Improving Hospital Efficiency by using Nonparametric Method

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Abstract: Healthcare systems around the world were facing the new challenges every time and everywhere. New regulations, new technologies, and new organizations are being created continuously as a result of public policy. Managers of healthcare need to be responded to these challenges with sound performance measure and decision making. The efficiency of hospitals and health care centers is a major concern for governments, which often provide the substantial funding to a medical organizations and hospitals. Leaders and managers need to make a decision-making such as performance and efficiency measurement. The Data Envelopment Analysis (DEA) model, according to constants scale to return (CCR) and variable scale to return (BCC) were applied to measure the technical efficiency of the ten (10) public hospitals operating in the Jordan, by using five (5) of the input variables (hospitals resources) and five (5) of the output variables (services provided in hospitals). The python software was using to run the analysis. The public hospitals in Jordan operate according to its ideal size by 93%, and there is no statistically significant relationship between hospital size and the efficiency degree.

INTRODUCTION

In today's social & economic environment, performance and efficiency measurement are essential for organizations to survive and raise their market share. The world economic crisis has put all governments under pressure [1]. The efficiency of hospitals is a major concern for every government which often provides substantial funding to hospitals (Bao & Bardhan, 2017). In the Hashemite Kingdom of Jordan, health services are provided to citizens by three main sectors (National Health Strategic Plan, 20152019). According to Helal & Elimam (2017), providing quality health services to society is one of the biggest challenges faced by hospital administrators and the health centers, as these services are directly related to the health, life, and the ability of individuals to give and produce. The first challenge is the administrators and policymakers need to measure the performance efficiency of the hospitals (Wang, et. al 2015). The Jordanian health system is under great pressure to provide exceptional health services in the context of limited resources, and the circumstances

surrounding the country are the regional conflicts and the influx of displaced persons and refugees (Chowdhury, et. al 2014). Measuring the efficiency of hospitals is a critical research problem in the healthcare sector (Derek, et. al 2017). The aim of the study is to measure the efficiency of the performance of government hospitals in Jordan using the data envelopment analysis, to contribute to the improvement of hospitals efficiency, in the period 2013 to 2016. In Jordan, health services are the focus of attention in academics and all segments of society, especially in light of the changes that are subject to this sector today in order to improve the efficiency of the services and also to achieve the desired targets. Due to the lack of sufficient studies in this vital sector, therefore this study aims to shed more light on this subject by helping the health service providers in the Kingdom to achieve their objectives by focusing on the efficiency indicators as one of the most important tools to guide decision-makers. A major problem facing the services providers' management is how to identify ways of improving the performance, as it concerns with the limited resources and the need to meet

patients' requirements. The main question is how to improve the efficiency of public hospitals. Public spending on healthcare in Jordan is still enormous (Higher Health Council, 2015).

LITERATURE REVIEWS

Many researchers have studied the efficiency of hospitals, the DEA was applied as an efficiency analysis tool (Qian, et al, 2018). Wang & Gao, (2017) in their study entitled "Efficiency Measurement and Resource Allocation for Hospitals" regarded that measuring the efficiency of hospitals is necessary, they used the data envelopment analysis method to integrate the inputs (beds, physicians, nurses) and outputs (patients entries, surgeries, outpatients visit) to develop the efficiency measures of the hospitals. Farzianpour, et al, (2016) determined the technical efficiency of Hospitals in Tabriz City, their analysis was based on performance indicators that applied the mathematical model of data envelopment analysis. The data envelopment analysis was first introduced by Charnes et. al. (1978), it is a non-parametric programming method to measure the relative efficiency of peer decision-making units (DMUs) with multiple inputs and outputs. Sherman (1984) was first in using the DEA to evaluate the overall hospital efficiency (Chenyuan Wang, et .al 2015). Measuring performance within the healthcare service sector presents a number of challenges. Hospitals cater to a wide segment of patients, from the poor who require subsidized and free treatment to the rich who can afford premium treatment. Hospitals also operate with multiple business objectives and deliver a much more diversified range of service offerings, while operating in uncertain political environments (Manchester, 2015). (Ajlouni et al., 2013) indicate that the basic performance measurement for healthcare must be identified by the economy, efficiency, and effectiveness. Economy measures the relationship between the costs or expenses incurred for procuring certain inputs, and the output obtained from them. It represents the number of quality inputs, and the costs needed to complete a healthcare activity. Efficiency is a measure of the ratio between the output and the resources used. It refers to the activities that can be monitored and controlled. Effectiveness specifies the degree to which the required objectives are met. Factors such as the quality and quantity of the results are also important. Several studies are extended to measure the performance of healthcare organizations. (Gollhofer, 2015) used both financial and nonfinancial measures to determine the performance of public health care organizations the non-financial measures included the satisfaction of internal and external customers, the self-improvement system of the organization and the ability of the organization to adapt and change.

