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Technical Efficiency of Thermal Electricity Generators in Kenya

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ABSTRACT

The Government of Kenya introduced energy sector reforms in the late 1990s aimed at improving efficiency in the supply of energy. After over two decades of reforms, there has been no comprehensive study to estimate the technical efficiency amongst electricity generators in Kenya. This study examined 27 thermal electricity generating plants in Kenya using data sourced from Energy Regulation Commission for the period July 2015 to December 2017. The study applied two methods to estimate efficiency, viz., the Stochastic Frontier Analysis and Data Envelope Analysis. The results indicated that there is inefficiency in thermal power generation. The average efficiency score was 71% meaning the industry was missing its technical potential by about 29%. The plants experienced increasing returns to scale and were improving on efficiency and productivity. Age and public ownership contributed to inefficiency while grid connection had a positive effect on efficiency. The government should encourage private investment in future power generation projects while at the same time increasing connection of the isolated areas to the national grid. The regulator should also revisit the current specific fuel targets used in determining the fuel pass through costs to consumers to encourage efficiency.

Keywords: Technical Efficiency, Electricity Generation, Stochastic Frontier Analysis, Data Envelope Analysis, Kenya
JEL Classifications: D24, L11, L25

1. INTRODUCTION

From the 1990s, the Government of Kenya embarked on power sector reforms. The objectives of the reforms were to commercialize energy services, increase operational efficiency and allow private investment in energy. Unbundling reforms were initiated by the Electric Power Act of 1997 that separated generation from transmission and distribution. The Act also allowed private sector investment in generation through Independent Power Producers (IPPs) and established an independent regulator. Kenya Electricity Generating Company (KenGen) the national electricity generator, would from henceforth compete with IPPs. These reforms were expected to encourage competition with the aim of lowering electricity tariffs (Republic of Kenya, 2004). The first IPPs in Kenya were mainly thermal plants. By the year 2000 there were four IPPs, three using fossil fuel and one using geothermal to generate electricity. The number of IPPs has since increased to twelve with an installed capacity of 691MW of 76% are thermal power plants. KenGen, the state owned generator, dominates generation contributing over 70% of the electricity (KPLC, 2017). KenGen mainly uses hydro technology and the government has invested heavily in this area.

The electricity sector has been struggling with high tariffs that the government has attributed to low investments and operational inefficiencies (Republic of Kenya, 2004). This is despite the reforms that aimed at broadening generation and increasing efficiency in the supply of power (Republic of Kenya, 1997; 2004). Consequently, the government has continued with more reforms aimed at improving efficiency in electricity supply and ensuring competitive power supply (Republic of Kenya, 2018). However, the reform agenda has been pursued without any study on the productive efficiency levels of firms involved in the supply of electricity. Before this study, there was no comprehensive study on the efficiency levels of electricity generating power plants in Kenya even though its known that efficiency brings competitive pricing. This study tried to fill this gap by evaluating the efficiency of electricity generators in Kenya and examining the determinants of efficiency. In order to examine efficiency in similar technologies the study focused on thermal power plants. Evidence on the operational efficiency of electricity generating plants and the determinants of efficiency in Kenya is critical for future policy interventions, reforms and regulatory incentives. The information also benefits the Ministry of Energy in deciding whether future power projects should be implemented by public or private owned companies.

2. LITERATURE REVIEW

Productivity and efficiency measures assess the performance of decision making units. Electricity generation plants produce a homogenous output that is electrical energy but their inputs differ based on the technology applied (Jamasb, 2007). This means productivity and efficiency measures can be used to assess their performance for similar electricity generation technologies. Several studies dating back to the 1990s have measured the productive efficiency of electricity generating companies. Most of these studies use data envelope analysis (DEA) and stochastic frontier analysis (SFA). Golany et al. (1994) analyses the efficiency of 87 plants owned by Israeli electric company and finds only 39 plants were efficient. Chang and Toh (2007) study for three electricity generation companies in Singapore for the years 1999-2004 finds efficiency using SFA to be 90.35% and using DEA to be 98.33%. Shanmugam and Kulshreshtha (2005) study for India's 56 coal thermal based power plants finds the efficiency level to be on average 72.7%. A recent study by Vijai (2018) for 20 coal power plants in India find a mean efficiency level of 88.2%.

