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Measuring the Efficiency of Knowledge Output at Saudi Public Universities: An Application of Data Envelopment Analysis

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Abstract

The aim of this research was to measure the relative efficiency of knowledge output at Saudi public universities via data envelopment analysis. A performance assessment of 28 Saudi public universities was conducted using constant returns to scale (CRS) and variable returns to scale (VRS) models. The models were designed to include five variables: three input variables (enrolled students; faculty members; and administrators and technicians) and two knowledge output variables (research publications in journals with an impact factor and indexed in the Institute for Scientific Information (ISI) Web of Knowledge; and the number of graduates in the previous year). Data were analysed for the 2019/2020 academic year, a period significantly impacted by the COVID-19 pandemic. The results revealed that 82% of the studied universities were inefficient in using their resources. The CRS model produced an average score of 0.769, with 76% of the universities achieving efficiency at their output level during the selected academic year. The VRS model produced an average efficiency score of 0.888 under variable returns to scale. The results also indicated that some of the institutions had become so inefficient that they were not fit to serve as benchmarks for others. These findings highlight the need to examine how policy modifications and higher education governance affect the knowledge output efficiency of universities and how efficiently universities perform in general.

Keywords: Data Envelopment Analysis, Constant Returns to Scale, Variable Returns to Scale, Saudi Public Universities.

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1. Introduction

Knowledge output at universities involves knowledge production (research), knowledge transfer (teaching and producing graduates) and knowledge use (community service) (Al-Amin & Gazar, 2020; Ferro & D'Elia, 2020), and governments evaluate and produce reports on the performance of their education sectors to ensure that allocated budgets are effectively used (Berbegal-Mirabent, 2018; Johnes et al., 2017; Salerno, 2003). However, this type of evaluation tends to result in aggregation analyses, with educational institutions grouped together rather than analysed individually. In addition, governmental reports on universities sometimes overlook generated knowledge outputs (Berbegal-Mirabent, 2018).

Universities represent a nation's conscience and are the backbone of development and economic growth, which are important pillars of the Kingdom of Saudi Arabia's 2030 vision (Saudi Vision 2030, n.d.). The outcomes of international and regional conferences and colloquies have confirmed that enhancing the educational system is a key factor in raising productivity in the long term and must be included in national visions, such as the Global Education Summit programme. In Saudi Arabia, education is the cornerstone of development and progress(Maspul, 2024). This has resulted in the Kingdom working energetically to diversify its education sector, not only quantitatively and qualitatively but also theoretically, practically, politically and pedagogically. Consequently, the development of higher education is no longer optional but necessary to respond to today's challenges such as technological revolutions, evolving work and employment patterns and sustainable development demands. It must constantly be reviewed—in terms of its philosophy, systems, methods and, primarily, internal and external competence—to ensure that it is a future-aligned and forward-looking component of an educational system that contributes to the industrial sector and shapes the future (Alexander, 2000; Altbach et al., 2019).

In 2024, the Saudi government allocated SAR 195 billion to meet these demands (Ministry of Finance, 2024).

Despite the achievement of multiple and diverse educational goals, including increasing the number of universities, the enrolment rate and the number of qualified teachers and staff, further efforts are required to build a modern educational system that can respond to local and global changes and provide students with the necessary skills to thrive in n today's knowledge-driven, information-rich, and technologically advanced era. The impact of the Fourth Industrial Revolution on education has led to calls for a reassessment of the quality of education provided in educational and vocational institutions. Scholars suggest that the Fourth Industrial Revolution will lead to create new disciplines in the labour market and, consequently, in the education sector, where teachers play an essential role in preparing students for new types of jobs (Azmi, 2019, p. 67; Nwosu et al., 2023; Alalwani & Alharbi, 2025). Since educational transformations accelerate, the education sector face increasing pressure to adapt; therefore, identifying the factors that enhance the effectiveness of education has become a social necessity.

