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# Evaluation on Higher Education Using Data Envelopment Analysis

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**Abstract:** *The goal of higher education is to provide students an equal opportunity to access their education for success. With significant competition within the peer group, potential students look for quality, flexibility, and affordability in the educational environment. In addition, the relationship between students and the institution involves a concentrated and more specific set of expectations. In order to improve students' academic performance and fulfill individual needs, universities aim to enhance the quality of students' learning environment and academic achievements. The higher education system relies on efficient operation and strategic planning to fulfill students' needs through an internal emphasis on institutional performance improvement. A study on measuring the performance of higher education is presented. The research was focused on four-year and above, public and not-for-profit private universities in the southern region (AL, AR, KY, LA, MS, OK, TN, and TX) of the United States. The data includes 270 universities which were obtained from the Institute of Education Sciences, U.S. Department of Education. This study applied the Data Envelopment Analysis (DEA) approach; the purpose is to use a linear programming model to demonstrate a novel benchmarking process of higher education institutional performance and determine an overall benchmark for institutions within each classified group. From the results, suggestions are provided for the general guidance of planners and decision makers in the higher education system.*

**Keywords-** *Higher education; Performance evaluation; DEA; Institutional benchmarking*

## 1. INTRODUCTION

Higher education is very expensive compared to elementary and secondary education, and institution's offerings may often fall short of the public's need (Sharma, 2009). With the present state of the economy, potential students are looking for both affordable and quality education prior to deciding on a college (Reider, 2001). Over the past 10 years (from 2002 to 2012), the enrollment in four-year and above institutions has increased at a faster rate (33.7 percent), from 10.1 million to 13.5 million. Much of this percentage growth came from the enrollments of private institutions, which rose 50.0 percent while the number of enrollments in public institutions only rose 25.6 percent (National Center for Education Statistics, 2014). As a result, private institutions (especially small, faith-based) are challenged to accomplish their missions and goals in the present environment of scarce sources of revenue. Meanwhile, public institutions also face the challenge of competition coming from private institutions which boast small class size, customized education service, and student-centered orientation (Duderstadt & Womack, 2011). However, during the recent economic recession, private education institutions struggled to receive funding from the necessary supports (such as appropriations) from the state and local governments. Since administrators, legislators, and students alike depend on reliable information on the performance of higher education institutions, these factors underscore the importance of assessment of these institutions' best practices over the spectrum of outputs. Though several models exist, this paper asserts the use of a linear programming model to demonstrate a novel benchmarking process for higher education performance, and identifies the efficient practice of institutions among the peer group as well as each classified group. In this study, we used Data Envelopment Analysis (DEA), a non-parametric technique using linear-programming models, to evaluate the relative efficiencies among the chosen group. This paper uses a multi-outcome DEA model to evaluate higher education performance by using and comparing a data set of 76 private four-year and above universities with institutional size between 1000 and 4999 students and 194 public four-year and above universities with institutional size over 1000 students in the southern region of the United States (i.e. AL, AR, KY, LA, MS, OK, TN, and TX). The data were obtained from the U.S. Department of Education, Institute of Education Sciences - National Center for Education Statistics (2014). Originally, our data set contained 95 private and 236 public institutions. Some missing values were observed from some institutions; consequently, we have removed 19 private and 42 public institutions from our data set, resulting in 76 private and 194 public institutions in our final study. The purpose of this paper is to demonstrate the benchmarking process of higher education performance and determine the overall benchmark for the inefficient institutions. The results of this paper can be used by either private or public higher education institutions to evaluate their performance in terms of students' retention and graduation rates. Areas of general guidance are identified for other higher education institutions. The remainder of the paper is organized as follows: Methodology, including the education performance model and the multi-outcome DEA model is described in section 2. Results and discussion of the analyses are presented in section 3. Finally, conclusions and areas for future research are shown in section 4.