Some studies have analysed efficiency for thermal industries using regions as the decision making unit. Lam and Shiu (2001) study for China's thermal power generation industry using 30 provinces as the decision making units finds the average efficiency to be 88.8% in 1995 and 90.3% in 1996. Fatima and Barik (2012) also uses 14 states in India as the DMU in estimating efficiency of thermal plants, the study finds efficiency to average 80.35%.

Other studies focus on a comparative analysis of efficiency based on the ownership of the power plants. Saleem (2007) studies 21 electricity generating plants in Pakistan, 12 private and 9 public and finds a mean efficiency of 78%. Public ownership is found to be affecting efficiency. This is finding is confirmed by a recent study by Khan (2014) which finds IPPs to be more efficient than public owned power plants. A study for Spain by Arocena and Waddams (2002) find public owned generators to be more efficient than privately owned generators.

Efficiency analysis has also been used to analyse power generating plants in island and non-island locations. Domah (2002) compares technical efficiency of fossil-fired generators in 16 small island economies and 121 investor owned generators in the US. The study finds no difference between islands and non-islands generators. Riaz et al. (2013) study of the efficiency of Asian energy firms using DEA approach finds larger firms and those with more liquid assets more technically efficient.

Another area that has been studied is the impact of reforms on efficiency of plants. Malik et al. (2011) studies the impact of unbundling on efficiency of state thermal power plants in India. Using unbalanced panel of 385 coal electricity generating units for the years 1988-2009, the study finds that unbundling has not improved thermal efficiency. It has however improved plant availability and reduced outages.

Studies use electricity generated as output and capital, labour and fuel as the inputs (Shanmugam and Kulshreshtha, 2005; Lam and Shiu, 2001; Fatima and Barik, 2012; Arocena and Waddams, 2002; Domah, 2002; Vijai, 2018). Studies using DEA consider other outputs; operational availability, pollutant emissions, deviation from load and operation parameters (Golany et al., 1994; Arocena and Waddams, 2002). Other inputs considered include; internal power consumed by the plant, capital, manpower, fuel stock and all non-labour expenses (Golany et al., 1994; Fatima and Barik, 2012). The studies also estimate the determinants of efficiency. Some of the determinants identified include technical manpower, richness of the state and unbundling reforms (Fatima and Barik, 2012); size, liquidity and leveraging firms (Riaz et al., 2013); capacity utilization (Domah, 2002) and ownership (Arocena and Waddams, 2002; Saleem, 2007; Khan (2014).

The literature reviewed is mainly from US, Europe and Asia and there is paucity of research in this area for the Africa region. There is a research gap on the level of efficiency amongst electricity generators in Kenya too. This study will add to literature by estimating the efficiency of electricity generators in Kenya.

3. METHODOLOGY

Parametric and non-parametric techniques are used to estimate firm level efficiency. DEA is non-parametric and involves mathematical programming. SFA is parametric and involves econometric methods. Following Saleem (2007) and Domah (2002) this study used DEA and SFA methods in the analysis.

3.1. SFA

Battese and Coelli (1995) specify an inefficiency model for panel data as;

$$Y_{it} = \exp(x_{it}\beta + v_{it} - u_{it}) \tag{1}$$

where Y_{it} is the production of the i^{th} firm ($i = 1,2,\ldots,N$) at the t^{th} observation ($t = 1,2,\ldots,T$). x_{it} is a vector of inputs of production for the i^{th} firm at t^{th} observation. β is a vector of unknown parameters to be estimated. v_{it} are random errors and u_{it} are random variables associated with inefficiency. u_{it} is assumed to have a mean of $z_{it}\,\delta$ where z_{it} is a vector of explanatory variables associated with technical inefficiency and δ is a vector of unknown coefficients. The panel does not need to be balanced (Battese and Coelli 1995). Following Saleem (2007) and Domah (2002), and assuming a transcendental logarithmic transformation, the function representing the underlying technology of power generating plants in Kenya was specified as.

