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Effect of Reforms on Technical Efficiency of Electricity Production in Kenya Relative to Other Developing Countries

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Abstract

The current structure of the Kenyan electricity sector has resulted from many changes brought about by both donor and government driven reforms. The sector which was once run as a government owned monopoly is now a more market-oriented entity. The reforms have resulted in splitting of generation, transmission and distribution into independent entities, establishment of an independent regulatory authority, private sector participation in generation and institution of other complementary entities. One of the drivers of these reforms was the need to improve the economic performance of the sector to make it capable of supporting the economy. This study uses Data Envelopment analysis and stochastic frontier methods to analyse the effect of the reforms on the efficiency of Kenya's power sector in relation to other countries in similar stage of development. The findings reveal that Kenya's Power sector has been experiencing positive changes in technical efficiency over the period after the reforms. The countries which have undertaken reforms, to a larger extent, appear to be more efficient. However, they experience huge system losses which need to be reduced to better the sector's efficiency

Keywords: Reforms, Technical efficiency, Data envelopment analysis, Stochastic frontier analysis
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1. INTRODUCTION

Electricity reforms have brought major organizational structure changes in Kenya's electricity sub-sector. Notable among them are vertical unbundling, introduction of private sector participation, introduction of competition and strengthening of regulation, legislation and policy making. Proponents of these reforms claimed that this reforms would among other things positively impact on sector's efficiency and overall performance of the sector (Vickers and Yarrow, 1988, Joskow, 1998).

One of the main goal of power sector in an economy is to supply adequate and affordable electricity at all times. However, the sector investments are usually quite huge. The high investment costs when coupled with technical inefficiencies lead to rising cost of electricity and power shortages (Meibodi, 1998). The most economical way of maintaining equilibrium between energy demand and resources is enhancing energy efficiency (Kenya Power Generation and Transmission Master Plan, PGTMP 2016).

Energy efficiency measures aims at cutting down energy consumption without compromising on output or raising the cost of production. Efficiency in electricity production, transmission and distribution is an important factor in the utilization of energy. Increasing electricity efficiency lowers the need for increased investment on the supply side. Energy efficiency measures reduce the losses both on the supply side and the demand side thus helping in reducing the level of electricity demanded. It allows more people to access electricity through the existing installed capacity. This improves the competitiveness of the country while mitigating adverse effects of GHG emissions.

The Kenya National Energy Policy 2014 highlighted a number of urgent factors to enhance energy efficiency and conservation. The high energy cost, limited supply, need to reduce GHG emissions and the continuous depletion of energy sources have been noted in the Kenya's national energy policy 2014, as issues that can be addressed through energy efficiency measures.

Among the policies and strategies articulated in the Kenya's National Energy Petroleum policy, (2015) is the development and implementation of a regulatory framework that will provide incentives and or penalties aimed at reducing the high system losses. The policies appreciate the need to enhance efficiency both on the supply and the demand side.

Extensive measures to encourage efficiency in all subsectors of the power sector have been effected by the Ministry of Energy and Petroleum. Several reforms have been undertaken by the government to deal with the problem of inefficiency in power generation and to improve the competitiveness of the country as an investment destination. However, as noted in the PGTMP, the impact of the measures remains modest. Despite the interventions, the cost of power has continued to rise over the reform period. The plan notes that energy efficiency measures would lead to a reduction in generation cost by about 6%. Some manufacturing firms have closed down or relocated to other countries due to high electricity tariffs (Karekezi and Kimani,2002).This begs the question: what is the effect of reforms on technical efficiency of electricity production in Kenya?

2. LITERATURE REVIEW

The efficiency with which a firm employs input to generate a certain level of output is determined by both external and internal factors. One of the external factors is the nature of the market. A competitive market characterized by free information, technical knowhow and price competition drives agents to make more efficient choices. A highly competitive market therefore reduces inefficiencies (Caves and Barton,1990,Lovell,1993).

Ownership of the firm is also another important factor sited in the literature. Due to the limited participation of the public in decision making, agents (managers) have no drive to improve efficiency. In contrast, private sector owners have direct supervision or management of their entities and are motivated to make efficient choices to make profits and reduce cost (Gumbau-Albert and Maudos, 2002). Size of the firm and technical investment are also positively related to efficiency (Caves, 1992). Other factors that are internal to the firm include changes in demand, technological innovation, and changes in management and so on which may impact positively or negatively on efficiency.

