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Research Article

An Investigation of Technical and Scale Efficiency of Public Universities in Saudi Arabia

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Abstract: Higher education sector in Saudi Arabia had a phenomenal growth over the last decade. This study sets out to empirically examine the technical and scale efficiency of government universities in Saudi Arabia. In general, the technical efficiency of Saudi public universities appears to be high. However, majority of public universities relative performance is a dismal when the scale efficiency is taken into consideration. Only two universities out of the total sample of twenty are on the frontier in comparison to five universities based on the VRS efficiency.

Keywords: DEA, Saudi government universities, technical and scale efficiency

INTRODUCTION

In Saudi Arabia the higher education sector has seen great strides in the past few years (Alamri, 2011; Alebaikan and Troudi, 2010). Enormous development plans were implemented by Ministry of Higher Education (MOHE), Saudi Arabia covering entire spectrum of the educational process successfully applied oin accordance to population density in 13 mintaqah idariyya or regions. The number of universities has increased from 20 in 2005 (15 of which were public and five were private) to 33 universities in the Kingdom in 2012 (24 of which were public and eight were private).

A large number of education promotion programs are in progress. For instance, in 2005, Ministry of Higher Education started a scholarship program to meet the requirements of trained human resources for Saudi markets and to fill the gap of competent faculty shortage in Saudi universities. This program attracted more than 70,000 students studying all over the world at baccalaureate, master and doctoral level (Alamri, 2011). Another program started in 2010 sponsors Saudi students for studying in private universities in the Kingdom. For further details of this rapid growth in higher education in KSA see Alamri (2011). Notwithstanding the tremendous growth, Alebaikan and Troudi (2010) noted that the capacity of universities and colleges in Saudi Arabia is limited compared with the rapid growth of students applying for higher education.

The rapid growth, however, also brings challenges to the universities. The influx of resources in HE sector requires managing the university performance and increasing efficiency. Performance management of the universities is important for acquisition of further resources, internal improvement, to maintain adequate supply of competent human resources to Saudi market and to meet the demands of relevant stakeholders including government, funders, industry, market, students, faculty, university management and accreditation and professional bodies, etc. This study is one step in this direction. Its purpose is to make use of the Data Envelopment Analysis (DEA) to compare the efficiency of Saudi government universities.

DEA is useful in investigating the efficiency of universities in transforming multiple inputs into multiple outputs. The technique can help in determining configurations of inputs that can result in higher outputs without necessarily increasing the use of resources (Avkiran, 2001). The technique also points to the potential improvements in inputs and outputs to improve the efficiency. The objective of this study is to demonstrate the measurement of technical and scale efficiency of government universities in Saudi Arabia. This is of particular interest to different stakeholders that includes policy makers, funders, future students, industry looking for collaboration opportunities, faculty and administrators. Essentially, our objective is to demonstrate a process rather than seeking the ranking of universities.

This study's key contribution is to present a framework for measuring the efficiencies of universities in Saudi Arabia. It also highlights the identification of robust measures given the numerous potential inputs and outputs for measuring efficiency in a particular context.

CONCEPTUAL FRAMEWORK

Data envelopment analysis: Data Envelopment Analysis (DEA) was first proposed by Charnes *et al*.