The productive efficiency of an organisation or institution is indicative of its proper use of available allocated resources and capabilities and the extent to which they are commensurate with its outputs (Alatawi et al., 2020). Brdesee's (2021) review revealed a scarcity of information about the efficiency and productivity of educational systems in the Saudi context; to the best of the researcher's knowledge, only three studies have evaluated the efficiency and productivity of Saudi universities, each using different methods, data collection periods and variables. Al-Mutairi and Al-Shami (2015) assessed the research productivity of 25 universities (but only in the science fields) over a 25-year period (1988–2013) using regression equation analyses. They found that six Saudi universities contributed 82% of the publications listed in the Scopus database, while the remaining 19 universities accounted for only 18%. Another study, which focused on the efficiency of 25 universities, used data envelopment analysis (DEA) with faculty and administrators as input variables and the number of entrants, enrollees and graduates as output variables (Alabdulmenem, 2017). It was found that most of the studied public universities used their resources efficiently while some did not. Similarly, Albar (2023) measured the effective performance of 27 Saudi universities using data spanning 2010–2015. Four factors (general, budget, academic staff and non-academic staff) were used to assess significant outputs, including enrolled and graduated students. The efficiency of these universities increased in some cases and decreased in others. These studies indicate an urgent need to further study the efficiency and productivity of Saudi educational systems to ensure that they enable learners to cope with the current era's requirements and complexities, conform to its basic features and adapt to its diverse and rapidly changing variables (Albar, 2023; Brdesee, 2021; Conole, 2012; Sarrico et al., 2010).

In this study, the performance of 28 Saudi public universities was assessed using two models: constant returns to scale (CRS) and variable returns to scale (VRS). The input variables were enrolled students; faculty members; and administrators and technicians. The output variables were research publications in journals with an impact factor indexed in the Institute for Scientific Information (ISI) network and graduates of the previous year. Data from the 2019–2020 academic year were used for the analysis. The research questions addressed in this study are as follows:

1. When CRS and VRS models are used, what is the degree of efficiency of selected Saudi public universities in terms of knowledge output variables (i.e. research publications and graduates)?
2. What are the requirements for improving efficiency in Saudi public universities that have not achieved optimal efficiency?

2. Theoretical Framework :

Many researchers have attempted to define and study productive efficiency measures for institutions, with most relying on the use of multiple mathematical and statistical formulas, including ratio analysis, the least squares method and stochastic frontier analysis (Titus et al., 2017; Witte & López-Torres, 2017). In the field of education, some methodological measurements have emerged, particularly in the context of the deepening of education economics studies. For instance, simple correlation methods have been used to study the relationship between education and economic growth, benefit–cost analyses are performed, and many qualitative and quantitative measures of educational outputs have been developed based on traditional methods. Other methods, such as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), have been developed to measure and evaluate institutional performance efficiency. Comparative benchmarks and indicators have been devised to determine the overall success and adequacy of educational, service or productive institutions in investing their available resources to achieve high operating competitiveness levels (Hsiao et al., 2024).

The relative efficiency index is a performance assessment tool that includes economic and effectiveness

indicators and is used to improve the efficiency of administrative units (Avkiran, 2001). According to Cooper et al. (2006), such efficiency can be measured and expressed as a percentage by comparing weighted outputs and inputs. Farrell (1957) concluded that it was possible to determine the efficiency of a single input and output without forming any hypotheses related to the production function formula. Later, Charnes et al. (1978) generalised this notion by developing a method for measuring the efficiency of a system with multiple and varied inputs. This method – DEA – is now one of the most common methods used when analysing the efficiency of governmental organisations (Ji & Lee, 2010). It has been used in data routing studies to assess the technical efficiency of a group of similar entities or decision-making units (Bhagavath, 2006) and is classified within operations research or linear mathematical programming. DEA is named as such because administratively efficient units remain in the foreground and surround (encapsulate) inefficient administrative units. Thus, it is used to analyse data encapsulated by efficient units (Tone & Sahoo, 2003).

DEA is considered a quantitative methodology that is used for the comparative measurement, performance evaluation and relative efficiency measurement of several organisational units (e.g. capacity to reach goals and level of work activity) and is dependent on the acquisition of accurate quantitative data for each unit's inputs and outputs. The general objective of performing DEA is to implement best practices to maximise outputs, reduce inputs and efficiently achieve the organisational units' objectives (Bevilacqua & Braglia, 2002). With reference to the above definition, it is necessary to include administrative units or so-called decision-making units in a DEA. Such units work within the same field or perform the same function – for example, universities, banks, hospitals or their branches. The relative efficiency of each of these units is measured and compared to the remaining units within a group. These administrative units use the same set of inputs and outputs, and the general objective is to maximise the quantitative outputs of the units or reduce their quantitative inputs (Cooper et al., 2006).

