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A Dea CCR Approach with Super-Efficiency Ranking for Performance Evaluation of Malaysian Public Universities

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Abstract: The efficiency and productivity of a country's higher education system significantly influence its ability to develop and flourish. Furthermore, efficiency becomes a crucial performance metric for universities overall, assisting decision-makers in formulating policies that promote the intended outcomes and prudently allocate resources. There is a lot of pressure on public higher education around the world to perform better and be of higher quality. This study applies Data Envelopment Analysis (DEA) to evaluate the performance of 20 public universities in Malaysia using input-oriented and output-oriented CCR (Charnes, Cooper, and Rhodes) models, as well as the Super Efficiency model. Three inputs and five outputs are determined to measure the performance of the universities. The number of postgraduate students enrolled, the number of undergraduate students enrolled, and the number of academic staff are the inputs, while the number of graduates, the number of graduates working, the number of graduates who choose to further their studies, the number of graduates who choose to develop skills, and the number of graduates waiting for work placement are the outputs. The findings show that out of 20 public universities, 13 public universities are efficient with an efficiency score equal to 1 using the input-oriented CCR model and output-oriented CCR model. Meanwhile, the remaining seven public universities showed inefficient score results. UNIMAP received 4.103862 for the Super Efficiency score, which was ranked first out of thirteen efficient public universities in 2023, making it the most efficient public university. By ranking public universities, interested parties, such as the higher education sector or university administration, can take steps to enhance and maximize university performance.

Keywords: CCR Model, Efficiency, Data Envelopment Analysis (DEA), Performance, Super Efficiency.

1 Introduction

As of 2024, Malaysia's higher education system consists of 20 public universities along with 36 polytechnic institutions and 105 community colleges. In addition, the country hosts approximately 434 private higher education providers, which include private universities, university colleges, private colleges, and branch campuses of foreign universities. These figures represent the latest institutional classifications reported under the Ministry of Higher Education (MOHE). A wide range of tertiary programmes is offered by Malaysia's Higher Education Institutions (HEIs) at comparatively affordable fees. Among the twenty public universities in the country, five have been designated as research universities and receive additional funding to support research, development, and commercialization activities. The remaining fifteen institutions are categorized as either comprehensive or focus universities. In a New Year announcement in 2012, the Minister of Higher Education revealed that five public universities had been granted greater autonomy in areas such as financial management, human resources, academic offerings, and student admissions. These institutions are Universiti Malaya, Universiti Kebangsaan Malaysia, Universiti Sains Malaysia, Universiti Putra Malaysia, and Universiti

Teknologi Malaysia. The policy aims to strengthen the overall quality and competitiveness of higher education in Malaysia. The Malaysian Qualifications Agency (MQA) plays a central role in upholding educational standards through the implementation of the Malaysian Qualifications Framework. It oversees both public and private higher education providers and is tasked with quality assurance processes, programme accreditation, and related regulatory responsibilities.An important goal for the MOHE has identified the global expansion of Malaysia's higher education system as a major strategic priority. To achieve this, numerous measures have been implemented, including efforts to raise the international visibility of Malaysian universities, initiatives to attract 150,000 international students by 2015, the establishment of additional Malaysian academic chairs at overseas institutions, and the strengthening of joint academic and research activities with leading global universities. The government also remains committed to creating conditions that encourage reputable foreign universities to set up branch campuses or specialised faculties in Malaysia. At the same time, Malaysian HEIs have broadened their role in cross-border education through new international partnerships and the creation of their own branch campuses abroad.

As highlighted by Dzulkarnain et al. (2024), a fundamental step toward elevating the performance of public universities is conducting a comprehensive assessment of their operational efficiency. Efficiency has increasingly become a central performance benchmark, guiding policymakers in formulating strategies that lead to improved outcomes and more effective distribution of resources. The efficiency of higher education has been frequently assessed using DEA models (Ramzi & Ayadi, 2016). As stated by Panwar et al. (2022), Data Envelopment Analysis (DEA), which is a methodology proposed by Charnes et al. in 1978, approximately twenty years later, is used to determine the relative efficiency of units based on an input and numerous outputs. Efficiency can be understood as the proportion of total outputs to total inputs, with each weighted according to its significance. The Data Envelopment Analysis (DEA) technique offers several key advantages: it accommodates both numeric and non-numeric data, allows for multiple inputs and outputs measured in different units, and helps management pinpoint areas where performance improvements are possible. Traditionally, DEA has been applied most extensively in banking and educational institutions, likely due to the availability of shared datasets. Recently, its applications have expanded into newer fields such as polymer research, remote sensing, operations research, and corporate economics.