The effectiveness with which power utilities transform inputs to outputs has been analyzed using efficiency and productivity measures (Jamasb 2007). The inputs and outputs used in the analyses have differed among the studies reviewed. Installed capacity is widely taken as one of the inputs. In many developing countries the level of installed capacity is limited by lack of resources, this therefore is seen to impede on the level of production (Yunos and Hawdon, 1996, Kumbhakar and Hjalmarsson, 1998). The other argument on this is that the challenge of storing energy implies that installed capacity ought to grow with demand to ensure that the market attains equilibrium. Failure to achieve this will give rise to an oversupply or a short fall in supply (Fatima and Barik, 2012).Labour is used as an input in almost all efficiency studies reviewed. The commonest measure of labour is the number of employees engaged. Electricity generation requires use of energy as a form of input. Fuel consumption in electricity generation is also a common input used in efficiency studies.

The existing literature suggests that reforms have had mixed results with respect to improving the efficiency of power utilities. In Chile reforms resulted major improvements in efficiency. (Fischer, Gutierez and Serra, 2003). Privatization resulted in increased profitability of the firms, labour productivity and physical productivity also improved considerably in Chile. Power generated per worker rose, number of clients per worker grew, annual sales for electricity more than doubled and customer base grew. As a result of these improvements, electricity consumers benefited from the energy prices decline. In UK and Côte d'Ivoire restructuring and privatization also improved efficiency of the power utilities considerably (Newberry and Pollit, 1997, Plane, 1999).

In other countries reforms have not given the desired outcomes. In India for example, a study by Fatima and Barik, 2012, found that technical efficiency had declined during the post- restructuring period. In Africa, a study of 12 distribution companies observed no major change in technical efficiency resulting from the reform (Estache, Tovar and Trujillo, 2008). This was attributed to the failure to use labor and capital effectively. Similarly in Malysia Yunos and Hawdon, 1996 found no enhancement in efficiency from privatization of the power utility

Parametric and non-parametric methods have been employed to establish the effectiveness of firms in transforming inputs into outputs (Jamasb et al 2015). Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) are the commonest methods in use. Corrected Ordinary Least Square (COLS) has also been employed. A number of studies have used a combination of these methods. Stochastic frontier methods use production and or cost functions (Jamasb et al 2015). DEA uses mathematical programming to estimate the performance of a decision making unit relative to the frontier (Jamasb et al 2015).

The studies are inconclusive on the outcome of the reforms as far as efficiency enhancement is concerned. Some studies suggest that there have been higher levels of efficiency in the sector after the reforms. Others find no clear relationship between reforms and efficiency .There is therefore need to carry out more empirical work to confirm the case for a specific country such as Kenya.

3. METHODOLOGY

We use two competing efficiency measuring techniques (DEA and SFA) and compare the results.

3.1 Data Envelopment Analysis (DEA)

DEA is a non-parametric linear programming technique for measuring technical efficiency of a Decision Making Unit (DMU). Charnes, Cooper and Rhodes (1978) present an input-oriented measure of DMU's efficiency model with constant returns to scale. A variable returns to scale (VRS**)** model is also proposed by Charnes and Cooper (1984).

Constant Returns to scale (CRS) DEA model.

As illustrated in Coelli (1995), it is possible to come up with a non-parametric envelopment frontier over the data points of K inputs and M outputs of each N firm. The data points that lie furthest from the origin constitute the frontier of efficient firms. The data points below the frontier are of inefficient firms. The CRS assumption allows construction of an isoquant in the input-output space. The model problem is specified as

$\mathrm{Max}_{u,v}\ (u'm_i/v'k_i)$,

St $u'm_i/v'k_i \leq 1, i=1,2\ldots, N,$
$u, v \geq 0$……………………………………………………………………………………………1

Where m,k are outputs and inputs, respectively. u and v are variable weights determined by the solution to the problem.

The duality problem is,
$\mathrm{Min}_{\theta,\lambda}\theta,$
st $-mi + M\lambda \geq 0,$
$\theta k_i - K\lambda \geq 0,$
$\lambda \geq 0$……………………………………………………………………………………………...2

The value of θ which satisfies $\theta \leq 1$ is the efficiency level of the DMU. It ranges between 0 to 1.A value of 1 denotes that a DMU is efficient and a score less than 1 shows that the DMU is inefficient. The CRS DEA model is only suitable when the DMUs are working at an optimal scale. Using the CRS model when some firms are not operating optimally will result in measures of technical efficiency that also include scale efficiencies. VRS model is preferred when firms are not operating optimally, say, due to imperfect competition, financial constraints or government regulations. This is the most probable situation in most developing countries.

