MEASURING THE ACADEMIC EFFICIENCY OF THE FOUR CAMPUSES OF THE UNIVERSITY FOR DEVELOPMENT STUDIES USING DATA ENVELOPMENT ANALYSIS

Sebil, Charles, MPhil, B.Sc
Kwame Nkrumah University of Science and Technology, Ghana
Quainoo, Albert Kojo, PhD, MSc, BSc, Dip.
Sam, Napoleon Bellua, MSc, BSc, HND
University for Development Studies, Ghana

Abstract:

The purpose of this paper was to utilize data envelopment analysis (DEA) to measure academic efficiency of the four campuses of the University for Development Studies (UDS) Ghana. DEA has been recognized as a robust tool that is used for evaluating the performance of profit and non-profit institutions. The proposed approach was deployed based on empirical data collected from the four campuses. On an efficiency scale of 0–1.0, DEA analysis assesses the relative efficiency of every campus relative to the rest of the campuses in terms of academic performance. For inefficient campuses, DEA analysis provides quantitative guidance on how to make them efficient. The 2010/11 academic year data from the four campuses of UDS were used. Four input variables and five output variables were identified. The input variables were lecture to student ratio, cost per student, library facilities and academic staff to non-academic staff ratio. Output variables were estimated as: classes obtained (that is first class, second class upper, second class lower, third class and pass). Three campuses (Tamale, Nyankpala and Wa) formed the efficiency frontier and the fourth campus (Navrongo) was found inefficient for the academic year. There was an indication that reduction in academic staff to non-academic staff ratio as input has a larger effect on efficiency of Navrongo campus than does in input cost per student ratio. For Navrongo campus to be on the efficiency frontier, it is better for cost per student ratio as input to be reduced more than the library facilities.

Keywords: Data Envelopment Analysis, efficiency frontier, quantitative guidance, empirical data, relative efficiency and inefficient.

Introduction

The scrutiny on Governments has demanded public organizations to increase the efficiency in using the resources they manage. Moreover, there has been greater autonomy for the governmental units resulted from the decentralization processes that recently took place in a number of countries. These changes call for the use of new management techniques able to value the performance of these units and to provide tools that can contribute to the improvement of decision-making processes in the public sector. However, to evaluate activities framed inside the non-lucrative public sector, the usefulness of certain representative indicators of the effectiveness and efficiency of an organization becomes rather limited. This is indeed the case of fundamental concepts such as profitability, commonly applied in the case of lucrative organizations, which cannot readily be applied to analyzing public issues. As Boussofiane and Dyson (1991) indicated profitability should not be the only performance measure even for profit making organizations. They argue that environment factors outside the company control can affect performance. Thus, when the unit of analysis in an organization (public or private) without lucrative aims, subject to multiple objectives and whose outputs cannot always be expressed in quantitative terms; the assessment of its activity needed a combination of performance indicators. In situations in which each input and output cannot be added in a significant index of productive efficiency, it is useful that the application of the Data Envelopment Analysis model (DEA) be used as a tool to measure the relative efficiency of a group of homogeneous Decision Making Units (DMU). The study describes the use of DEA methodology to assess academic efficiency of the four campuses within the University for Development Studies (UDS) according to data of the year 2010/2011.

Methodologies

Charnes, and associates (1978) were the first to propose the DEA methodology as an evaluation tool for decision units. DEA has been applied successfully as a performance evaluation tool in many fields including manufacturing, school, banks, pharmacies ,universities, small business development centers, and nursing home chains. Seiford (1990) provided an excellent bibliography of DEA applications. We employed a mathematical planning model (CCR model) to measure the efficiency frontier based on the concept of Pareto optimum. The basic idea of DEA is to identify the most efficient decision-making unit (DMU) among all DMUs. The most efficient DMU is called a Pareto-optimal unit and is considered the standard for comparison for all other DMUs. In this, a single firm is considered DEA Pareto efficient if it cannot increase any output or reduce any input without reducing other output or increasing other input. An efficient firm can enjoy efficiency scores of unity, while an inefficiency firm receives DEA scores of less than unity.