This study evaluates the performance of public universities using the Charnes, Cooper, and Rhodes (CCR) methodology. Both input-oriented (CCR-I) and output-oriented (CCR-O) CCR models are employed to measure overall efficiency, while the super-efficiency (SE) approach is applied to identify the universities that perform at the highest efficiency levels and to highlight top performers among them. Many application areas have made substantial use of the SE model, including ranking efficient Decision-Making Units (DMUs), finding extreme efficient DMUs, and measuring efficiency regions (Panwar et al., 2022).

2 Method of Study

Hussain et al. (2015) stated that DEA is a non-parametric method that Charnes et al. (1978) proposed that uses mathematical programming. It is principal goal is to evaluate the comparative effectiveness of a homogeneous peer set of decision-making units (DMUs) that use various inputs to generate different outputs (Taleb et al., 2023). The methodology uses to evaluate Malaysia public universities' performance in 2023 use the input-oriented CCR (CCR-I) model and output-oriented CCR (CCR-O) also Super Efficiency (SE) models. DEA models can be categorized into radial and non-radial categories, with radial models accounting for proportional changes in output or input variables and non-radial models handle each output and input variable's slacks independently before combining them into an efficiency metric (Panwar et al., 2022). The CCR model makes the assumption that evaluated DMUs' constant returns to scale (CRS). On the other hand, because the BCC model has a convexity requirement, it is assumed that variable returns to scale (VRS) (Taleb et al., 2023). According to Durana et al. (2020), a production unit that is inefficient can use the input-oriented model (CCR-I), which suggests lowering input while keeping output at the same level, or the output-oriented model (CCR-O),

which suggests raising output while keeping input at the same level. Meanwhile, in order to differentiate between efficient DMUs, Anderson and Peterson (1993) proposed the Super Efficiency measure. It provides the ability to rank effective DMUs that are defined by similar relative efficiency scores that are equal to one under the initial DEA model's estimation. This allows the decision maker to investigate the greatest radial changes in inputs and/or outputs necessary for an observation to stay within the efficiency frontier (Ramzi & Ayadi, 2016). This part describes the methodology employed to conduct the study, which evaluated the efficiency of 20 Malaysian public universities using the CCR-I, CCR-O, and Super Efficiency (SE) models within the DEA framework. The procedure is illustrating in Figure 1 as below.

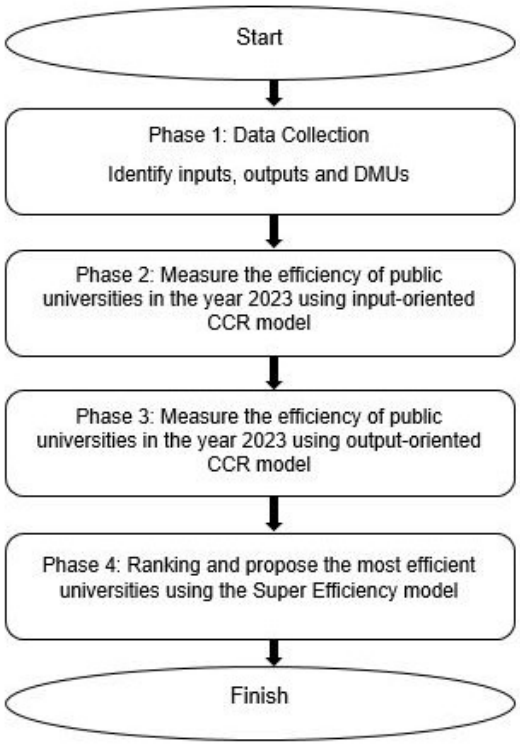

Figure 1: Flowchart of the methodology

2.1 Data Collection

For this study, data from the Ministry of Higher Education were utilized to evaluate the efficiency of twenty public universities in Malaysia, with each institution considered as a Decision-Making Unit (DMU). A summary of these universities and their corresponding data is provided in Table 1.

