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A Non-Parametric Approach to Assess the Performance of Egyptian Universities

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Abstract

This paper aims to assess the performance of Egyptian universities with data reported to 2010/2011. This study applied the Data Envelopment Analysis (DEA) methodology. DEA based on non-parametric mathematical models. It evaluates the performance of each observation with a multidimensional perspective. The study used a data of 12 universities for which were obtained the scores of technical and scale efficiency. The technical efficiency scores indicated the benchmark universities, demonstrating the potential of DEA. For purposes of analysis, this research used DEA with Charnes, Cooper and Rhodes (CCR) or Constant Returns to Scale (CRS) and Banker, Charnes, Cooper (BCC) or Variable Returns to Scale (VRS) for both Input-Oriented model and Output-Oriented model. The results of CRS model suggested that; five universities are technically efficient,

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while the results of VRS showed that ten universities are pure technically efficient and of these ten, only five are scale efficient which indicates that these universities are operating at their ideal scale of operations. The overall inefficiency for two universities in the CCR is caused by inefficient operations rather than the scale inefficiency, while for five universities is attributed to disadvantageous conditions.

Keywords: Data Envelopment Analysis (DEA); Efficiency measurement; Technical efficiency; Scale efficiency; Decision-Making Units (DMUs); Charnes; Cooper and Rhodes ratio (CCR)

1 Introduction

Efficiency has been the subject of research in a wide range of production activities. It is expressed as a percentage which can calculate as the ratio total output power to total input power under specified conditions. Efficiency analysis has always been linked to the relative difficulty encountered is assessing the performance of Decision-Making Units (DMUs), especially for service units such as universities, to find its weakness so that subsequent improvements can be made [17].

Increasing responsibility of universities to their providers and educational administrators' desire to better utilize unusual resources indicate that efficiency analysis will become more common among universities. Conversely, failure to make efficiency analysis a standard practice would certainly lead to less than efficient allocation of educational resources [2].

The available empirical literature on tertiary education efficiency mostly uses the Data Envelopment Analysis (DEA) framework. For instance, some related references are: Breu and Raab (1994) for the US; Coelli (1996) for

Australia; McMillan and Datta (1998) for Canada; Johnes (1999) for Britain; Førsund and Kalhagen (1999) for Norway; Avkiran (2001) for Australia, Calhoun (2003) for the US; Afonso and Santos (2004) for Portugal; Warning (2004) for Germany; Taylor and Harris (2004) for South Africa; Cherchye and Abeele (2005) for the Netherlands; and Johnes (2006) for England; Fandel (2007) for Germany; and Monaco (2012) for Italy.

Data Envelopment Analysis, originating from Farrell's (1957) seminal work and popularized by Charnes, Cooper and Rhodes (1978), provides a suitable way to estimate a multiple input–output efficient technique that measures the relative efficiency of DMUs using a linear programming based model [18]. The approach involves defining a non-parametric frontier and then measuring efficiency of each unit relative to that frontier. The frontier technology consists of convex input and output sets enveloping the data points with linear facets [23]. The DEA frontier DMUs are those with maximum output levels for given input levels or with minimum input levels for given output levels. DEA provides efficiency scores for individual units as their technical efficiency measure, with a score of one assigned to the frontier (efficient) units [18].

Unlike the statistical regression method that tries to fit a regression plane through the centre of the data. DEA floats a piecewise linear surface to rest on top of the data by linear programming techniques [21]. In other words, the statistical regression method estimates the parameters in the assumed functional form by single optimizations over all DMUs whereas DEA uses optimizations for different DMUs without a priori assumptions on the underlying functional forms. Because of this unique feature, DEA has been applied to various areas of efficiency evaluation, for example, individual physician practice, program evaluation, macroeconomics performance of countries or cities, pollution prevention, reorganization of forest districts and pupil transportation and others [23].

The main advantages of DEA that make it suitable for measuring the efficiency of universities are:

(1) It allows the simultaneous analysis of multiple outputs and multiple inputs,

(2) It does not require an explicit a priori determination of a production function,

(3) Efficiency measured relative to the highest observed performance rather than against some average,

(4) It does not require information on prices [21],

(5) Its ability to identify sources and amounts of inefficiency in each input and each output for each university, and

(6) Its ability to identify the benchmark members of the efficient set used to effect these evaluations and identify these sources (and amounts) of inefficiency [10].