## 2. METHODOLOGY

### 2.1 Education Performance Model

The U.S. Department of Education, Institute of Education Sciences (2014) provides detailed information such as institutional characteristics, students' enrollments, financial indicators, and related information. The collected data were divided into independent input variables and dependent output variables. A Data Envelopment Analysis (DEA) method was applied to determine the relative efficiency of each institution by comparing its performance with others in the same environment. In this study, we used the education performance model created by Liu and Liu (2010) shown in Figure 1 in annexure to evaluate the higher education performance. Under the model, we assume that all higher education institutions have the same operational goal of maximizing the students' retention and graduation rates. Table 1 in annexure indicates the variable descriptions. Based on previous studies and historical data (Liu & Liu, 2010; Hess, Schneider, Carey, & Kelly, 2009; Stolk, Tiessen, Clift, & Levitt, 2007; Fry, 2002), many students have successfully enrolled in post-secondary education but were unable to finish it. In this study, students' retention rate and graduation rate are considered dependent output variables. From the related bodies of knowledge ("US College Drop-out", 2005), the factors which may affect students' retention and graduation within 150 percent of their "expected" time include financial supports, academic status, the comfort of the educational atmosphere, and the qualifications/ backgrounds of admitted students. The most recent selected data is obtained from the U.S. Department of Education, Institute of Education Sciences (2014); a backward stepwise regression with an alpha level of 0.05 was also applied to confirm if those input variables are significant and contain power to explain the dependant variables.

### 2.2 Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a non-parametric method which was used to evaluate institutions' efficiencies and to identify the efficient institution(s) among the peer group. Each institution under evaluation is referred to as a decision making unit (DMU). Given the inputs and outputs of each DMU, a DEA efficiency score is calculated as a ratio of the weighted outputs to weighted inputs (Ragsdale, 2015). More specifically, DEA utilizes a linear-programming method to determine the weights of each input and each output so that the possible efficiency of the unit under consideration is maximized. The linear-programming model allows DEA to deal with multiple inputs and outputs of units simultaneously. The weights of inputs and outputs are allowed to vary across DMUs and are not required as *a priori* information (Liu & Farris, 2009). According to Paradi, Smith, and Schaffnit-Chatterjee (2002), DEA models can be classified by the orientation which maximizes efficiencies; an orientation which is decided based on the direction of the projection of the inefficient unit onto the frontier (see Figure 2 in annexure for the demonstration). In the graph below, there are four DMUs; the efficient units are the points (i.e. A, B, and C) in the frontier. According to Cooper, Seiford, and Tone (2007), there are three types of DEA models: (1) output-oriented models which determine DMU efficiency by maximizing outputs given input levels; (2) input-oriented models which minimize inputs given output levels; and (3) additive models which combine both output- and input-oriented models into a single one which optimizes the balance between inputs and outputs. There is no significant literature indicating which type of model is superior to the others (Cooper, Seiford, and Tone, 2007). Furthermore, DEA models can assume different returns to scale. Two of the most commonly used models are CCR model assuming constant returns to scale (CRS), which was introduced by Charnes, Cooper, and Rhodes (1978) and BBC model assuming variable returns to scale (VRS), which was introduced by Banker, Charnes, and Cooper (1984). In this study, we adopted the output-oriented model from Liu and Liu (2010) and the basic DEA formulation from Zhu (2003). Readers can also refer to Liu and Farris (2009) and Liu and Liu (2010) for a concise overview of this methodology. In this study, we were interested in determining efficiency among various DMUs (i.e. higher education institutions) within the chosen group. Essentially, we used a DEA method to determine the relative efficiency of each institution by comparing its performance with others in the same environment. We also believed that performing both output-oriented modeling (i.e. maximizing the students' retention and graduation rate) and input-oriented modeling (i.e. minimizing any input variables) fulfills an institution's purpose and goal since most higher education institutions have used the same standard and scale. The common rule of thumb for DEA models is that the number of units being analyzed should be at least twice of the number of inputs, multiplied by the number of outputs (Dyson, Allen, Camanho, Podinovski, Sarrico, & Shale, 2001). In this study, we have 76 and 194 valid data sets of private and public institutions, respectively, satisfying both sample size conditions. Additionally, data transformation procedures were applied to any undesirable output (i.e. "percentage of students receiving loans"), resulting in a normalized variable. Finally, we assumed homogeneity among all DMUs in the chosen group (Dyson et al., 2001). A Kruskall-Wallis test was used to evaluate the difference on DEA efficiency across institutions. The results showed that there was no significant efficiency difference detected among the institutional locations.

