A Decision Approach for Performance Evaluation of Higher Education Institutions

Nazli Goker and Mehtap Dursun

***Abstract*—**Recently, with the increasing emphasis placed on higher education, it is important to improve university performance management. University performance has important effect on the social influence of universities. It is affected by many factors such as teaching, research and citations, thus it is difficult to optimize all factors because of resource restriction. In this research, data envelopment analysis (DEA) is employed to measure the performance of universities. The data are collected from Times Higher Education website that provides a resource for readers to understand the different missions and successes of higher education institutions.

***Index Terms*—**Data envelopment analysis, Education, Performance management, University rankings

I. Introduction

Performance measurement is defined as a process of quantifying the efficiency and effectiveness of actions [1]. It is seen as a pre-cautionary and diagnostic management control system to help managers to keep track of performance in organizational activities. Performance management is a means of auditing and managing system-wide activity.

New public management reform exerts great pressure on public organizations to increase their quality of services, efficiency and effectiveness in utilization of resource. Universities also experienced great changes since they are considered as one kind of public organizations. Globalization, the fourth industrial revolution, the high demand for higher education, increasing competition and the collapse of geographic boundaries, amongst other factors, forced higher education into a highly competitive business environment where efficiency and performance are essential for survival [2].

The ideology of university gains importance in systematic coordination in recent years [3]. The academic roles of higher education institutions comprise three major components: teaching, research, and service. Universities are responsible for themselves in resources seeking and market seeking. University managers need to ensure that the university resources are properly allocated. Thus, they require more on performance measurement mechanisms to acquire the information in management control [4].

Recently, researchers focus on performance management in Universities. Taylor and Baines [5] employed balanced scorecard to measure the performances of UK universities. Adams [6] provided a perspective on sustainability reporting and performance management in the university sector making a case for increased accountability, improved (management of) performance and greater innovation in approach. Karuhanga [7] used principal component analysis for evaluating implementation of strategic performance management in public universities in Uganda. Angiola et al. [8] analyzed whether and to what extent the adoption of better performance management systems could improve the performance levels of a public university. Zhang et al. [9] combined linguistic hesitant fuzzy sets with the decision-making trial and evaluation laboratory method to identify key performance indicators for improving the level of university performance management. Ahmed et al. [10] analyzed how inventory management techniques affected university performance in Ethiopia. Biondi and Russo [11] investigated the link between strategic planning systems and performance management systems in Italian universities by answering some research questions.

This study aims to measure the performance of universities by employing data envelopment analysis (DEA). The data are collected from Times Higher Education website that creates university rankings to assess university performance on the global stage and to provide a resource for readers to understand the different missions and successes of higher education institutions.

The remaining part of the study is organized as follows. DEA is explained in Section 2. Section 3 illustrates the case study. Conclusions are provided in the last Section.

II. Data envelopment analysis

The original data envelopment analysis model, also named as the CCR (Charnes, Cooper, & Rhodes) model, proposed by Charnes et al. [12], computes the relative efficiency of a decision-making unit (DMU) by maximizing the ratio of its total weighted outputs to its total weighted inputs subject to the condition that the output to input ratio of every DMU be less than or equal to unity. The conventional DEA formulation can be represented as follows:

$$\max E_{j_0} = \frac{\sum_{r=1}^{s} u_r y_{rj_0}}{\sum_{i=1}^{m} v_i x_{ij_0}}$$

subject to (1)

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$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \quad \forall j,$$
$$u_r, v_i \geq \varepsilon, \quad \forall r, i,$$

where E_{j_0} is the efficiency score of the evaluated DMU, u_r is the weight assigned to output r, v_i is the weight assigned to input i, y_{rj} is the quantity of output r generated and x_{ij} is the amount of input i consumed by DMU j, respectively, and ϵ is a small positive scalar.

Formulation (1) possesses non-linear and non-convex properties, however, it can be converted into a linear programming model via a transformation [13]. The linear programming model for computing the relative efficiency of a DMU is as

$$\max E_{j_0} = \sum_{r=1}^{s} u_r y_{rj_0}$$

subject to (2)

$$\sum_{i=1}^{m} v_i x_{ij_0} = 1$$
$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \quad \forall j,$$
$$u_r, v_i \geq \varepsilon, \quad \forall r, i.$$

The efficiency scores of DMUs are calculated by solving Formulation (2) n times, where n is the number of DMUs. Formulation (2) classifies DMUs with efficiency score of 1 as efficient while DMUs with lower efficiency scores are considered as inefficient. In order to eliminate the unrealistic weight dispersion and improve the poor discriminating power of DEA, a number of approaches have been proposed [14]. To avoid the unrealistic weight dispersion and improve the poor discriminating power of DEA, Wong and Beasley [15] employed weight restrictions which enforce some frontiers on weights. Another widely used mathematical technique to improve the discriminating power of DEA is cross-efficiency analysis [16]. Alternatively, minimax and minsum efficiency measures do not give favorable consideration to the evaluated DMU unlike the conventional DEA model. Minimax efficiency minimizes maximum deviation from efficiency. Likewise, minsum efficiency is to minimize the total deviation from efficiency [17].