Efficiency is the ratio of the weighted sum of a firm to the weighted sum of inputs. The efficiency of any firm is computed as the maximum of a ratio of weighted firms to weighted inputs, subject to the condition that similar ratios, using the same weights, for all other firms under consideration, are less than or equal to one. Here, we denote the maximum efficiency as E_k, Y_{kj} as the *j*th output of the *k*th DMU and X_{ki} as the *i*th input of the *k*th DMU. If a DMU employs *p* input to produce *q* output, the score of *k*th DMU, E_k, is a solution from the fractional linear programming problem:

$$Max\ E_k = \frac{\sum_{j=1}^{q} U_j Y_{kj}}{\sum_{i=1}^{p} V_i\ X_{ri}} \quad i = 1,2,\ldots\ldots,p \quad j = 1,2,\ldots\ldots,q$$

$$s.t \quad \frac{\sum_{j=1}^{q} U_j Y_{rj}}{\sum_{i=1}^{p} V_i\ X_{ri}} \leq 1 \quad r = 1,2,\ldots\ldots,K,\ldots\ldots,R$$

$$U_j, V_i \geq \varepsilon > 0 \quad for\ i,j$$

Where U_j and V_i are the variable weights in the *j*th output and the *i*th input, respectively.

The former model can be reformulated by adding $\sum_{r=1}^{r} \lambda_r = 1$ to the problem, which provides
valuable information about the cost benefits:

$$Min\ TE = \theta - \varepsilon\left(\sum_{i=i}^{p} S_{ki}^{-} + \sum_{i=i}^{p} S_{kj}^{+}\right)$$

$$\text{s.t.} \quad \sum_{r}^{r} \lambda_r X_{ri} - \theta X_{ki} + S_{ki}^{-} = 0$$

$$\sum_{r}^{r} \lambda_r Y_{rj} - S_{kj}^{+} = Y_{rj}$$

$$\sum_{r=1}^{r} \lambda_r = 1$$

$$\lambda_r \geq 0, \qquad S_{ki}^{-} = 0, \qquad S_{kj}^{+} \geq 0, \qquad for\ \ i,j,k,r$$

Where θ is the efficiency score and ε is a non-archimedean quantity which is very minute.

We can calculate the relative efficiency score from the above model and further estimate the
targeted value for each output/input of each campus.

Results and Analysis

DEA model for a given campus system can be formulated as follows:

$$\text{Target DMU (Max } \theta) = v_1 y_{1o} + v_2 y_{2o} + \cdots + v_r y_{ro}$$

$$\text{s.t. } u_1 x_{1o} + u_2 x_{2o} + \cdots + u_m x_{mo} = 1$$

$$v_1 y_{1i} + v_2 y_{2i} + \cdots + v_r y_{ri} \leq u_1 x_{1i} + u_2 x_{2i} + \cdots + u_m x_{mi}, \qquad i = 1, \ldots, n$$

$$u_1, u_2, \ldots, u_m \geq 0$$

$$v_1, v_2, \ldots, u_r \geq 0.$$

y_r= amount of output r

v_r= weight assigned to output r

x_i= amount of input i

u_i= weight assigned to input i

The linear programming formulated out of the data:
Max: Tamale = $6v_1 + 114v_2 + 59v_3 + 10v_4;$

Subject to: $0.0390u_1 + 57u_2 + u_3 + u_4 = 1;$

$$6v_1 + 114v_2 + 59v_3 + 10v_4 - (0.0390u_1 + 57u_2 + u_3 + u_4) \leq 0;$$

$$v_1 + 181v_2 + 227v_3 + 10v_4 - (0.0310u_1 + 121u_2 + u_3 + 0.5255474u_4) \leq 0$$

$$v_1 + 185v_2 + 307v_3 + 21v_4 + 4v_5 - (0.0205u_1 + 130u_2 + u_3 + 1.1076923u_4) \leq 0$$