## 3. RESULTS AND DISCUSSION

The higher education efficiency performance of 76 private and 194 public institutions was evaluated using the DEA model. The DEA model was applied using DEA Frontier software, a DEA add-in for Microsoft Excel (Zhu, 2003). Table 2 in annexure shows the number of both private and public higher education institutions in different efficiency ranges. For the private institutions, 29 out of 76 were identified as efficient units (i.e. efficiency = 1.0), indicating that about 38% of the institutions were considered efficient performers, and efficiency scores ranged from 0.649 to 1.0, with an average efficiency of 0.8992. By contrast, using the same model on public higher education, only 22 out of 194 institutions in the chosen group were identified as efficient units, which accounts for only 11%. The efficiency scores ranged between 0.495 and 1.0, with an average efficiency of 0.8286.In Table 3 in annexure, we further analyzed the efficient unit(s) in each state for both private and public institutions. This table displays (1) the total number of institutions evaluated and how many were classified as an efficient unit, (2) the efficiency ratio (i.e. the total number of efficient institutions over the total number of institutions in that particular state), shown within parentheses, and (3) the average efficiency. There are two part of information: private institutions and public institutions. Among all of the states in the southern region, it appears that the institutions in Texas (TX) within the chosen group have the lowest average efficiency compared to those in other states. Moreover, private institutions performed better than public ones within the same state. The average efficiency scores range from 0.84899 to 1.0 for private institutions, and from 0.787839 to 0.908619 for public institutions. It was interesting to see that, within the chosen group, the state of Arkansas (AR) has three private and 12 public institutions; all of the private institutions have an efficiency score of 1.0, but none of the public institutions are classified as efficient units. It should be noted that when there is zero or only one efficient institution in the same state, the efficient ones located in the surrounding states should be considered the most likely candidate for having achieved best practices or an efficiency benchmark. In addition to statewide analyses, efficiency with respect to different institutional size is also of interest. Tables 4-1 and 4-2 in annexure demonstrate the analyses on public and private institutions, respectively. The tables show the same types of information as Table 3 with additional data on minimum efficiency and the institution with the best practice ranking (e.g. Table 4-1), and the efficient institutions in the same range of institutional size (e.g. Table 4-2). Table 4-1 indicates that the institutions with 1000 to 1999 students have the highest average efficiency and 46% of those are considered efficient performers; the institutions with 3000 to 3999 students have the lowest average efficiency and only 25% qualify as efficient institutions. The institution with the lowest efficiency under evaluation is also in this institutional size range. Institution 22xx98 located in Tennessee (TN) has been referred to by non-efficient units 33 times, achieving the title of highest reference frequency, and was consequently identified as the best practice institution among all of the institutions within the chosen private institutions. Institution 15xx48 located in Louisiana (LA), institution 15xx48 located in Kentucky (KY), and institution 17xx53 located in Mississippi (MS) can be the potential choices for the efficiency benchmark in the same criteria as well. In contrast to the private institutions, larger institutional size seems to be a better framework for the public institutions in terms of average efficiency, since the institutional size between 1000 and 4999 students has the lowest average efficiency compared to other size groups. Although this group has a greater number of efficient institutions and with higher efficiency ratio (i.e. 14% of the institutions qualify as efficient performers), this may result from the fact that this group has more institutions (see Table 4-2). The result also implies that in some states, such as TN, KY, and OK, institutions with 1000 to 4999 students are the only ones performing well among the public institutions, and in states such as LA and TX, efficient institutions are more equally distributed among different institutional sizes. As a result, if the same institutional size is preferred by any educational planners under the evaluation of efficiency, the institutions of different types (i.e. public or private) or of different geographic locations may have different benchmarks (see Table 3, Table 4-1, and Table 4-2 in annexure).