However, DEA lacks any explanatory power in determining drivers of technical efficiency. Furthermore, DEA assumes that decision making units (DMUs) have full control over inputs, suggesting that such variables are discretionary. This is however a weak assumption since non-discretionary inputs are present in virtually all industrial and commercial sectors which must be incorporated into production models so as to correctly measure efficiency [22].

The purpose of this paper is to assess the performance of Egyptian universities in 2010/2011 by applying a non-parametric methodology, DEA, to a set of 12 universities.

2 Methodology

DEA is a technique to measure relative efficiency of a set of DMUs having similar multiple inputs to produce similar multiple outputs. The relative efficiency of a DMU is defined as the ratio of the sum of its weighted outputs, to the sum of its weighted inputs. The objectives are to identify units that are relatively inefficient and setting targets for them based on examining the operational practices of the units classified as efficient [16]. A range of DEA models have been developed that measure efficiency in different ways. These largely fall into the categories of being either input oriented or output oriented models.

2.1 Input-Oriented DEA Model

With input oriented DEA, the linear programming model is configured to determine how much the input use of a firm could contract if used efficiently in order to achieve the same output level. Consider a set of n observations on the DMUs. Each observation, DMU_j $(j = 1,...,n)$, uses m inputs $x_{ij}(i = 1,2,...,m)$ to produce s outputs $y_{rj}(r = 1,2,...,s)$. The CCR ratio model can be expressed as follows:

$$\max h_o(u,v) = \sum_r u_r y_{ro} / \sum_i v_i x_{io} \qquad (1)$$

Where $u_r's$ are the variables and $v_i's$; $y_{ro}'s$ and $x_{io}'s$ are the observed output and input values, respectively, of the DMU_o, the DMU to be evaluated. Of course, without further additional constraints equation (1) is unbounded.

A set of normalizing constraints (one for each DMU) reflects the condition that the virtual output to virtual input ratio of every DMU, including $DMU_j = DMU_o$, must be less than or equal to unity. The mathematical programming problem may thus be stated as:

$$\max h_o(u,v) = \sum_r u_r y_{ro} / \sum_i v_i x_{io}$$

Subject to:

$$\sum_r u_r y_{rj} / \sum_i v_i x_{ij} \le 1 \qquad for \ j = 1,...,n, \qquad (2)$$

$$u_r, v_i \ge 0$$

The above ratio form yields an infinite number of solutions; if (u^*, v^*) is optimal, then $(\alpha u^*, \alpha v^*)$ is also optimal for $\alpha > 0$. However, the transformation developed by Charnes and Cooper (1962) for linear fractional programming selects a representative solution [i.e., the solution (u, v) for $\sum_{i=1}^{m} v_i x_{io} = 1$] which and yields the equivalent linear programming problem [the change of variables from (u, v) to (μ, ν) is a result of the Charnes-Cooper transformation],

$$\max z = \sum_{r=1}^{s} \mu_r y_{ro}$$

Subject to:

$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} \nu_i x_{ij} \le 0 \qquad (3)$$

$$\sum_{i=1}^{m} \nu_i x_{io} = 1$$

$$\mu_r, \nu_i \ge 0$$

The dual program of (3) is

$$\theta^* = \min \theta$$

Subject to:

$$\sum_{j=1}^{n} x_{ij} \lambda_j \le \theta x_{io} \qquad i = 1,2,\ldots,m; \qquad (4)$$

$$\sum_{j=1}^{n} y_{rj} \lambda_j \ge y_{ro} \qquad r = 1,2,\ldots,s;$$

$$\lambda_j \ge 0 \qquad j = 1,2,\ldots,n$$

Since $\theta = 1$ is a feasible solution to model (4), the optimal value to model (4), $\theta^* \le 1$ .If $\theta^* = 1$ then the current input levels cannot be reduced (proportionally), indicating that DMU_o is on the frontier. Otherwise, if

