Measuring Technical Efficiency of Algiers Hospitals

قياس كفاءة المؤسسات الاستشفائية لولاية الجزائر

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Abstract:

The purpose of this paper is to measure and analyze the technical Efficiency of Algeries hospitals during 2017 of public hospitals. Furthermore, this paper used Data Envelopment Analysis technique (DEA) based on model - CCR, with an input-oriented approach. This model includes two inputs and one output. (The number of staff nurses and doctors as inputs), and (Inpatients representing output), for seven hospitals, results indicated that only two hospitals (28.57 %) are efficient, while the remaining five (71.43%) are relatively inefficient. The average PTE score of inefficient hospitals was 64.60 percent over the period in question, which implies that inputs could be reduced reduced by 35.40 per cent without it impacting in any way on the service provided.

Key words: *Data envelopment analysis (DEA), Technical efficiency, inefficient, Hospital.*

ملخص:

سعت هذه الدراسة إلى قياس وتحليل كفاءة بعض المستشفيات العمومية لولاية الجزائر خلال سنة 2017 واقتراح مختلف التحسينات المطلوبة للمستشفيات الغير الكفؤة، ومن أجل هذا الغرض تم استخدام أسلوب تحليل مغلف البيانات DEA لقياس الكفاءة، وبالضبط نموذج عوائد الحجم الثابتة CCRبالتوجه المدخلي، تم استخدام عدد الأطباء والممرضين في المستشفيات العينة كمدخلات النموذج، وعدد المرضى الداخلين كمخرجات للنموذج وتضمنت الدراسة 07مستشفيات لسنة 2017. حيث توصلت النتائج أن مستشفيين فقط (28.57 %) من تتسم بالكفاءة، بينما 05 المتبقية (71.43 %) غير كفؤة نسبيًا وبلغ متوسط درجة PTE للمستشفيات غير الفعالة 64.60 % خلال الفترة المعنية، مما يعني أنه يمكن تخفيض المدخلات بنسبة 35.40 في المائة دون التأثير بأي شكل من الأشكال على الخدمة المقدمة .

الكلمات المفتاحية: تحليل مغلف البيانات، الكفاءة التقنية، غير كفؤ، مستشفى .

1. INTRODUCTION

One of the basic objectives pursued by most countries is to improve their health system in terms of both quality services and efficiency and the extent to which its resources are put to good use. So one fundamental reason to promote research into the efficiency of Algeria hospitals is the need to establish the bases for the best distribution and use of healthcare resources (optimum planning) and to detect the set of problems of various kinds, which affect their efficiency and capacity to offer top-quality services to the population.

The Algeria government spends a considerable percentage on health care from its national income, this spending is rising. In 2010, health care spending represented 4.5 percent of the total government budget and in 2017, it reached a high of 7.25 percent. A large proportion of the expenditure was spent on public hospital services, accounting for 62 percent of total health expenditure in 2107.

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Despite this increase in health services, Algerians seeking treatment in public hospitals find that there are a huge number of patients being refused immediate treatment, which leads to the general perception in Algeria of inefficient health care supply. The technical inefficiency is sometimes associated with the high level of spending on hospital services. This led to a surge in interest in measuring the efficiency of Algeria public hospitals to provide a useful framework for improving their efficiency and ensuring that all resources are utilised to their full extent. Therefore, identifying the best manner in assigning capitals is done by the efficiency analysis. Technical efficiency describes the relationship between output and the quantity of resources used to produce that output.

1.1 Significance of the Study:

This study is motivated by the current lack of empirical evidence in the literature regarding measurement of technical efficiency of the health care system in Algeria. Taking into account the outcome of this study, health care decision-makers can tailor their policies in order to utilize their existi.ng resources more efficiently.

Understanding the cost structure of hospitals and their effectiveness in utilizing resources is crucial for making health care policies and budgeting decisions. Hospitals operating at a higher level of efficiency are likely to help control the use of resources, which ultimately will assist in providing a more robust and effective service to the public.

