Economics Bulletin

Volume 0, Issue 0

Technical efficiency of electric companies in sub-saharan africa

Alastaire Sèna Alinsato
Université d''Abomey-Calavi

Franck Nkeudjoua
Université d''Abomey-Calavi

Boris Houenou
Viasat Inc and School of Economic Sciences, Washington State University

Abstract

This article focuses on the technical efficiency of Africa electric companies. A measurement of productive efficiency is obtained by econometrically estimating an output distance function using a stochastic frontier analysis from a panel of African electric companies, using data from 2008 to 2017. The study shows that countries with incentive pricing have technically more efficient electric companies than other countries. This result puts more in perspective the incentive instruments stemming from Laffont and Tirole's theory of incentives and contracts and guides the regulatory authorities in the electricity sector on the scope of the various levers that encourage the technical efficiency of electric companies. However, the reach of its incentive mechanisms depends on an enabling institutional environment.

Citation: Alastaire Sèna Alinsato and Franck Nkeudjoua and Boris Houenou, (2021) ''Technical efficiency of electric companies in sub-saharan africa'', *Economics Bulletin*, Vol. 0 No. 0 p.A225.
Contact: Alastaire Sèna Alinsato - alastaires@yahoo.fr, Franck Nkeudjoua - nkeudjouafranck@yahoo.fr, Boris Houenou - borishouenou@gmail.com.
Submitted: March 02, 2021. **Published:** December 29, 2021.

Economics Bulletin

Volume 41, Issue 4

Technical efficiency of electric companies in sub-saharan africa

Alastaire Sèna Alinsato
Université d''Abomey-Calavi

Franck Nkeudjoua
Université d''Abomey-Calavi

Boris Houenou
Viasat Inc and School of Economic Sciences, Washington State University

Abstract

This article focuses on the technical efficiency of Africa electric companies. A measurement of productive efficiency is obtained by econometrically estimating an output distance function using a stochastic frontier analysis from a panel of African electric companies, using data from 2008 to 2017. The study shows that countries with incentive pricing have technically more efficient electric companies than other countries. This result puts more in perspective the incentive instruments stemming from Laffont and Tirole's theory of incentives and contracts and guides the regulatory authorities in the electricity sector on the scope of the various levers that encourage the technical efficiency of electric companies. However, the reach of its incentive mechanisms depends on an enabling institutional environment.

Citation: Alastaire Sèna Alinsato and Franck Nkeudjoua and Boris Houenou, (2021) ''Technical efficiency of electric companies in sub-saharan africa'', *Economics Bulletin*, Vol. 41 No. 4 pp.2601-2611 .
Contact: Alastaire Sèna Alinsato - alastaires@yahoo.fr, Franck Nkeudjoua - nkeudjouafranck@yahoo.fr, Boris Houenou - borishouenou@gmail.com.
Submitted: March 02, 2021.   **Published:** December 29, 2021.

1. Introduction

The electricity sector in Africa has gone through several phases of reorganisation. The previously predominant model of centralised provision of electricity services by vertically integrated public monopolies resulted from the deliberate relinquishment of the largely private and decentralised provision of those services. This model, with more governments, was further promoted by official development assistance and the expansion of national budgets. To a large extent, it has had mixed results (Williams and Ghanadan, 2006; Kessides, 2014).

The 1980s and 1990s were marked by a new wave of reforms in market structures, private sector involvement and regulatory regimes that reflected a radical transformation in attitudes towards ownership, organisation and regulation in the electricity sector. Starting in England and the United States by the then-dominant liberal regimes, those series of reforms spread to other countries.

In Africa, several countries are engaged in electricity sector reforms, notably through disintegration - total or partial privatisation of public monopolies or opening competitive or attractive segments of its to competition (Nepal and Jamasb, 2015). For instance, Senegal has implemented a series of legislative and regulatory reforms and instruments in the electricity sector since the 1998's by opening up the sector to private entities and redefining the role of the government. In 1990, Côte d'Ivoire privatised its electricity sector through a lease contract. In Gabon, the Energy and Water Company (SEEG) was privatised in 1997 through a 20-year concession deal. That contract ended in 2019, and the SEEG returned to public control. In Uganda, the focus on organisational reforms began in 1997 with vertical disintegration into a public entity specialised in electricity generation, Uganda Electricity Generation Company Limited (UEGCL), and a public entity specialised in electricity transmission and distribution, Uganda Electricity Transmission Company Limited (UETCL). Common to all the countries that have undertaken reforms is the creation of independent regulatory authorities responsible for implementing a tariff policy that aims, among other things, to provide incentives to companies to improve service, reduce costs and tariffs.