Variable returns to scale (VRS) DEA model

Variable returns to scale (VRS) DEA is an extension of the constant returns to scale (CRS) DEA. It assumes imperfect competition among firms and accommodates variable returns to scale. The problem here is to
$\mathrm{Min}_{\theta,\lambda}\theta,$
st $-mi + M\lambda \geq 0,$
$\theta k_i - K\lambda \geq 0,$
$N1'\lambda = 1$
$\lambda \geq 0$……………………………………………………………………………………………3

$N1'\lambda = 1$ is the convexity constraint. The variable returns to scale model gives technical efficiency scores less than or equal to the constant returns to scale scores.

Output oriented models and input-oriented models are similar and can be represented as
$\mathrm{Max}_{\Phi,\lambda,}\Phi,$
St $-mi + M\lambda \geq 0,$
$\Phi k_i - K\lambda \geq 0,$
$N1'\lambda = 1,$
$\lambda \geq 0$…………………………………………………………………………………...4

Φ is the relative increase in output that could be attained by a DMU.

One of the shortcomings of the DEA is that it fails to take recognize the likely effect of a measurement error in the data. In addition, efficiency scores are dependent on the choice of inputs and outputs while the number of efficient firms tends to rise with the number of inputs and outputs used. However, it has the advantage of not requiring assumptions concerning the functional form of the frontier and the distributional form of the error term u (Charnes, Cooper and Rhodes, 1978). Additionally, DEA can handle multiple inputs and outputs with ease, and is applicable no matter the input and output measurements.

3.2 Malmquist productivity index analysis

Malmquist (1953) came up a quantity index for application in consumption analysis. This was later modified by Caves et al. (1982) for use in production analysis. The productivity index uses distance functions to determine productivity change. We use the Malmquist output oriented productivity index decomposition to give insights on the causes of efficiency change.

The Malmquist output oriented productivity index was defined as follows: Assume a set or vectors of inputs x^t and a vector of outputs y^t in period t. Let $D_0^t(x^t,y^t)$ be defined as within period output distance function while $D_0^t(x^{t+1},y^{t+1})$ and $D_0^{t+1}(x^t,y^t)$ are adjacent period output distance functions as in Shephard (1970). The distance functions are used in the decomposition of the Malmquist productivity index (Fare 1970)

Period t+1 Malmquist productivity index is
$M_0^t(x^t,y^t,x^{t+1},y^{t+1}) = \frac{D_0^{t+1}(x^{t+1},y^{t+1})}{D_0^{t+1}(x^t,y^t)}$……………………………………………………………………5

Period t+1 output- oriented Malmquist productivity index decomposes as
$M_0^t(x^t,y^t,x^{t+1},y^{t+1}) = \Delta TE\,(x^t,y^t,x^{t+1},y^{t+1}) * \Delta T^{t+1}(x^t,y^t,x^{t+1},y^{t+1})$
$= \frac{D_0^{t+1}(x^{t+1},y^{t+1})}{D_0^t(x^t,y^t)} * \frac{D_0^t(x^{t+1},y^{t+1})}{D_0^{t+1}(x^{t+1},y^{t+1})}$……………………………………………………………………6

Where ΔTE (.) refers to technical efficiency change and ΔT(.) refers to technical change.

3.3 The Stochastic Frontier Analysis (SFA)

The stochastic production frontier proposed independently by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) is define by

$Y_i = f(\mathbf{X_i}, \boldsymbol{\beta}) \exp(v_i - u_i)$, $i = 1,2,\ldots\ldots.,N$
$Y_i = f(\mathbf{X_i}, \boldsymbol{\beta}) \exp(\varepsilon)$, $\varepsilon = (v_i - u_i)$ $i = 1,2,\ldots\ldots.,N$……………………………………………………………...7
where, Y is output , f is the deterministic part of the frontier production function, X is an input vector, β is a vector of parameters to be estimated, v captures stochastic shocks u captures inefficiency/ shortfall from the maximum possible output
$\varepsilon = (v - u)$
The model assumes that $E(v_i) = 0$, $E(v_i^2) = \sigma_v^2$, $E(v_i v_j) = 0$ for all $i \neq j$, and $E(u_i^2)$ = constant, $E(u_i u_j) = 0$ for all $i \neq j$, $u \geq 0$