1.2 Purpose of the Study:

In this study, we have the following objectives:

1. To study the relative efficiency of 07 district hospitals
2. Identification of efficient and inefficient district hospitals based on the efficiency scores
3. To construct the peer group for the inefficient hospitals
4. To carry out the projection analysis
5. Ranking of decision-making units (DMUs)

1.3 general problematic:

Using data envelopment analysis to measure the extent of technical efficiency of capital hospitals

2.THEOERICAL FRAMEWORK AND PREVIOUS:

In this study, Technical efficiency of the hospital is determined by DEA. Efficiency generally means using the minimum number of inputs for a given number of outputs, while performance can be defined as an appropriate combination of efficiency and effectiveness[1].

2.1. Definition of concepts theoretical:

In this context, will be identified the most important concepts theoretical in this study.

A. Definition of efficiency and Effectiveness[2]:

- **Efficiency :**

This term expressed achievement or the capability to achieve a task or output with minimum expenditure of cost and time. In terms of medicine, the opposite of efficiency is waste. The acquisition of efficiency has confused many policy makers and physicians in relation to the requirement to cut back on healthcare services. Other clinicians and policy makers, however, have emphasized readily making more resources accessible for healthcare by reducing the waste in the system.

- **Effectiveness:**

Effectiveness. This term can be defined as the extent to which the outputs of service providers accomplish the defined goals of that service. In terms of medical science, effectiveness can be defined as "the extent to which the healthcare organizations are meeting the demands of a treatment

B. Definition of Performance measurement[3]:

- **Performance.**

The performance of an organization is defined in correspondence with the precise goals reflecting the values of stakeholder's such as regulators, profession, patients, and insurers.

- **Performance measurement.**

This term is defined as the process of gathering, examining, and reporting information about the performance of departments and individuals within an organization. The process of performance measurement involves examining the current strategies followed by an organization. Performance measurement is utilized to determine whether the outputs are in line with defined objectives.

2. 2. Measures of Efficiency .

There are various measures of efficiency that have been widely used to measure levels of efficiency, such as, the ratio analysis, linear regression analysis, stochastic frontier analysis (SFA) and DEA. However, DEA is preferred over other measures for the following reasons—minimal a priori assumption, does not require a specific functional form, accommodates multiple inputs and multiple outputs and does not face problems of multicollinearity and heteroscedasticity.

DEA is a non-parametric mathematical programming technique based on linear programming (LP) to measure the relative performance of a group of organizational units, such as, firms, plants and entities also known as decision-making units (DMUs). The phrase DMU was coined by Charnes, Cooper and Rhodes to include non-market agencies, such as, schools, hospitals and courts [4](Ray, 2004). There are two basic models of DEA—the CCR model[5] and the BCC[6] model. Apart from these, there are many other models that have been developed over time, but the selection of the model depends of the nature of the production technology. These models generally differ in terms of orientation (input or output), disposability (weak or strong), returns to scale (constant, diminishing or increasing) and the type of measures (radial, non-radial or hyperbolic).

The theoretical framework of DEA was first introduced in the operations research literature by Charnes et al. in 1978 in their seminal work. This framework was widely known as CCR model as it was framed by Charnes, Cooper and Rhodes. The CCR model is an extension of the single-output–input TE measure, introduced by Farrell in 1957, into a multiple-output–input relative efficiency measure. Many other extensions of the original models have been made since then. The original CCR model assumed a production technology with constant returns to scales (CRS). This was rather restrictive, as it is often unlikely that CRS would hold in many realistic cases. As a result, the CCR model was extended to a more flexible and refined model by Banker et al. in 1984, popularly known as the BCC model. This model generalized the original model for technologies exhibiting increasing, constant and decreasing returns to scale[7] .In other words, the BCC model relaxed the assumptions of CRS to allow for variable returns to scale (VRS).