Compared to other regions of the world, sub-Saharan Africa lags in terms of installed electricity generation capacity and low per capita electricity consumption. The total electricity generation capacity in the region, which has a total population of just over 1 billion, is less than 100 gigawatts (half that without South Africa), i.e. less than the total generation capacity of Spain, which has 46 million inhabitants (IEA, 2017).

Serious inefficiencies in operations, high operating costs of small generation centres and excessive use of expensive fossil fuels to generate electricity have increased the cost of electricity supplied to consumers in Africa. In contrast, the inability of many customers to pay for electricity services and under-pricing has reduced operators' revenues. Due to high costs and low revenues, African operators are unable to respond to demand and reliably supply electricity, a deficiency compounded by years of inadequate maintenance and an increase of expenditures. Consumers experience frequent load shedding, and new connections have difficulty keeping pace with population growth.

This paper attempts to answer whether the reforms undertaken by the public electric monopolies in Sub-Saharan Africa are satisfactory from the point of view of technical efficiency and to what extent the tariff policy contributes to this.

Specifically, this paper aims to estimate the technical efficiency score of power utilities in Sub-Saharan Africa and evaluate the effects of the incentive reforms adopted on the technical inefficiency of these utilities. The adoption of the stochastic distance frontier model introduced by Shephard (1970) will enable to respond to these different objectives. The calculation of the

Malmquist index provides an additional understanding of the effects of the reforms on the temporal evolution of the productivity of these companies.

To our knowledge, few papers have dealt with the productive efficiency of electricity companies in Africa apart from the work from Plane (1999), Holfman and Plane (2001), Estache et al. (2008). The contribution of this study rests on the empirical assessment of the effects of incentive reforms, in particular incentive pricing, on the productive efficiency of power companies in sub-Saharan Africa. The calculation of the Malmquist index obtained by a non-parametric approach provides an additional understanding of the said reforms on the temporal evolution of the productivity of the said companies.

The paper is structured as follows: section 2 discusses data and methodology; section 3 presents the study results; section 4 is the concluding section that summarizes the findings and discusses policy implications.

2. Methodology

The following section presents the different approaches to calculating the effectiveness and details the methodology used for this study.

2.1. Conceptual model and Empirical specification

In the recent literature, parametric and semi-parametric approaches where no assumptions are made about the functional form of the production frontier have been developed (Yao et al., 2019). Introduced by Shephard (1970), the distance frontier constitutes, through these different properties, a bridge between parametric and non-parametric approaches in the calculation of efficiency. Two types of distance functions exist (Fare and Primont, 1995). The output-oriented one maximizes the optimal production from a fixed quantity of input and the input-oriented one minimizes the inputs to obtain a fixed quantity of output. The choice of the output orientation in this study is explained by the irreversible nature of the investments made. Formally, suppose a technology P^t of a DMU who combines the vector x inputs with $x^t \in R^K$ for producing the output vector $y^t \in R^M$. P^t can be formalised as follows in equation (1):

$$P^t(x^t) = \{y^t \in R^M : x^t \text{ can produce } y^t\} \quad (1)$$

The study considered that the technology satisfies the axioms listed in Färe and Primont (1995). The output distance function may be defined on the output set $P^t(x^t)$ as :

$$D_0^t(x^t, y^t) = min\left\{\theta : \left(\frac{y^t}{\theta}\right) \in P^t(x^t)\right\} \quad (2)$$

Where in equation (2) $D_0^t(x^t, y^t)$ is the distance frontier DMU's output set to the efficient frontier, and θ is a scalar parameter that denotes how much the output vector will be radially expanded to the feasible efficient frontier. According to Färe and Primont (1995), $D_0^t(x^t, y^t)$ is non-decreasing, positively linearly homogeneous and convex in output y^t, and decreasing in input x^t.y is located on the outer boundary of the production possibility set if $D_0^t(x^t, y^t) = 1$.

The estimation of the parameters of the distance function requires the definition of an appropriate functional form. According to Coelli and Perelman (2000), the translogarithmic functional form meets these conditions thus it is chosen in this study. For the case of M outputs and K inputs, the translogarithmic distance function could be represented by:

$$\begin{aligned} \ln D_0^t\left(x^t, y^t\right) = \beta_0 + \sum_{m=1}^{M}\beta_m \ln y_{mit} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M}\beta_{mn} \ln y_{mit} \ln y_{nit} + \sum_{k=1}^{K}\alpha_k \ln x_{kit} + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K}\alpha_{kl} \ln x_{kit} \ln x_{lit} \\ + \sum_{m=1}^{M}\sum_{k=1}^{K}\tau_{mk} \ln y_{mit} \ln x_{kit} + \varphi_1 t + \sum_{m=1}^{M}\varphi_{ym} \ln y_{mit} t + \sum_{k=1}^{K}\varphi_{xk} \ln x_{kit} + \frac{1}{2}\varphi_{11} t^2 \end{aligned} \quad (3)$$

Where in equation (3) $D_0^t(x^t, y^t)$ is the output distance function, y^t is vector of outputs, x^t is vector of inputs, down script t is time, i relates to the ith DMU and $\beta, \alpha, \tau, \varphi$ are the parameter to be estimated.