Among the numerous DEA models, there are two main basic types: the Charnes, Cooper and Rhodes model and the Banker, Charnes and Cooper model (El-Razik, 2014). They differ in their returns to scale approach.

In CRS models, quantitative changes in the inputs of an inefficient unit have a constant effect on the quantity of services produced (outputs). This is known as 'constant return on production', and it is only appropriate to measure this property when all comparable units are working at their optimal size. However, there are some obstacles that may prevent units from achieving optimal size, such as incomplete competition and funding restrictions (Kao, 2016).

The first VRS model was developed by Banker et al. (1984). Unlike CRS models, VRS models distinguish between two types of efficiency: technical and volumetric. VRS models are used when the percentage increase in the outputs is greater than that of the inputs, which is called 'increased returns to scale'. They are also used when the percentage increase in the outputs is less than that of the inputs, known as 'decreasing returns to scale'. As mentioned above, when the outputs increase at the same rate as the inputs, a CRS occurs.

A third type of model has also been developed: The macro model combines the characteristics of the input- and output-oriented models (Liu et al., 2010) with a parametric efficiency curve. Input-oriented models infer that inefficient units will become efficient if they reduce their inputs while maintaining the same level of production, while output-oriented models infer that inefficient units will increase their quantitative outputs while maintaining the same level of input. In contrast, macro models infer that inefficient economic units will become efficient if there is a simultaneous reduction in inputs and an increase in outputs (Dinc & Haynes, 1999).

The fixed weights of the inputs and outputs are considered unknown or predetermined, and they are not the same for all units but are calculated during the estimation process to fit the relevant unit. This distinctive feature of DEA enables objectivity, particularly when estimating the improvements required by inefficient units. DEA allows for multiple inputs and outputs, which can be expressed using different measurement units. It also allows for non-compliance with the type of data used or the relationship between these data, as in the case of regression techniques (in which the input and output can be quantitative and qualitative) (Kao & Hung, 2005).

3. Methodology

In this study, the performance of 28 Saudi public universities were assessed using the CRS and VRS models. Table 1 shows the universities and the input and output data. Five variables were examined: three input variables (enrolled students, faculty members and administrators and technicians) and two knowledge output variables (research publications in journals with an impact factor indexed in the Institute for Scientific Information (ISI)

Web of Knowledge and graduates of the previous year). Data from the 2019–2020 academic year were used in this study. The COVID-19 pandemic period was chosen as a case study to assess the knowledge output of Saudi Arabian universities. This gave researchers a unique opportunity to evaluate the universities' effectiveness and responsiveness during a historic disruption in global education systems and to gain valuable insights into how these universities enhanced their resilience and adaptability, particularly for dealing with similar disruptions in the future.

The xlDEA program was employed to calculate the relative efficiency of the studied universities using the CRS and VRS models and to calculate their size efficiency using an output-oriented approach.

The efficiency index for each university was calculated as the sum of the weighted outputs divided by the total weighted inputs, and the weights were estimated either objectively or non-objectively. In DEA methodology, certain weights are assumed in view of what efficiency is required for both the value-weighed unit and the unit's value in the selected sample. In this study, output-oriented CRS and VRS models were employed in measuring the relative efficiency of the universities' academic work to ultimately improve the inputs-to-outputs ratio.