2.3. Previous Studies:

Several studies have used a DEA model to study the efficiency of hospitals whether foreign or domestic studies.:

A.Foreign Studies on Data envelopment Analysis (DEA):

Several foreign studies influenced this researcher's desire to investigate hospital benchmarking using DEA.

- The research of Dino Rizzi and Vincenzo Rebba(2006**)** applied DEA method to measure the efficiency of 85 (public and private) hospitals in Veneto, a Northern region of Italy. They found that the imposition of a lower bound on the virtual weight of acute care discharges weighted by case-mix (in order to consider policy-maker objectives) reduced average hospital efficiency. Moreover, they showed that, in many cases, low efficiency scores were attributable to external factors, which were not fully controlled by the hospital management; especially for public hospitals low total efficiency scores could be mainly explained by past policy decisions makers on the size of the hospitals or their role within the regional health care service. Finally, non-profit private hospitals exhibited a higher total inefficiency while both non-profit and for-profit hospitals are characterized by higher levels of scale inefficiency than public ones.
- The research of Al-Shayea (2011) applied DEA for measuring the relative efficiencies of units delivering similar services. This technique is applied to study the performance and efficiency of King Khalid University hospital departments. The results showed that only two departments out of nine have 100% efficiencies throughout the 12 months period
- The research of Sahin and Bulent (2011), investigated the efficiencies of hospitals in Turkey with respect to their ownerships for the years (2001-2006) by adopting DEA, they found that the average efficiencies of state hospitals remarkably increased while the average efficiencies of private hospitals decreased especially after the starting of reforms in the state-owned hospitals
- Barnum, et al.(2011), developed efficiency indicators valid for non-substitutable variables by using a sample of 87 community hospitals, they compared the new measures' efficiency estimates with those of conventional DEA measures. DEA substantially overestimated the hospitals' efficiency on the average, and reported that many inefficient hospitals to be efficient. Further, it greatly overestimated the efficiency of some hospitals but only slightly overestimated the efficiency of others, thus making any comparisons among hospitals questionable.

B. Studies on Data envelopment Analysis (DEA) in Algeria :

Few studies in the Algeria are also found in the DEA literature OF hospitals

- The research of Muhammad Qureshi and Haj Arraba (2011) applied DEA for measuring the relative efficiencies and study the efficiency of the 10 hospitals located in East Algerian. They introduced two input variables: numbers of doctors and nurses, and two output variables: in-patient and outpatient. The study was based on model - CCR, with an input-oriented and output oriented approach. The results showed that 03 of the 1O hospitals were efficient (02 public hospitals and 02 Specialized hospitals) , 05 were input efficient and output inefficient (03 public hospitals and 02 Specialized hospitals) exposing the remaining 10 hospitals to be input and output inefficient , needing to considerably raise their game in order to be on a par with that of their peer group Recently .
- The research of Haj Arraba (2012**)** applied DEA method to measure the efficiency of human resources in Algeria hospitals during 2010 of 04 hospitals. The study was based on a comparison between the indicators of the World Health Organization and the calculated indicators for these hospitals. The results showed that all calculated indicators in these hospitals below the global average for health. This study concluded that should be taken with these indicators when preparing the human resources planning.

Consequently, by of these Previous Studies concluded that DEA is constructive technique for health care managers to investigate opportunities in accordance to efficiency improvements

3. METHODS AND MATERIALS:

3. 1. Data envelopment analysis (DEA):

The objective of this study is to evaluate the efficiency of hospitals in Algeria. DEA has two orientations—input and output. For the present study, the output-orientated model has been selected; however, both the input- and output-oriented models have been discussed in brief. The assumption of CRS does not hold true in a realistic situation; hence, VRS is assumed. However, one must be careful in assuming VRS, which sometimes leads to a higher number of DMUs being efficient.

The main advantages of the DEA methodology in the hospital efficiency measurement are the following:[8]

_ It can be used in DMU (Decision Units) which uses multiple inputs to generate multiple outputs.

_ It fits to models where prices of resources and products are unknown.

_ None required functional specialization between inputs and outputs.