## 4. CONCLUSION

In this study, a multi-outcome model using DEA was developed for evaluating higher education performance aimed at students' success with respect to the institutions' missions. The evaluation of higher education based on different types of institutions included the overall efficiency and the identification of the efficient institution in terms of institutional type, institutional location, and institutional size. The results suggest that private institutional performance is superior to public institutions. Generally speaking, both public and private institutions have the potential to achieve higher efficiency, but private institutions with smaller institutional size (i.e. between 1000 and 1999 students) have higher opportunities to achieve this goal under the current study; on the other hand, public institutions with larger institutional size may find it easier to achieve higher efficiency based on the evaluation within the peer group. Recommendations for the future research may also focus on the designations of the institution (i.e. I, IIA, IIB, III, and IV) and other factors, such as population and average income related to the geographical locations, which can contribute to successful and sustained improvement.

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# ANNEXURE

Input Factors

- Living costs (+)
- Admitted rate (+)
- Full-time faculty (+)
- Percentage of students receiving loans (-)
- Tuition and fees as a percentage of core revenues (+)
- Total enrollment (+)

Output Factors

- Graduation rate
- Retention rate

**Figure 1: Education Performance Model**

**Table 1: Variable Description**

| | |
|---|---|
| Graduation rate (GR) | This rate is calculated as the total number of completers within 150% of normal time divided by the revised cohort minus any allowable exclusion. |
| Retention rate (RR) | This rate is calculated as the weighted percentage of the full-time and part-time fall cohort from the prior year minus exclusions from the full-time and part-time fall cohort, which enrolled at the institution as either full- or part-time in the current year. |
| Living costs (LC) | Cost of attendance for full-time, first-time degree/certificate-seeking undergraduate students living on campus for an academic year. |
| Admitted rate (AR) | This rate is calculated as the number of total admissions divided by the total applicants. |
| Percentage of students receiving loans (SL) | The percentage of the full-time, first-time degree/certificate-seeking undergraduate students who received student loans. |
| Tuition and fees as a percentage of core revenues (TU) | Revenues from all tuition and fees assessed against students (net of refunds and discounts and allowances) for educational purposes, divided by total core revenues. |
| Total enrollment (ER) | Total full-time undergraduate students who enrolled for 12 or more semester credits, and part-time undergraduate students who enrolled for either 11 or less semester credits. |
| Full-time faculty (FA) | Total number of the full-time-equivalent of faculty either in 9-month or 12-month contract |

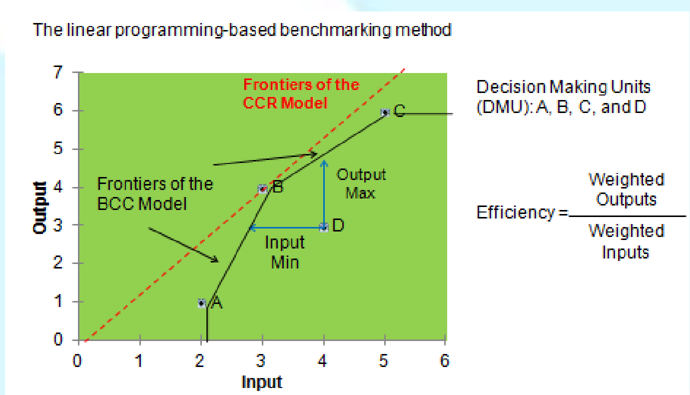


**Figure 2: Data Envelopment Analysis (DEA)**

**Table 2:Result of Efficiency Analysis**

| Institution Type \ Efficiency | # of institutions | **1 (Efficient Institution)** | 0.9 - 0.999 | 0.8 – 0.899 | 0.7 – 0.799 | < 0.7 |
|---|---|---|---|---|---|---|
| Private Institute | 76 | **29** | 14 | 16 | 14 | 3 |
| Public Institute | 194 | **22** | 37 | 59 | 49 | 27 |