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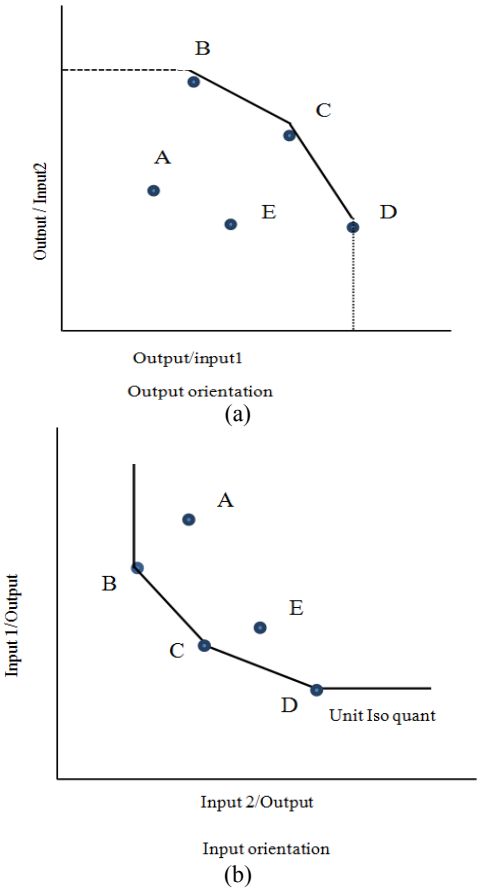

Fig. 1: Input and output orientation

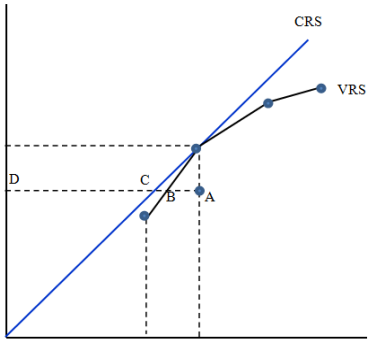

Fig. 2: CRS and VRS and different types of efficiencies

(1978) as a performance measurement technique. It is an application of linear programming to measure the relative efficiency of units with same goals and objectives (Anderson *et al*., 2007; Cooper *et al*., 2006). The entities whose performance is to be measured are called Decision Making Units (DMUs). There are two types of orientations of DEA analysis, i.e., input orientation and output orientation. The former is about reducing inputs as much as possible without dropping the output levels while the latter is about raising productivity without increasing the resource base. The two concepts are explained in Fig. 1.

Figure 1a shows output-orientation mode of the DEA which is concerned with output maximization, i.e., maximizing output using given inputs. There are two types of outputs X and Y from input Z. The ratios of outputs/input are drawn for five data points. Three BMUs B, C and D make the efficient frontier depicted by a solid line that represents achieved efficiency. The DMUs A and E, on the other hand, are not efficient since they need to increase their outputs to reach the efficient frontier. The efficient frontier envelops all other data points, therefore, giving rise to the name, data envelopment analysis. Figure 1b shows the input-orientation mode of the DEA which is about input minimization, for example achieving efficiencies using minimum resources. The ratios of inputs/output are drawn for five data points. The efficient frontier in this case is depicted by an iso quant line linking points B, C and D. The points A and E, on the other hand, are not efficient since they could achieve the output using the same level of inputs as those on the efficient frontier.

Constant returns to scale and variable returns to scale: The DEA analysis provides two options, i.e., Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS). CRS assumes that there is no significant relationship between the scale of operations and efficiency. If inputs are increased or decreased, outputs will change by the same proportions (if inputs are doubled, output will also be doubled). CRS represents an ideal condition. Using this option, input minimization and output maximization produce the same relative efficiency scores, provided all inputs are controllable. Variable Returns to Scale (VRS), on the other hand, mean that if inputs are changed, outputs will not change by the same proportions (if inputs are doubled, outputs will not be doubled). If a significant correlation between DMU size and efficiency is demonstrable, then VRS is preferred. This is shown in Fig. 2.

Types of efficiencies: In using CRS we assume that DMU operates at optimal scale. However, inefficiencies may arise because of DMUs size (scale) or other factors such as managerial practices. To determine the sources of inefficiencies VRS is conducted. The CRS efficiency scores represent technical efficiency. A DMU may not attain its optimal size due to market imperfections. Thus, a measure of technical efficiency would generally include scale efficiency apart from other factors. In Fig. 2, point A corresponds to the DMU being evaluated. By and large technical and scale efficiency is measured by the ratio DC/DA, by comparing it with point *A* to point *C*, which reflects the average productivity achievable at the most productive scale size. The pure technical efficiency of *A* is measured by the ratio DB/DA by comparing it with point *B* on the efficient production frontier with the same scale size as

A. Pure technical inefficiency, therefore, represents deviation from best practice management. Finally, the scale efficiency of *A* is measured by the ratio DC/DB, so that the overall technical and scale efficiency DC/DA is equal to the production of the technical efficiency DB/DA and the scale efficiency DC/DB. VRS allows technical efficiency, to be calculated without the influence of scale efficiencies.

