases treated, number of techniques performed, number of inpatient days, bed turnover and bed occupancy rate. The hospital objectives determine the output or combination of outputs which are used to evaluate hospital efficiency (Moshiri, Aljunid, & Amin, 2010).

The importance of measuring technical efficiency of hospital originates from its flexibility to compare hospitals in terms of actual utilization of inputs and outputs rather than costs or profits (Magnussen, 1996). Furthermore, the technical efficiency examines how well the process of production transforms inputs to outputs or its effective execution of production strategy (Avkiran, 1999).

2.4 Data Envelopment Analysis

The data envelopment analysis (DEA) was first developed by (Charnes, Cooper, & Rhodes, 1978), The DEA rephrases Farrell's concept into a mathematical problem. It is referred to as a linear programming technique whereby various best practices involve those that never make other decisions of a linear set of units with more than one of each output (particular input). The DEA technique is used to empirically determine the operating entities' relative efficiency. These operating entities are also known as decision making units (DMUs), and they are equally considered to consume equal inputs and generating equal outputs. Data envelopment analysis (DEA) never assumes any given functional form connecting inputs and outputs; therefore, it eliminates challenges of model misspecification efficiency (Ramírez-Valdivia, Maturana, Mendoza-Alonzo, & Bustos, 2015).

According to (Hollingsworth, 2003) the data envelopment analysis (DEA) is the most common method for measuring hospitals' efficiency. It is a non-parametric approach and DEA is the main method to measure relative efficiency through firms (hospitals) (Sarafidis, 2002). DEA is related to a method for estimating efficiency named frontier analysis. The frontier analysis contrasts an organization's (physicians' practice, hospitals) usage of real inputs and outputs to efficient mixtures of several inputs and/or outputs (Hussey et al., 2009). According (Rabar, 2017) the word 'envelopment' originates from the fact that a frontier envelopes a given set of observations. Thus, its key purpose is to measure relative efficiency (Ramírez-Valdivia et al., 2015). The capability of DEA to cope with a variety of hospital activities which are implemented by the hospital itself makes the DEA model a unique technique for measuring the technical efficiency of hospitals (Helal & Elimam, 2017). Moreover, the DEA can cope with multiple inputs and outputs, making it an attractive choice for measuring the efficiency of hospitals (Abou El-Seoud ,Said, 2013; Du, Wang, Chen, Chou, & Zhu, 2014).

The efficiency score is mostly stated as either a percentage from 0 to 100 or number between zero and one (Avkiran, 1999).

The DEA approach can be explained and employed using the following mathematical notations (Charnes et al., 1978);

$$Maximize\ \theta_O = \frac{\sum_{r=1}^{s} u_r\, y_{ro}}{\sum_{i=1}^{m} \text{vi xio}}$$

$$subject\ to = \frac{\sum_{r=1}^{s} u_r\, y_{rj}}{\sum_{i=1}^{m} \text{vi xij}} \leq 1$$

$$u_r, v_i \ \geq\ 0\ \ for\ all\ r\ and\ i.$$

Where,

θ_O = efficiency score for group of peer DMUs (j=1,,,, n)

u_r = weight of the outputs

y_{rj} = selected outputs (yrj, r =1, …., n)

vi = weight of the inputs

xij = selected inputs (xij, i=1,…,m)

The operational units for decision making (DMUs) are the hospitals.

DEA has several advantages that make it as a reliable tool in measuring hospital technical efficiency. The main benefit of DEA is its ability to create potential improvements to inefficient units and to identify units of measurement. The DEA model allows the researcher to choose inputs and outputs in line with an administrative motivation (Avkiran, 1999). The DEA model is moderately easy to recognize, thus several scholars desire to use it to evaluate efficiency (Blatnik, Bojnec, & Tušak, 2017).In DEA, the inputs prices are not required to estimate technical efficiency. Additionally, the DEA is non-parametric, therefore no accurate functional form is relevant on the data (Grosskopf & Valdmanis, 1993). The DEA has its capability to cope with complicated production environments with multiple inputs and outputs (Jacobs, 2001; Ruggiero, 2007).

