



## Full Length Research Paper

# Using DEA to evaluate efficiency of African higher education

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### ABSTRACT

The core aim of the higher education policy in any country is establishing a competitive, qualitative higher education with efficiently operating institutions. The question of efficiency needs special attention not only because of the decline of the state support but also the rapid raise of the student mass. In the education system, especially higher education, it's not easy to measure its efficiency. The situation is more complicated since those institutions have multiple inputs and outputs, and not all these outputs could be economically measured. In this case a possible method of determining efficiency is Data Envelopment Analysis. In this paper I adopt the two stage efficiency analysis and use it to compare the efficiency of African higher education systems in fifteen countries using DEA. and then I use the tobit regression to determine the most environmental factors that affecting the efficiency of this institute. The analysis shows that the most influential factors affecting efficiency are the growth rate, private share, and public expenditure on education.

**Keywords:** DEA, African Higher education, Efficiency, Tobit Regression.

## INTRODUCTION

With the limited resources African countries have, the Evaluation of the efficiency of higher education became one of the main subjects in studying the economies of African higher education. this evaluation which allow the countries not only to know the efficiency level of their higher education, but also the target level and the improvements needed to reach this level.

### *Higher Education Efficiency*

The concept of efficiency is an essential part of the process of evaluating the performance of educational institutions which consist of three main components: efficiency, effectiveness and productivity. The efficiency is an expression of the success of the production unit in tightening the relationship between resources used and outputs in an efficient manner designed to maximize output and reduce input. The efficiency is an expression

of the success of the production unit in achieving its objectives through the comparison between planned objectives and what has already been achieved.

Hence, the concept of economic efficiency of higher education includes two types of efficiency: Technical Efficiency which means the ability of the institution to produce the maximum amount of production using available inputs. And The functional efficiency or Allocative Efficiency which refers to the ability of the institution to use the optimal mix of inputs, taking into account the prices of these inputs and production techniques available. Thus, the overall economic efficiency means the ability of educational institutions to achieve both technical and allocative efficiency. There are other studies add another type of efficiency, especially when analyzing the efficiency of institutions of higher education which is the dynamic efficiency and that relate to the ability of the institution to innovate in production methods.

**Measuring the Efficiency of Higher education**

Measuring the efficiency of higher education is differ from measuring the efficiency of any regular production unit from two ways, First: higher education institutions use multiple inputs to produce multi outputs making it difficult to use the regular techniques to determine the optimal mix if these inputs and outputs. Secondly, some outputs of higher education can't be measured because of the nature of this output as social externalities of higher education or its impact on economic development. Generally there are two main methods to evaluate the efficiency of higher education, the parametric methods as stochastic frontier Analysis, and the Non parametric methods. There is also the two level efficiency analyses that combined both parametric and non parametric techniques. The idea of this method is to use the Data Envelopment Analysis to get the efficiency score of the African universities in the first stage and then regress this score on other external factors affecting efficiency level using tobit regression model.

**MATERIALS AND METHODS**

Data Envelopment Analysis (DEA) is defined as: a “data-oriented” approach for evaluating the performance of a set of peer entities called Decision-Making Units (DMUs), which convert multiple inputs into multiple outputs(Cooper 2011). DEA was introduced for the first time in 1978 by Charness, William Cooper and Rhodes who develop its Basic Model known by there names CCR Model(Toth 2009), assuming that DMUs works under constant returns to scale.

DEA can be interpreted with either input-oriented or output-oriented approaches. The output oriented approach focuses on how high maximal output can be achieved with the same amount of resources. The output-oriented approach is the appropriate one for higher education because the principle of cost minimization is not applied according to the market conditions. It should also be taken into consideration that the integration of resources is not always the same in the education process(Toth ; William Cooper 2007).

The original CCR model for n DMUj where j=1,...,n, that produce Y<sub>rj</sub> where (r= 1,..., s) using X<sub>ij</sub> where (i= 1,2,...,n), takes the following formula(Joe 2006):

$$MAX\theta = \sum_{r=1}^s U_r Y_{r0}$$

Subject to:

$$\sum_{r=1}^s U_r Y_{rj} - \sum_{i=1}^m V_i X_{ij} \leq 0, j=1,2,\dots,n$$

$$\sum_{i=1}^m V_i X_{i0} = 1$$

$$*U_r, V_i \geq 0, \quad r=1,2,\dots,s - i=1,2,\dots,m$$

Since 1978 DEA model is developed by researchers who drop the assumption of constant returns to scale of the original model. The new model was developed by Banker, Charnes and Cooper at 1984. the BCC model taking the following formula:

$$MIN\theta_0$$

Subject to:

$$\sum_{j=1}^n \lambda_j X_{ij} \leq \theta_0 X_{i0} \quad i = 1,2,\dots,m$$

$$\sum_{j=1}^n \lambda_j Y_{rj} \geq Y_{r0} \quad r = 1,2,\dots,s$$

$$\sum_{j=1}^n \lambda_j = 1$$

$$\lambda_j \geq 0$$

The difference between the efficiency Score of CCR model and BCC model shows the source of inefficiency of the DMU. While the efficiency score of CCR model shows the overall efficiency (technical and Scale efficiency) of the DMU, the score of BCC shows the pure technical efficiency. Then the scale efficiency of a DMU could be calculated by dividing the CCR efficiency by the BCC model(A. Boussofiene 1991).