$$145v_2 + 668v_3 + 21v_4 + 181v_5 - (0.0077u_1 + 77u_2 + 2u_3 + 1.2533333u_4) \leq 0$$

$$v_1, v_2, v_3, v_4, v_5, u_1, u_2, u_3, u_4 \geq 0$$

Max: Nyankpala = $v_1 + 181v_2 + 227v_3 + 10v_4;$

Subject to: $0.0310u_1 + 121u_2 + u_3 + 0.5255474u_4 = 1;$

$$6v_1 + 114v_2 + 59v_3 + 10v_4 - (0.0390u_1 + 57u_2 + u_3 + u_4) \leq 0;$$

$v_1 + 181v_2 + 227v_3 + 10v_4 - (0.0310u_1 + 121u_2 + u_3 + 0.5255474u_4) \leq 0$

$v_1 + 185v_2 + 307v_3 + 21v_4 + 4v_5 - (0.0205u_1 + 130u_2 + u_3 + 1.1076923u_4) \leq 0$

$145v_2 + 668v_3 + 21v_4 + 181v_5 - (0.0077u_1 + 77u_2 + 2u_3 + 1.2533333u_4) \leq 0$

$v_1, v_2, v_3, v_4, v_5, u_1, u_2, u_3, u_4 \geq 0$

Max: Navrongo = $v_1 + 185v_2 + 307v_3 + 21v_4 + 4v_5$;
Subject to: $0.0205u_1 + 130u_2 + u_3 + 1.1076923u_4 = 1$;

$6v_1 + 114v_2 + 59v_3 + 10v_4 - (0.0390u_1 + 57u_2 + u_3 + u_4) \leq 0$;

$v_1 + 181v_2 + 227v_3 + 10v_4 - (0.0310u_1 + 121u_2 + u_3 + 0.5255474u_4) \leq 0$

$v_1 + 185v_2 + 307v_3 + 21v_4 + 4v_5 - (0.0205u_1 + 130u_2 + u_3 + 1.1076923u_4) \leq 0$

$145v_2 + 668v_3 + 21v_4 + 181v_5 - (0.0077u_1 + 77u_2 + 2u_3 + 1.2533333u_4) \leq 0$

$v_1, v_2, v_3, v_4, v_5, u_1, u_2, u_3, u_4 \geq 0$

Max: Wa = $145v_2 + 668v_3 + 21v_4 + 181v_5$;

Subject to: $0.0077u_1 + 77u_2 + 2u_3 + 1.2533333u_4 = 1$;

$6v_1 + 114v_2 + 59v_3 + 10v_4 - (0.0390u_1 + 57u_2 + u_3 + u_4) \leq 0$;

$v_1 + 181v_2 + 227v_3 + 10v_4 - (0.0310u_1 + 121u_2 + u_3 + 0.5255474u_4) \leq 0$

$v_1 + 185v_2 + 307v_3 + 21v_4 + 4v_5 - (0.0205u_1 + 130u_2 + u_3 + 1.1076923u_4) \leq 0$

$145v_2 + 668v_3 + 21v_4 + 181v_5 - (0.0077u_1 + 77u_2 + 2u_3 + 1.2533333u_4) \leq 0$

$v_1, v_2, v_3, v_4, v_5, u_1, u_2, u_3, u_4 \geq 0$

Table 1: Descriptive statistics for DEA results

Items	Scores
Total number of DMUs	4.00
Number of efficient DMUs	3.00
Number of inefficient DMUs	1.00
Maximum efficiency	1.00
Minimum efficiency	0.86
Average efficiency	0.97

Source: Author's construct, April 2012

Table 1 summarizes the descriptive statistics of the results. The maximum efficiency score was 1.00, while the minimum efficiency score was 0.86.The efficiency score average is 0.97.This implies that the input for an average unit may be reduced by 3%.