Despite the advantages of using DEA in hospital studies, a limited number of disadvantages are reported in literature. DEA provides relative efficiency scores and performance in DEA analysis is assessed on the basis of a physical transformation process without considering the objectives of the service providers (Nunamaker, 1983). It also minimizes resource consumption and measures efficiency against the benchmark of current practices (Jacobs, 2001). Furthermore, DEA does not allow for measurement error and deviation from efficiency. It is a model specific and the efficiency measurement can differ depending on the input-oriented versus output-oriented models (Du et al., 2014).

In the DEA model, the researcher must take into considerations the specifications of DEA model. There are four specifications which are model type, return to scale, model orientation, and input-output combination (Cantor & Poh, 2018). The model type specification is classified into CCR (Charnes-Cooper-Rhodes) and BBC (Banker-Charnes-Cooper). These two models give the ability of DMUs to measure its relative efficiency considering how much the ratio that can be increased or decreased in all of its inputs (outputs) against known its outputs (inputs) in accordance with technological restrains. Return to scale takes two forms which are constant return to scale (CRS) or variable return to scale (VRS). Its assumption is related to the property of production function and it is suitable to suppose that a particular organization operation adheres to a CSR or VRS. The model orientation can be input-oriented or output-oriented. The input-oriented refers to where outputs are assumed constant and inputs are reduced. The output-oriented assumes that inputs are constant and outputs are increased. The input and output combination refer to the several inputs and several outputs in organizational actions that utilize in the production process (Cantor & Poh, 2018).

2.5 Review Literature

In this section, a review of selected studies that employed DEA in measuring technical efficiency of hospitals is presented. (Ali, Debela, & Bamud, 2017) used DEA to measure technical efficiency for 12 hospitals in Eastern Ethiopia for six years from 2007 to 2013. The study employed BCC as the model type, a variable return to scale (VRS) and an output-oriented model orientation. The inputs involved number of beds, number of health staff and cost of drug supplies. Outputs consisted number of outpatient visits, number of inpatient days and number of surgeries. Another study is that conducted by (Li, Wang, Ni, & Wang, 2017) to assess technical efficiency for 12 country-level hospitals in Anhui, China for the years 2010 to 2015. The study used CCR as the model type, a constant as return to scale (CRS) and an input-oriented model specification. The inputs included the number of actual doctors, number of actual nurses, number of actual beds and total expenditure. The outputs consisted of number of emergency visits, number of discharged and number of hospitalized patients.

(Surat, Dalbir, & Kamlesh, 2017) recruited 20 public hospitals to evaluate technical efficiency in Haryana, India from 2013 to 2015. The study applied both CCR and BCC as the model type, both CRS and VRS and the model orientation was input-oriented. The inputs were the number of support staff and number of doctors. The number of inpatients and number of outpatients were the outputs. (Wang et al., 2017) conducted a study for 127 county public hospitals to examine technical efficiency in China from 2012 to 2015. The study employed CCR as the model type, CRS and input-oriented as orientation model. The number of nurses, number of technicians, number of physicians, and number of open beds were the inputs. The outputs included number of outpatient and emergency visits, and number of inpatient days. (Kakeman, Forushani, & Dargahi, 2016) employed 52 hospitals to evaluate technical efficiency in Iran for the year 2014. The study used BCC as model type, VRS and the orientation model was input-oriented. The inputs were number of physicians, number active beds, number of nurses and number of other medical staff. The outputs were the number of outpatient visits, number of surgery procedures, average of patient length of stay (ALOS), and number of hospitalization days.