$$lnq_{it} = \beta_0 + \beta_1 \ln k_{it} + \beta_2 \ln l_{it} + \beta_3 \ln f_{it} + \frac{1}{2}\left[\beta_{11}\left(\ln k_{it}^{2}\right) + \beta_{22}\left(\ln l_{it}^{2}\right) + \beta_{33}\left(\ln f_{it}^{2}\right)\right] + \beta_{12}\ln k_{it} \times \ln l_{it} + \beta_{13}\ln k_{it} \times \ln f_{it} + \beta_{23}\ln l_{it} \times \ln f_{it} + v_{it} - u_{it} \quad (2)$$

where q_{it} = Units generated by the ith plant in month t in MWh
k_{it}= Installed capacity for the ith plant in month t in MW
l_{it}=Number of employees for the ith plant in month t
f_{it}=Fuel used by the ith plant in month t in liters
i=1…27
t=1…30
ln is the natural log
$\beta_0 \ldots \beta_{33}$ are parameters to be estimated,
v_{it} are random errors
μ_{it} are the random variables associated with inefficiency.
μ_{it} are assumed to be independently distributed. The distribution of μ_{it} is truncated at zero of the normal distribution with a mean of m_{it} and a variance of $,\sigma_\mu^2$ that is. $N\left(m_{it}, \sigma_\mu^2\right)$ The technical inefficiency equation is specified as in Battese and Coelli (1995).

$$m_{it} = \partial z_{it} \quad (3)$$

where z_{it} is a vector of variables likely to influence the efficiency of the firm and ∂ are the parameters to be estimated. Equation 3 was assumed to take the form.

$$m_{it} = \partial_1 age_{it} + \partial_2 grid_{it} + \partial_3 ownership_{it} \quad (4)$$

where, *age* = Number of years the plant has been in operation
Grid = Whether on grid connected or not (on-grid = 1 and isolated = 0)
Ownership = Whether public or privately owned (public =1, private = 0).

Estimation of equation 2 including determinants of inefficiency as specified in equation 4 was undertaken using Belotti et al. (2013) method and commands in Stata.

3.1.1. Elasticities and returns to scale

The partial elasticity of output with respect to each of the inputs E_k in equation 2 can be specified as in Saleem (2007) and Ngui (2008).

$$E_k = \frac{\partial lnq_{it}}{\partial lnx_k} = \beta_k + \beta_{kk} lnx_{kit} + \sum_{j \neq k} \beta_{kj} lnx_{jit} k = 1,2,3; j = 1,2,3 \quad (5)$$

and x represents k, l and f in equation 2.

The returns to scale was calculated from the sum of the partial input elasticities, and expressed as,

$$RTS = \sum_{k=1}^{K} E_k \quad (6)$$

3.2. DEA Malmquist Productivity Index

This study followed Saleem (2007) and Domah (2002) and included variables likely to affect the efficiency of plants as outputs. Consider firms that transform a set of inputs into $x \in R_+^n$ outputs $q \in R_+^m$, and each firm uses $x^{it} = x_1^{it}, \ldots, x_n^{it}$ inputs to produce outputs, $q^i t = q_1^i t, \ldots, q_m^i t$ with $I = 1, \ldots, I_t$ observations over period of time. The output- based Malmquist productivity change index was specified as follows;

$$m_0\left(q_{t+1}, X_{t+1}, q_t, X_t\right) = [m_0^{t+1}\left(q_{t+1}, X_{t+1}, q_t, X_t\right) \times m_0^t\left(q_{t+1}, X_{t+1}, q_t, X_t\right)]^{\frac{1}{2}} =$$

$$\left[\frac{d_0^t(X_{t+1}, q_{t+1})}{d_0^t(X_t, q_t)} \times \frac{d_0^{t+1}(X_{t+1}, q_{t+1})}{d_0^{t+1}(X_t, q_t)}\right]^{1/2} =$$

$$\frac{d_0^{t+1}(X_{t+1}, q_{t+1})}{d_0^t(X_t, q_t)}\left[\frac{d_0^t(X_{t+1}, q_{t+1})}{d_0^t(X_t, q_t)} \times \frac{d_0^{t+1}(X_{t+1}, q_{t+1})}{d_0^{t+1}(X_t, q_t)}\right]^{1/2} \quad (7)$$