Table 2: Efficiency scores of the campuses

Campuses	Efficiency
Tamale	1.00
Nyankpala	1.00
Navrongo	0.86
Wa	1.00

Source: Author's construct, April 2012

Table 2 shows the scores of the four campuses obtained from DEA using CCR model. These efficiency scores were under the following conditions:

1. All data and all weights are positive
2. Efficiency scores must lie between zero and unity
3. The same weights for the target campus are applied to all campuses

The following three (3) campuses (Tamale, Nyankpala and Wa) were efficient and are considered to have better academic performances. These efficient campuses have an efficiency score equal to one (1.00) and on the efficient frontier. The three campuses were more efficient in converting inputs into better academic performance of students as compared to Navrongo campus (0.86) which was inefficient. Navrongo campus efficiency may be determined by comparing it to any of the three efficient campuses.

Table 3: Optimal weights for Tamale as the target DMU

Name	Original value	Final value
Weight (V_1)1st class	1.0000	0.0000
Weight (V_2) 2nd class upper	1.0000	0.0087
Weight (V_3) 2nd class lower	1.0000	0.0001
Weight (V_4) 3rd class	1.0000	0.0000
Weight (V_5) pass	1.0000	0.0000
Weight(U_1) lecture to student ratio	1.0000	0.0000

Weight (U_2) cost per student ratio	1.0000	0.0118
Weight (U_3) library facilities	1.0000	0.0000
Weight (U_4) academic to non-academic staff ratio	1.0000	0.3281

Source: Author's construct, April 2012

Tables 3 , the optimal solution to linear programming (LP) has the value one (1) and the best input and output weights were $U_1 = 0, U_2 = 0.0118, U_3 = 0,$ $U_4 = 0.3281,$

$V_1 = 0, V_2 = 0.0087, V_3 = 0.0001, V_4 = 0$ and $V_5 = 0$.

Let now observe the difference between the optimal weights $U_2 = 0.0118$

and $U_4 = 0.3281$.The ratio $\frac{U_4}{U_2} = 28$ suggested that it was advantageous for

Navrongo campus to weight input (Academic to non academic staff ratio) 28 times more than input weight (Cost per student ratio) in order to maximize the efficiency. It shows that a reduction in input U_4 has a bigger effect on

efficiency than does a reduction in input U_2.

Table 4: Constraints of the Model for Tamale as the target DMU

Name	Cell value	Formula	Status	Slack
Tamale weighted input	1.0000	L2=1	Not binding	0.0000
Tamale working	0.0000	N2<=0	Binding	0.0000
Nyankpala working	0.0000	N3<=0	Binding	0.0000
Navrongo working	-0.2557	N4<=0	Not binding	0.2557
Wa working	0.0000	N5<=0	Binding	0.0000

Source: Author's construct, April 2012

Table 4, also indicated that the three working constraints (Tamale, Nyankpala and Wa) with a slack value of zero were said to be binding because they are satisfied with equality at the LP optimal.

Table 5: Sensitivity report on the optimal weights for Tamale as the target DMU

Name	Final value	Reduced cost	Objective coefficient	Allowable increase	Allowable decrease
Weight (V_1)1st class	0.0000	0.0000	6	0	1E+30
Weight (V_2) 2nd class upper	0.0087	0.0000	114	0	0
Weight (V_3) 2nd class lower	0.0001	0.0000	59	0	0

Weight (V_4) 3rd class	0.0000	0.0000	10	0	1E+30
Weight (V_5) pass	0.0000	0.0000	0	0	1E+30
Weight(U_1) lecture to student ratio	0.0000	0.0000	0	0	1E+30
Weight (U_2) cost per student ratio	0.0118	0.0000	0	0	0
Weight (U_3) library facilities	0.0000	0.0000	0	0	1E+30
Weight (U_4) academic to non-academic staff ratio	0.3281	0.0000	0	0	0

Source: Author's construct, April 2012

From Table 5, having, $U_1 = 0, U_2 = 0.0118, U_3 = 0,$ $U_4 = 0.3281, V_1 = 0, V_2 = 0.0087, V_3 = 0.0001, V_4 = 0$ and $V_5 = 0$. Suppose we varied the coefficient of V_2 in the objective function, the solution value for V_2 was 0.0087 and the objective function coefficient for V_2 was 114.The allowable increase or decrease tells us that, provided the coefficient for V_2 in the objective function lies between 114 + 0=114 and 114-0 = 114, the values of the variables in the optimal LP solution will remain unchanged.