Table 1. Data Envelopment Analysis Inputs and Outputs for Saudi Public Universities

University	Inputs			Outputs	
	Administrators and technicians	Faculty members	Enrolled students	Previous year graduates	Research publications in indexed journals with an impact factor
Umm Al-Qura University	2,625	4,906	105,531	14,946	479
Islamic University	1,396	949	15,461	2,506	83
Imam Muhammad ibn Saud Islamic University	4,503	3,874	176,488	13,441	278
King Saud University	13,504	7,159	62,771	7,273	4,271
King Abdulaziz University	6,739	7,527	145,751	21,739	3,977
King Fahd University of Petroleum and Minerals	2,081	1,089	12,550	942	1,392
King Faisal University	1,542	2,214	103,059	19,594	460
King Khalid University	2,605	3,494	62,198	9,355	1,220
Qassim University	4,099	4,028	71,216	9,238	516
Taibah University	3,013	3,159	69,357	9,276	804

University	Inputs			Outputs	
	Administrators and technicians	Faculty members	Enrolled students	Previous year graduates	Research publications in indexed journals with an impact factor
University of Taif	1,400	2,780	61,706	10,595	385
King Saud bin Abdulaziz University for Health Sciences	2,816	1,131	12,671	760	526
Jazan University	1,770	3,471	60,570	8,981	351
Hail University	1,030	1,972	34,684	3,443	205
Al-Jouf University	1,005	1,655	26,774	3,794	388
Tabuk University	1,100	1,759	37,230	6,186	342
Al-Baha University	882	1,670	22,939	3,850	103
Najran University	695	1,535	19,433	1,944	152
Princess Nourah bint Abdulrahman University	5,162	2,151	39,119	7,904	301
Northern Border University	671	1,000	25,405	2,230	160
Shaqra University	1,055	1,691	31,331	6,110	207
Prince Sattam bin Abdulaziz University	1,841	2,190	28,961	4,397	580
Imam Abdulrahman bin Faisal University	3,961	3,372	37,930	5,846	795
Al-Majma'ah University	2,132	1,412	21,030	3,022	348
Saudi Electronic University	778	543	25,645	570	55
University of Jeddah	714	1,521	23,391	1,404	553
Bisha University	522	1,128	16,987	2,843	107

University	Inputs			Outputs	
	Administrators and technicians	Faculty members	Enrolled students	Previous year graduates	Research publications in indexed journals with an impact factor
University of Hafr Al Batin	422	780	21,513	1,851	80

Note. Source: General Authority for Statistics in Saudi Arabia; Statistical Yearbook 2019

4. Results

The descriptive statistics associated with the inputs and outputs for the 28 Saudi public universities during the 2019–2020 academic year are presented in Table 2. Notably, all the variables were approximately average values, with some variation within the efficiency scores. Therefore, it was necessary to perform a correction to identify the highly interrelated variables.

Table 2. Descriptive Statistics for the 28 Saudi Public Universities

Variable	Mean	Standard Deviation	Minimum	Maximum
Inputs				
Enrolled students	48989.3214	40696.66976	12550.00	176,488
Faculty members	2505.7143	1760.06342	543	7,527
Administrators and technicians	2502.2500	2666.05395	422.00	13504.00
Outputs				
Research publications in indexed journals with an impact factor	682.7857	1024.42455	55.00	4271.00
Previous year graduates	6572.8571	5536.68036	570	21,739

Table 3 shows the correlation coefficients of the study variables. Clearly, there was a strong direct correlation between most of the study variables (inputs and outputs), mainly between enrolled students and faculty members (0.9741) and between enrolled students and research publications (0.9516). This indicated that our careful selection of each of the inputs and outputs resulted in the inclusion of appropriate variables. Although most relationships were strong, the correlation between enrolled students and previous year graduates (0.60) was relatively weak. Overall, the clear relationships between the inputs and outputs suggested that the teaching efficiency of each of the studied universities was properly represented.

Table 3. Correlation Coefficients of the Study Variables

Variable	Enrolled students	Faculty members	Administrators and technicians	Research publications in indexed journals with an impact factor	Previous year graduates
Enrolled students	1.000				
Faculty members	0.9741	1.000			
Administrators and technicians	0.899	0.71099	1.000		
Research publications in indexed journals with an impact factor	0.9516	0.791	0.778	1.000	
Previous year graduates	0.60	0.733	0.8158	0.8124	1.000

We then addressed the first research question: When CRS and VRS models are used, what is the degree of efficiency of selected Saudi public universities in terms of knowledge output variables (i.e. research and graduates)?