Toloo [18] presented a mixed integer programming approach that minimizes the maximum deviation from efficiency and applied it to 40 professional tennis players problem.

Initially, Toloo [18] developed the following programming model for determining the maximum value of the non-Archimedean infinitesimal.

$$\max \varepsilon$$

subject to (3)

$$d_{\max} - d_j \geq 0, \quad \forall j,$$
$$\sum_{r=1}^{s} u_r y_{rj} + d_j = 1 \quad \forall j,$$
$$\sum_{j=1}^{n} \theta_j = n - 1,$$
$$d_j \leq \theta_j \quad \forall j,$$
$$\theta_j \leq M d_j \quad \forall j,$$
$$d_j \geq 0 \quad \forall j,$$
$$\theta_j \in \{0,1\} \quad \forall j,$$
$$u_r \geq \varepsilon,$$

Using the optimal solution obtained from the Formulation (3), Toloo [18] proposed Formulation (4) for ranking the DMUs and indicate the most efficient one.

$$\min d_{max}$$

subject to (4)

$$d_{\max} - d_j \geq 0, \quad \forall j,$$
$$\sum_{r=1}^{s} u_r y_{rj} + d_j = 1 \quad \forall j,$$
$$\sum_{j=1}^{n} \theta_j = n - 1,$$
$$d_j \leq \theta_j \quad \forall j,$$
$$\theta_j \leq M d_j \quad \forall j,$$
$$d_j \geq 0 \quad \forall j,$$
$$\theta_j \in \{0,1\} \quad \forall j,$$
$$u_r \geq \varepsilon,$$

where M is a sufficiently large positive number, and θ_j is a binary variable. The model has an improved discriminating power, and does not require a discriminating parameter, k. However, it requires a penalty value, M, and an auxiliary binary variable θ_j. Furthermore, the author guarantees to identify the single best efficient DMU by adding a constraint with binary variables that restricts to obtain more than one efficient DMU. The model is applicable when the problem has a dummy input and multiple outputs.

III. Case Study

In this section, performance assessment of the best performing 50 universities as of 2022 throughout the world is provided by employing common-weight DEA model addressed in Toloo [18]. The DMUs are evaluated according to five outputs indicated in Times Higher Education, namely “teaching”, “research”, “citations”, “industry income”, and “international outlook”. The data of 50 universities are given in Table 1 [19].

TABLE I: THE DATA OF 50 UNIVERSITIES

DMUs	Name of the university	Teaching	Research	Citations	Industry income	International outlook
1	University of Oxford	91	99.6	98	74.4	96.3
2	California Institute of Technology	93.6	96.9	97.8	90.4	83.8
3	Harvard University	94.5	98.9	99.2	48.9	79.8
4	Stanford University	92.3	96.8	99.9	91	79.7
5	University of Cambridge	90.9	99.5	96.2	56.7	95.8
6	Massachusetts Institute of Technology	90.9	94.4	99.7	93.7	89.9
7	Princeton University	89.5	96	99	88.8	80.7
8	University of California, Berkeley	85.7	96	99.1	84.7	77.6
9	Yale University	90.7	93	97	56.2	69.9
10	The University of Chicago	87.2	90.6	98.3	56.3	74.4
11	Columbia University	87.8	89.6	97.3	48	79.8
12	Imperial College London	81.4	88.3	97.6	70.8	97.5
13	Johns Hopkins University	80	90.8	97.2	93.7	74.6
14	University of Pennsylvania	84.5	89.2	97.1	77.6	69.7
15	ETH Zurich	81.3	92.4	90.7	62.5	97.9
16	Peking University	91.4	94.6	81.7	93.1	65.1
17	Tsinghua University	88.1	95.7	86.8	100	50.6
18	University of Toronto	77.6	93	92.6	61.2	89.1
19	UCL	76.8	88.9	96.9	44.7	96.7
20	University of California, Los Angeles	82.1	89.8	96	56.5	65.1
21	National University of Singapore	76.3	90.6	87.3	75.4	94.4
22	Cornell University	78.6	85.4	97.2	38.3	75.4
23	Duke University	79.2	78.6	95.6	99	66.6
24	University of Michigan-Ann Arbor	78.6	85.4	94	48.9	59.5
25	Northwestern University	74.3	82.1	97.6	81.6	65.3
26	New York University	75.4	83.1	94.7	41.4	72.3
27	London School of Economics and Political Science	68	80.8	94.4	35.8	92.7
28	Carnegie Mellon University	64.7	80	99	59	80.8
29	University of Washington	68.8	78.8	99	46.3	61.7
30	University of Edinburgh	66.1	74.2	95.6	40.2	95.2
31	University of Hong Kong	66.2	72.2	95	58.5	98.8
32	LMU Munich	68.1	77.9	90.3	100	69.1
33	University of Melbourne	67.5	73.8	88.4	74.9	94
34	University of California, San Diego	60.5	75.6	97.9	96.6	68.1
35	King’s College London	57.6	71.2	96.9	43.7	95.9
36	The University of Tokyo	86.9	90.3	58.2	88.1	42
37	University of British Columbia	61.6	74	89.4	47.4	94.9
38	Technical University of Munich	64.5	74.8	85.5	100	76.1
39	Karolinska Institute	55.1	71	94.2	70.5	86.2
40	École Polytechnique Fédérale de Lausanne	63.8	67	85.5	74.9	98.3