Where *d* was the distance function from the frontier, superscript *t* represented period technology, superscript *t*+1 represented period *t*+1 technology, subscript represented an output function.

Equation 7 represented the productivity of production point (X_{t+1}, q_{t+1}) relative to the production point (X_t, q_t). A value >1 indicated total factor productivity growth from period *t* to *t*+1 (Coelli, 1996a).

The ratio outside the brackets was,

$$\frac{d_0^{t+1}(X_{t+1}, q_{t+1})}{d_0^t(X_t, q_t)} = \text{Efficiency change} \quad (8)$$

and the ratio inside the brackets was,

$$\text{Technicalchange} = \left[\frac{d_0^t(X_{t+1}, q_{t+1})}{d_0^t(X_t, q_t)} \times \frac{d_0^{t+1}(X_{t+1}, q_{t+1})}{d_0^{t+1}(X_t, q_t)}\right]^{1/2} \quad (9)$$

3.3. Data Type, Source and Measurement

The data consisted of monthly records for all the 27 thermal generators existing in the system in the period July 2015 to December 2017. The period was informed by the available data from the Energy Regulatory Commission (ERC). The data was unbalanced since some of the plants were retired or not dispatched in some of the months. The data was from grid connected thermal generators and isolated stations that served areas not connected to the Grid. All the 19 isolated stations were owned by public sector utilities, 2 by KenGen and 17 by KPLC. 2 of the grid connected thermal generators belonged to KenGen while the remaining 6 were owned by IPPs or private companies.

4. RESULTS AND DISCUSSION

4.1. Partial Productivity Analysis

Partial productivity analysis for grid and isolated power projects were analysed for the period July 2015 to December 2017. Capital, labour and fuel productivity was analysed.

4.1.1. Labour productivity

Labour productivity for grid connected projects was more volatile than that for isolated projects (Figure 1). This can be attributed to changes in monthly generated output. Grid connected power plants generated power based on economic merit order. Thus competitively priced plants were allowed to generate first (Electricity Regulatory Board, 2005). The existence of other competing forms of generation may have caused the variability in energy generated from thermal plants. Thermal power plants tend to be more expensive than hydro and geothermal depending on the price of fuel.

4.1.2. Capital productivity

The capital productivity fluctuated in both grid and isolated power plants (Figure 2). The capital productivity increased in the grid connected plants from July 2016 to June 2017. This can be attributed to increased use of thermal power plants in the 2016/17 financial year following inadequate rains that reduced hydro inflows affecting generation from hydro power plants.

4.1.3. Fuel productivity

Fuel productivity remained less volatile over the period for both grid and isolated power plants (Figure 3). This could be attributed to power plants adherence to the fuel efficiency targets set by the regulator. The regulator issued specific fuel consumption targets in kg/kWh for each of the power plants (Electricity Regulatory Board, 2005). Power plants that missed their targets were not compensated for the fuel costs above the set targets.