Table 4 presents the efficiency results of the CRS and VRS models. When the CRS model was used, the average efficiency rate for public universities in Saudi Arabia was 0.769. When the VRS model was used, the rate was 0.888. These results indicate that there was a 0.231 increase in the outputs when the CRS model was used and a 0.112 increase when the VRS model was used, assuming that the input levels exceeded the available ratios. Among the 28 universities, five (17.8%) used their inputs optimally (achieved the condition of $3 < 0$) and were deemed efficient: King Fahd University of Petroleum and Minerals, King Faisal University, Princess Nourah bint Abdulrahman University, Shaqra University and Jeddah University. In each case, the relative efficiency value was equal to one integer in the CRS and VRS models. With a value of 0.174, Saudi Electronic University was the least efficient institution.

CRS and VRS models provide significant information for assessing the efficiency of universities. The VRS model found six universities (21.4%) to be efficient: Islamic University, King Saud University, King Abdulaziz University, Saudi Electronic University, Bisha University and University of Hafr Al Batin. On the other hand, the CRS model identified 17 universities (60.71%) as inefficient. Among the inefficient universities, six (35.2%) achieved high relative efficiency (0.989–0.997): Umm Al-Qura University, King Abdulaziz University, Taif University, Jazan University, Prince Sattam bin Abdulaziz University and Imam Abdulrahman Al-Faisal University. The following five universities did not achieve high or complete relative efficiency: King Fahd University of Petroleum and Minerals, King Faisal University, Princess Nourah bint Abdulrahman University, Shaqra University and Jeddah University. These results indicate that the CRS and VRS models are both effective for assessing the efficiency of universities and identifying the factors that can be addressed to improve efficiency.

Table 4 also shows that the returns to scale value was low for eight universities (28.5%). Hence, these universities must increase their outputs relative to their inputs (i.e. the number of employees, professors or students) to improve efficiency. The returns to scale value was high for 15 universities (53.5%), meaning that they should continue to expand their outputs relative to their inputs to maintain efficiency.

To verify these results, we performed DEA using only two variables (graduates from and enrolled students at the same university). The results showed that both the University of Computer and Information Sciences and the University of Applied Medical Sciences were fully efficient when the VRS model was used.

We then addressed the second research question: What are the requirements for improving efficiency in Saudi public universities that have not achieved optimal efficiency? To answer this question, we calculated the efficiency of each university using CRS and VRS output-oriented models. The results are shown in Table 5. It was found that five universities (17.8%) had achieved maximum efficiency based on the resources available to them and that 23 universities (82%) had not achieved efficiency.

Table 4. Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) Efficiency Indicators for Saudi Public Universities

University	Crste	Vrste	Scale	Yield Size	Peers	Peer Count
Umm Al-Qura University	0.989	0.747	0.739	Drs	19 6 7 21	0
Islamic University	0.814	1.000	0.814	Irs	6 7 19 21 26	4
Imam Muhammad ibn Saud Islamic University	0.918	0.436	0.400	Irs	7 2	0
King Saud University	0.944	1.000	0.944	Drs	6 7 19 21 26	1
King Abdulaziz University	0.989	1.000	0.989	Drs	6 7 19 21 26	1
King Fahd University of Petroleum and Minerals	1.000	1.000	1.000	-	6	15
King Faisal University	1.000	1.000	1.000	-	7	12
King Khalid University	0.984	0.891	0.877	Drs	4 5 7 6	0
Qassim University	0.984	0.687	0.676	Drs	21 19 6 7	0
Taibah University	0.988	0.743	0.734	Drs	19 6 7 21	0
University of Taif	0.997	0.909	0.906	Irs	21 6 7 27	0
King Saud bin Abdulaziz University for Health Sciences	0.530	0.990	0.525	Irs	6	0
Jazan University	0.995	0.778	0.774	Drs	19 6 7 21	0
Hail University	0.864	0.619	0.535	Irs	6 27 7 26	0
Al-Jouf University	0.906	0.885	0.801	Irs	7 27 6 26	0
Tabuk University	0.970	0.918	0.890	Irs	16 21 27 6 7	0
Al-Baha University	0.921	0.933	0.859	Irs	21 2 27	0
Najran University	0.635	0.863	0.548	Irs	6 27	0
Princess Nourah bint Abdulrahman University	1.000	1.000	1.000	-	7	7
Northern Border University	0.573	0.860	0.493	Irs	7 27 2 28 6	0
Shaqra University	1.000	1.000	1.000	-	21	9
Prince Sattam bin Abdulaziz University	0.995	0.864	0.860	Irs	21 19 6 27	0
Imam Abdulrahman bin Faisal University	0.992	0.869	0.862	Drs	19 6 7 21	0
Al-Majma'ah University	0.898	0.876	0.787	Irs	6 19 27 2	0
Saudi Electronic University	0.174	1.000	0.468	Irs	6 7 19 21 26	1
University of Jeddah	1.000	1.000	1.000	-	6 7 19 21 26	2
Bisha University	0.869	1.000	0.869	Irs	6 7 19 21 26	9
University of Hafr Al Batin	0.468	1.000	0.468	Irs	6 7 19 21 26	1
Average efficiency for Saudi universities	0.769	0.888	0.871			