In this study, we apply an input-oriented efficiency measure since hospital management has greater control over inputs than over outputs. In health care Therefore, the model evaluates the efficiency solving in problem:

A.The Input-Oriented CCR (I) MODEL [9]

The CCR model for measuring the input-oriented efficiency value of a test DUM can be written as proposed by Charnes et al. (1978) as follows

$$\mathbf{Min}\theta_0 - \varepsilon\left(\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} s_r^+\right)$$

Subject to

$$\sum_{j=1}^{m} x_{ij}\,\lambda_j + S_i^- = \theta_0 x_{i0} \qquad i = 1\ldots\ldots m$$

$$\sum_{j=1}^{m} y_{ij}\,\lambda_j - s_r^+ = y_{ro} \qquad r = 1\ldots\ldots s$$

$$\lambda_j, s_r^+, s_i^- \geq 0 \qquad j = 1\ldots\ldots n$$

Where

n: Number of DMUs

j: Indexes for DMUs

m: Number of inputs

i = 1,2…m: Index for inputs

S: Number of outputs

r = 1,2…s: Index for outputs

Xij: The ith input of DMUj

Yrj: The rth output of DMUj

λj : The decision variables that represent the weights used to form a weighted average frontier composite

θ : The efficiency for the DMUs

ε : The non-Archimedean defined to be smaller than any positive real number

Si: The value of slack for the ith input.

Sr: The value of slack for the rth output .

B. The Input-Oriented BCC (I) Model [10]

The following BCC model is an input-oriented model, such that the inputs are minimized and the outputs remain static (Banker et al., 1984):

$$\mathbf{Min}\theta_0 - \varepsilon\left(\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} s_r^+\right)$$

Subject to

$$\sum_{j=1}^{m} x_{ij}\lambda_j + S_i^- = \theta_0 x_{i0} \quad \text{i=1…n}$$

$$\sum_{j=1}^{m} y_{ij}\lambda_j - s_r^+ = y_{ro} \quad \text{r=1….s}$$

$$\text{J=1….m} \qquad \sum_{j=1}^{m} \lambda_j = 1$$

$$\lambda_j, s_r^+, s_i^- \geq 0 \quad \text{For all j, r and i}$$

The BCC model differs from the CCR model in the adjunction of the condition: $\sum_{j=1}^{m} \lambda_j = 1$

Two models are similar and must be run individually for all the states.

DMUs (or states) having an efficiency score equal to 1 indicate an efficient unit and scores less than 1 as an inefficient unit. Apart from indicating the efficient and inefficient levels, the DEA results also tell about the reductions or increments to be made by the DMUs to reach the frontier, thereby becoming efficient. Next, the DMUs that are inefficient also identify the various 'peers' or benchmarks that it can follow, which are actually the efficient DMU's. In other words, peers show a mix of efficient DMUs the inefficient DMUs should follow such that they become efficient. The results and findings are discussed in the subsequent sections

In our study, we use the CCR (Charles, Cooper and Rhodes) Model has been used; therefore, it has been Considered that hospital activity presents increasing performances.

The CCR model is a radial model, which, for input orientation, means that inefficient units reduce inputs to reach the efficiency limit, while the relationship between the reduced level over the initial level is the efficiency index .

3. 2. Somme Definitions:

Will be identified the most important indicators in this model.

A. Definition of Technical efficiency(TE):[11]

It reflects the ability of a DMU to obtain the maximum output from a given set of inputs. It is the efficiency score evaluated from CCR model.

B. Definition of Pure Technical Efficiency (PTE) [12]

It refers to the proportion of technical efficiency which is attributed to the efficient conversion of inputs into output given the scale size. It is the efficiency score evaluated from BCC model**.**

C.Peer

A peer is an efficient DMU, which acts as a reference point for inefficient DMUs.

D. Input Oriented Measure

The input oriented technical efficiency measures the input quantities which can be proportionally reduced without changing the output quantity produced.