$\theta^* < 1$ then DMU_o is dominated by the frontier. Where θ^* represents the (input oriented) efficiency score of DMU_o. In fact, both input and output slack values may exist in model (4). Usually, after calculating model (4), we have,

$$\begin{cases} s_i^- = \theta^* x_{io} - \sum_{j=1}^{n} \lambda_j x_{ij} & i = 1,2,\ldots,m \\ s_r^+ = \sum_{j=1}^{n} \lambda_j y_{rj} - y_{ro} & r = 1,2,\ldots,s \end{cases} \quad (5)$$

Where s_i^- and s_r^+ represent input and output slacks, respectively. Therefore, we use the following linear programming model to determine the possible non-zero slacks after model (2) is solved,

$$\max \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$$

Subject to:

$$\sum_{j=1}^{n} x_{ij} \lambda_j + s_i^- = \theta^* x_{io} \qquad i = 1,2,\ldots,m; \qquad (6)$$

$$\sum_{j=1}^{n} y_{rj} \lambda_j - s_r^+ = y_{ro} \qquad r = 1,2,\ldots,s;$$

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

Therefore, it can be said that, the performance of DMU_o is fully (100%) efficient if and only if both (i) $\theta^* = 1$ and (ii) all slacks $s_i^{-*} = s_r^{+*} = 0$ .On the other hand, The performance of DMU_o is weakly efficient if and only if both (i) $\theta^* = 1$ and (ii) $s_i^{-*} \neq 0$ and/or $s_r^{+*} \neq 0$ for some i and r. The efficient target of a specific DMU under evaluation is

$$\begin{aligned} \hat{x}_{io} &= \theta^* x_{io} - s_j^{-*} & i = 1,2,\ldots,m \\ \hat{y}_{ro} &= y_{ro} + s_r^{+*} & r = 1,2,\ldots,s \end{aligned} \quad (7)$$

In fact, models (4) and (6) represent a two-stage DEA process involved in the following DEA model,

$$\min \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\,\lambda_j + s_i^- = \theta\, x_{io} \qquad i = 1,2,\dots,m; \qquad (8)$$

$$\sum_{j=1}^{n} y_{rj}\,\lambda_j - s_r^+ = y_{ro} \qquad r = 1,2,\dots,s;$$

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

The occurrence of the non-Archimedean ε in the objective function (equation 8) effectively allows the minimization over θ to preempt the optimization involving the slacks, s_i^- and s_r^+ Thus, model (8) is calculated in a two-stage process with maximal reduction of inputs being achieved first, via the optimal θ^* in model (4); then, in the second stage, movement onto the efficient frontier is achieved via optimizing the slack variables in model (6).

The frontier determined by the above DEA models exhibits constant returns to scale (CRS). Thus, the above DEA models are called CRS Input-Oriented DEA models (CRS-I). The constraint on $\sum_{j=1}^{n}\lambda_j$ in the envelopment models actually determines the returns to scale (RTS) type of an efficient frontier. If we add $\sum_{j=1}^{n}\lambda_j = 1$ we obtain VRS (variable RTS) Input-Oriented DEA models (VRS-I).

2.2 Output-Oriented DEA Model

With output oriented DEA, the linear programming is configured to determine a firm's potential output given its inputs if it operated efficiently as firms along the best practice frontier. If we consider the following DEA model,

$$\min \sum_i v_i x_{io} / \sum_r u_r y_{ro}$$

Subject to:

$$\sum_i v_i x_{ij} / \sum_r u_r y_{rj} \geq 1 \qquad for\ j = 1,\ldots,n, \qquad (9)$$

$$u_r, v_i \geq \varepsilon \geq 0$$

where $\varepsilon > 0$ is the previously defined non-Archimedean element, then we have the following output oriented multiplier DEA model,

$$\min q = \sum_{i=1}^{m} v_i x_{io}$$

Subject to:

$$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} \mu_r y_{rj} \geq 0 \qquad (10)$$

$$\sum_{r=1}^{s} \mu_r y_{rj} = 1$$

$$\mu_r, v_i \geq \varepsilon, \qquad \forall r, i$$

The dual program of model (10) is

$$\phi^* = \max \phi$$

Subject to:

$$\sum_{j=1}^{n} x_{ij} \lambda_j \leq x_{io} \qquad i = 1,2,\ldots,m; \qquad (11)$$

$$\sum_{j=1}^{n} y_{rj} \lambda_j \geq \phi y_{ro} \qquad r = 1,2,\ldots,s;$$

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

As above, both input and output slack values may exist in model (11), therefore, we use the following linear programming model to determine the possible non-zero slacks after model (11) is solved,

$$\max \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\,\lambda_j + s_i^- = x_{io} \qquad i = 1,2,\ldots,m; \qquad (12)$$

$$\sum_{j=1}^{n} y_{rj}\,\lambda_j - s_r^+ = \phi^* y_{ro} \qquad r = 1,2,\ldots,s;$$