Key:

CRSTE: Constant Returns to Scale Efficiency

VRSTE: Variable Returns to Scale Efficiency

DRS: Decreasing Returns to Scale

IRS: Increasing Returns to Scale

Table 5 shows the actual and target values for the number of graduates and research publications for each of the studied universities against the three input elements. The efficiency data presented in Table 4 were used to calculate these values. For example, in Table 4, Umm Al-Qura University attained an efficiency value of 0.747 when the VRS model was used, and its efficiency value increased to 0.989 when the CRS model was applied. This indicates decreasing returns to scale, meaning the university's outputs increase at a slower rate than the inputs. As a result, the university would need to increase its outputs by 0.261 to achieve full efficiency (reference university: King Faisal University). Umm Al-Qura University could expand its size by 26%, as shown by the volumetric efficiency index in Table 4, which would result in a greater increase in inputs compared to outputs. Table 5 shows the proposed number of graduates (648 graduates) that the university would need to produce to achieve efficiency, along with the proposed values for reducing some of its input elements.

In another example in Table 4, Northern Border University was found to be very inefficient (CRS: 0.573; VRS: 0.860). Given the increasing trend of its returns to scale value, the university needed to increase its outputs by 42.7% (CRS) or 14% (VRS) to achieve full efficiency (reference universities: University of Bisha, King Faisal University, King Fahd University of Petroleum and Minerals, University of Hafr Al Batin and Islamic University). Northern Border University could expand its output volume by 50.7%, as shown by the volumetric efficiency index in Table 4. Table 5 shows the proposed number of graduates (CRS: 4,523; VRS: 19,594) that the university would need to produce to achieve efficiency and the proposed values that would need to be achieved to reduce some of its input elements.

Finally, Table 5 shows that the efficiency of King Fahd University of Petroleum and Minerals was constant, as the CRS and VRS models were equal to one integer each, and the returns to scale value was constant. These results indicate that this university and its counterparts attained their optimal size. These include King Faisal University, King Khalid University, Princess Nourah bint Abdulrahman University, Shaqra University, and University of Jeddah, all of which also exhibited a CRS and VRS value of one.

Table 5. Requirements for Saudi Public Universities to Achieve Efficiency (Per the Results of the Output-Oriented Models)

University	Value	Enrolled students	Faculty members	Administrators and technicians	Research publications in indexed journals with an impact factor	Previous year graduates
Umm Al-Qura University	Actual	105,531	4,906	2,625	479	14,946
	CRS target	26,739	4,906	665	648	20,225
	VRS target	39,119	2,151	5,162	301	7,904
Islamic University	Actual	15,461	949	1,396	83	2,506
	CRS target	15,461	949	1,396	102	3,079
	VRS target	15,461	949	1,396	83	2,506
Imam Muhammad bin Saud	Actual	176,488	3,874	4,503	278	13,441
	CRS target	99,582	3,874	2,540	695	33,602