The main aim of estimating a stochastic frontier model, is to obtain technical efficiency u_i. Firm j uses inputs X_j to obtain output Y_j. Which has corresponding frontier output Y_j^*. Y_j is less than the corresponding frontier output because it is associated with the random error term V which is negative. Technical efficiency is the ratio of the observed output to the output of the corresponding frontier.
$Y_i = f(\mathbf{X_i}, \boldsymbol{\beta}) \exp(v_i - u_i)$,
$\ln Y = \ln Y^* \exp(-u)$
$TE_i = \exp(-u_i)$,
$TE_i = Y_i/Y_i^* = (f(\mathbf{Xi}, \boldsymbol{\beta}) \exp(vi - ui))¦(f(\mathbf{Xi}, \boldsymbol{\beta}) \exp(vi))$
$= \exp(-u_i)$…………………………………………………………….8
This measure lies between a value of 0 and 1 ($0 \leq TE \geq 1$)
The model was estimated using maximum likelihood method:
$\ln Y_{it} = \alpha + \beta_1 \ln L_{it} + \beta_2 \ln K_{it} + \beta_3 \ln E_{it} + \beta_3 \ln E_{it} + \beta_4 \ln R_{it} + v_{it} - u_{it}$ ………………………………………9
Where LnY is the log of gross electricity generated (Gwh) of country i at time t, lnL is log of labour for country i at time t. LnK is log of installed capacity(Kilowatts) of country i at time t and lnE is log of fuel consumed in power generation (kteo) of country i at time t. and R_{it} is the reform score of country i at time t obtained from (http://www.esmap.org/rethinking_power_sector_reform).

3.4 Data sources.

Data on installed capacity was collected from IEA, World Bank database, data on labour was obtained from the annual financial reports and International Labour Organization (ILO). Fuel input data was gathered from United Nations Energy Statistics and the reform score were obtained from World Bank research paper (http://www.worldbank.org/prwp).

4. RESULTS AND DISCUSSION

4.1.Technical Efficiency indices for selected countries.

We compared technical efficiency scores obtained from the data on the two most distant years namely 1987 and 2015. This indicated the efficiency scores for the period before the reforms and after the reforms. DEA results were compared under both constant returns to scale(crs) and variable returns to scale (vrs).

Table 1: Technical efficiency scores for selected countries from DEA analysis, 1987-2015

DMU	1987			2015		
	crst	**vrst**	**scale**	**crst**	**vrst**	**scale**
Kenya	0.096	0.335	0.287irs	0.099	0.393	0.252 irs
Senegal	0.619	1.000	0.619 irs	0.506	1.000	0.506 irs
Tanzania	0.562	0.749	0.750 irs	0.489	0.648	0.754 irs
Uganda	1.000	1.000	1.000 -	1.000	1.000	1.000 -
Mean	0.569	0.771	0.664	0.523	0.760	0.628

crste = technical efficiency from CRS DEA,vrste = technical efficiency from VRS DEA,scale = scale efficiency = crste/vrste.Source: Author's computations from EAI, WDI, ILO and AFREPREN data.

In 1987 just before the reforms began, electricity utility in Uganda was found to be technically efficient under both variable returns to scale and constant returns to scale models. Electricity utility in Senegal was also found technically efficient under the variable returns to scale model. In 2015, the period after sector reforms, Uganda was still found to be technically efficient under both variable and constant returns to scale while Senegal maintained its technical efficiency under variable return to scale. Among the selected countries Kenya was in 1987 the least efficient and also in 2015, albeit with a slight improvement. Tanzania also improved slightly in the period after the reforms. Power utilities operate under imperfect market characterized by regulations, imperfect information, financial limitations among other imperfections; this explains the higher technical efficiency scores under variable returns to scale.

All the selected countries exhibited increasing returns to scale in both periods, an indication that they were smaller than their most productive size. Kenya had technical efficiency score of 39.3% and a scale efficiency score of 25.2% in 2015. It was operating at increasing returns to scale. Thus, 60.7% (100 – 39.3%) of inputs into the electricity subsector could have been saved by improving operational efficiency. More output could have been achieved with the same inputs. All the other countries are more efficient than Kenya.

4.2. Efficiency and technical change in the electricity sectors of selected African countries.

Table 2: Malmquist indices of electricity sectors in selected African countries, 2010-2017

Malmquist index summary					
DMU	**Efficiency change**	**Technical change**	**Pure efficiency change**	**Scale efficiency change**	**Total factor productivity change**
Kenya	1.000	1.446	1.000	1.000	1.446
Senegal	1.004	1.464	1.004	1.000	1.470
Tanzania	1.017	1.458	1.017	1.000	1.482
Uganda	1.027	1.523	1.027	1.000	1.564
Mean	1.012	1.472	1.472	1.000	1.490

Source: Author's computations from EAI, WDI, ILO and AFREPREN data.