**Table 3 :Analyses on Efficient Institution and Average Efficiency based on States**

| **Private Institute** | | | **Public Institute** | | |
|---|---|---|---|---|---|
| State | Total vs. Efficient (%) | Avg. Efficiency | State | Total vs. Efficient (%) | Avg. Efficiency |
| AL | 9 → 4 (44%) | 0.93433 | AL | 22 → 4 (18%) | 0.878273 |
| AR | 3 → 3 (100%) | 1.0 | AR | 12 → 0 (0%) | 0.840750 |
| KY | 13 → 7 (54%) | 0.92037 | KY | 22 → 2 (9%) | 0.811182 |
| LA | 4 → 1 (25%) | 0.86089 | LA | 21 → 4 (19%) | 0.908619 |
| MS | 4 → 2 (50%) | 0.94064 | MS | 11 → 3 (27%) | 0.893636 |
| OK | 5 → 3 (60%) | 0.87886 | OK | 17 → 1 (6%) | 0.810706 |
| TN | 21 → 6 (29%) | 0.90442 | TN | 33 → 3 (9%) | 0.808212 |
| TX | 17 → 3 (18%) | 0.84899 | TX | 56 → 5 (9%) | 0.787839 |
| **Total** | 76 → **29** (38%) | **0.89923** | **Total** | 194 → **22** (11%) | **0.828557** |

**Table 4-1: (Private Institution)**
**Analyses on Efficient Institution and Average Efficiency based on institutional size**

| Institutional Size (# of students) | Average Efficiency (Min. Eff.) | Total vs. Efficient (%) | The Institutions with the Highest Reference Frequency | |
|---|---|---|---|---|
| | | | Institution ID (Reference Frequency) | Institutional Size (State) |
| 1000~1999 | 0.94312 (0.71453) | 37 → 17 (46%) | 22xx98 (33) | 1981 (TN) |
| 2000~2999 | 0.85298 (0.71939) | 20 → 6 (30%) | 15xx48 (15) | 2742 (LA) |
| 3000~3999 | 0.83411 (0.64948) | 12 → 3 (25%) | 15xx48 (4) | 3365 (KY) |
| 4000~4999 | 0.919435 (0.77016) | 7 → 3 (43%) | 17xx53 (4) | 4741 (MS) |

**Table 4-2: (Public Institution)**
**Analyses on Efficient Institution and Average Efficiency based on institutional size**

| Institutional Size (# of students) | Average Efficiency (Min. Eff.) | Total vs. Efficient (%) | The Institutions with the Efficiency = 1 Institution ID (State) |
|---|---|---|---|
| 1000~4999 | 0.814771 (0.495) | 105 → 15 (14%) | 10xx93 / 10xx09 / 10xx77 (AL)<br>21xx39 / 22xx01 / 22xx51 (TN)<br>15xx95 / 15xx08 (KY)<br>15xx48 / 16xx74 (LA)<br>17xx16 / 17xx35 (MS)<br>22xx43 / 22xx67 (TX)<br>20xx22 (OK) |
| 5000~9999 | 0.846216 (0.587) | 37 → 4 (11%) | 22xx57 / 22xx80 (TX)<br>10xx06 (AL)<br>16xx21 (LA) |
| 10000~19999 | 0.84229 (0.701) | 31 → 2 (6%) | 16xx58 (LA)<br>17xx17 (MS) |
| Above 20000 | 0.846095 (0.528) | 21 → 1 (5%) | 22xx78 (TX) |