The homogeneity constraint implied that one of the outputs is arbitrarily chosen. If the output y_{Mit} is chosen, the following expression is obtained:

$$\ln D_0^t\left(x^t,\frac{y^t}{y_{Mit}}\right)=\beta_0+\sum_{m=1}^{M}\beta_m\ln y_{mit}^*+\frac{1}{2}\sum_{m=1}^{M-1}\sum_{n=1}^{M-1}\beta_{mn}\ln y_{mit}^*\ln y_{nit}^*+\sum_{k=1}^{K}\alpha_k\ln x_{kit}+\frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K}\alpha_{kl}\ln x_{kit}\ln x_{lit}$$
$$+\sum_{m=1}^{M-1}\sum_{k=1}^{K}\tau_{mk}\ln y_{mit}^*\ln x_{kit}+\varphi_1 t+\sum_{m=1}^{M}\varphi_{ym}\ln y_{mit}^* t+\sum_{k=1}^{K}\varphi_{xk}\ln x_{kit}+\frac{1}{2}\varphi_{11}t^2 \quad (4)$$

After rearranging the terms, the above function (4) may be rewritten by:

$$-\ln y_{Mit}=\beta_0+\sum_{m=1}^{M}\beta_m\ln y_{mit}^*+\frac{1}{2}\sum_{m=1}^{M-1}\sum_{n=1}^{M-1}\beta_{mn}\ln y_{mit}^*\ln y_{nit}^*+\sum_{k=1}^{K}\alpha_k\ln x_{kit}+\frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K}\alpha_{kl}\ln x_{kit}\ln x_{lit}$$
$$+\sum_{m=1}^{M-1}\sum_{k=1}^{K}\tau_{mk}\ln y_{mit}^*\ln x_{kit}+\varphi_1 t+\sum_{m=1}^{M}\varphi_{ym}\ln y_{mit}^* t+\sum_{k=1}^{K}\varphi_{xk}\ln x_{kit}+\frac{1}{2}\varphi_{11}t^2-\ln D_0^t \quad (5)$$

Where in equation (5), $-\,ln\,D_0^t$ is non-observable and can be interpreted as an error term. Thus, if $-\,ln\,D_0^t$ is replaced with a composed error term (u_{it}, v_{it}) where v_{it} captures random noise and u_{it} represent technical inefficiency, the Battese and Coelli (1995) version of the traditional stochastic frontier model proposed by Aigner and al.(1977) and Meeusen and Van den Broeck (1977) will be obtained. Finally, the following expression is obtained:

$$-\ln y_{Mit}=\beta_0+\sum_{m=1}^{M}\beta_m\ln y_{mit}^*+\frac{1}{2}\sum_{m=1}^{M-1}\sum_{n=1}^{M-1}\beta_{mn}\ln y_{mit}^*\ln y_{nit}^*+\sum_{k=1}^{K}\alpha_k\ln x_{kit}+\frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K}\alpha_{kl}\ln x_{kit}\ln x_{lit}$$
$$+\sum_{m=1}^{M-1}\sum_{k=1}^{K}\tau_{mk}\ln y_{mit}^*\ln x_{kit}+\varphi_1 t+\sum_{m=1}^{M}\varphi_{ym}\ln y_{mit}^* t+\sum_{k=1}^{K}\varphi_{xk}\ln x_{kit}+\frac{1}{2}\varphi_{11}t^2+u_{it}+v_{it} \quad (6)$$

Where in equation (6) v_{it} is assumed to be independently and identically distributed as $N(0,\sigma_v^2)$ According to Battese and Coelli (1995) and Kumbhabar and Lovell (2000), the technical inefficiency, u_{it} is assumed to be a non-negative random variable, independently distributed as truncations at zero of $N(\mu,\sigma_u^2)$ distribution where μ is explained by a set of environmental variables.

Specifically, $\mu_{it}=\pi_0+\sum_d \pi_d\, Z_{d,it}$ (7)

Where in equation (7) Z_d, is a vector of exogenous variables that affects technical inefficiency by affecting the mean of the distribution on u_{it}.