Again, the solution value for V_3 was 0.0001 and the objective function coefficient for V_3 was 59, the allowable increase or decrease tells us that, provided the coefficient for V_3 in the objective function lies between 59±0 =59, the values of the variables in the optimal LP solution will remain unchanged. Similar conclusions may be drawn about $U_1, U_2, U_3, U_4, V_1, V_4$, and V_5.

Table 6: Sensitivity report on the Constraints of the Model for Tamale as Target DMU

Name	Final value	Shadow price	Constraint R.H. side	Allowable increase	Allowable decrease

Tamale weighted input	1.0000	1.0000	1	1E+30	0.999999999
Tamale working	0.0000	1.0000	0	0.036725235	0.812757636
Nyankpala working	0.0000	0.0000	0	0.354022117	0.516530473
Navrongo working	-0.2557	0.0000	0	1E+30	0.255716675
Wa working	0.0000	0.0000	0	1.319066139	0.043313299

Source: Author's construct, April 2012

From Table 6, we can study the effect of changing the right-hand side of Wa constraint. If the right-hand side of Wa constraint lies between 0+1.319066=1.319066 and 0- 0.043313= -0.043313, the objective function change will be exactly zero (0).
Again, if the right-hand side of Tamale constraint lies between 0+0.0367252=0.0367252 and 0-0.8127576 = -0.8127576, the objective function change will be exactly one (1).

Table 7: Optimal weights for Nyankpala as the Target DMU

Name	**Original Value**	**Final Value**
Weight (V_1) 1st class	1.0000	0.0000
Weight (V_2) 2nd class Upper	1.0000	0.0051
Weight (V_3) 2nd class Lower	1.0000	0.0003
Weight (V_4) 3rd class	1.0000	0.0000
Weight (V_5) pass	1.0000	0.0000
Weight(U_1) lecture to student ratio	1.0000	0.0000
Weight (U_2) cost per student ratio	1.0000	0.0063
Weight (U_3) library facilities	1.0000	0.2448
Weight (U_4) academic to non-academic staff ratio	1.0000	0.0000

Source: Author's construct, April 2012

From Tables 7, the optimal solution to linear programming (LP) has the value one (1) and the best input and output weights were $U_1 = 0, U_2 = 0.0063$, $U_3 = 0.2448$,

$U_4 = 0$, $V_1 = 0$, $V_2 = 0.0051$, $V_3 = 0.0003, V_4 = 0$ and $V_5 = 0$.

Let now observe the difference between the optimal weights $U_2 = 0.0063$ and $U_3 = 0.2448$. The ratio $\frac{U_3}{U_2} = 39$ suggested that it was advantageous for Navrongo campus to weight input (Library facilities) 39 times more than input weight (Cost per student ratio) in order to maximize the efficiency. It shows that a reduction in input U_3 has a bigger effect on efficiency than does a reduction in input U_2.

Table 8: Constraints of the Model for Nyankpala as the Target DMU

Name	Cell value	Formula	Status	Slack
Tamale working	0.0000	N2<=0	Binding	0.0000
Nyankpala working	0.0000	N3<=0	Binding	0.0000
Navrongo working	-0.0080	N4<=0	Not binding	0.0080
Wa working	0.0000	N5<=0	Binding	0.0000
Nyankpala weighted input	1.0000	L3=1	Not binding	0.0000

Source: Author's construct, April 2012

Table 8, also indicates that the three working constraints (Tamale, Nyankpala and Wa) with a slack value of zero were said to be binding because they were satisfied with equality at the LP optimal.