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

Therefore, it can be said that, the performance of DMU_o is fully (100%) efficient if and only if both (i) $\phi^* = 1$ and (ii) all slacks $s_i^{-*} = s_r^{+*} = 0$.On the other hand, The performance of DMU_o is weakly efficient if and only if both (i) $\phi^* = 1$ and (ii) $s_i^{-*} \neq 0$ and/or $s_r^{+*} \neq 0$ for some i and r. The efficient target of a specific DMU under evaluation is

$$\hat{x}_{io} = x_{io} - s_j^{-*} \qquad i = 1,2,\ldots,m$$
$$\hat{y}_{ro} = \phi y_{ro} + s_r^{+*} \qquad r = 1,2,\ldots,s \qquad (13)$$

In fact, models (11) and (12) represent a two-stage DEA process involved in the following DEA model

$$\max \phi - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\,\lambda_j + s_i^- = x_{io} \qquad i = 1,2,\ldots,m; \qquad (14)$$

$$\sum_{j=1}^{n} y_{rj}\,\lambda_j - s_r^+ = \phi y_{ro} \qquad r = 1,2,\ldots,s;$$

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

As before, model (14) is calculated in a two-stage process. First, we calculate

ϕ^* by ignoring the slacks. Then we optimize the slacks by fixing ϕ^* in model (12). The above DEA models are called CRS Output-Oriented DEA models (CRS-O). If we add $\sum_{j=1}^{n} \lambda_j = 1$ we obtain VRS (variable RTS) Output-Oriented DEA models (VRS-O) [9].

2.3 Decomposition of Technical Efficiency

It is an interesting subject to investigate the sources of inefficiency that a DMU might have. Is it caused by the inefficient operation of the DMU itself or by the disadvantageous conditions under which the DMU is operating? For this purpose, comparisons of the CRS and VRS scores deserve considerations. The CRS model assumes the constant returns-to-scale production possibility set, i.e., it is postulated that the radial expansion and reduction of all observed DMUs and their nonnegative combinations are possible and hence the CRS score is called global technical efficiency. On the other hand, the VRS model assumes the convex combinations of the observed DMUs as the production possibility set and the VRS score is called local pure technical efficiency.

If a DMU is fully efficient (100%) in both the CRS and VRS scores, it is operating in the most productive scale size. If a DMU has the full VRS efficiency but a low CRS score, then it is operating locally efficiently but not globally efficiently due to the scale size of the DMU. Thus, it is reasonable to characterize the scale efficiency of a DMU by the ratio of the two scores. Let the CRS and VRS scores of a DMU be θ^*_{CRS} and θ^*_{VRS} respectively. The scale efficiency is defined by;

$$SE = \theta^*_{CRS} \,/\, \theta^*_{VRS} \tag{15}$$

SE is not greater than one. For a VRS-efficient DMU with CRS characteristics, i.e., in the most productive scale size, its scale efficiency is one. The CRS score is called the global technical efficiency (TE), since it takes no account of scale effect. On the other hand, the VRS expresses the local pure technical efficiency (PTE) under variable returns-to-scale circumstances. Using these concepts, relationship (15) demonstrates a decomposition of efficiency as:

$$Technical\ Eff.\ (TE) = \left[Pure\ Technical\ \ Eff.(PTE) \times Scale\ Eff.\ (SE)\right] \qquad (16)$$

This decomposition, which is unique, depicts the sources of inefficiency, i.e., whether it is caused by inefficient operation (PTE) or by disadvantageous conditions displayed by the scale efficiency (SE) or by both, as mentioned in model (16). Although the above scale efficiency is input oriented, we can define the output oriented scale efficiency using the output oriented scores, as well [10].