In this study, the translogarithmic function is specified with two outputs (y_1, y_2) and two inputs (x_1, x_2), where y_1, y_2 are the annual electricity production and annual number of customers respectively and x_1, x_2 refer respectively to the capital and labour. The equation (6) can therefore be specified as follows:

$$-\ln y_{2it}=\beta_0+\beta_1\ln\left(\frac{y_{1it}}{y_{2it}}\right)+\frac{1}{2}\beta_{11}\ln\left(\frac{y_{1it}}{y_{2it}}\right)\ln\left(\frac{y_{1it}}{y_{2it}}\right)+\sum_{k=1}^{K=2}\alpha_k\ln x_{kit}+\frac{1}{2}\sum_{k=1}^{K=2}\sum_{l=1}^{K=2}\alpha_{kl}\ln x_{kit}\ln x_{lit}$$
$$+\sum_{k=1}^{K=2}\tau_{1k}\ln\left(\frac{y_{1it}}{y_{2it}}\right)\ln x_{kit}+\varphi_1 t+\sum_{m=1}^{M=1}\varphi_{ym}\ln\left(\frac{y_{1it}}{y_{2it}}\right)t+\sum_{k=1}^{K=2}\varphi_{xk}\ln x_{kit}+\frac{1}{2}\varphi_{11}t^2+u_{it}+v_{it} \quad (8)$$

The output in equation (8) was normalized by the annual number of customers(y_2).β, α, τ and φ are the parameters to be estimated. According to Battese and Coelli (1995), the technical inefficiency effects are assumed to be independently distributed and u_{it} arises by the normal distribution truncated at zero with mean and variance (μ, σ_u^2) defined by:

$$\mu_{it} = \pi_0 + \pi_1 Z_{1it} + \pi_2 Z_{2it} + \pi_3 Z_{3it} + \pi_4 Z_{4it} + \pi_5 Z_{5it} + \pi_6 t_{it} \quad (9)$$

Where

μ_{it} is the mean of technical inefficiency
Z_{1it} is the density of the network;
Z_{2it} is the percentage of energy produced from a thermal source;
Z_{3it} is the share of energy produced by independent power producers in the total volume of electricity distributed;
Z_{4it} means the pricing policy and
Z_{5it} is the Electricity Reform Index.
i stands for a company and t the time period.

In order to account for the dynamics over time of technical inefficiency, the time variable (t) is included in equation (9) (Coelli and Battese 1996).

Multi-output consideration enables to capture the heterogeneity of the companies in the sample. Recent literature considers the problem of endogeneity in the analysis of productivity in the stochastic approach. The statistical approach using instrumental variables and the system approach constitute solutions to the problem of endogeneity (Kumbhakar and al, 2020). However, the one-step estimation of stochastic distance frontiers considers the endogeneity problem and therefore gives consistent estimators (Tsionas and al, 2015). Also, the regulated structure of the power companies considerably minimizes a possible endogeneity problem.

The maximum likelihood estimation method was used to estimate the parameters of the model.

2.3. Data and Variables Description

The measurement of the technical efficiency of African electricity companies in this study is done through the prism of generation activity. The choice of inputs and outputs is based on the work of Jamasb et al. (2004). The annual electricity production of each utility measured in gigawatts hours and the numbers of customers were the outputs variables in this paper. Following See and Coelli (2012), the inputs given by capital and labour are measured respectively by the installed capacity and the total number of employees of each company. Technical progress captured by a time variable is inserted in the model (Hattori, 2002).

Many factors explain the efficiency score. This study considered five variables. The density of grids, the source of thermal generation, the share of electrical energy from independent electricity producers in the total volume of electricity distributed, tariff policy, the degree of development of power sector.

In this study, tariff policy is a determinant of technical efficiency. There are generally two pricing schemes for natural monopolies in the literature: traditional pricing and incentive pricing. Two policies characterize traditional pricing, namely first rank pricing, which consists of marginal cost pricing (Hotelling, 1938) and second rank pricing which, consists of average cost pricing (Boiteux, 1949). The problems raised by the implementation of traditional pricing relate to the distorting effects of levies, the perverse effects of subsidies on the management of the monopoly and the loss of consumer surplus. Incentive pricing is also made up of cost-plus regulation based on the ex-post reimbursement of costs observed by the regulated company and the price cap based on two principles. First, to set the company's remuneration ex-ante over several years and to match this remuneration with productivity targets. Second, let the regulated company retain some of the productivity gains it achieves. However, incentive pricing does not solve the problem of information asymmetry between the regulator and the regulated company. Consequently, the pricing policy is measured by a dummy variable which takes the value 1, when the electricity company is subject to at least one of the modes of incentive pricing, and 0 otherwise.

Network density is measured by relating the number of subscribers to the length of the electrical network, all voltages combined (Lesueur and Plane, 1995). Thermal generation source is measured by the percentage of energy generated from a thermal source (Hofman and Plane, 2001). The power sector reform index is calculated from Foster et al., (2017).