Table 1: List of Public Universities in Malaysia and Their DMU's codes (2023)

	DMU	Code
Universiti Malaya	A	UM
Universiti Sains Malaysia	B	USM
Universiti Kebangsaan Malaysia	C	UKM
Universiti Putra Malaysia	D	UPM
Universiti Teknologi Malaysia	E	UTM
Universiti Utara Malaysia	F	UUM
Universiti Islam Antarabangsa Malaysia	G	UIAM
Universiti Malaysia Sarawak	H	UNIMAS
Universiti Malaysia Sabah	I	UMS
Universiti Pendidikan Sultan Idris	J	UPSI
Universiti Teknologi Mara	K	UiTM
Universiti Sultan Zainal Abidin	L	UniSZA

Universiti Malaysia Terengganu	M	UMT
Universiti Sains Islam Malaysia	N	USIM
Universiti Tun Hussein Onn Malaysia	O	UTHM
Universiti Teknikal Malaysia Melaka	P	UTeM
Universiti Malaysia Pahang Al-Sultan Abdullah	Q	UMPSA
Universiti Malaysia Perlis	R	UNIMAP
Universiti Malaysia Kelantan	S	UMK
Universiti Pertahanan Nasional Malaysia	T	UPNM

Choosing the right inputs and outputs is important when measuring how efficiently public institutions operate. Ratio analysis is used to make basic comparisons and to get an initial understanding of their performance. These indicator shows the number of results generated as well as the financial, human, and material resources used to support institutional services (Katharaki & Katharakis, 2010). According to Ismail et al. (2014), academic staffs are employed by universities to teach students and generate graduates of a particular excellence. As a result, teaching efficiency reflects how effectively universities deliver education to undergraduate and graduate students. In this context, student quality serves as an input, based on the idea that higher admission criteria are likely to produce more capable graduates. The outputs of teaching are represented by the graduates themselves. Graduate employability indicates how employers perceive the competency of university alumni, while the academic achievement of graduates is assessed through graduation rates and academic performance.

Next, the study uses secondary data obtained from the Ministry of Higher Education's website, which provides statistics on Malaysian public universities for the year 2023. Data Envelopment Analysis (DEA) is utilized to evaluate and compare the input-oriented CCR model with the output-oriented CCR model. The assessment of efficiency involves three input factors and five output factors. Information from all twenty public universities is summarized in Table 2, enabling an analysis of their performance and overall efficiency. Subsequently, the data were processed using LINGO 20.0 to generate the corresponding efficiency scores.

Table 2: The DMUs of Data Acquisition

	Input			Output				
DMUs	Post-graduate students enrolled	Under-graduate students enrolled	Academic staff	Number of graduates	Graduates working	Graduates who choose to further study	Graduates choose to develop skills	Graduates waiting for work placement
A	13887	22292	2194	8373	5257	570	205	248
B	12871	22201	1983	8153	4632	307	375	758
C	13155	19949	1990	8957	5416	296	86	371
D	10365	17171	1795	6534	3807	342	640	410
E	8105	21092	1654	6497	4485	558	690	211
F	5135	25317	1186	6629	4026	55	156	765
G	3501	17922	2064	4726	2578	281	106	300
H	2322	13432	867	3841	2758	297	182	218
I	2651	15568	1101	4121	3273	194	199	402
J	5601	19097	844	7497	5771	586	150	481
K	10242	168479	8909	54109	28563	13952	268	399
L	1803	12953	773	3555	1978	1064	129	119
M	1377	9543	647	2387	1824	240	31	46
N	1193	11622	832	3122	2448	150	52	173
O	2574	16164	1129	4836	3333	820	76	160
P	1159	12972	868	3369	2501	513	120	52
Q	1413	11483	758	4886	3460	713	141	130
R	1072	11092	1121	3554	2287	583	439	99
S	751	13598	524	2159	2309	103	49	186
T	380	3400	392	1661	1307	99	10	22

2.2 Input-Oriented CCR, Output-Oriented CCR and Super Efficiency model

In order to determine the efficient of public universities, the initial is CCR which is foundation of Data Envelopment Analysis (DEA). The second model called SE model which provides the ability to rank efficient DMUs that are defined by similar relative efficiency score. This allows the decision maker to investigate the greatest radial changes in input and/or outputs necessary for observation to stay within the efficiency frontier (Ramzi & Ayadi, 2016). There are three models used to measure the efficiency of public universities in Malaysia, which are the input-oriented CCR, output-oriented CCR and super efficiency model.