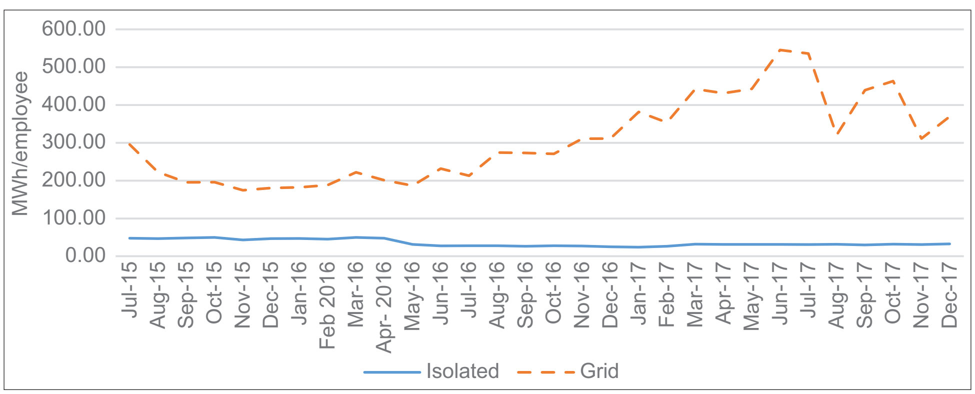
4.2. SFA Results

4.2.1. Elasticities and returns to scale

Three estimates were undertaken, one for all the thermal generators and two separate estimates for grid connected generators and isolated generators. This allowed for the assessment of the differences in the results. Grid connected plants were larger in size compared to the isolated power plants. Table 1 presents the results of the three estimates.

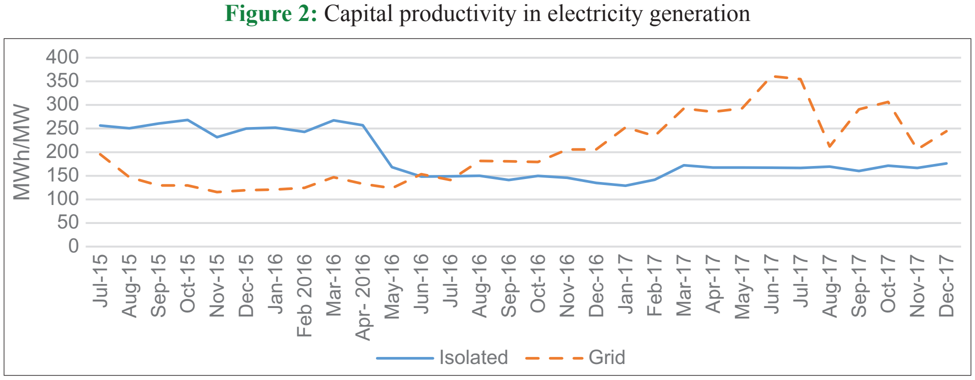
The estimates for all the generators indicated that the partial output elasticity with respect to fuel was positive and significantly different from zero. A similar result was reported for the separate estimates for grid and isolated power plants. This indicates that adding fuel by 1% to the generators is likely to increase the amount of electricity generated by 1.68% for all thermal plants, 1.74% for grid connected projects and 2.97% for isolated power plants while holding capital and labour constant. The estimates for grid connected power projects also found capital to be significant determinants of electricity generation. Increasing capital by 1% was also likely to increase the electricity produced by these power plants by 0.6% while holding labour and fuel constant. These findings are consistent with other studies. The study for India by Shanmugam and Kulshreshtha (2005) found fuel (coal) and capital to be the

Figure 1: Labour productivity in electricity generation



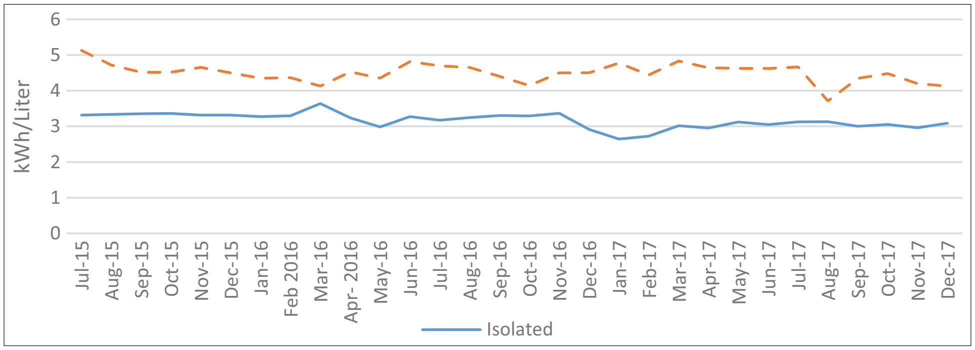
Source: Author's estimation from ERC, KenGen, IPPs and KPLC data