In the perspective of HEI, TE implies that a university cannot deliver more given the existing level of inputs including faculty, infrastructure, capital, etc. Given the limited resources available to a HEI and demands for high quality education and research, TE provides a strong measure of the efficiency of universities. Abbott and Doucouliagos (2003) noted that "next to the delivery of quality education, technical efficiency is probably the only valid measure of performance of tertiary institutions". A HEI may have technical efficiency but may be using relatively more inputs. This information is derived from scale efficiency. For instance, point B in Fig. 2 lies on the efficient frontier, is technically efficient but consumes relatively more inputs. Scale efficiency measures the extent to which a HEI can take advantage of returns to scale by changing its size toward the optimal size-the CRS line (Abbott and Doucouliagos, 2003).

After VRS is completed and scale efficiency scores are computed, the analysis can advance to

Table 1: An illustrative list of inputs and outputs in universities for measuring efficiency

Measure	Description	Limitations (if any)	References
Examples of inputs			
Total number of faculty	Number of faculty is a critical resource that determines the efficiency of a university.	N/A	Abbott and Doucouliagos (2003), Leitner *et al*. (2007) and McMillan and Datta (1998)
Percentage faculty with doctorates	This input is an important determinant of research and teaching efficiencies of universities.	N/A	Avkiran (2001) and Breu and Raab (1994)
Number of support staff	Non-academic staff generally facilitates teaching and research processes of a university.	N/A	Abbott and Doucouliagos (2003), Leitner *et al*. (2007) and McMillan and Datta (1998)
Operating expenditures (including student services, libraries, computers, equipment and supplies, maintenance, buildings etc.)	These resources are required to promote quality of teaching and research. They make the overall infrastructure required for core academic processes of a university.	N/A	Abbott and Doucouliagos (2003), Leitner *et al*. (2007) and McMillan and Datta (1998)
Total expenditures	Operating expenditures and faculty salaries constitute a critical input in HE.	N/A	To study cost efficiency, a single input, total expenditures (i.e., other expenditures plus faculty salaries), is utilized (McMillan and Datta, 1998)
Examples of outputs			
Research publications	Commonly used means for determine research efficiency of universities.	N/A	Koksal and Nalcaci (2006), Leitner *et al*. (2007) and McMillan and Datta (1998)
Number of Equal Full Time Students (EFTS)	EFTS is a measure of teaching output.	N/A	Abbott and Doucouliagos (2003), Koksal and Nalcaci (2006) and McMillan and Datta (1998)
Research projects secured	Research projects reflect the research efficiency of a university.	N/A	Koksal and Nalcaci (2006), Leitner *et al*. (2007)
Research grants	Reflect the market value of the research.	Grants are criticized since they are spent not only on research but also on other facilities which are input into research and teaching. Their inclusion could be a duplication of count.	Abbott and Doucouliagos (2003)
Student credit hours	Student credit hours reflect teaching output.	Credit hours vary from one program to another. Students with lab work may have more credits than, for instance, humanities subjects. Overall, it is a weak measure and is applicable only if similar programs are compared.	McMillan and Datta (1998)
Number of graduates/degrees awarded	This measure reflects teaching output.	This measure does not count those who attend but do not graduate, nor does it consider the length of degree programs. It can be applicable if similar programs are compared.	Avkiran (2001), Koksal and Nalcaci (2006) and McMillan and Datta (1998)
Number of patents, monographs	These measures reflect research output.	N/A	Koksal and Nalcaci (2006) and Leitner *et al*. (2007)
Number of examinations; number of supervised theses	These measures reflect teaching output.	N/A	Koksal and Nalcaci (2006) and Leitner *et al*. (2007)

compute increasing or decreasing returns to scale. DEA is carried out with Non-Increasing Returns to Scale (NIRS). It implies CRS or DRS. So if under VRS conditions, efficiency scores equal NIRS score, then it implies the DMU operates under DRS. On the other hand, if the score under VRS is not equal to NIRS, then the unit is operating under IRS. These procedures are automated in DEA software's (Avkiran, 2001).