Model 1: Input-Oriented CCR (CCR-I) model

The CCR-I model for DMU_0 set up, respectively, as:

Minimum $\tau = t$

Subject to

$$\sum_{j=i}^{n} x_{ij}u_j + {t_i}^- \leq tx_{i0}$$

$$\sum_{j=1}^{n} y_{rj}u_j - {t_r}^+ \leq y_{r0}$$

$$u_j \geq 0, {t_r}^+ \geq 0, {t_i}^- \geq 0$$

where n is the number of DMU, y_{r0} is the output of DMU_0, y_{rj} is the output of DMU_j, x_{i0} is the input of DMU_0 and x_{ij} is the input of DMU_j.

Model 2: Output-Oriented CCR (CCR-O) model

The CCR-O model for DMU_0 set up, respectively, as:

Minimum $\tau = t$

Subject to

$$\sum_{j=i}^{n} x_{ij}u_j - {t_i}^- \leq x_{i0}$$

$$\sum_{j=1}^{n} y_{rj}u_j + {t_r}^+ \leq ty_{r0}$$

$$u_j \geq 0, {t_r}^+ \geq 0, {t_i}^- \geq 0$$

where n is the number of DMU, y_{r0} is the output of DMU_0, y_{rj} is the output of DMUj, x_{i0} is the input of DMU_0 and x_{ij} is the input of DMU_j.

Model 3: Super Efficiency model

The Super Efficiency (SE) model that used to rank various of DMU_0 is defined as follows:

Maximum $\sum_{r=1}^{s} y_{r0}u_r$

Subject to

$$\sum_{i=1}^{m} x_{i0}v_i = 1$$

$$\sum_{r=1}^{s} y_{rj}u_r - \sum_{i=1}^{m} x_{ij}v_i \leq 0$$

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

where $v_i(i = 1, \dots, m)$ and $u_r(r = 1, \dots, s)$ be the weights of the ith input and rth output, respectively. In this model, $i = 1, \dots, m$ is the total number of inputs, $r = 1, \dots, s$ is the total number of the output. Hence, x_{i0} and y_{r0} are the input and the output for a particular DMU respectively. Arabmaldar et al. (2017) stated that the Super Efficiency (SE) model subtracts this DMU from the group of DMUs in order to calculate the SE score of the DMU that is being evaluated. Following this removal, the efficient frontier takes on a new form, and the new score calculates the separation between the original DMU and the new frontier.

3 Results and Discussions

The efficiency of the 20 DMUs in this study was assessed using the input-oriented CCR model, output-oriented CCR model, and the Super Efficiency (SE) model. The resulting efficiency scores from each model are presented in Table 3, Table 4, and Table 5, respectively.

3.1 The efficiency scores of Input-Oriented CCR model

The CCR-I model produced the efficiency scores for 20 public universities in Malaysia. Table 3 below presents the implementation's efficiency score using CCR-I model.

Table 3: CCR-I score for 20 public universities in Malaysia

DMUs	Code	CCR-I Score
A	UM	0.839169
B	USM	1.000000
C	UKM	1.000000
D	UPM	1.000000
E	UTM	1.000000
F	UUM	1.000000
G	UIAM	0.750110
H	UNIMAS	0.854842
I	UMS	1.000000
J	UPSI	1.000000
K	UiTM	1.000000
L	UniSZA	1.000000
M	UMT	0.618031
N	USIM	0.974581
O	UTHM	0.794814
P	UTeM	0.813387

Q	UMPSA	1.000000
R	UNIMAP	1.000000
S	UMK	1.000000
T	UPNM	1.000000

The efficiency score of DMU using the CCR-I modelling is shown in Table 3 above. The scores are obtained by the use of LINGO software. Each DMU's performance is shown using the efficiency scores obtained from the CCR-I model in Table 4. Accordingly, a DMU is considered efficient if its efficiency score is 1, and inefficient if it is less than that, following evaluation and implementation using Lingo software. For the CCR-I model, the universities identified as efficient include USM, UKM, UPM, UTM, UUM, UMS, UPSI, UiTM, UniSZA, UMPSA, UNIMAP, UMK, and UPNM. The seven universities with efficiency scores below 1, considered inefficient under this model, are UM, UIAM, UNIMAS, UMT, USIM, UTHM, and UTeM.