Figure 2: Capital productivity in electricity generation



Source: Author's estimation from ERC, KenGen, IPPs and KPLC data

Figure 3: Fuel productivity in electricity generation



Source: Author's estimation from ERC, KenGen, IPPs and KPLC data

Table 1: SFA estimates of elasticities of thermal power production in Kenya

Variable	Combined grid and isolated power plants	Grid connected power plants only	Isolated power plants only
Constant	−8.379*** (1.323)	−26.457*** (6.278)	−9.896 (6.727)
Capital	−0.093 (0.399)	0.596* (5.162)	−0.536 (2.099)
Labour	0.807 (0.604)	−1.232 (3.879)	0.433 (1.499)
Fuel	1.685*** (0.169)	1.742*** (0.248)	2.969** (1.066)
Returns to scale	2.4	1.11	3.94
Log likelihood ratio	126.6	166.7	173.4

Source: Author's estimation from ERC, KenGen, IPPs and KPLC data. *** indicates significance at 1% level, ** indicates significance at 5% level and * indicates significance at 10% level. Standard errors are in paranthesis. SFA: Stochastic frontier analysis, ERC: Energy Regulatory Commission, IPP: Independent power producers

Table 2: SFA average efficiency for thermal power generators in Kenya

Name of power plant	Average efficiency score (%)
Hola	92.07
Marsabit Diesel	91.78
Lodwar Diesel	89.58
Habasweni	89.27
Lokichogio	89.24
Baragoi	89.12
Mfangano	88.32
Merti	87.65
Lamu	86.51
Elwak	86.36
Eldas	85.71
Takaba	85.63
Rhamu	85.09
Laisamis	84.54
Mandera Diesel	84.27
Lokori	83.56
Garissa (Kengen)	82.50
North Horr	79.72
Wajir	76.71
Rabai	40.26
Iberafrica	38.97
Tsavo	38.29
Gulf Power	37.51
Kipevu 1	36.42
Triumph Power	34.83
Kipevu Diesel Plant 3	34.34
Thika Power	33.70

Source: Author's estimation from ERC, KenGen, IPPs and KPLC data. SFA: Stochastic frontier analysis, ERC: Energy Regulatory Commission, IPP: Independent power producers

determinants of coal based generation. Saleem (2007) also found capital to be significant in determining thermal power generation in Pakistan.

All the three estimates indicated increasing returns to scale. This means the plants can generate more output to reach the optimal scale. The finding of increasing returns of 1.11 for grid connected power plants is close to that of Knittel (2002) study for US coal and natural gas power plants. The study found coal power plants to have mild increasing returns to scale of 1.0644 and natural gas plants to have constant returns to scale. The isolated power plants as well as the combined isolated and grid power plants estimates indicated stronger increasing returns to scale of 3.94 and 2.4 respectively. Strong increasing returns of 3.21 have been reported in Saleem (2007) study for Pakistan electricity generation sector.

4.2.2. Efficiency of thermal power generation in Kenya

The efficiency estimates for all the thermal generators and two separate estimates for grid connected generators and isolated generators are presented on Tables 2-4. As explained, the separate estimates for grid connected plant and isolated plants was occasioned by the sizing of the plants where grid connected plants were larger in size compared to the isolated power plants.

The mean efficiency score for all the thermal power plants was found to be 71.06% indicating inefficiency in the thermal industry. None of the plants was found to be efficient. The least efficient power plant was found to be Thika power with an average score of 33.7%. Hola was the most efficient with an average score of 92.07%.