Selection of inputs and outputs in Higher Education Institutions (HEI): The appropriate selection of inputs and outputs is the critical part of the DEA. Those outputs should be selected that are critical to the performance of the DMU and the resources should support the key outcomes. As a rule of thumb, the number of observations in the data set should be at least three times the sum of the number of input and output variables (Cooper *et al*., 2006). In case of HEI, a number of inputs are possible for DEA analysis including faculty, support staff, library, student service, computers, supplies, equipment etc. These inputs can be described in terms of expenditures (McMillan and Datta, 1998). Some examples of inputs and outputs are provided in Table 1.

The measures of input and output provided in Table 1 are only illustrative. Numerous other measures are also possible. For example, space of a university and office hours of faculty could make input in the DEA. Similar industry-academia collaboration can also constitute an output in DEA (Leitner *et al*., 2007). The selection of inputs and outputs for a particular research would be determined by the objective of a research. Availability of data about a particular measure is another determinant in the selection of inputs and outputs.

RESEARCH DESIGN

Data and sample: In our study we assess the relative efficiency of a set of universities in Saudi Arabia in 2012. Specifically, we use data for 20 public or government universities which are listed in Table 2 alongside their code.

Measures of inputs and outputs used: As noted earlier, that selection of inputs and outputs needs to be carried out carefully. This is because many measures may have certain limitations. For example, as noted in Table 1, 'research grants', 'student credit hours' and 'number of graduates' or 'degrees awarded' are weak measures of output. Such limitations combined with unavailability of relevant data determine the set of inputs and outputs.

Table 3 provides the measures of inputs and outputs used in this study. In this study we use an innovative output measure in terms of 'virtual impact' due to the importance of web presence of HEIs. We compute the virtual impact based on the definition provided by webometrics, a web portal for ranking universities globally.

Table 2: Sample of government universities in KSA

S.N.	Academic institution	Code
1	Umm Al-Qura University	UQU
2	Al-Imam Mohammad Ibn Saud Islamic University	IMSU
3	King Saud University	KSU
4	King Abdulaziz University	KAU
5	King Fahd University of Petroleum and Minerals	KFUPM
6	King Faisal University	KFU
7	King Khalid University	KKU
8	Qassim University	QU
9	Taibah University	TYU
10	Taif University	TAU
11	Jazan University	JU
12	University of Ha'il	UH
13	Al Jouf University	JU
14	University of Tabuk	UT
15	Al Baha University	BU
16	Najran University	NU
17	Princess Nora bint Abdulrahman University	PNU
18	Northern Borders University	NBU
19	Salman bin Abdulaziz University	SAU
20	University of Dammam	UD

Table 3: Measures of input and output used

Inputs	Outputs
I1-total number of faculty	O1-research publications (based on number of articles produced by faculty members during the year 2012-13)
I2-percentage faculty with doctorate	O2-number of equal full time students
I3-operating budget (in million SAR)	O3-virtual impact (based on link visibility data is collected from the majestic SEO website

Selecting analysis options in DEA: Charnes *et al*. (1978) extended Farrell (1957) piecewise-linear convex hull approach to frontier estimation by expanding multiple inputs and single output to multiple inputs and multiple outputs and utilized linear combination to convert it to single virtual input and output. Their model assumed Constant Returns to Scale (CRS) to measure the relative efficiency of each DMU which is between 0 and 1 and can determine whether a DMU is in constant, increasing or decreasing returns to scale. However, in order to accommodate more specific needs, Banker, Charnes *et al*. (1984) modified the CCR model to produce a DEA model under the assumption of variable returns-to-scale (VRS; i.e., increasing, decreasing and constant returns-to-scale). This BCC model exhibits some or all of the attributes of VRS and allows for the determination of technical inefficiency (i.e., waste) and scale inefficiency (i.e., increasing or decreasing returns-to-scale).