Tanzania's and Uganda's electricity sector efficiency improved under constant returns to scale while Senegal's improved marginally (Efficiency change > 1). Kenya's sector efficiency change remained unchanged (Efficiency change =1). All the sampled countries experienced positive technical change between 2010 and 2017(Technical change>1). Uganda experienced the highest level of technical changed followed by Senegal, Tanzania and Kenya respectively. From a variable returns to scale perspective, the technical efficiency of electricity sectors in the selected countries was similar to those of constant return to scale. None of the four selected countries experienced a fall in the efficiency level. Over the entire period all countries experienced constant scale efficiency. Uganda also experienced the biggest rise in total factor productivity change of 56.4%. Kenya's total factor productivity change of 44.6% emanated fully from technical change.

4.3. Stochastic Frontier Analysis results

To allow for comparison between the DEA and SFA findings we use the same output and inputs in the two methods. The production function of the industries is taken to be a function of three inputs, namely: Labour as measured by the number of employees, installed capacity measured in Kilowatts and fuel consumed measured in kilotons of oil equivalent (kteo) and output is gross electricity measured in Gwh.

The regression results obtained from the SFA production function are as in the table below.

Table 3: Stochastic frontier regression results of TE in electricity sector of selected developing countries, 2010-2017

Parameter	Estimate and z-values
Labour	0.2826(2.80)**
Capital	0.640(4.62)**
Energy	0.1671(2.53)**
Reform score	0.4966 (0.54)
Sigma_ u = σ_{μ}	0.3653(0.82)
Sigma_ v = σ_{v}	0.0627(4.75)**
Prob>chi2	0.0000
Wald chi(3)	70153.96
Log likelihood	30.5319

** Significant at 1% significance level, Source: Author's computations from EAI, WDI, ILO and AFREPREN data.

All the parameters have the expected sign. The results confirm that labour, capital and energy are the most important inputs in production of electricity in the four countries considered. Following Aigner, Lovell and Schmidt (1977) the variance parameters are parameterized to

$$\sigma^2 = \sigma_v^2 + \sigma_u^2$$

$$\lambda^2 = \frac{\sigma_u^2}{\sigma_v^2} \geq 0$$

λ is the proportion of change in the error term that is due to inefficiency. If λ is equal to zero then there is no technical inefficiency. The SFA results obtained above were then used to predict the technical efficiencies of the four countries following the method suggested by Aigner, Lovell and Schmidt (1977). The findings are presented in table 2.6 below.

Table 4: Stochastic Frontier results of average technical efficiency scores of electricity sector in selected African countries, 2010 -2017

Country	**Year**	**Average reform score**	**Average Technical efficiency score**
Kenya	2010-2017	51	0.985
Senegal	2010-2017	35.6875	0.877
Tanzania	2010-2017	40.875	0.962
Uganda	2010-2017	61.8125	0.990

Source: Author's computations with data from EAI, WDI, ILO and AFREPREN

As in the DEA results we observe that Uganda has the highest average technical score. With the inclusion of the reform variable, Kenya assumed the second position, Tanzania the third and lastly Senegal.It was clear from the SFA results that a positive relationship exists between the reform score and the level of technical efficiency. The higher the reforms score for a given country, the higher was the level of technical efficiency.

5. CONCLUSION AND POLICY DIRECTION.

The findings of this study are that the technical efficiency under variable returns to scale increased in the four DMUs considered between the two periods. In Kenya the efficiency rose from 33.5% 1987(before the reforms) to 39.3% (after the reforms). The sector's efficiency is very low and more output can be realized with the same inputs if efficiency is fast tracked. Uganda and Senegal were the most efficient during the two periods. The Malmquist total factor productivity index showed that TFP change in Kenya mainly stemmed from technical efficiency change unlike in the other DMUs where the Total factor productivity emanated from both technical and pure efficiency change. The stochastic frontier Analysis confirms our choice of the inputs. Labour capital and energy contribute significantly to electricity generation in the four countries. The only variation with DEA findings, is that with the inclusion of the reform score Kenya now is seen to be more efficient than Senegal. Uganda however maintains the lead.

From these results, reforms measures taken so far have had a positive impact on the efficiency of the sector. Uganda which scores way above the international benchmark on utility restructuring and private sector participation is also the most efficient of the four countries. Failure to embrace more reforms could be one of the contributing factors of the low technical scores in Kenya. Data from sector shows that there are still high transmission and distribution losses (about 20%) which confirm the need to improve the efficiency levels in the sector.

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