3 Data Description

In this study, we assess the efficiency of a set of Egyptian universities in 2011. More precisely, we use data for 12 universities. These are drawn from the Supreme Council of Universities (SCU) which is produces detailed annual statistics for all higher education in Egypt. In the present study, there are four measures of inputs and two measures of output. The definitions and the descriptive statistics of the inputs and outputs variables are presented in Table 1.

Table 1: Definitions of input and output variables used in the DEA of Egyptian universities

Variables		Definition	Min	Max	Mean	Std. Deviation
Inputs	X_1	Undergraduate enrolments	25065	150588	79038	41163.15
	X_2	Academic staff	1436	11689	4942	2927.62
	X_3	Total of budget appropriation	306488	2145569	8538745	560146.15
	X_4	Postgraduate enrolments	1800	32816	11340	10793.51
Outputs	Y_1	Undergraduate degrees awarded	5501	35397	20340	9665.38
	Y_2	Postgraduate degrees awarded	221	2592	1108	714.11

Source: Ministry of Higher Education, Supreme Council of Universities (SCU), Egypt.

4 Statistical Analysis

4.1 Input-Oriented DEA Model Results

Tables 2 and 3 summarize the results obtained by applying DEA-Solver software to all of the data, under CRS-I model, only Alexandria, Zagazig, Helwan, Suez Canal, and South Valley are fully global technical efficient because $\theta^* = 1$ with zero slacks. While Cairo, Ain Shams, Assiut, Tanta, Mansoura, Minia, and

Minufiya fail to be efficient because $\theta^* < 1$ and nonzero slacks.

Table 2: Efficiency scores of Egyptian Universities according to Input-Oriented DEA Model

University	Input-Oriented DEA Model: First stage				
	CRS-I Global technical efficiency		VRS-I Pure technical efficiency		Scale Efficiency
	θ^*	%	θ^*	%	
Cairo	0.874	87.4	1	100	0.874
Alexandria	1	100	1	100	1
Ain Shams	0.915	91.5	1	100	0.915
Assiut	0.842	84.2	0.874	87.4	0.963
Tanta	0.896	89.6	1	100	0.896
Mansoura	0.866	86.6	1	100	0.866
Zagazig	1	100	1	100	1
Helwan	1	100	1	100	1
Minia	0.936	93.6	1	100	0.936
Minufiya	0.921	92.1	0.949	94.9	0.970
Suez Canal	1	100	1	100	1
SouthValley	1	100	1	100	1
GM	0.936	93.6	0.985	98.5	0.950

Note: GM denotes Geometric Mean. CRS denotes constant returns to scale. VRS denotes variable returns to scale.

One plan for the improvement of Assiut University is to reduce all input values by multiplying them by 0.842, in other word, reduce all input values by

0.158 of their observed values and further reduce X_3 and X_4 by 0.26 and 0.04 respectively. Under VRS-I model, all Universities are fully Pure technically efficient except Assiut and Minufiya. One plan for the improvement of Assiut University is to reduce all input values by multiplying them by 0.874, in other word, reduce all input values by 0.126 of their observed values and further reduce X_3 and X_4 by 0.30 and 0.14 respectively, in addition increase Y_2 by 0.164. It can be noticed that every University efficiently in CRS model will also be in the VRS model.

Table 3: Input and output slacks rates for Egyptian Universities according to Input-Oriented DEA Model

University	Input-Oriented DEA Model: Second Stage											
	Input slacks rates								Output slacks rates			
	s_1^-		s_2^-		s_3^-		s_4^-		s_1^+		s_2^+	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
Cairo	0	0	0	0	0.19	0	0.54	0	0.10	0	0	0
Alexandria	0	0	0	0	0	0	0	0	0	0	0	0
Ain Shams	0	0	0	0	0.09	0	0	0	0	0	0	0
Assiut	0	0	0	0	0.26	0.30	0.04	0.14	0	0	0	0.164
Tanta	0.03	0	0	0	0	0	0	0	0	0	0	0
Mansoura	0	0	0	0	0.11	0	0	0	0	0	0	0
Zagazig	0	0	0	0	0	0	0	0	0	0	0	0
Helwan	0	0	0	0	0	0	0	0	0	0	0	0
Minia	0	0	0	0	0	0	0.21	0	0	0	0	0
Minufiya	0	0.05	0	0	0	0.01	0.28	0.28	0	0	0	0
Suez Canal	0	0	0	0	0	0	0	0	0	0	0	0
SouthValley	0	0	0	0	0	0	0	0	0	0	0	0