This study uses annual data from a sample of ten power companies in Sub-Saharan Africa between 2008-2017. The choice of the study period and the companies included in the sample is based on the availability of data. The list of these companies is shown in Table 4. Data on the reform index come from the World Development Indicators (World Bank) database. All the other data in the study come from the annual activity report of the various electricity companies included in the study sample on the one hand, and the other hand from the annual activity report of the regulatory authorities of electricity from the countries concerned (ARSE-Togo, ARSE-Burkina, ANARE-Côte d'Ivoire, ARSEL-Cameroon, EWARU-Tanzania, EPRA-Kenya, NIRP-Namibia, BERA-Botswana).

Table 1 below presents the descriptive statistics in panel data of the different variables used in the study.

Table 1: Descriptive Statistics

Variable	**Obs**	**Mean**	**Std.Dev.**	**Min**	**Max**
Production (GWh)	100	2374.200	2002.691	37	6250
Installed power (MWh)	100	610.2957	405.140	26.7	1637
Number	100	3278.840	2573.996	850	11295
Network density	100	37.608	18.307	8.4	78
Share of thermal production (%)	100	39.985	33.957	0	100
Independent producer share (%)	100	23.561	22.675	0	83.4
Reform Index	100	40.140	16.042	6	63
Pricing policy (dummy, 1=incitative pricing, 0=otherwise)	100	0.600	0.049	0	1

Electricity production installed power and workforce are, on average, somewhat lower compared to other regions of the world. Indeed, electricity production in Sub-Saharan Africa (excluding South Africa) was 250.69 TWh in 2017 (IEA, 2019) for a population of 965 million inhabitants. However, it was 1061 TWh in Japan and 557 TWh in France in 2017 (IEA, 2019) for a population of 127 million inhabitants and 67 million inhabitants, respectively. The installed capacity in sub-Saharan Africa was 80GW in 2017, excluding South Africa, while it was 160GW for France (IEA, 2019).

3. Results

This section presents the estimation of the technical efficiency scores of electricity companies in Sub-Saharan Africa, the analysis of the determinants of their level of productive efficiency and productivity change.

Before interpreting the parameters of the estimate, hypothesis tests are performed. A likelihood ratio test confirms the translog form's choice as the production technology's functional form (Table 2). Also, the value and significance at the 1% threshold of the gamma estimator γ indicates the presence of technical inefficiencies in the African utilities in the study. This gamma value illustrates that the variation at the level of the production units studied is explained by the 86% inefficiency of the power companies.

Table 2: Test for Functional form

LR Test for	Parameter	Statistic	Degree of	X^2 critical	Outcome

Functional form	Restrictions		Freedom	Value 1%	
Translog vs Cobb-Douglas	H0: $\alpha_{kl} = \beta_{mn} = \tau_{km} = 0$ For all k, l, m, n	34.65	14	28.485	Translog model is more adequate

The estimation results of the distance frontier parameters are presented in Table 3 indicate that 70% of the estimated coefficients are statically significant at 5%. The variables were divided by their geometric mean before estimation. Therefore, the first-order coefficients can be directly interpreted as elasticities.

Table 3: Output distance parameter estimates

Variables	Parameters	Coefficients	P>|Z|
Distance function			
Constant	β_0	-0.137	0.190
ln (Power)	α_1	-0.874	0.000
ln (Number)	α_2	-0.163	0.502
ln (Production/ Subscribers)	β_1	0.478	0.000
½ ln(Production/ Subscribers)^2	β_{11}	0.155	0.000
1/2ln(Power)^2	α_{11}	0.165	0.589
1/2ln(number)^2	α_{22}	2.180	0.003
ln(Power)*ln (Number)	α_{12}	-1.976	0.036
ln(Production/Subscribers)* ln(Power)	τ_{11}	0.142	0.115
ln(Production/Subscribers)* ln (Numb)	τ_{12}	-0.065	0.621
Time	φ_1	-0.019	0.664
½(Time)^2	φ_{11}	-0.007	0.338
Time * ln(Production/ Subscribers)	φ_{y1}	-0.026	0.007
Time * ln (Power)	φ_{x1}	0.110	0.000
Time* ln (number)	φ_{x2}	-0.146	0.000
Technical inefficiency effects model			
Time	π_1	-0.295	0.233
Density	π_2	0.143	0.026
Thermal source	π_3	0.091	0.014
Reform Index	π_4	-0.062	0.276
Pricing policy	π_5	-3.408	0.045
Independent power producers	π_6	0.013	0.704
Constant	π_0	-9.386	0.006
Variance parameter			
Sigma-squares	σ^2	0.599	0.000
Gamma	γ	0.860	0.001
Log likelihood		-0.333	0.000