Also, (Mahate & Hamidi, 2016) assessed the technical efficiency of 96 private and public hospitals in United Arab Emirates in 2012. The study applied both of CCR and BCC as model type, both CRS and VRS while the orientation model was output-oriented. The inputs were number of doctors, number of beds, number of dentists, number of nurses, number of pharmacists and allied health staff and number of administrative staff. The number of treated inpatients, number of outpatients and average length of stay represents the outputs. (Mujasi, Asbu, & Puig-Junoy, 2016) examined the technical efficiency of 17 hospitals in Uganda for the financial year from 1st July 2012 to 30th June 2013. The study employed both of CCR and BCC as model type, both CRS and VRS and an output-oriented model. The inputs included the number of medical staffs and number of hospital beds. Outputs were the number of outpatient visits and number of in-patient days.

(Applanaidu, Samsudin, Ali, Dash, & Chik, 2014), evaluated the technical efficiency for 9 public hospitals in Kedah, Malaysia for the period from 2008 to 2010. The study used BCC as model type, VRS and the model orientation was input-oriented. The inputs were the number of doctors, number of nurses and number of beds. The number of outpatients, number of inpatients, number of surgeries and the number of deliveries represent the outputs. Another study was conducted by (Harrison & Meyer, 2014) to estimate technical efficiency of 165 hospitals and 167 hospitals in 2007 and 2011 respectively in the USA. The study applied BCC as model type, VRS and an input-oriented as model. The inputs were the operating expenses, number of hospital beds and number of in full time employee (FTE) staff. The number of inpatient days, number of surgical procedures and number of outpatient visits represented the outputs. , (Jehu-Appiah et al., 2014) assessed the technical efficiency of 128 hospitals in Ghana for the year 2005. The study employed BCC as model type, VRS and an input-oriented model. The inputs included the number of doctors, number of nurses, and number of beds. The outputs were the number of outpatients, number of inpatients. number of surgeries and number of deliveries.

Besides the above, (Abou El-Seoud ,Said, 2013) evaluated the technical efficiency of 20 hospitals in Saudi Arabia for the year 2011. The study used both of CCR and BCC as the model type, both CRS and VRS and both input-oriented and output-oriented as models. The inputs were the number of specialists (doctors), number of nurses, number of allied health staff and number of beds. The number of outpatient visits, number of patients’ admissions, number of laboratory tests and number of beneficiaries of radiological imaging represented the outputs. (Kounetas & Papathanassopoulos, 2013) examined the technical efficiency of 114 hospitals in Greece for the year 2008. The study applied both CCR and BCC model types, both of CSR and VRS while the model orientation was input-oriented. The inputs were the number of beds, number of doctors and number of nurses. The outputs were the number of patients’ days of treatment, number of days of treatment in the outpatient departments, total number of surgeries and number of total medical examinations.

The studies listed show that different researchers around the world used the DEA approach in measuring the technical efficiency of hospitals which indicates that DEA is a desirable tool in measuring efficiency.

3.0 Methodology

DEA is a linear mathematical programme for evaluating the relative efficiency of decision making units (DMUs) that have several inputs and outputs (Charnes et al., 1978). It is important for the researcher, student, and health care manger to deeply understand the suitable methodology for DEA when evaluating the efficiency of a health care facility (Cook, Tone, & Zhu, 2014). In this section, the crucial steps necessary for measuring the technical efficiency of hospitals are presented.

3.1 Study Design

This type of study is an evaluation study. It is usually use retrospective panel data collected from hospitals which are under investigation. A panel data analysis study was selected as it is one of the most popular approaches in assisting researchers and health care managers to measure and evaluate the efficiency of hospitals for a given period of time (Ozcan & Tone, 2008).

It is necessary that the researcher determines which orientation model will be used for the DEA model either input-oriented approach or output-oriented approach or both (Coelli et al., 2005). As stated in section 1.1, the input-oriented approach refers to the ratio that all inputs need to be reduced to achieve technically efficient production (Coelli et al., 2005). According to this method, mangers of healthcare facilities have more control over the inputs than over the number of patients coming either for outpatient follow up or advise (Ozcan & Tone, 2008). On the other hand, the output-oriented approach refers to the output amounts that can be proportionately increased without changing the input amounts employed (Coelli et al., 2005).