The average efficiency score estimates for grid connected plants was found to be 98.78%. None of the power plants was found to be efficient. The most efficient grid connected power plant was found to be Iberafrica with a mean efficiency score of 99.75%. The least efficient power plant was found to be Kipevu 3 with a

Table 3: SFA average efficiency for grid connected thermal power generators in Kenya

Name of power plant	Average efficiency score (%)
Iberafrica	99.75
Tsavo	99.68
Kipevu1	99.62
Rabai	99.38
Thika Power	98.56
Gulf Power	97.94
Triumph	97.87
Kipevu3	97.30

Source: Author's estimation from ERC, KenGen, IPPs and KPLC data. SFA: Stochastic frontier analysis, ERC: Energy Regulatory Commission, IPP: Independent power producers

Table 4: SFA average efficiency for isolated power plants in Kenya

Name of power plant	Average efficiency Score (%)
Garissa	94.53
Lamu	91.86
Lokichogio	91.85
Lodwar	91.70
Merti	91.31
Hola	90.98
Baragoi	89.69
Habasweni	88.52
Marsabit	88.46
Mandera	87.89
Mfangano Diesel	86.59
Takaba Diesel	85.30
Elwak	83.80
Rhamu	83.25
Eldas	81.47
Wajir	79.75
Laisamis	70.49
Lokori	65.41
North Horr	38.55

Source: Author's estimation from ERC, KenGen, IPPs and KPLC data. SFA: Stochastic frontier analysis, ERC: Energy Regulatory Commission, IPP: Independent power producers

mean efficiency score of 97.30%. Iberafrica is a privately owned power plant while Kipevu is owned by KenGen, a public utility.

The average efficiency for isolated power plants was estimated to be 82.73%. The most efficient isolated power plant was found to be Lamu with an average efficiency score of 94.53%. The least efficient plant was North Horr with a mean efficiency score of 38.55%.

The estimates from combined grid and isolated plants were different from the results realised from estimating grid and isolated plants separately. Grid connected power plants were found to be more efficient when estimated separately from isolated plants. This can be attributed to the small sizes of the isolated power plants relative to the grid connected power plants. Further, the isolated power plants are limited to the energy requirements in their regions.

4.2.3. Determinants of efficiency

Age, grid and ownership were found to be significant determinants of technical efficiency in the combined grid and isolated plants estimates (Table 5). Age had a negative sign, indicating that age is likely to reduce the efficiency of generating plants. Grid connection was found likely to have a positive effect on efficiency. Public ownership had a negative sign indicating the possibility that public ownership is likely to reduce efficiency.

Table 5: Effects of age, connection and ownership on technical efficiency of thermal power plants

Variables	Combined grid connected and isolated plants	Grid connected power plants	Isolated power plants
Age	−0.0026034** (0.002)	−0.0042498 (0.066)	−10.25921*** (0.199)
Grid			
On-grid=1	0.6402017*** (0.022)		
Isolated=0	0.1388421		
Ownership			
Public=1	−0.1106151*** (0.025)	−0.0362599 (0.341)	
Private=0	0.1388421	0.0422385	

Source: Author's estimation from ERC, KenGen, IPPs and KPLC data. *** indicates significance at 1% level, ** indicates significance at 5% level and * indicates significance at 10% level. Standard errors are in paranthesis. SFA: Stochastic frontier analysis, ERC: Energy Regulatory Commission, IPP: Independent power producers

4.2.4. DEA Malmquist index results

The same sample data was used, but to ensure a balanced panel 6 plants were dropped. The plants had either been retired, not dispatched or commissioned between the period July 2015 and December 2017. This plants include Gulf power, Garissa, Lamu, Hola, Laisamis, North Horr and Lokori.