The signs of the first-order coefficients in input and output are in accordance with the theory. Indeed, a negative coefficient of any input factor implies that an increase in subscribers is positively associated with an increase in that input factor. All factors of production contribute positively to the increase in electricity production. However, the contribution of the labour factor is not significant. This could be explained by the quality of the recruitment policy coupled with an effective artificial promotion policy within regulated public enterprises (Sandbrook, 1987; Hofman and Plane, 2001). Installed capacity contributes significantly to electricity production. A 10% increase in installed capacity leads to an 8.7% increase in electricity production. These results are similar to Hofman and Plane, (2001). Also, the sum in the absolute value of the coefficients of the first of the factors of production is 1.04, which shows the presence of economies of scale of the electric companies.

Table 4 shows the technical efficiency score of power utilities in sub-Saharan Africa in the study sample.

Table 4: Average Technical Efficiency Score by Utility Companies

Countries	Electric companies	Efficiency score in %
Senegal	SENELEC	55
Kenya	KPLC	97
Tanzania	TANESCO	99
Gabon	SEEG	68
Cameroun	ENEO	98
Cote d'ivoire	CIE	98
Namibia	NamPower	99
Botswana	BPC	94
Burkina-Faso	SONABEL	83
Togo	CEET	89
Average		**87**

On average, electric companies have a technical efficiency level of 87% for the entire sample. This implies that there is still potential for increasing electricity production without additional input.

The difference between the minimum and maximum efficiency values supports the hypothesis of the heterogeneity of the power companies in terms of technical performance.

Several factors can explain variations in technical efficiency in a firm, including regulated public or private monopolies (Lesueur and Plane, 1995). The incentive theory of electricity monopolies proposes the pricing system as an incentive mechanism (Laffont and Tirole, 1988, 1993 and 1994). In connection with these authors, the effect of the tariff system is tested on the productivity effort of companies. In this sense, Table (3) presents the results of the estimation. The negative sign of the coefficient of a determinant reflects the positive contribution of this variable to the increase in the technical efficiency score.

Three variables prove to have a significant impact on the technical inefficiency of power utilities: network density, thermal source, and pricing policy.

The sign of the pricing policy variable is negative and significant at the 5% threshold, implying that the adoption of an incentive pricing policy negatively affects electricity companies' inefficiency. Otherwise, adopting an incentive pricing policy improves the technical efficiency of the utilities in the sample. This result is in accordance with the analysis of the incentive regulation of natural monopolies of Laffont and Tirole (1993).

The percentage of thermal output has a positive effect on technical efficiency in this study, which is in accordance with the results of Hofman and Plane (2001). This positive contribution reflects the fact that the production from thermal activity requires a more labour-intensive technology and inevitably lends itself to more difficulties in managing the agents' effort. An important result is the Electricity Regulation Index, which positively effects the technical efficiency of the utilities in the sample. However, it is not significant. This lack of significance could be due to the composite value of this index. The separate action of each component that determines the construction of the index would provide further understanding. This is how some studies put the different reform strategies into perspective. Vertical disintegration, for example, has a positive impact on the efficiency of electric companies (Faye, 2000).

To understand the Malmquist index, it is important to understand that a value greater than one reflects an improvement in productivity and vice versa.

Tableau 5: Malmquist index and its decomposition

Year	Efficiency change	Technical change	Scale effet	Malmquist Index
2008				
2009	0.942	1.022	1.003	0.966
2010	1.015	1.013	0.995	1.023
2011	1.074	1.074	0.881	1.016
2012	1.066	1.121	1.017	1.215
2013	1.007	1.023	1.137	1.171
2014	0.623	1.036	1.127	0.728
2015	1.025	1.055	1.051	1.137
2016	0.869	1	1.007	0.875
2017	1	1	1	1
Mean	**0.947**	**1.037**	**1.022**	**1.004**

Over the 2008-2017 period, the overall productivity of power utilities in Sub-Saharan Africa grew by 0.4% (Table 5).