University	Value	Enrolled students	Faculty members	Administrators and technicians	Research publications in indexed journals with an impact factor	Previous year graduates
Islamic University	VRS target	103,059	2,214	1,542	460	19,594
King Saud University	Actual	62,771	7,159	13,504	4,271	7,273
	CRS target	62,771	7,159	13,504	4,524	7,704
	VRS target	62,771	7,159	13,504	4,271	7,273
King Abdulaziz University	Actual	145,751	7,527	6,739	3,977	21,739
	CRS target	145,751	7,527	6,739	4,021	21,981
	VRS target	145,751	7,527	6,739	3,977	21,739
King Fahd University of Petroleum and Minerals	Actual	12,550	1,089	2,081	1,392	942
	CRS target	12,550	1,089	2,081	1,392	942
	VRS target	12,550	1,089	2,081	1,392	942
King Faisal University	Actual	103,059	2,214	1,542	460	19,594
	CRS target	103,059	2,214	1,542	460	19,594
	VRS target	103,059	2,214	1,542	460	19,594
King Khalid University	Actual	62,198	3,494	2,605	1,220	9,355
	CRS target	6,769	3,494	283	1,391	106,558
	VRS target	62,771	7,159	13,504	4,271	7,273
Qassim University	Actual	71,216	4,028	4,099	516	9,238
	CRS target	22,311	4,028	1,284	763	13,666
	VRS target	31,331	1,691	1,055	207	6,110
Taibah University	Actual	69,357	3,159	3,013	804	9,276
	CRS target	17,836	3,159	774	1,095	12,638
	VRS target	39,119	2,151	5,162	301	7,904

University	Value	Enrolled students	Faculty members	Administrators and technicians	Research publications in indexed journals with an impact factor	Previous year graduates
University of Taif	Actual	61,706	2,780	1,400	385	10,595
	CRS target	5,594	2,780	126	425	11,694
	VRS target	31,331	1,691	1,055	207	6,110
King Saud bin Abdulaziz University for Health Sciences	Actual	12,671	1,131	2,816	526	760
	CRS target	121	1,131	26	1,002	1,448
	VRS target	12,550	1,089	2,081	1,392	942
Jazan University	Actual	60,570	3,471	1,770	351	8,981
	CRS target	13,426	3,471	392	453	11,603
	VRS target	39,119	2,151	5,162	301	7,904
Hail University	Actual	34,684	1,972	1,030	205	3,443
	CRS target	13,211	1,972	392	383	4,448
	VRS target	12,550	1,089	2,081	1,392	942
Al-Jouf University	Actual	26,774	1,655	1,005	1,005	3,794
	CRS target	3,088	1,655	115	1,878	7,091
	VRS target	26,774	1,655	388	1,005	3,794
Tabuk University	Actual	37,230	1,759	1,100	342	6,186
	CRS target	3,065	1,759	90	304	6,950
	VRS target	37,230	1,759	1,100	342	6,186
Al-Baha University	Actual	22,939	1,670	882	103	3,850
	CRS target	1,537	1,670	59	120	4,482
	VRS target	31,331	1,691	1,055	207	6,110
Najran University	Actual	19,433	1,535	695	152	1,944
	CRS target	1,535	1,535	695	277	3,547

University	Value	Enrolled students	Faculty members	Administrators and technicians	Research publications in indexed journals with an impact factor	Previous year graduates
	VRS target	69,357	3,159	3,013	804	9,276
Princess Nourah bint Abdulrahman University	Actual	39,119	2,151	5,162	301	7,904
	CRS target	39,119	2,151	5,162	301	7,904
	VRS target	39,119	2,151	5,162	301	7,904
Northern Border University	Actual	25,405	1,000	671	160	2,230
	CRS target	3,564	1,000	94	324	4,523
	VRS target	103,059	2,214	1,542	460	19,594
Shaqra University	Actual	31,331	1,691	1,055	207	6,110
	CRS target	31,331	1,691	1,055	207	6,110
	VRS target	31,331	1,691	1,055	207	6,110
Prince Sattam bin Abdulaziz University	Actual	28,961	2,190	1,841	580	4,397
	CRS target	3,924	2,190	249	674	5,113
	VRS target	31,331	1,691	1,055	207	6,110
Imam Abdulrahman bin Faisal University	Actual	37,930	3,372	3,961	795	5,846
	CRS target	4,971	3,372	519	922	6,782
	VRS target	39,119	2,151	5,162	301	7,904
Al-Majma'ah University	Actual	21,030	1,412	2,132	348	3,022
	CRS target	2,602	1,412	263	480	3,840
	VRS target	12,550	1,089	2,081	1,392	942
Saudi Electronic University	Actual	25,645	543	778	55	570
	CRS target	25,645	543	778	316	3,276
	VRS target	25,645	543	778	55	570
University of	Actual	23,391	1,521	714	553	1,404