For this study, it cannot be assumed that the HEIs are operating at optimal scale. Thus, in order to

accommodate the possibility of VRS, the BCC model was used to determine TE for each DMU. However, in order to obtain as much information as possible from the DEA analysis, TE was also determined under CRS using the CCR model.

When carrying out DEA analysis an option has to be made between variable returns and constant returns to scale. Under constant returns to scale the relationship between the scale of operations and efficiency is assumed to be constant. In other words, in the transformation of inputs to outputs larger universities are not more efficient than their smaller counter parts.

On the other hand, under variable returns to scale an increase in inputs results in a disproportionate increase in their outputs, for instance, due to decreasing marginal returns. For all our specifications we report in the paper both set of results but we will centre our analysis on the variable returns to scale efficiency scores.

TECHNICAL AND SCALE EFFICIENCY IN SAUDI UNIVERSITIES

We use different blends inputs and outputs while performing the DEA analysis; including a three- input and three-output model. This is important since the choice of inputs and outputs can influence the ranking of efficiency scores. Figure 3 and table 4 present the efficiency scores for sample of public universities with two outputs, i.e., research publications measured as number of articles produced by faculty members for the period January 2012 to June 2013 using Google scholar and virtual impact as a proxy for institutional prestige and with all the three inputs, i.e., results relate to DEA with input orientation, allowing for Variable Returns to Scale (VRS) so as to estimate scale efficiency.

In general, the technical efficiency of government or public universities in Saudi Arabia appear to be high, ranges between 56 to 100%. Nevertheless, it does not mean that there is no possibility for improvement in efficiency. Nor can it be concluded that the government universities are efficient when compared to universities elsewhere.

When the scale efficiency is taken into consideration majority of public universities relative performance is a dismal. Only two universities (i.e., KSU and KFUPM) out of the total sample of twenty are on the frontier in comparison to five universities (i.e., KSU, KAU, KFUPM, NU and NBU) based on the VRS efficiency.

Concerning NU-Najran University and NBU-Northern Borders University being on the frontier with the input-oriented VRS efficiency results seems to be apprehensive; as these two universities are established in the year 2006 and 2007, respectively.