By solving the model equations we get the efficiency scores of the African higher education systems. After that tobit regression model is applied to show which non discretionary or external variable has significant effect on the performance of the higher education systems. Tobit regression is a type of regression models in which the dependent variable is censored or limited by a maximum or a minimum value or both(Esmeralda A. Ramalho 2010), this model was introduced by James Tobin in 1958(Tobin 1958):

$$y_i = \begin{cases} y_i^* = \beta x_i + u_i & \text{if } y_i^* > 0 \\ 0 & \text{if } y_i^* \leq 0 \end{cases}$$

$$u_i \sim IIDN(0, \sigma^2)$$

For the case of efficiency the Dependent variable has two bounds (0 and 1), so the model takes the formula:

$$Y_i^* = \beta_i X_i + U_i \quad \text{if } 0 < y < 1$$

$$Y_i = 1 \quad \text{if } y^* \geq 1$$

$$Y_i = 0 \quad \text{if } y^* \leq 0$$

In this study, I apply two inputs and two outputs variables for comparing the African higher education systems in 15 African countries, chosen according to the availability of data. The input variables are: total expenditure on

**Table 1.** DEA input and Output Variables

Country	No. published papers***	Education Exp. (million)**	Student Per teacher*	No. Staff Members (1,000)	Gross Enroll. (1,000)	No. of Graduates (1,000)
Angola	47	3472.678	33	2	66	6
Benin	277	299.52	20.5	4	82	15
Burkina Faso	362	325.64	15.25	4	61	15
Burundi	28	121.9	14.5	2	29	3
Cameroon	776	776.51	55	4	220	40
Comoros	13	40.66	12.5	0.4	5	1
Ethiopia	943	1340.722	27.1875	16	435	75
Ghana	834	1439.295	35.75	8	286	28
Madagascar	213	274.88	18.5	4	74	16
Namibia	144	750.465	20	1	20	6
Algeria	3264	6044.811	28.6	40	1144	168
Morocco	2737	5848	20.95	20	419	76
Niger	107	204.554	9	2	18	3
Rwanda	143	245.152	21	3	63	10
Zimbabwe	323	140.625	23.75	4	95	31

Source: UNESCO: Global Education Digest 2012 (Paris: UNESCO, 2012).

\* Calculated by the researcher using Colum 2 & 3 Data.

\*\* World Bank: African Development Indicators 2011 (Washington D.C.: WB, 2012).

\*\*\* SCImago Journal & Country Rank, International Science Ranking 2011, at: <http://www.scimagojr.com/countryrank.php>

**Table 2.** Tobit Regression Variables

Country	Education (Gov%) Exp	GDP growth Rate (00-09)*	Private Enroll (%)*	People Under Poverty Line**
Angola	8.9	32.9	37	54.3
Benin	18.2	13.8	28	39
Burkina Faso	20.8	14.4	22	46.4
Burundi	25.1	8.4	58	66.9
Cameroon	17.9	11.2	14	39.9
Comoros	24.1	12	23	44.8
Ethiopia	25.4	16.9	18	38.9
Ghana	24.4	25	11	28.5
Madagascar	13.4	9.5	23	68.7
Namibia	22.4	13.3	88	38
Algeria	20.3	14.6	0	24
Morocco	25.7	11.6	12	9
Niger	16.9	13.8	25	59.5
Rwanda	16.9	15	50	58.5
Zimbabwe	8.3	-3.6	13	72

Source: UNESCO: Global Education Digest 2012.

\* African Development Indicators 2011.

\*\* UNDP: African Human Development Report 2012.

**Table 3.** DEA Efficiency Score

Country	Efficiency CCR	Efficiency BCC	Scale Efficiency	BCC Reference Units
Angola	0.047	0.248	0.28	Algeria, Niger
Benin	0.7	0.779	0.78	BF, Comoros, Niger, Zimbabwe
Burkina Faso	1	1	1	Burkina Faso
Burundi	0.149	0.816	0.15	Comoros, Niger, Zimbabwe
Cameroon	0.743	1	0.74	Cameroon
Comoros	0.139	1	0.14	Comoros
Ethiopia	1	1	1	Ethiopia
Ghana	0.713	0.778	0.71	Cameroon, Ethiopia, Zimbabwe
Madagascar	0.619	0.816	0.62	Niger, Ethiopia, Zimbabwe
Namibia	0.229	0.468	0.23	Niger, Algeria
Algeria	1	1	1	Algeria
Morocco	1	1	1	Morocco
Niger	0.487	1	0.49	Niger
Rwanda	0.394	0.644	0.39	Comoros, Niger, Zimbabwe
Zimbabwe	1	1	1	Zimbabwe

education and no. of student enrolled in higher education for each university staff member. The output variables are: no. of university graduates and no. of yearly scientific published papers (Table 1).