There are two types of study design in the DEA model. The first type is the one stage DEA design which mainly focuses on evaluating the technical efficiency scores of hospitals. The second type consists of the first type of DEA study design combined with the use of specific statistical tests such as Tobit regression to identify efficiency determinants.

This manuscript specifically discuses in detail the one stage DEA study design. This is similar to a study conducted by (Zere et al., 2006) that aimed to evaluate technical efficiency of 30 district hospitals which used one stage DEA.

3.2 Orientation Model

It is important that the researcher specifies the objectives of the DEA analysis. The researcher must clarify the purpose of the analysis, whether input-oriented or output-oriented (Cook et al., 2014).

A study was conducted by (Li et al., 2017) which aimed to measure technical efficiency for 12 county-level hospitals applying input-oriented DEA in Anhui, China. Another study conducted by (Ali et al., 2017) aimed to measure technical efficiency for 12 hospitals using output-oriented DEA in Eastern Ethiopia.

3.3 Homogeneity of Hospitals (DMUs)

The type of DMUs must be selected from the same population. In DEA, the selection of a homogeneous group of DMUs is required. This reduces the effect of covariates and generates more comparable results (Avkiran, 1999). Moreover, it is supposed in the DEA model the set of DMUs in evaluation comprise a homogeneous set. Thus, all DMUs have similar inputs and generate similar output (Li, Liang, Cook, & Zhu, 2016). According to (Cook et al., 2014) the selection of inputs and outputs depend on a well-defined DMUs that will be evaluated. This was applied in a study managed by (Wang et al., 2017) which aimed to evaluate technical efficiency for 127 county public hospitals in China.

3.4 DEA Inputs and Outputs (The DEA Variables)

The input in DEA refers to any factor that an organization uses as a resource to produce an output. On the other hand, outputs are said to be factors which are used to describe the quantity of goods and services or other results that are obtained from the production process (Harrison, Ogniewski, & Hoelscher, 2009). Thus, the inputs and outputs in the DEA model are considered as independent variables.

There are a wide spectrum of DEA inputs and outputs which might be used in the DEA model. A study by (Azreena, Hanafiah Juni, & Rosliza, 2018) aimed to specify the common use of inputs and outputs in evaluating technical efficiency of hospital using DEA. The study showed the common inputs include the number of beds, number of doctors, number of nurses, number of medical staff, number of other non-medical staff, number of total employed staff, total expenditure, total non-labour cost, value of fixed capital and cost of drug supply. With regards to inputs, they mostly involved total patients, average daily admission, number of outpatients, number of surgeries, number of deliveries, average length of stay, bed occupancy rate and total revenue. The selection of inputs and outputs is based on the hospital's objectives (Azreena et al., 2018).

3.5 DMUs Sample Size (Number of DMUs)

The level of freedom within the envelopment model is expected to increase as the number of data management units increase and decline as the amount of inputs and outputs decrease. If the amount of inputs and outputs combined ($m + s$) are more than the number of data management units (n), a large portion of the data management units are said to have been efficient. However, a bias in DMUs efficiency can be debated because of an inadequate amount of degrees of freedom. It is therefore necessary to ensure that the amount of data management units (n) always exceed the number of inputs and outputs combined ($m + s$). As a matter of fact, a rough rule of thumb model may provide guidance as follows:

$$n \geq max\{m \times s, 3(m + s)\}$$

Where n represents the number of DMUs, *m* the amount of inputs while *s* represents the amount of outputs.

(Cooper, Seiford, & Tone, 2007, p.116, 284) argue that input and output element selection is important for effective use of DEA. A requirement of DEA is that the sum of the input and output amount should be triple the number of medical facilities being investigated (Gannon, 2005).

According to a study conducted by (Azreena et al., 2018), the number of DMUs is varies from 12 DMUs as the lower limit to 3391 DMUs as the upper limit. There is no static number of DMUs, as the above-mentioned the combination of number inputs and outputs ought to be equivalent or bigger than the threefold number of on DMUs.