University	Value	Enrolled students	Faculty members	Administrators and technicians	Research publications in indexed journals with an impact factor	Previous year graduates
Jeddah	CRS target	23,391	1,521	714	553	1,404
	VRS target	23,391	1,521	714	553	1,404
Bisha University	Actual	16,987	1,128	522	107	2,843
	CRS target	16,987	1,128	522	123	3,271
	VRS target	16,987	1,128	522	107	2,843
University of Hafr Al Batin	Actual	21,513	780	422	80	1,851
	CRS target	21,513	780	422	171	3,955
	VRS target	21,513	780	422	80	1,851

Tables 4 and 5 show that some universities performed well as peer institutions. These universities could thus be reliable models for the development of other associated universities. King Fahd University of Petroleum and Minerals was the top-ranked peer institution, followed by King Faisal University. Overall, the findings of this analysis lend credence to the theory that, although external elements do affect a university's effectiveness, universities mostly rely on their internal resources and competencies to accomplish their goals (Berbegal-Mirabent, 2018).

5. Discussion and Conclusions

This study offers insights into the efficiency of Saudi public universities in terms of their knowledge output (via research publications and graduates) based on CRS and VRS modelling. Our analysis revealed that 82% of the studied universities did not use their resources efficiently. When the CRS model was used, the average efficiency score was 0.769, demonstrating that the universities attained efficiency at their current output levels, with 76% ultimately achieving efficiency. Furthermore, when the VRS model was used, the average efficiency score was 0.888. Surprisingly, Alabdulmenem (2017) reported that 15 of 25 Saudi universities were operating with perfect efficiency. It seems that, despite the existence of publication and knowledge output strategies, universities have failed to continue to work efficiently. This could be the result of policies and the priorities outlined within them. We have observed that Saudi universities have recently been working intensively on institutional accreditation and quality issues, consequently assigning managerial tasks to faculty members. This forces faculty members to spend time and energy on managerial tasks rather than academic activities, such as conducting research. In addition, Saudi universities struggle with assigning staff to administrative activities and appointing new administrators due to budget restrictions. Such factors have been identified in efficiency studies conducted in Spain (Berbegal-Mirabent, 2018). Hence, the results of this study highlight the need to examine the impact of policy changes and governance in higher education on the efficiency of knowledge output in particular and the efficiency of performance in general.

The efficiency of some universities, such as Northern Border University, has declined to such an extent that they cannot be used as benchmarks for other universities. Comparatively, Albar's (2023) assessment of the efficiency of Saudi universities based on four factors (general, budget, academic staff and non-academic staff) revealed that relative efficiency increased in some universities and decreased in others over a six-year period. Thus, impliesthat multiple factors and variables associated with the main features of each evaluated university, such as the proportion of scientific departments and the diversity of disciplines, impact a university's performance efficiency.

There is no doubt that the expansion of natural sciences and engineering departments leads to increased resource consumption compared to the expansion of humanities and social science departments. This is because natural science and engineering departments require considerable resources to manage and conduct laboratory experiments. Thus, expanding a department can affect the overall efficiency of the university. However, increasing the diversity of the fields of study within a university can positively affect the level of general competence of the institution, as there may be certain university policies on admission, registration, graduation standards and other factors that affect the university's efficiency.

There are limitations to consider when interpreting the findings of this study. First, we included only Saudi public universities and data from a single academic year. Second, while we used both output-oriented CRS and VRS models, we included only three input variables and two output variables. Although DEA is a reliable methodology, it should be highlighted that the model specifications—that is, the variables and the orientation—have a significant impact on the sensitivity of the results. Therefore, future studies should include and examine more input variables, such as funding, accessibility and community knowledge activity, to determine how efficiently public universities use allocated resources.

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