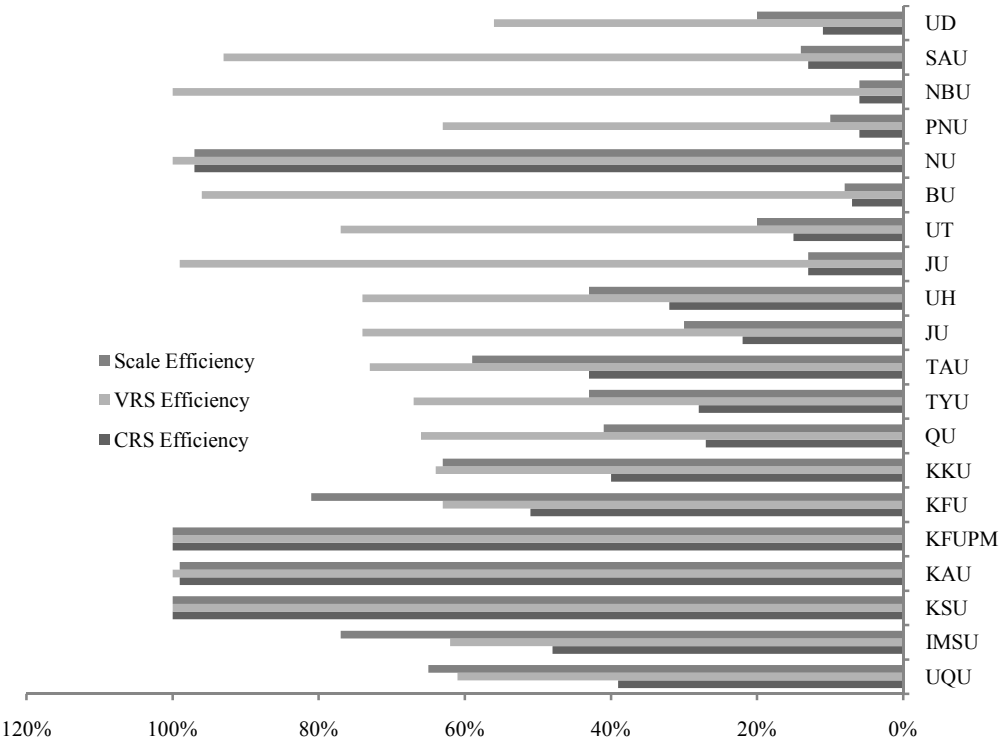

Fig. 3: Technical and scale efficiency scores for government universities in Saudi Arabia

Table 4: Technical and scale efficiency scores for government universities in Saudi Arabia

DMU No.	DMU name	CRS efficiency (%)	Rank	VRS efficiency (%)	Rank	Scale efficiency (%)	Rank
1	UQU	39	9	61	19	65	7
2	IMSU	48	6	62	18	77	6
3	KSU	100	1	100	1	100	1
4	KAU	99	3	100	1	99	3
5	KFUPM	100	1	100	1	100	1
6	KFU	51	5	63	16	81	5
7	KKU	40	8	64	15	63	8
8	QU	27	12	66	14	41	12
9	TYU	28	11	67	13	43	11
10	TAU	43	7	73	12	59	9
11	JU	22	13	74	10	30	13
12	UH	32	10	74	11	43	10
13	JU	13	16	99	6	13	17
14	UT	15	14	77	9	20	15
15	BU	7	18	96	7	8	19
16	NU	97	4	100	1	97	4
17	PNU	6	20	63	17	10	18
18	NBU	6	19	100	1	6	20
19	SAU	13	15	93	8	14	16
20	UD	11	17	56	20	20	14

Table 5: Distribution of technical and scale efficiency scores

Efficiency interval	Technical efficiency (%)	Scale efficiency (%)
0<0.60	05	60
0.60<0.80	55	15
0.80<0.90	0	05
0.90<0.95	05	0
0.95-1.00	35	20

Table 5 shows the distribution of the technical and scale efficiency scores for the sample of public universities. The proportions of universities falling within the specified efficiency score intervals are illustrated in this table.

As regards technical efficiency, it may be possible for universities which are below the efficiency interval of 0.80 to catch up with what is best practice with relatively little innovation and good governance. On the other hand, there is also scope for improving performance for universities which are on the frontier and/or universities with efficiency intervals above 0.9. It may be possible for them to expand the frontier with new technological adoption.

CONCLUSION

Universities play a vital role in human capital formation. Governments believe them to play an essential role in boosting the economy and thus they take a bigger share of taxpayers' money. Moreover, the influx of resources in education sector requires managing the university performance and increasing efficiency. In this study, DEA was used to assess the relative technical efficiency and scale efficiency for public universities in Saudi Arabia.

The technical efficiency results suggest that the Saudi Arabian public universities are working at a moderately high level of efficiency relative to each other, while still there is room for improvement in many universities. High relative efficiency scores do not imply excellence. Using innovation, better management and utilization of resources, inefficient DMUs may catch up the best performer.

Further research is desirable into the Saudi Arabian university system with private universities mushrooming these days. Efficiency being a static concept, a panel data can be used to shed light on changes in efficiency over time, as well as total factor productivity and technical change.

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