3.6 Study instrument

As the DEA approach depends on secondary data, a proforma can be used for collecting the data of variables of interests from hospitals under investigation. It comprises of a checklist of information that ought to be obtained from selected hospitals. The benefit from using the checklist is to help the researchers to collect data which can be relevant, identical and comparable from hospitals under investigation. A study conducted by (Kakeman et al., 2016) used a checklist with 3 sections of background data inputs and outputs to collect data from 52 in Iran hospitals to evaluate their technical efficiency.

3.7 Data Analysis

3.7.1 Statistical Analysis

The Statistical Package for Social Science (IBM SPSS) can be used to analyse data for descriptive statistics. Mean, standard deviation, and median are used in defining all the continuous variables.

3.7.2 Data Envelopment Analysis

For calculating technical efficiency score the DEAP software can be used. This is a computer program that runs in the DOS system. The program is designed to carry out data envelopment analysis (Coelli, n.d.).

The DEA analyst must take into account the specifications that are included when running the DEA model to avoid avoiding any misinterpreting of the results. These specifications are regarding the model type whether CCR or BCC or both, return to scale whether CSR or VRS or both, model orientation whether input-oriented or output-oriented or both as well as the type or number of inputs and outputs combination (Cantor & Poh, 2018).

A study conducted by (Surat et al., 2017) employed DEAP software to calculate the technical efficiency score for 20 public hospitals in Haryana, India from 2013 to 2015. The study applied both CCR and BCC as model type, both of CRS and VRS, and an input-oriented model. The inputs were number of doctors and number of support staff. The number of outpatients and number of inpatients were the outputs.

3.8 Interpretation of Technical Efficiency Scores from DEA Model (Dependent Variables)

According to (Zere et al., 2006) the technically efficient hospitals are quantified by a score of 1 or 100%, while technically inefficient hospitals that have efficiency scores of less than 1%. The efficiency score in the DEA model considers dependent variables. A study conducted by (Applanaidu et al., 2014) aimed to evaluate the technical efficiency of 9 public hospitals in Kedah, Malaysia. The data was pooled for three years from 2008 to 2010 which equates to 27 numbers of DMUs. The input variables included number of beds, number of nurses and number of doctors. The outputs variables were number of inpatients, number of outpatients, number of deliveries and number of surgeries. Due to the difficulty of hospitals to control their output level, the study employed the input-oriented method. The reason behind using an optimized model in this study in terms of input-oriented DEA model was in order to diminish inputs while retaining the existing output levels for hospitals under investigations. The input-oriented model for the hospital j_0, in accordance with the BBC model was:

$$\text{Minimize } \Theta$$

$$\text{s:t:}$$

$$\sum_{j=1}^{27} \lambda_j x_{ij} \leq \Theta x_{ijo} \; \forall i$$

$$\sum_{j=1}^{27} \lambda_j y_{rj} \geq y_{rjo} \; \forall r$$

$$\sum \lambda_j = 1$$

$$\lambda_j \geq 0, \qquad j = 1, \ldots, 27$$

Where;

Θ = is the amount of all inputs which might be minimized in each specific hospital while retaining output.

x_{ij} = input i for hospital j

y_{rj} = the level of output r for hospital j

λj (j = 1, ..., 27) = the decision variables which denote the weights employed in creating a weighted average frontier combination. The resolution to the input reduction model places the point on the frontier which enables the inputs of the hospital under investigation, represented by j_0 to be retracted as much as feasible. Therefore, the frontier combination should be equal or better than hospital j_0, by the model trying to find the frontier point which enables greatest input diminution.

The findings from this study showed that 74% of 27 DMUs (9 hospitals multiplied by 3 years) are technically efficient which located on the best-practice frontier. While the technical efficiency scores of inefficient hospitals varying between 0.780 and 0.991 with average of 0.935 (Applanaidu et al., 2014).

3.9 Expected Outcome

The expected outcome from this manuscript is a manifest of conceptual approaches that could enable policy makers, hospitals managers and novice researchers over the world particularly in Saudi Arabia to determine the technical efficiency scores of the hospitals and to define the production level of hospitals in terms of technical efficiency.