After the technical efficiencies are calculated in VRS and CRS models, it is followed by the calculation of the efficiency scale. As Table 2 shows the Universities of Alexandria, Zagazig, Helwan, Suez Canal, and South Valley are operating at optimal scale. Thus, they are considered the benchmark Universities. Assiut and Minufiya have a low VRS score and relatively high scale efficiency, meaning that the overall inefficiency in the CCR is caused by inefficient operations rather than the scale inefficiency. On the other hand, Cairo, Ain Shams, Tanta, Mansoura and Minia have a fully efficient VRS score and low scale efficiency. This can be interpreted to mean that the global inefficiency of these universities under CCR score is mainly attributed to disadvantageous conditions.

Table 4: Improvements and benchmarks for Assiut University according to Input-Oriented Model

Input-Oriented DEA Model: Efficient target rates and benchmarks					
		CRS-I		VRS-I	
Input	Actual	Target	%	Target	%
X_1	56513	47612	-15.8	49417	-12.6
X_2	3461	2916	-15.7	3026	-12.6
X_3	842242	493414	-41.4	483285	-42.7
X_4	4702	3792	-19.4	3431	-27
Output	Actual	Target	%	Target	%
Y_1	14170	14170	-	14170	-
Y_2	604	604	-	703	16.4%
Benchmarking		Alexandria, Suez Canal & South Valley		Zagazig, Suez Canal & South Valley	

Table 4 reports the improvements and benchmarks for Assiut University according to input oriented DEA Model. Under CRS-I model; Assiut University should reduce all input values by 15.8%, 15.7%, 41.4% and 19.4% respectively to be fully efficient, and Alexandria, Suez Canal & South Valley Universities are the benchmarks for Assiut University.

Under VRS-I model, Assiut University should reduce all input values by 12.6%, 12.6%, 42.7% and 27% respectively; in addition increase Y_2 by 16.4% to be fully pure efficient, and Zagazig, Suez Canal & South Valley Universities are the benchmarks for Assiut University.

4.2 Output-Oriented DEA Model Results

Tables 5 and 6 summarize the results of output oriented DEA Model. We noted that, the results obtained from CRS-I Model are equal to, especially efficiency scores, the results obtained from CRS-O Model. Only Alexandria, Zagazig, Helwan, Suez Canal, and South Valley are fully efficient because $\phi^* = 1$ with zero slacks. While Cairo, Ain Shams, Assiut, Tanta, Mansoura, Minia, and Minufiya fail to be efficient because $\phi^* > 1$ and nonzero slacks. The main plan for the improvement of Assiut University is to increase all output values by multiplying them by 1.187, in other word, increase all output values by 0.187 of their observed values, in addition reduce X_3 and X_4 by 0.305 and 0.043 respectively. Under VRS-O model, all Universities are fully pure efficient except Assiut and Minufiya. The main plan for the improvement of Assiut University is to increase all output values by multiplying them by 1.131, in other word, increase all output values by 0.131 of their observed values, and further increase Y_2 by 0.24, in addition reduce X_3 and X_4 by 0.353 and 0.151 respectively.

Table 5: Efficiency scores of Egyptian Universities according to Output-Oriented DEA Model

University	Output-Oriented DEA Model: First stage				
	CRS-O Global technical efficiency		VRS-O Pure technical efficiency		Scale Efficiency
	ϕ^*	%	ϕ^*	%	%
Cairo	1.144	87.4	1	100	0.874
Alexandria	1	100	1	100	1
Ain Shams	1.093	91.5	1	100	0.915
Assiut	1.187	84.2	1.131	88.4	0.953
Tanta	1.116	89.6	1	100	0.896
Mansoura	1.155	86.6	1	100	0.866
Zagazig	1	100	1	100	1
Helwan	1	100	1	100	1
Minia	1.068	93.6	1	100	0.936
Minufiya	1.086	92.1	1.063	94	0.980
Suez Canal	1	100	1	100	1
SouthValley	1	100	1	100	1
GM	1.069	93.6	1.015	98.5	0.950

Note: GM denotes Geometric Mean. CRS denotes constant returns to scale. VRS denotes variable returns to scale.