METHODOLOGY

The first step to measure the efficiency of public hospitals by using data envelopment analysis, input and output variables should be defined (Kirigia et. al., 2013). More recently, Kirigia et. al, (2013) used doctors and nurses as inputs, whilst Hajialiafzali et al. (2014) used doctors, nurses, and other personnel. Outputs can be difficult to aggregate because of the wide variation in the types of medical procedures. Wang & Gao, (2017) used outpatients visits, patients entries, surgeries. In this study use data envelopment analysis (DEA), according to constants return to scale (CCR), and according to variable return to scale (BCC) was applied to measure the efficiency of public hospitals in Jordan, using 5 input variables and 5 output variables. The software tool analysis is known as PY-DEA. The data envelopment analysis was conducted by using the CCR & BCC models that compute the efficiency of each DMU in Python to solve the equations of the models by entering the equations, input and output data in addition to the DMUs.

CCR-DEA model (Charnes, Cooper, and Rhodes, 1978) showed that the goal of DMUs is to reduce the number of input to the maximum extent possible while maintaining at least their current output levels Ozcan, (2014).

$$Max_{u,v} \ h_o = \frac{\sum_{r=1}^{t} u_r \ yrj_o}{\sum_{i=1}^{m} v_i \ xij_o}$$

$$Subject \ to \ \frac{\sum_{r=1}^{t} u_r \ yrj}{\sum_{i=1}^{m} v_i \ xij} \leq 1 ; \qquad j$$
$$= 1,2,\dots n ; \ u_r, \ v_i \geq \varepsilon \quad \forall \ r \ , \ i$$

BCC-DEA model (Banker, Charnes, and Cooper, 1984) assumed that the efficiency associated with a certain volume of operations and specifies the possibility of a variable rate of return (constant, increasing or decreasing), Ozcan, (2014).

$$Min_{\lambda} \ Zo$$

$$subject \ to: \ xij_o \ z_o \geq \sum_{j=1}^{n} \lambda \ i \ xij_o \ ; i$$
$$= 1,2,\dots,m$$

$$\sum_{j=1}^{n} \lambda \ j \ y_{rj_o} > y_{rj_o} ; \qquad r = 1,2,\dots,t$$

$$\lambda_j \geq 0 \qquad ; j = 1,2,\dots,n$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

Say we have a institutions of n productive units DMU1, DMU2… DMUn. Each unit produces s outputs while consuming m inputs. Let us write an input matrix X = [xij, i = 1, 2, …, m, j= 1, 2, …, n] and an output matrix Y = [yij, i = 1, 2, …, s, j= 1, 2, …, n]. The q-th line – i.e. Xq and Yq, of these

matrixes thus shows quantified inputs/outputs of unit DMUq. The efficiency rate of such a unit can then be generally expressed as five input measures and five output measures were selected to measure the efficiency of each hospital.

Table 1. Inputs of DMUs

Inputs / DMUs	Beds	Doctors	Nurses	Health Professionals	Administrative
DMU1	130	52	201	81	70
DMU2	433	237	560	161	211
DMU3	112	65	192	90	75
DMU4	159	73	293	94	87
DMU5	202	266	341	209	178

Table 2. Outputs of DMUs

Outputs / DMUs	Entries	Outpatient	Imaging	Laporotary test	Surgical
DMU 1	9016	98660	734653	524456	1645
DMU 2	22026	172208	3428197	2227189	7490
DMU 3	11875	39848	622409	1249753	626
DMU 4	10859	122657	968386	902559	2201
DMU 5	22589	359618	1828016	1747956	6229

Data envelopment analysis is a Linear programming is a method to achieve the best outcome in a mathematical model whose requirements are represented by linear relationships. The fundamental principle of linear programming is providing an optimization platform (Nayar et al., 2013). A multiple-input, multiple-output efficiency measurement tool.
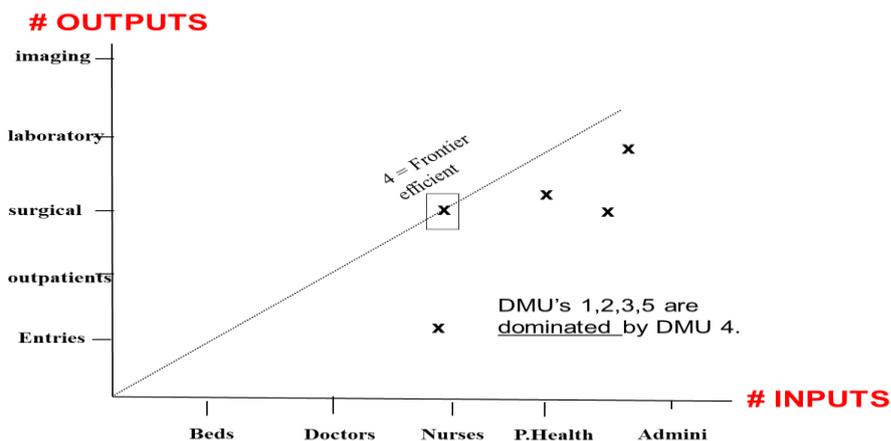
RESULTS