Table 9: Sensitivity report on the optimal weights for Nyankpala as the target DMU

Name	Final value	Reduced cost	Objective coefficient	Allowable increase	Allowable decrease
Weight (V_1)1st class	0.0000	0.0000	1	0	1E+30
Weight (V_2) 2nd class Upper	0.0051	0.0000	181	0	0
Weight (V_3) 2nd class lower	0.0003	0.0000	227	0	0
Weight (V_4) 3rd class	0.0000	0.0000	10	0	1E+30
Weight (V_5) pass	0.0000	0.0000	0	0	1E+30
Weight(U_1) lecture to student ratio	0.0000	0.0000	0	0	1E+30
Weight (U_2) cost per student ratio	0.0063	0.0000	0	0	0
Weight (U_3) library facilities	0.2448	0.0000	0	0	0
Weight (U_4) academic to non-academic staff ratio	0.0000	0.0000	0	0	1E+30

Source: Author's construct, April 2012

From table 9, having, $U_1 = 0$, $U_2 = 0.0063$, $U_3 = 0.2448$, $U_4 = 0$, $V_1 = 0$, $V_2 = 0.0051$, $V_3 = 0.0003$, $V_4 = 0$ and $V_5 = 0$. Suppose we varied the coefficient of V_2 in the objective function, the solution value for V_2 was 0.0051 and the objective function coefficient for V_2 was 181. The allowable increase or decrease tell us that, provided the coefficient for V_2 in the objective function lies between 181 + 0=181 and 181-0 = 181, the values of the variables in the optimal LP solution will remain unchanged.

Again, the solution value for V_3 was 0.0003 and the objective function coefficient for V_3 was 227. The allowable increase or decrease tells us that provided the coefficient for V_3 in the objective function lies between 227±0 =227, the values of the variables in the optimal LP solution will remain unchanged. Similar conclusions can be drawn about U_1, U_2, U_3, U_4, V_1, V_4, and V_5.

Table 10: Sensitivity report on the Constraints of the model for Nyankpala as target DMU

Name	Final value	Shadow price	Constraint R.H. side	Allowable increase	Allowable decrease
Tamale working	0.0000	0.0000	0	0.093959195	0.021407078
Nyankpala working	0.0000	1.0000	0	0.006730093	0.243534189
Navrongo working	-0.0080	0.0000	0	1E+30	0.007972781
Wa working	0.0000	0.0000	0	0.088676431	0.242708808
Nyankpala weighted input	1.0000	1.0000	1	1E+30	0.999999997

Source: Author’s construct, April 2012

From Table 10, we can study the effect of changing the right-hand side of Wa constraint. If the right-hand side of Wa constraint lies between 0+0.0887=0.0887 and 0- 0.2427= -0.2427, the objective function change will be exactly zero (0).

Again, if the right-hand side of Nyankpala constraint lies between 0+0.0067= 0.0067 and 0-0.2435 = -0.2435, the objective function change will be exactly one (1).

Table 11: Optimal weights for WA as the Target DMU

Name	Original Value	Final Value
weight (V_1)1st Class	1.0000	0.0000
weight (V_2) 2nd Class Upper	1.0000	0.0066
weight (V_3) 2nd Class Lower	1.0000	0.0001
weight (V_4) 3rd Class	1.0000	0.0000
weight (V_5) Pass	1.0000	0.0000
weight(U_1) Lecture to Student Ratio	1.0000	0.0000
weight (U_2) Cost per Student Ratio	1.0000	0.0090
weight (U_3) Library Facilities	1.0000	0.0000
weight (U_4) Academic to Non-Academic Staff Ratio	1.0000	0.2493

Source: Author's construct, April 2012

From Tables 11, we can see that the optimal solution to linear programming (LP) has the value one (1) and the best input and output weights were $U_1 = 0, U_2 = 0.0090, U_3 = 0,$

$U_4 = 0.2493, V_1 = 0, V_2 = 0.0066, V_3 = 0.0001, V_4 = 0$ and $V_5 = 0$.

Let now observe the difference between the optimal weights $U_2 = 0.0090$ and $U_4 = 0.2493$. The ratio $\frac{U_4}{U_2} = 28$ suggested that it was advantageous for Navrongo campus to weight input (Academic to Non academic staff ratio) 28 times more than input weight (Cost per Student ratio) in order to maximize the efficiency. It shows that a reduction in input U_4 has a bigger effect on efficiency than does a reduction in input U_2.