As Table 5 shows the Universities of Alexandria, Zagazig, Helwan, Suez Canal, and South Valley are operating at optimal scale. Assiut and Minufiya have a low VRS score and relatively high scale efficiency, meaning that the overall inefficiency in the CCR is caused by inefficient operations rather than the scale inefficiency. On the other hand, Cairo, Ain Shams, Tanta, Mansoura and Minia have a fully efficient VRS score and low scale efficiency. This can be interpreted to mean that the global inefficiency of these universities under CCR score is mainly attributed to disadvantageous conditions.

Table 6: Input and output slacks rates for Egyptian Universities according to Output-Oriented DEA Model

	Output-Oriented DEA Model: Second Stage											
	Input slacks								Output slacks			
	s_1^-		s_2^-		s_3^-		s_4^-		s_1^+		s_2^+	
University	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
Cairo	0	0	0	0	0.22	0	0.62	0	0.12	0	0	0
Alexandria	0	0	0	0	0	0	0	0	0	0	0	0
Ain Shams	0	0	0	0	0.10	0	0	0	0	0	0	0
Assiut	0	0	0	0	0.305	0.353	0.043	0.151	0	0	0	0.24
Tanta	0.03	0	0	0	0	0	0	0	0	0	0	0
Mansoura	0	0	0	0	0.13	0	0	0	0	0	0	0
Zagazig	0	0	0	0	0	0	0	0	0	0	0	0
Helwan	0	0	0	0	0	0	0	0	0	0	0	0
Minia	0	0	0	0	0	0	0.22	0	0	0	0	0
Minufiya	0	0.04	0	0	0	0	0.30	0.30	0	0	0	0
Suez Canal	0	0	0	0	0	0	0	0	0	0	0	0
SouthValley	0	0	0	0	0	0	0	0	0	0	0	0

Table 7: Improvements and benchmarks for Assiut University according to Output-Oriented DEA Model

Output-Oriented DEA Model: Target rates and benchmarks

		CRS-O		VRS-O	
Input	Actual	Target	%	Target	%
X_1	56513	56513	-	56513	-
X_2	3461	3461	-	3461	-
X_3	842242	585656	-30.5	544909	-35.3
X_4	4702	4501	-4.3	3991	-15.1
Output	Actual	Target	%	Target	%
Y_1	14170	16819	18.7	16025	13.1
Y_2	604	717	18.7	830	37.4
Benchmarking		Alexandria, Suez Canal & South Valley		Zagazig, Suez Canal, & South Valley	

Table 7 reports the improvements and benchmarks for Assiut University according to output oriented DEA Model. Under CRS-O model, Assiut University should increase all output values by 18.7% and 18.7% respectively, in addition reduce X_3 and X_4 by 0.305 and 0.43 respectively to be fully efficient and Alexandria, Suez Canal & South Valley Universities are the benchmarks for Minufiya University.

Under VRS-O model, Assiut University should increase all output values by 13.1% and 37.4% respectively, in addition reduce X_3 and X_4 by 0.353 and 0.151 respectively to be fully pure efficient, and Zagazig, Suez Canal, &South Valley Universities are the benchmarks for Minufiya University.

5 Conclusions

In this paper, a non-parametric methodology was applied, Data Envelopment Analysis, to assess the relative efficiency of Egyptian universities with data reported to 2010/2011. Our input measures were based on information for undergraduate enrolments, academic staff, total of budget appropriation, and postgraduate enrolments. We used as output measures, the undergraduate degrees awarded and postgraduate degrees awarded. The results suggested that, under CRS model, five universities are technically efficient, while under VRS, ten universities are pure technically efficient and of these ten, only five are scale efficient which indicates that these universities are operating at their ideal scale of operations. The overall inefficiency for two universities in the CCR is caused by inefficient operations rather than the scale inefficiency, while for five universities is attributed to disadvantageous conditions. In conclusion, the results suggest that there seems to be some theoretical “waste” of resources.