Table 6 presents the Malmquist productivity change index summary results. In the estimates that combined both grid and isolated plants, technical and scale efficiency change was 1.002 indicating an improvement in efficiency of about 0.2%. Total factor productivity was also found to have improved by 0.3%. There was no technological change in the period. This could be attributed to the short period under consideration in the study. The estimates for grid connected power plants found technical efficiency change, when assuming constant returns to scale (CRS) technology, to have improved by 1%. This was slightly higher than the 0.1% realised for isolated power plants. Technical efficiency change assuming variable returns to scale (VRS) situation was found to have improved by 0.6% for grid connected power plants. Isolated power plants efficiency change relative to VRS technology reduced by 0.1%. The scale efficiency was also estimated to have improved by 0.3% for grid connected power plants and 0.2% for isolated plants. Technological change favoured isolated power plants with an improvement of 0.4% compared to grid connected power plants that reduced with 0.9%. Technological change represents a frontier shift (Domah, 2002). The inward shift in the grid connected plants could be attributed to the growth in the grid energy mix bringing in competition and affecting the use of the thermal power plants. The outward shift in the isolated plants could be attributed to demand growth in their locations. Consequently, isolated power plants experienced more increased total factor productivity of 0.6% compared to the grid connected power plants growth of 0.1%.

Table 6: Malmquist efficiency change

Power plants	Technical efficiency change (Relative to CRS technology)	Technological change	Pure technical efficiency change (Relative to VRS technology)	Scale efficiency change	Total factor productivity change
Combined grid and isolated power plants	1.002	1.000	1.000	1.002	1.003
Grid only	1.01	0.991	1.006	1.003	1.001
Isolated only	1.001	1.004	0.999	1.002	1.006

Source: Author's estimation from ERC, KenGen, IPPs and KPLC data

5. CONCLUSIONS

The mean efficiency score for all the thermal power plants (combined grid and isolated power plants) was found to be 70.62%. Grid connected power plants efficiency averaged 98.78% while that of isolated power plants was found to be 82.73%. None of the power plants was found to be efficient. This indicated that the thermal power industry in Kenya was inefficient and underutilised its technical potential. The Malmquist index indicated improvement in efficiency and productivity. The estimated efficiency change for combined grid and isolated power plants was found to be 0.2% with a total factor productivity growth of 0.3%. Estimates for grid connected power plants found efficiency improvements of 0.6% and total factor productivity of 0.1%. Technological change was found to be 0.991, indicating a possible inward frontier shift for grid connected power plants. Isolated power plants were also found to have experienced efficiency improvement of 0.2% and total factor productivity growth of 0.6%.

The SFA estimates indicated that fuel has a positive elasticity and is significantly different from zero for the three estimated models that is combined grid and isolated plants, grid connected plants and isolated plants. Capital was also found to be a positive and significant determinant of electricity production for grid connected power plants. The return to scale results indicated increasing returns to scale. Age, grid and ownership were found to be significant determinants of the technical efficiency. Age and public ownership coefficients negatively affected the efficiency of generating plants, while grid connection had a positive effect on efficiency.

6. POLICY RECOMMENDATIONS

Efficiency requires the government to deepen reforms, competition and regulations. Reforms meant to achieve efficiency in the sector have not realised this objective yet as thermal power generation industry still showed inefficiency. The government should continue with the reform agenda and particularly consider encouraging private investment in power generation. The government should also continue connecting the isolated areas to the grid. Areas not connected to the grid have the potential of benefiting from private owned generation plants.

The industry is operating on increasing returns to scale. This finding is critical as it indicates capacity to improve performance in the sector. With the same inputs currently being deployed output could be expanded. ERC should therefore consider using the findings of these paper to implement incentive regulation by rewarding or penalising thermal power plants based on their performance relative to other firms. Removing the current protection accorded to the generators in the long term take or pay power purchase agreements is likely to improve on the plants efficiency. This can be done through the introduction of a wholesale generation market and signing take and pay contracts.

The fuel elasticity of output was found to be high and significant. ERC can look at how to regulate fuel use whose costs are currently passed on to consumers leaving the generators with a minimal risk on it. Generators may not be motivated to use it efficiently. ERC could explore the possibility of reducing the cost of fuel transferred to consumers with a view to make generators use the same fuel amount to produce more energy. This could be done by downward revision of the specific fuel targets per unit generated.

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