Table 12 : Constraints of the Model for WA as the target DMU

Name	Cell Value	Formula	Status	Slack
Tamale working	0.0000	N2<=0	Binding	0.0000
Nyankpala working	0.0000	N3<=0	Binding	0.0000
Navrongo working	-0.1943	N4<=0	Not Binding	0.1943
Wa working	0.0000	N5<=0	Binding	0.0000
Wa weighted input	1.0000	L5=1	Not Binding	0.0000

Source: Author's construct, April 2012

Table 12, also indicated that the three working constraints (Tamale, Nyankpala and Wa) with a slack value of zero were said to be binding because they were satisfied with equality at the LP optimal.

Table 13: Sensitivity report on the optimal weights for WA as the target DMU

Name	Final value	Reduced cost	Objective coefficient	Allowable increase	Allowable decrease
Weight (V_1)1st class	0.0000	0.0000	0	0	1E+30
Weight (V_2) 2nd class upper	0.0066	0.0000	145	0	0
Weight (V_3) 2nd class lower	0.0001	0.0000	668	0	0
Weight (V_4) 3rd class	0.0000	0.0000	21	0	1E+30
Weight (V_5) pass	0.0000	0.0000	181	0	1E+30
Weight(U_1) lecture to student ratio	0.0000	0.0000	0	0	1E+30
Name	**Final value**	**Reduced cost**	**Objective coefficient**	**Allowable increase**	**Allowable decrease**
Weight (U_2) cost per student ratio	0.0090	0.0000	0	0	0
Weight (U_3) library facilities	0.0000	0.0000	0	0	1E+30
Weight (U_4) academic to non-academic staff ratio	0.2493	0.0000	0	0	0

Source: Author's construct, April 2012

From Table 13, having, $U_1 = 0, U_2 = 0.0090, U_3 = 0,$ $U_4 = 0.2493, V_1 = 0, V_2 = 0.0066, V_3 = 0.0001, V_4 = 0$ and $V_5 = 0.$

Suppose we varied the coefficient of V_2 in the objective function, the solution value for V_2 was 0.0066 and the objective function coefficient for V_2 was 145.The allowable increase or decrease tells us that, provided the coefficient for V_2 in the objective function lies between 145 + 0=145 and 145-0 = 145, the values of the variables in the optimal LP solution will remain unchanged.

Again, the solution value for V_3 was 0.0001 and the objective function coefficient for V_3 was 668. The allowable increase or decrease tells us that provided the coefficient for V_3 in the objective function lies between 668±0 =668, the values of the variables in the optimal LP solution will remain unchanged. Similar conclusions can be drawn about $U_1, U_2, U_3, U_4, V_1, V_4$, and V_5.

Table 14: Sensitivity report on the Constraints of the Model for WA as the target DMU

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
Tamale working	0.0000	0.0000	0	0.027850805	0.648476839
Nyankpala working	0.0000	0.0000	0	0.273395209	0.383659681
Navrongo working	-0.1943	0.0000	0	1E+30	0.194340416
Wa working	0.0000	1.0000	0	0.989298497	0.032931782
Wa weighted input	1.0000	1.0000	1	1E+30	0.999999999

Source: Author's construct, April 2012

From Table 14, we can study the effect of changing the right-hand side of Wa constraint. If the right-hand side of Wa constraint lies between 0+0.9893=0.9893 and 0- 0.03293= -0.03293, the objective function change will be exactly one (1). Again, if the right-hand side of Tamale constraint lies between 0+0.02785=0.02785 and 0-0.6485 = -0.6485, the objective function change will be exactly zero (0).

Conclusion

When considering this analysis as a whole, one must also give consideration to the variables selected as outputs and inputs. When classes obtained were selected as outputs and lecture to student ratio, cost per student ratio, library facilities and academic to nonacademic staff ratio were selected as inputs, they were selected in an attempt to show the most important attributes pertinent to the problem at hand.