3.2 The efficiency scores of Output-Oriented CCR model

Next is the CCR-O model produced the efficiency scores for 20 public universities in Malaysia. Table 4 below presents the implementation's efficiency score using CCR-O model.

Table 4: CCR-O score for 20 public universities in Malaysia

DMUs	Code	CCR-O Score
A	UM	1.000000
B	USM	1.000000
C	UKM	1.000000
D	UPM	1.000000
E	UTM	0.984742
F	UUM	1.000000
G	UIAM	1.000000
H	UNIMAS	0.817725
I	UMS	0.849121
J	UPSI	0.663447
K	UiTM	1.000000
L	UniSZA	1.000000
M	UMT	1.000000
N	USIM	0.954555
O	UTHM	0.855927
P	UTeM	1.000000
Q	UMPSA	0.594090
R	UNIMAP	1.000000
S	UMK	1.000000
T	UPNM	1.000000

The efficiency score of DMU using the CCR-O modelling is shown in Table 4 above. The scores are obtained through the use of LINGO software. Each DMU's performance is shown using the efficiency scores obtained from the CCR-O model in Table 5. For the CCR-O model, the universities considered efficient are UM, USM, UKM, UPM, UUM, UIAM, UiTM, UniSZA, UMT, UTeM, UNIMAP, UMK, and UPNM. The universities identified as inefficient under this model include UTM, UNIMAS, UMS, UPSI, USIM, UTHM, and UMPSA.

3.3 Summary of CCR-I and CCR-O scores

Figure 2 shows how efficiently Malaysia's public universities performed based on the CCR-I and CCR-O models. From the results, thirteen universities reached an efficiency score of 1 in both approaches. Under the CCR-I model, the universities that achieved full efficiency are USM, UKM, UPM, UMS, UPSI, UiTM, UniSZA, UMPSA, UNIMAP, UMK, and UPNM. For the CCR-O model, the universities identified as fully efficient are UM, USM, UKM, UPM, UUM, UiTM, UniSZA, UMT, UTeM, UNIMAP, UMK, and UPNM.

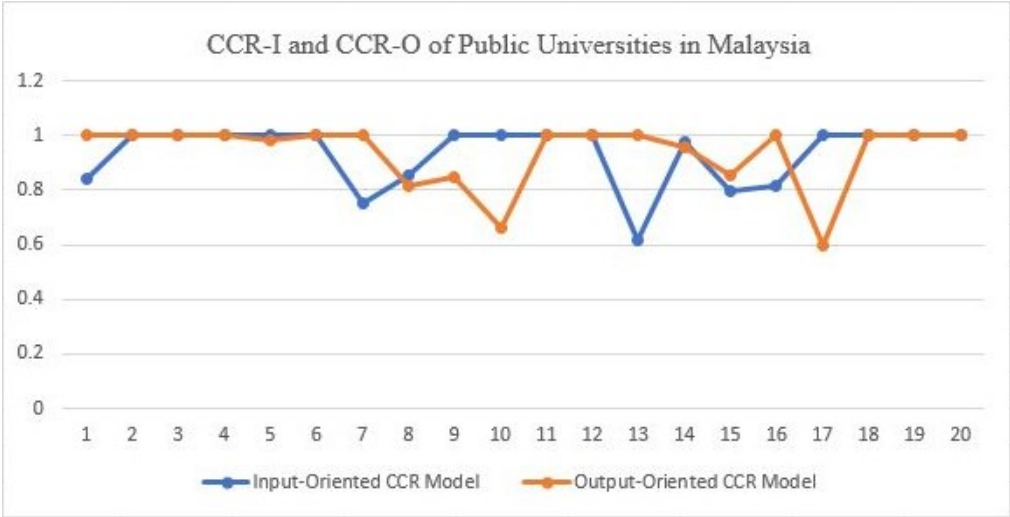

Figure 2: Efficiency Scores of Public Universities in Malaysia using input-oriented CCR model and output-oriented CCR model