4.0 Conclusion

The understanding of conceptual approaches towards studying the efficiency of hospitals using the DEA model could encourage and motivate the researchers, students, hospitals managers and policy makers to evaluate the technical efficiency of hospitals among Saudi Arabia and allow the determination if available resources are utilized optimally.

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Since this manuscript discussed a conceptual approach entirely and there were no human subjects included, it did not require ethical approval. The authors would like to thank the staff of the department for their support during preparation of this manuscript.

Declaration

Authors declare that there is no conflict of interest on the publication on the manuscript.

Authors contribution

Author 1: Information gathering, preparation and editing of manuscript.
Author 2: Final reviewing of manuscript.
Author 3: Final reviewing of manuscript.
Author 4: Final reviewing of manuscript,
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References

Abou El-Seoud ,Said, M. (2013). Measuring Efficiency of Reformed Public Hospitals in Saudi Arabia: An Application of Data Envelopment Analysis. *International Journal of Economics and Management Sciences*, *2*(9), 44–53.

Ali, M., Debela, M., & Bamud, T. (2017). Technical efficiency of selected hospitals in Eastern Ethiopia. *Health Economics Review*, *7*(24), 1–13. https://doi.org/10.1186/s13561-017-0161-7

Applanaidu, S.-D., Samsudin, S., Ali, J., Dash, U., & Chik, A. R. (2014). Technical and Scale Efficiency of Public District Hospitals in Kedah, Malaysia- A Data Envelopment Analysis (DEA). *Journal of Health Management*, *16*(3), 327–335. https://doi.org/DOI: 10.1177/0972063414539595

Avkiran, N. K. (1999). An application reference for data envelopment analysis in branch banking: helping the novice researcher. *International Journal of Bank Marketing*, *17*(5), 206–220. https://doi.org/10.1108/02652329910292675

Azreena, E., Hanafiah Juni, M., & Rosliza, A. M. (2018). A Systematic Review Of Hospital Inputs And Outputs In Measuring Technical Efficiency Using Data Envelopment Analysis. *International Journal of Public Health and Clinical Sciences*, *5*(1), 17–35.

Blatnik, P., Bojnec, Š., & Tušak, M. (2017). Measuring efficiency of secondary healthcare providers in Slovenia. *Open Medicine (Wars)*, *21*, 214–225. https://doi.org/10.1515/med-2017-0031

Cantor, V. J. M., & Poh, K. L. (2018). Integrated Analysis of Healthcare Efficiency: A Systematic Review. *Journal of Medical Systems*, *42*(8), 1–23. https://doi.org/10.1007/s10916-017-0848-7

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, *2*(6), 429–444. https://doi.org/10.1016/0377-2217(78)90138-8

Coelli, T. (n.d.). *A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program* (96 No. 8). Australia. Retrieved from http://www.une.edu.au/econometrics/cepawp.htm

Coelli, T., Rao, P., O'Donnell, C., & Battese, G. (2005). *An Introduction To Efficiency And Productivity Analysis* (Second). New York: Springer.

Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. *Omega (United Kingdom)*, *44*, 1–4. https://doi.org/10.1016/j.omega.2013.09.004

Cooper, W. W., Seiford, L. M., & Tone, K. (2007). *DATA ENVELOPMENT ANALYSIS A Comprehensive Text with Models, Applications, References and DEA-Solver Software Second Edition*. (490, Ed.) (2nd ed.). New York: Springer.

Du, J., Wang, J., Chen, Y., Chou, S. Y., & Zhu, J. (2014). Incorporating health outcomes in Pennsylvania hospital efficiency: an additive super-efficiency DEA approach. *Annals of Operations Research*, *221*(1), 161–172. https://doi.org/10.1007/s10479-011-0838-y

Farrell, M. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*, *120*(3), 253–290. https://doi.org/doi:10.2307/2343100

Gannon, B. (2005). Testing for variation in technical efficiency of hospitals in Ireland. *The Economic and Social Review*, *36*(3), 273–294.