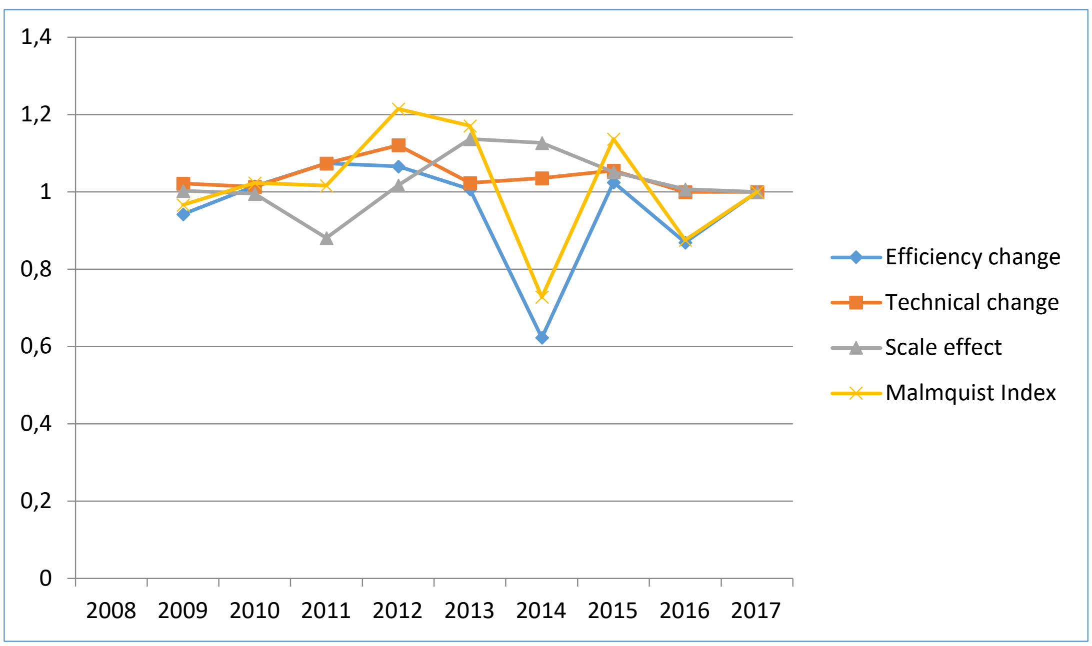

Figure 1: Decomposition of total factor productivity trend of Electric Companies in Sub-Saharan Africa

This change in productivity is driven by three components (Figure 1). The change in the productivity of the utilities in the study sample is mainly due to the positive contribution of technological change and returns to scale. The contribution of technological progress could be explained by a maturity in the technical mastery of the utilities. Also, these companies make good use of economies of scale. The change in technical efficiency negatively affects the change in productivity.

4. Conclusion

Electricity is an essential economic good for stimulating economic growth, but it must be noted that Africa in general and Sub-Saharan Africa, in particular, remains the continent where the performance of electricity supply is particularly weak. The specificity of the electricity sector requires regulation so that the monopolies in place do not abuse their positions and, at the same time, are encouraged to make efforts to meet the demand efficiently. The main objective of this paper is to analyze the effects of incentive mechanisms, particularly pricing, on the technical efficiency of electric companies in Sub-Saharan Africa.

To measure the technical efficiency and explain the level of inefficiency of electric companies in Sub-Saharan Africa, an output distance function with a stochastic frontier analysis on a sample of ten African electric companies was used.

The results show that, on average, it is possible to improve production with the same levels of production factors or to maintain the same level of production with fewer production factors. Also, the value of the Malmquist index showed a growth of 0,4% of electric companies in Sub Saharan Africa.

These results suggest at least three policy implications. First, developing countries need to impose cost-reflective pricing to make their systems financially and ultimately operationally sustainable. That needs to be done through effective incentive pricing policy mechanism, in particular the price-cap. However, this should be done in the presence of a prudent rebalancing mechanism between economic efficiency and social equity to offset the undesirable social effects of higher tariffs. Second, enhance the regulatory correctness of the electricity sub-sector. This can be manifested by creating an enabling environment for market contestability at the generation and marketing segment (Nepal and Jamasb, 2015). Third, public authorities must create a dynamic framework for adopting new technologies by power companies. Indeed, the results showed that the effect of technological change partly drives productivity growth.

References

Aigner, D.J., Lovell, C.A.K., Schmidt, P., (1977) ‘‘Formulation and estimation of stochastic frontier function models’’ *Journal of econometrics*, **6**(1), 21 – 37. https://doi.org/10.1016/0304-4076(77)90052-5.

Battese, G.E., Coelli, T.J., (1995) ‘‘A model for technical inefficiency effects in a stochastic frontier production function for panel data’’ *Empir. Econ.* **20**, 325–332. 26 (1): 1-16

Boiteux, M., (1949) “La tarification des demandes de pointe: application de la théorie de la vente au coût marginal” Revue Générale d’Electricité, août, p.321-340.

Coelli, T., Battese, G., (1996) ‘‘Identification of factors which influence the technical inefficiency of Indian farmers’’ *Aust. J. Agric. Econ.* **40** (2), 102–128. https://doi.org/10.1111/j.1467-8489.1996.tb00558.x.

Coelli,T., Perelman, S., (2000) “Technical efficiency of European railways: A distance function approach” *Applied Economics* **32**(15), 1967–76. https://doi.org/10.1080/00036840050155896.