TABLE I: THE DATA OF 50 UNIVERSITIES (CONT.)

DMUs	Name of the university	Teaching	Research	Citations	Industry income	International outlook
41	Paris Sciences et Lettres – PSL Research University Paris	69.1	71.2	80.1	78.7	80.5
42	Universität Heidelberg	67.9	59.9	95.5	54.2	69.6
43	KU Leuven	59.1	73.2	86.2	99.2	74.2
44	McGill University	63.3	70.9	83.9	45.3	91.5
45	Georgia Institute of Technology	58.2	69.4	91.4	71.4	77.7
46	Nanyang Technological University, Singapore	57.2	70.3	85.1	87	93.9
47	University of Texas at Austin	67.9	71.5	89.4	50.1	39.8
48	University of Illinois at Urbana-Champaign	65.7	77.3	80.9	50	55.4
49	Chinese University of Hong Kong	55.1	58.6	95	60.2	95
50	University of Manchester	56.4	65	89.1	45.6	92.4

First, Formulation (3) is solved to obtain the maximum value of non-Archimedean infinitesimal. The optimum value of that programming model is indicated as 0.002134. By utilizing this value, Formulation (4) is employed and the DMUs are ranked according to their deviation scores in descending order. The deviation score of DMU_6, which is Massachusetts Institute of Technology, is equal to zero, hence it is the best performing DMU, followed by California Institute of Technology and Stanford University. Full ranking of 50 universities is given in Table 2.

TABLE II: RANKING OF 50 UNIVERSITIES

DMUs	$d(j)$	Rank
1	0.0198	4
2	0.013	2
3	0.1009	13
4	0.019	3
5	0.063	7
6	0	1
7	0.0312	5
8	0.0544	6
9	0.1319	18
10	0.1319	19
11	0.1411	22
12	0.0704	9
13	0.0689	8
14	0.1078	16
15	0.0935	11
16	0.0911	10
17	0.1012	14
18	0.1176	17
19	0.1379	21
20	0.1688	30
21	0.0952	12
22	0.2	35
23	0.1058	15
24	0.2181	41
25	0.1445	23
26	0.217	40
27	0.2068	36
28	0.1816	32
29	0.2433	46
30	0.2076	37
31	0.1662	29
32	0.1349	20
33	0.1494	26
34	0.1492	25
35	0.2204	43
36	0.22	42
37	0.2162	39
38	0.1445	24
39	0.1955	34
40	0.1688	31
41	0.1899	33
42	0.2593	48
43	0.1637	28
44	0.2426	45
45	0.2145	38
46	0.1603	27
47	0.3199	50
48	0.2973	49
49	0.2234	44
50	0.2563	47

IV. CONCLUSIONS

Recently, the ideology of university gains importance in systematic coordination. It is important to improve university performance management. In this research, data envelopment analysis is employed to measure the performance of universities. The data are collected from Times Higher Education website that provides a resource for readers to understand the different missions and successes of higher education institutions. The deviation score of DMU_6, which is Massachusetts Institute of Technology, is calculated as zero, hence it is the best performing DMU, followed by California Institute of Technology and Stanford University.

Future research directions may focus on employing other performance measurement techniques to find the rankings of higher education institutions.

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