E.Output Oriented Measure

The output oriented technical efficiency measures the output quantities that can be proportionally expanded without altering the input quantities used.

F. Returns to Scale (RTS) [13]**:**

It refers to the magnitude of the change in the rate of output relative to the change in scale.

- Constant Returns to Scale (CRS)

The output changes in proportion to the change in inputs.

- Variable Returns to Scale (VRS)

The output may increase more than the proportion increment in inputs (Increasing returns to scale) and increase less than the proportion increment in inputs (Decreasing returns to scale).

4. Data sources:

To fulfill the main objective of this article, a comparative study was conducted in 07 hospitals of Algeria More specifically, the study into hospital efficiency was conducted in three main hospital Activities: medical emergency, maternity and Medical imaging activity. These three activities were selected in terms of waiting lists, that is they were chosen for this study because they presented the longest waiting lists and had, therefore, the strongest need to detect any possible inefficiencies ,All the data were provided by the Ministry of Health Algeria for the year 2017.

4.1. Defining inputs and outputs variables.

It is noteworthy that the hospitals studied included 08 public hospitals those located in the wilaya of algeries numbered from 1 to 08 are considered as DMUs. For each DMU, the following three inputs are considered:

2. Number of doctors

3.Number of nurses

For each DMU, the following three outputs are considered:

1. Number of out patients treated

Table .1. Inputs and Outputs for Hospitals of Algeria

DMUs	Hospital	Inputs		Outputs
		Number of nurses	Number of doctors	Number of out patients treated
H1	Ain Taya	250	73	353814
H2	Rouiba	300	118	227976
H3	kouba	391	136	190470
H4	Bouloughine	301	69	256976
H5	El harach	380	67	276267
H6	Bir terraria	231	51	330336
H7	El mouradia	84	35	100873

Source: (Ministry of Health Algeria for the year 2017)

Table 2. Descriptive Statistics of Hospitals of Algeria

Statistics	Inputs		Outputs
	Number of nurses	Number of doctors	Number of out patients treated
Mean	276.71	78.42	248101.71
Standard deviation	103.92	35.98	85841.28
Minimum	84	35	100873
Maximum	391	136	353814

Source: (DEA solver).

Table 2 shows the descriptive statistics for all input and output variables used in the study all the other inputs and outputs show wide variations as can be seen from the maximum and minimum values

5. RESULTS AND DISCUSSION :

5.1. Efficiency Score of CCR (I)

Table 3 gives the TE scores for the 07 Hospitals. A score of 1.0 is considered to be efficient, thus lying on the efficiency frontier, while scores below 1.0 indicate inefficiency which lies below the

frontier. Of these 07 DMUs, two DMUs (**H1, H6**) are efficient with a score equal to 1, lying on the efficiency frontier, while the other 05 DMUs (**H2, H3, H4, H5, H7**) are inefficient. Kouba (H3) was the least efficient hospital with a TE score of 0.34, followed by rouiba(H2) (0.55). The efficient hospitals are seen to have comparatively better deliveries than the inefficient hospitals because they are utilizing low levels of health manpower

Table 3. Efficiency Score of CCR (I)

DMUs	CCR (I) TE
H1	1.00
H2	0.53
H3	0.34
H4	0.76
H5	0.85
H6	1.00
H7	0.75

Source: (DEA solver).

5.2. Peers for Inefficient Hospitals of CCR (I).

Data envelopment analysis helps us to identify a smaller group of best performers specific to the characteristics of an individual hospital (based on the weights given to inputs and outputs) So, The next step is the benchmarking process or identifying 'peer' groups of the different inefficient units. Peers are a set of potential role models who a unit can emulate to become efficient. On a frontier, each DMU tries to move either horizontally or vertically, that is, increasing its outputs or reducing its inputs by following the closest DMU to become efficient. For each inefficient DMU, a single or a set of efficient DMUs acts as peers, which the inefficient DMU needs to follow to become efficient. **Table 4** summarizes the peers for all the inefficient hospitals. **H1 (Ain taya hospital**) has emerged to be the best efficient hospital to be emulated by all the inefficient hospitals. It has the optimal levels of inputs to achieve the output.