Estache, A., Tovar, B., and Trujillo, L., (2008) “How efficient are African electricity companies? Evidence from the Southern African countries” Energy Policy, 36(6), 1969-1979. doi:10.1016/j.enpol.2008.02.011

Färe, R. & D. Primont (1995) “Multi-output Production and Duality: Theory and Applications” In: *Färe, R., Primont, D., (Eds.), (1995), Kluwer Academic Publishers*, Boston.

Foster, V., et al., (2017) “Charting the Diffusion of Power Sector Reforms across the Developing World” Rapport de recherches sur les politiques 8235, World Bank, Washington, DC. https://doi.org/10.1596/1813-9450-8235.

Hattori, T., (2002) “Relative Performance of U.S. and Japanese Electricity Distribution: An Application of Stochastic Frontier Analysis” *Journal of Productivity Analysis*, **18**, 269–284. https://doi.org/10.1023/A:1020695709797.

Hofman, L., Plane, P., (2001) “Électricité en Afrique et performance productive : une évaluation par les frontières » *L'Actualité économique*, **77** (3), 385–408. https://doi.org/10.7202/602357ar CopiedAn.

Hotelling, H., (1938) “The general welfare in relation to problems of taxation and of railway and utility rates” *Econometrica,* 6(3):242-269.

IEA., (2019) Key world energy statistics, IEA, Paris https://www.iea.org/reports/key-world-energy-statistics-2020.

Jamasb, T., Newbery, D., Pollitt, M., (2004) “Core indicators for determinant and performance of electricity sector in developing countries” Cambridge Working Paper in Economics, CWPE 0438. https://doi: 10.3233/IJR-120052.

Kumbhakar, S.C, Parmeter, Christopher F., Zelenyuk,Valentin, (2020) “Stochastic Frontier Analysis” *Foundations and Advances I. Handbook of production Economics*.

Laffont, J.J., Tirole, J., (1988) “Auctioning Incentive Contracts” *Journal of Political Economy*, **95** (5), 921– 37. https://doi.org/10.1086/261496.

Laffont, J.J., Tirole, J., (1993) ‘‘*A Theory of Incentives in Regulation and Procurement*’’ Cambridge, MA: MIT Press.

Laffont, J.J., Tirole, J., (1994) ‘‘Access pricing and competition’’ *European Economic Review*, **38**(9), 1673-1710.

Laffont, J.J., Tirole, J., (2000) ‘‘Competition in Telecommunication’’ *Cambridge, MA: MIT Press*.

Lesueur J.Y., Plane, P., (1995) ‘‘Frontière de production et mesure de l’efficacité technique: le cas de l’électricité dans dix entreprises subsahariennes’’ *Annals of Public and Cooperative Economics*, **66,** 299-319. https://doi.org/10.1111/j.1467-8292.1995.tb00995.x.

Meeusen, W., Van den Broeck, J., (1977) ‘‘Efficiency estimation from Cobb-Douglas production functions with composed error’’ *International economic review*, **18**(2), 435 – 444. https://doi.org/10.2307/2525757.

Nepal, R., Jamasb, T., (2015) ‘‘Caught between theory and practice: Government, market, and regulatory failure in electricity sector reforms’’ *Economic Analysis and Policy*, **46**, 16–24. https://doi.org/10.1016/j.eap.2015.03.001.

Sandbrook, R., (1987) ‘‘Personnalisation du pouvoir et stagnation capitaliste’’ *Politique Africaine*, **26**, 15-37

See, K. F., Coelli, T., (2012) ‘‘An analysis of factors that influence the technical efficiency of Malaysian thermal power plants’’ *Energy Economics*, **34**(3), 677–685. https://doi.org/10.1016/j.eneco.2011.09.005.

Shephard, R. W., (1970) ‘‘*Theory of Cost and Production Functions*’’ Princeton, Princeton University Press.

Tsionas Efthymios G., Kumbhakar Subal C., Malikov Emir, (2015) ‘‘Estimation of Input Distance Functions: A System Approach’’ *American Journal of economic* **97** (5), 1478-1493 https://onlinelibrary.wiley.com/journal/14678276.

Williams, J., Ghanadan, R., (2006) ‘‘Electricity reform in developing and transition countries: A reappraisal’’ *Journal of Energy* **31**, 815–844. https://doi.org/10.1016/j.energy.2005.02.008.

Yao, F., Zhang, F., Kumbhakar, S. C., (2019) ‘‘Semiparametric smooth coefficient stochastic frontier model with panel data’’ *Journal of Business & Economic Statistics* **37**(3), 556-572. https://doi.org/10.1080/07350015.2017.1390467.