For the CCR-I model, the seven universities with efficiency scores below 1 are UM, UIAM, UNIMAS, UMT, USIM, UTHM, and UTeM. Under the CCR-O model, the universities classified as inefficient include UTM, UNIMAS, UMS, UPSI, USIM, UTHM, and UMPSA. Both models consistently show that thirteen universities are operating efficiently, while the remaining seven are considered inefficient, although the specific universities identified differ slightly between the two models. According to Fancello et al. (2020), both input and output approaches can benefit from the strong hierarchy that the CCR model can offer. It appears that the CCR model offers a more unbiased and comprehensive evaluation of the DMU's performance.

3.4 The result of Super Efficiency model and ranking

To determine the ranking of public universities, this study uses the efficiency scores from the CCR-I model to compute super efficiency. Since the CCR-I approach aims to reduce inputs without affecting output levels, it is well-suited for resource-constrained sectors like education, where funding is closely monitored. The results of the Super Efficiency (SE) analysis and the corresponding rankings of Malaysian public universities are shown in Table 5.

Table 5: The result of SE model and rank of public universities in Malaysia

DMUs	Code	SE Score	Rank
R	UNIMAP	4.103862	1
K	UiTM	2.346671	2
S	UMK	1.853650	3
J	UPSI	1.621997	4
F	UUM	1.380591	5
T	UPNM	1.375702	6
Q	UMPSA	1.280364	7
D	UPM	1.234119	8
B	USM	1.225754	9
L	UniSZA	1.187288	10

E	UTM	1.114992	11
I	UMS	1.098185	12
C	UKM	1.028754	13

According to Pyra and Adamowicz (2021), the Super Efficiency (SE) model is an additional variation of the CCR model (CCR-I). In the SE–CCR model, both efficient and inefficient units can be ranked in detail, expanding on the CCR-I model's ability to differentiate only inefficient performers. This enhancement was introduced by Andersen and Petersen in 1993, allowing efficient units to be identified as "super-efficient" when they outperform other top scorers. Based on the findings in Table 5, UNIMAP ranked as the most efficient public university in 2023, followed by UiTM in second place and UMK in third. Ranking universities through super-efficiency analysis is particularly valuable for the higher education sector, as it supports strategic planning and policy decisions. By providing deeper insight into how each institution performs, the results help stakeholders understand areas needing improvement and guide efforts to enhance overall institutional performance. Additionally, university administrators can use these insights to gauge their institution's effectiveness and make necessary adjustments to ensure continued progress.

4 Conclusion

DEA is Data Envelopment Analysis (DEA) is employed to assess and compare the efficiency and performance of various Decision-Making Units (DMUs). The research introduces a framework for evaluating Malaysian public universities using the input-oriented CCR model, output-oriented CCR model, and the Super Efficiency (SE) model. By analysing university performance and providing detailed insights, the findings aim to assist higher education stakeholders in identifying strategies to enhance institutional performance. Additionally, the results offer university administrators a clearer understanding of their institution's effectiveness, enabling them to implement improvements for future growth. Specifically, the CCR-I and CCR-O models are applied to measure the efficiency of public universities, while the SE model identifies the highest-performing institutions in 2023. By removing the upper-bound restriction in efficiency assessment, the study provides a more comprehensive evaluation of effective universities, allowing efficiency scores above 1 to be recognized without compromising the assessment of less efficient institutions. For future research, it is suggested that DEA be applied to other sectors such as hospitality, sports, agriculture, fisheries, transportation, tourism, healthcare, and automotive industries to evaluate organizational performance. Moreover, when public or non-profit organizations exhibit variable returns to scale (VRS), the Banker, Charnes, and Cooper (BCC) model an extension of the CCR model can be utilized to assess the technical efficiency of specific DMUs.

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Conflict of Interest Statement

The authors declare no conflict of interest in relation to the research, authorship, or publication of this article.

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