According to the CCR model, the technical efficiency of ten public hospitals in Jordan was measured for the 2013 data. Six hospitals scored a 100% degree in the sense that it has full technical efficiency. The degree of technical efficiency is ranged between 85.5% to 100%. The average efficiency of all units was 94.6%, which means that the public hospitals in Jordan collectively account for 5.4% of unexploited resources which can improve the services provided to patients. The score for Karak Hospital is 85.5%, and this hospital has the lowest degree of technical efficiency.

For 2015, there were differences between the number of input and output (either increase or decrease), hence the results have changed for the ten hospitals.

The efficiency was recorded between 59.4% to 100%. Al-Eman Hospital got an efficiency level of 100%. Husain hospital scored lowest level of efficiency which was 59.4%.

The technical efficiency indicators using a variable return to scale (BCC) for the ten hospitals based on the 2013 data. Five of these hospitals were 100% efficient and this result was considered to be efficient. The efficiency of all units was between 85.5% to 100%.

The average efficiency score for all units was 94.3%, which means that the public hospitals in Jordan collectively account for 5.7% of untapped resources that can be accessed from improving the services provided to patients if the analysis takes into account the size of their operations when performing the analysis.   Based on the 2015 BCC model, the

DISCUSSIONS

According to the CCR model, the average efficiency units for the total units is equal to 33% (12 out of 40), with an average efficiency of 90.6%. This means that public hospitals in Jordan must be able to provide the same level number of outputs using only 90.6% of their current inputs in order to become efficient. In

CONCLUSIONS

This study opens up a new way of measuring hospital efficiency, although the methodologies developed in this study are specific to the measurement of performance public hospitals in Jordan, they could be generalized to measure the levels of hospital efficiency in general by selecting suitable inputs and outputs, using methods that have not been implemented previously in the measurement of hospitals performance in Jordan is one of the main motivations behind the current research. It is hoped that this study will encourage future research on data envelopment analysis (DEA) applications using the (CCR) approach, as well as applications of the (BCC) approach. data envelopment analysis (DEA) does not rank the efficient hospitals, but only identifies them as 100% efficient, which means that additional information would be required to enable comparisons between efficient hospitals. Therefore, the superefficiency approach by (Khani et al., 2012), which is a statistical method for ranking DMUs in the DEA literature, could be adopted for future research. Similarly, other methodologies in the DMUs ranking field, such as the cross-efficiency approach of (Valdmanis, 1992), the neutral DEA model of Wang & Chin (2010), and the new super-efficiency DEA method of (Cheng et al., 2015) could be implemented. The use of more specific inputs and outputs is also worth considering in the process of obtaining results that are more accurate. Among

findings showed that, two of the ten hospitals scored 100%, and this result is considered to be efficient. The efficiency of all units was between 73.9 % and 100%. The average efficiency score for all units was 93.6%, which means that the public hospitals in Jordan collectively account for 6.4% of untapped resources that can be accessed from improving the services provided to patients if the analysis takes into account the size of their operations when performing the analysis.

We must assess the extent of interest in the surplus of inputs in 2015, and this enables us to find out what will happen to hospitals that have moved from efficiency to inefficiency, due to the number of staff and services they provide in Karak Hospital taking low efficiency.

other words, it must reduce its current inputs of 9.4% while maintaining the current level of outputs to become efficient.

However, according to the BCC model, the average efficiency of the total units is 31%, (11 out of 40) with an average efficiency of 88.9%, this means that the public hospitals in Jordan should be able to deliver the same level of output using only 88.9% of their current inputs, so that they become efficient when considering the size of operations.

these inputs is the quality of staff (nurses, doctors, and specialists) such as their qualifications and experience. Among these outputs are hospital patient survival rate and the associated mortality rate. (Feroz, Raab, Schultz, & Ulleberg, 2017).

The results indicate that overall hospital efficiency scores are moderate and some hospitals' performance in a stable manner while others fluctuate with varying levels of scores. Through the data envelopment analysis (DEA) technique, hospitals can be identified as efficient or inefficient, compared either with itself from different years or with peers from the same year. Moreover, the slacks of each hospital assist decisionmakers to figure out how to allocate resources more efficiently. This technique is ready to be applied in many other industries and settings, (Basarkar & Saxena, 2016).

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