Grosskopf, S., & Valdmanis, V. (1993). Evaluating Hospital Performance with Case-Mix-Adjusted Outputs. *Medical Care*, *31*(6), 525–532. Retrieved from http://www.jstor.org/stable/3766133

Harrison, J. P., & Meyer, S. (2014). Measuring Efficiency Among US Federal Hospitals. *Health Care Manager*, *33*(2), 117–127. https://doi.org/10.1097/HCM.0000000000000005

Harrison, J. P., Ogniewski, R., & Hoelscher, S. (2009). The Improving Efficiency of Critical Access Hospitals. *The Health Care Manager*, *28*(3), 209–217.

Helal, S. M. A., & Elimam, H. A. (2017). Measuring the Efficiency of Health Services Areas in Kingdom of Saudi Arabia Using Data Envelopment Analysis (DEA): A Comparative Study between the Years 2014 and 2006. *International Journal of Economics and Finance*, *9*(4), 172. https://doi.org/10.5539/ijef.v9n4p172

Hollingsworth, B. (2003). Non-Parametric and Parametric Applications Measuring Efficiency in Health Care. *Health Care Management Science*, *6*(4), 203–218. https://doi.org/10.1023/A:1026255523228

Hollingsworth, B., & Peacock, S. J. (2008). *Efficiency Measurement in Health and Health Care*. (Charles Normand & Richard M. Scheffler, Eds.) (1st ed.). New York: Routledge

International Studies in Health Economics.
Hussey, P. S., De Vries, H., Romley, J., Wang, M. C., Chen, S. S., Shekelle, P. G., & McGlynn, E. A. (2009). A systematic review of health care efficiency measures: Health care efficiency. *Health Services Research*, *44*(3), 784–805. https://doi.org/10.1111/j.1475-6773.2008.00942.x
Jacobs, R. (2001). Alternative Methods to Examine Hospital Efficiency: Data Envelopment Analysis and Stochastic Frontier Analysis. *Health Care Management Science*, *4*(2), 103–115. https://doi.org/https://doi.org/10.1023/A:10114535
Jehu-Appiah, C., Sekidde, S., Adjuik, M., Akazili, J., Almeida, S. D., Nyonator, F., … Kirigia, J. M. (2014). Ownership and technical efficiency of hospitals: Evidence from Ghana using data envelopment analysis. *Cost Effectiveness and Resource Allocation*, *12*(1), 1–13. https://doi.org/https://doi.org/10.1186/1478-7547-12-9
Kakeman, E., Forushani, A. R., & Dargahi, H. (2016). Technical Efficiency of Hospitals in Tehran, Iran. *Iran J Public Health*, *45*(4), 494–502. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/27252919
Kontodimopoulos, N., Nanos, P., & Niakas, D. (2006). Balancing efficiency of health services and equity of access in remote areas in Greece. *Health Policy*, *76*(1), 49–57. https://doi.org/10.1016/j.healthpol.2005.04.006
Kounetas, K., & Papathanassopoulos, F. (2013). How efficient are Greek hospitals? A case study using a double bootstrap DEA approach. *European Journal of Health Economics*, *14*(6), 979–994. https://doi.org/10.1007/s10198-012-0446-z
Li, W., Liang, L., Cook, W. D., & Zhu, J. (2016). DEA models for non-homogeneous DMUs with different input configurations. *European Journal of Operational Research*, *254*(3), 946–956. https://doi.org/10.1016/j.ejor.2016.04.063
Li, Wang, C., Ni, H., & Wang, H. (2017). Efficiency and Productivity of County-level Public Hospitals Based on the Data Envelopment Analysis Model and Malmquist Index in Anhui, China. *Chinese Medical Journal*, *130*(23), 2836–2843. https://doi.org/10.4103/0366-6999.219148
Magnussen, J. (1996). Efficiency Measurement and the Operationalization of Hospital Production. *Health Services Research*, *31*(1), 21–37.
Mahate, A., & Hamidi, S. (2016). Frontier efficiency of hospitals in United Arab Emirates- An application of data envelopment analysis. *Journal of Hospital Administration*, *5*(1), 7–17. https://doi.org/10.5430/jha.v5n1p7
Milstein, A., & Lee, T. H. (2007). Comparing Physicians on Efficiency. *The New England Journal of Medicine* , *357*(26), 2649–2652. https://doi.org/10.1056/NEJMp0706521
Moshiri, H., Aljunid, S. M., & Amin, R. M. (2010). Hospital efficiency: concept, measurement techniques and review of hospital efficiency studies. *Malaysian Journal of Public Health Medicine*, *10*(2), 35–43.
Mujasi, P. N., Asbu, E. Z., & Puig-Junoy, J. (2016). How efficient are referral hospitals in Uganda? A data envelopment analysis and tobit regression approach. *BMC Health Services Research*, *16*(230), 1–14. https://doi.org/10.1186/s12913-016-1472-9
Nunamaker, T. R. (1983). Measuring Routine Nursing Service Efficiency: A Comparison of Cost per Patient Day and Data Envelopment Analysis Models. *Health Services Research*, *18*(2), 183–208. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/6874357
O'Kane, M., Corrigan, J., Foote, S. M., Tunis, S. R., Isham, G. J., Nichols, L. M., … Tooker, J. (2008). Crossroads in quality. *Health Affairs*, *27*(3), 749–758. https://doi.org/10.1377/hlthaff.27.3.749
Ozcan, Y. A., & Tone, K. (2008). *Health Care Benchmarking and Performance Evaluation:*