For the non discretionary variables that affecting efficiency I used four variables: population under poverty line as an index for household social and economic conditions, GDP growth rate as an index for the country economic level, the share of private higher education in the enrollment rate as an index for the role of private sector in higher education and public expenditure on education as an index of the government policy regarding education and its concern for it (Table 2). Using Data Envelopment Analysis Online Software (DEAOS), available on: [www.deaos.com](http://www.deaos.com), and running BCC model, the efficiency scores of fifteen African higher education systems were calculated as seen in (Table 3).

From the table, we can observe that seven countries are fully efficient according to BCC model while the no. of efficient DMUs was five units according to CCR Model. But although the relative high percentage of efficient units there is wide variation in efficiency score and a big gap between lower and higher efficiency score, Angola have the lower score about 25%. The table also shows the peer unit for each inefficient country.

In order to analyze the effect of environmental or external factors and its impact on efficiency, tobit model is adopted using STATA 11, the following table shows the

result of the model including the parameters estimates, and t-statistics for each estimate.

## RESULTS AND DISCUSSION

Previously I adopt the two stages efficiency analysis to evaluate the efficiency of fifteen African higher education systems, from this analysis the following result could be conclude:

First, comparing the results of the CCR model and BCC model showing that after dropping the assumption of constant rate of scale more DMUs appear to be efficient. This indicates that those units (Cameroon, Comoros and Niger) are technically efficient and the source of inefficiency in the first model was due to the environmental factors more than technical factors.

The analysis also shows that the five countries that are fully efficient in both models are working with the most productive scale size; those countries are Burkina Faso, Ethiopia, Algeria, Morocco and Zimbabwe. Other units that are inefficient in both models have neither technical nor scale efficiencies.

Second, from the tobit regression model, all variables are significant with 95% significant level, except the variable of population under poverty line.

There is a positive relationship between public expenditure on education and efficiency, this could be

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. tobit Efficiency Gov Private Growth Poverty, ll(0) ul(1)

Tobit regression               Number of obs   =       15
                               LR chi2(4)         =       24.88
                               Prob > chi2         =       0.0001
Log likelihood = 3.4729518     Pseudo R2       =       1.3873

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Efficiency	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
Gov	.0169709	.0076006	2.23	0.047	.0002422	.0336996
Private	-.0086897	.0013471	-6.45	0.000	-.0116546	-.0057247
Growth	-.0212317	.0051381	-4.13	0.002	-.0325405	-.0099228
Poverty	.0002119	.0028277	0.07	0.942	-.0060119	.0064356
_cons	1.108316	.312275	3.55	0.005	.4210031	1.795629
/sigma	.0891792	.0259601			.0320414	.146317

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Obs. summary:      0 left-censored observations
                   7 uncensored observations
                   8 right-censored observations at Efficiency>=1

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explained as the more government is concerned about education and believing in its importance, the more efficient are its educational systems. The analysis also shows the negative relationship between the size of private share and efficiency; this could be explained in the light of the nature of these systems in Africa with the lack of government supervision on those private institutes, large proportion of these institutes in Africa became profit seeking without any concern to the quality of education system itself.

The existence of a negative relationship between economic growth and efficiency contradicted the expectation of the nature of this relationship. But this negative relation may be explained due to the source of this growth which is usually from natural resource revenues, the growth that depends on natural resources that usually don't combine with human development and a development of a strong agricultural or industrial sectors that need the existence of strong education and training institutes.

The insignificance of the variable of population under poverty line implies the educational policy nowadays ensuring that personal and social circumstances such as gender, socio-economic status or ethnic origin, should not be an obstacle to achieving educational potential.

## CONCLUSION

The core aim of the higher education policy in any country is establishing a competitive, qualitative higher

education with efficiently operating institutions. The question of efficiency needs increased attention not only because of the decline of the state support but also the rapid rise of the student mass.

In the education system, especially higher education, it's not easy to measure its efficiency. The situation is more complicated since those institutions have multiple inputs and outputs. In this case a possible method of determining efficiency is Data Envelopment Analysis.

In this paper I adopt the two-stage efficiency analysis and use it to compare the efficiency of African higher education systems in fifteen countries. And then I use the tobit regression to determine the most influential factors that affect the efficiency of this institute. The analysis shows that the most influential factors affecting efficiency are the growth rate, private share, and public expenditure on education. The main results of the model are the negative impact of private higher education and economic growth on higher education efficiency, while there is a positive relationship between government expenditure on education and higher education efficiency.

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