References

[1] A. Afonso and M. Santos, *Public Tertiary Education Expenditure in Portugal: a Non-Parametric Efficiency Analysis*, *ISEG/UTL–Technical University of Lisbon*, Department of Economics, Journal of Economic Literature (JEL) *Working Paper*, (2004).

[2] A. Charnes, W. Cooper and E. Rhodes, Measuring the efficiency of decision making units, *European Journal of Operational Research*, (1978).

[3] B. C. Kengil, N. Gokmen and H. Tozan, Efficiency measures in the health services with DEA- an overview, *Journal of Naval Science and Engineering*, (2010).

[4] B. Taylor and G. Harris, *Relative efficiency among South African universities: A data envelopment analysis*, Higher Education, 2004.

[5] F.F. Liu and P. Wang, DEA Malmquist productivity measure: Taiwanese semiconductor companies, *International Journal of Production Economics*, (2008).

[6] F. Førsund and K. Kalhagen, *Efficiency and productivity of Norwegian Colleges*, University of Oslo, Department of Economics, 1999.

[7] G. Fandel, On the performance of universities in North Rhine-Westphalia, Germany: Governments redistribution of funds judged using DEA efficiency measures, *European Journal of Operational Research*, (2007).

[8] G. Johnes, The Management of Universities, *Scottish Journal of Political Economy*, (1999).

[9] J. Calhoun, *Data Envelopment Analysis of Relative Efficiencies of Institutions of Higher Learning*, Mimeo, University of Goeorgia, 2003.

[10] J. Johnes, Data envelopment analysis and its application to the measurement of efficiency in higher education, *Economics of Education Review*, (2006).

[11] J. Odeck, Theory and Methodology Assessing the relative efficiency and productivity growth of vehicle inspection services: An application of DEA and Malmquist indices, *European Journal of Operational Research*, (2000).

[12] L. Cherchye and P. Abeele, On research efficiency: A micro-analysis of Dutch university research in Economics and Business Management, *Research Policy*, (2005).

[13] L. Monaco, *Measuring Italian university efficiency: a non-parametric approach*, Munich Personal RePEc Archive (MPRA), (2012).

[14] M. Farrell, the Measurement of Productive Efficiency, *Journal of the Royal Statistical Society*, 1957.

[15] M. McMillan and D. Datta, The Relative Efficiencies of Canadian Universities: A DEA Perspective, *Canadian Public Policy*, (1998).

[16] M. Rayeni, G. Vardanyan and F. Saljooghi, the measurement of Productivity Growth in the academic departments using Productivity index, *Journal of Applied Sciences*, (2010).

[17] N. Avkiran, Investigating technical and scale efficiencies of Australian Universities through data envelopment analysis, *Socio-Economic Planning Sciences*, (2001).

[18] N. Kontodimopoulos and D. Niakas, Efficiency measurement of hemodialysis units in Greece with data envelopment analysis, *Health Policy*, (2005).

[19] P. Ouellette and V. Vierstraete, Technological change and efficiency in the presence of quasi-fixed inputs: A DEA application to the hospital sector, *European Journal of Operational Research*, (2004).

[20] R. D. Banker, A. Charnes and W. W. Cooper, *Some models for estimating technical and scale inefficiencies in data* envelopment *analysis*, *Management Science*, (1984).

[21] S. Warning, Performance Differences in German Higher Education: Empirical Analysis of Strategic Groups, *Review of Industrial Organization*, (2004).

[22] T. Breu and R. Raab, Efficiency and perceived quality of the nation's "top 25" national universities and national liberal arts colleges: an application of data envelopment analysis to higher education, *Socio-Economic Planning Sciences*, (1994).

[23] T. Coelli, *Assessing the Performance of Australian Universities using Data Envelopment Analysis*, Centre for efficiency and productivity analysis, University of New England, NSW, 1996.

[24] W. Cooper, L. Seiford and K. Tone, *A Comprehensive Text with Models, Applications, References and DEA-Solver Software*, Kluwer Academic Publishers, 2003.

[25] W. D. Cook and J. Zhu, *Modeling Performance Measurement: Applications and Implementation Issues in DEA*, Springer Science and Business Media, Inc., 2005.