An Assessment using Data Envelopment Analysis (DEA) (Second Edition). London: Springer. https://doi.org/10.1007/978-0-387-75448-2

Rabar, D. (2017). An overview of data envelopment analysis application in studies on the socio-economic performance of OECD countries. *Economic Research-Ekonomska Istraživanja*, *30*(1), 1170–1784. https://doi.org/10.1080/1331677X.2017.1383178

Ramírez-Valdivia, M., Maturana, S., Mendoza-Alonzo, J., & Bustos, J. (2015). Measuring the efficiency of chilean primary healthcare centres. *International Journal of Engineering Business Management*, *7*(15), 1–10. https://doi.org/10.5772/60839

Ruggiero, J. (2007). A comparison of DEA and the stochastic frontier model using panel data. *International Transactions in Operational Research*, *14*(3), 259–266. https://doi.org/10.1111/j.1475-3995.2007.00585.x

Sarafidis, V. (2002). *An Assessment of Comparative Efficiency Measurement Techniques Nonlinear Panel and Spatial Data Econometrics View project*. London. Retrieved from https://www.researchgate.net/publication/237314068

Surat, S., Dalbir, S., & Kamlesh, S. (2017). Efficiency and Total Factor Productivity of Public Hospitals in Haryana (India): A Data Envelopment Analysis. *International Journal of Advances in Management and Economics*, *6*(2), 71–84. Retrieved from http://managementjournal.info/index.php/IJAME/article/view/50

Wang, M., Fang, H., Tao, H., Cheng, Z., Lin, X., Cai, M., … Jiang, S. (2017). Bootstrapping Data Envelopment Analysis of Efficiency and Productivity of County Public Hospitals in Eastern, Central, and Western China after the Public Hospital Reform. *Journal of Huazhong University of Science and Technology [Medical Sciences]*, *37*(5), 681–692. https://doi.org/10.1007/s11596-017-1789-6

Zere, E., Mbeeli, T., Shangula, K., Mandlhate, C., Mutirua, K., Tjivambi, B., & Kapenambili, W. (2006). Technical efficiency of district hospitals: Evidence from Namibia using data envelopment analysis. *Cost Effectiveness and Resource Allocation*, *4*(5), 1–9. https://doi.org/10.1186/1478-7547-4-5