Table 4. Peers of Inefficient Hospitals

DMUs	Peer Weight λ_j
H1	$\lambda_1 = 1.00$
H2	$\lambda_1 = 0.580$ $\lambda_6 = 0.420$
H3	$\lambda_1 = 1.00$
H4	$\lambda_1 = 1.00$
H5	$\lambda_1 = 1.00$
H6	$\lambda_6 = 1.00$
H7	$\lambda_1 = 0.846$ $\lambda_6 = 0.154$

Source: (DEA solver).

5.3. Input Slacks of CCR (I).

These TE scores further indicate how these inefficient units can be made efficient by identifying input slacks. Slack refers to excess input or missing output that exists even after the proportional change in the input or the outputs. These are estimated only for the inefficient units and specified by the amount of input or output that could be increased or decreased to make the unit efficient. These input and output slacks have been given in **Table 5**. Almost all the DMUs require

augmenting their output levels as well as reducing their input levels to make to the frontier. H3, one of the inefficient DMUs, requires reducing the number of nurses and doctors by **7.21** and 8.87. Likewise, the rest of the hospitals need to make

Table 5. Input Slacks and its Projection

DMUs	Hospital	Inputs					
		Number of nurses (X)	Slack (x)	Projection (x)	Number of doctors(y)	Slack (y)	Projection (y)
H1	Ain Taya	250	---	250	73	---	73
H2	Rouiba	300	5.62	159.42	118	5.32	55.90
H3	Cuba	391	7.21	132.45	136	8.87	46.41
H4	Bouloughine	301	5.56	53.02	69	9.45	188.83
H5	El harach	380	6.32	203.01	67	3.76	57.01
H6	Bir terraria	231	---	231	51	---	51
H7	El mouradia	84	1.53	24.73	35		7.53

Source: (DEA solver).

6.Conclusion:

In this article, we used the DEA approach to measure technical and scale efficiencies of 07 public hospitals. The study shows that out of 07 hospitals, two (28 percent) indicate pure .

Technical efficiency. The mean PTE of hospitals is 74.71 percent, indicating that on average 28.19 percent of the technical potential of hospitals is not being utilised. We found H3 is the most inefficient hospital, its average efficiency score being 0.34. This score indicates that hospital of Cuba could reduce their current input number of nurses and doctors by 7.21 and 8.87 percent. It is also noted that during the during 2017, and the same most of the hospitals in the our study The results of CCR mode show that hospitals in only two hospitals (28.57 percent) are technically efficient, and therefore lie on the efficiency frontier the remaining 05 Hospitals (71.43 percent) are technically inefficient with an average total efficiency score of 0.74. Among the inefficient hospitals, two hospitals have efficiency scores above the average efficiency. This reveals that hospitals must reduce their current input endowments by 26 percent. Cuba‘s hospital is the least efficient hospitals.

With a technical efficiency score of 0.34. This score indicates that Cuba hospitals could reduce their current input number of nurses and doctors by 7.21 and 8.87 by 7.21 percent. The result of this paper could enable the health policy makers and hospitals managers to better understand the resources in the hospitals and to ensure that they are used effectively or not compared to other hospitals. The policy makers could also put forward some policies to stimulate hospitals to improve their performance.

However, the conclusion on the efficiency of hospitals needs to be considered cautiously, as the results of this study are dependent upon the choice of the inputs and outputs.

The study gives valuable information on the efficiency of public hospitals in Algeria , however, it has some limitations such as excluding some variables that may have affected the efficiency score. As in some other DEA studies, this work does not include any quality variables associated with hospitals. Hence it does not offer any insight into the hospital quality or patient satisfaction levels. Inclusion of these variables would make the study more complete. Further

research is clearly needed to eliminate the above deficiencies and to estimate technical efficiency at a more disaggregate level.

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