This paper contributes a DEA approach for academic performance of students. A point of departure for the DEA approach compared to existing methods is the input–output framework. Compared to each other, DEA measures the efficiency of academic performance of students in utilizing their expenses on students, lecture to student ratio and staff to maximize the classes obtained by students. Therefore, the DEA approach relates resources expended on students to academic performance. The analysis identifies Tamale, Nyankpala and Wa campuses as efficient. They serve as the ‘‘benchmark” for the campuses and can be utilized as role models to which inefficient campus (Navrongo) may adjust its resources in order to become efficient.

There was an indication that when Tamale was set as target DMU for Navrongo campus, the reduction in input that is academic to non-academic staff ratio has a larger effect on efficiency of Navrongo campus than does in input cost per student ratio. In otherwords, the cost per student ratio for Navrongo campus should be reduced by management.

There was also an indication that Navrongo constraint was not binding because it was not satisfied with equality at the LP optimal. Similar conclusions were drawn when Wa was set as target DMU for Navrongo campus.

Again, when Nyankpala campus was set as a target DMU for Navrongo campus, it indicated that in order to achieve Navrongo campus as efficient, it is better to reduce cost per student more than the library facilities. In other words, management may reduce the expenditure on students in order to be at the frontier.

References:

Banker, R.D., Charnes, A., Cooper, W.W., Some Models for Estimating Technical and Scale Ineficiency in Data Envelopment Analysis, Management Science, Vol. 31, No. 9, Sept. 1984.

Boussofiane, A and Dyson, R., Applied Data Envelopment Analysis.European
Journal of Political Research,52,pp 1-15, 1991.

Breu, T.M. and Raab, R.L., Efficiency and perceived quality of the nation`s Top 25 national universities and national liberal arts colleges: an application of DEA to higher education, Socio-Economic Planning Sciences, Vol.28, No.1, pp.35-45,1994.

Charnes A., Cooper W.W., and Rhodes E., A Data Envelopment Analysis Approach to Evaluation of the Program Follow Through Experiments in U.S. Public School Education,
Management Science Research Report No. 432, Carnegie-Mellon University, School of Urban and Public Affairs, Pittsburgh, P.A, 1978.

Cooper, W.W., Seiford, L M , Tone, K., Data Envelopment Analysis - A Comprehensive
Text with Models, Applications, References and DEA-Soiver Software, Kluwer Academic Publisher, 2000.

Fultron, L.V., Efficiency Analysis of 24 Military Hospitals for the years 2001-2003 were
Performed Using Data Envelopment Analysis. University of Texas at Austin.http://
respositories.lib.utexas.edu/bistream/handle/2152/1492/fultron125174.pdf?sequence=2.
06/06/12, 2005.

Kokkelenberg, E.C, Sinha E, Porter J.D, and Blose G.L., The Efficiency of Private
Universities As measured By Graduation Rates. http://digitalcommons.ilr.cornell.edu/cgi/
Viewcontent.cgi?article=1124&context=workingpapers. 06/06/2012, 2008.

Lin, W.C., Liu C.F., and Chu C.W., Performance efficiency evaluation of the Taiwan`s shipping industry: An application of data envelopment analysis. Proceedings of the Eastern Asia Society for Transportation Studies, 5: 467-476, 2005.

Lertworasirikul S., Fuzzy Data Envelopment Analysis. http://respository.lib.ncsu.edu/ir/bitstream/1840.16/3330/1/edt.pdf.06/06/12, 2002.

Martin E., An Application of the Data Envelopment Analysis Methodology in the performance Assessment of the Zaragoza University Developments. Department of Accounting and Finance, University of Zaragoza. www.dteconz.unizar.es/DT2003-06.pdf,06/06/2012, 2006.

Seiford, L., A bibliography of data envelopment analysis, University of Massachusetts,
working paper, 1990.

Stancheva N., and Angelova V., Measuring the Efficiency of University Libraries Using Data Envelopment Analysis. http:// www.bookpump.com/upb/pdf-b/9429500b.pdf.
06/06/2012, 2004.