International Scholars Journals

International Journal of Accounting, Auditing and Taxation ISSN: 2756-3634 Vol. 6 (4), pp. 001-010, April, 2019. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Cost and demand functions of electricity in Gambia from 1982 to 2007

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Accepted 13 November, 2018

This paper argues that an electricity demand should be estimated simultaneously with the supply. It then estimates the demand for and the supply of the electricity in the Gambia using reduced form regressions and vector error correction methods. The paper finds that systems of simultaneous equations cannot be simplified to reduced form regressions to satisfy the statistical requirements, but rather the theoretical modeling requirements determine the choice of the statistical model. The vector error correction method incorporating the theoretical restrictions of the model is found to better fit the data than the reduced form regressions. From the estimation results of this method, the electricity demand is found to be price elastic and income elastic. The electricity demand is found to shrink if the company charges an average price higher than 1.3 times of the per capita GDP growth rate; and since the demand is price elastic, increasing the electricity price will result in falling revenues for the company. The electricity industry, which here refers to the national electricity company, exhibits diseconomies of scale. The industry is found inefficient, and failing to innovate and accumulate knowledge to enable it to expand output with falling average unit cost. With the current operation, the expansion of output could be undertaken only with increasing average unit cost and hence increasing electricity price.

Key words: Electricity generation, economic growth.

INTRODUCTION

Electricity is the energy and engine of economic growth. It is the energy that powers the industrial production. It is costly and time consuming to set up an electricity generating system. But once it is in place, it is expected to experience decreasing average costs as the output expands. Over time, the system is also expected to innovate and make use of advances in technology and knowledge. These learning and experiences being gained on the production shall enable the system to expand and produce better output than previously due to the existence of economies of scale and learning effects. Gambia has never enjoyed an adequate supply of elec-tricity in its history; unmet demand and constant losses have been the characteristic of the electricity generation. Before independence, electricity was known only to some government headquarters. After the independence in 1965, the government corporatized a department to form Public Utilities Corporation, and it operated the electricity industry from 1965 – 1993 when the government decided to privatize its operations and maintenance to Management Services (MSG) Gambia Limited. The contract of MSG was terminated in 1995, and GUC was transformed to National Water and Electricity Company (NAWEC) as a limited liability company. It has seven provincial power stations and covers 30% of Greater Banjul area. But the supply is still far short of the demand, which is estimated to range from 15 to 30mw, and the performance is unsatisfactory as it continues to lose 40% of its production as unmetered consumption; and the electricity tariff at $0.18 per kWh[1] is extremely costly for the Gambian standard, which has an average monthly earning of $40.

Thus, the company has no option but to learn and innovate to improve the performance. Does the cost structure of NAWEC tell of economies of scale, learning and innovation? The answer to this question is one attempt this paper will make. The other attempt is to ana-lyze the structure of demand for electricity in the Gambia. Gambians increasingly purchase electrical appliances to

[1] http://wow.gm/africa/gambia/article/2007/7/1/the-energy-sector-electricity-LPG-and-renewable-energy.

consume the energy produced by NAWEC, or by chemical batteries, generators and solar panels. While the industrial consumers often set up stand-by generators to complement the NAWEC supply. It is not economical for every individual to operate his /her own electricity generating system. if the consumers in the Gambia increasingly demand or plan to demand high consumption of energy, it will be learned that they are willing to pay for the energy; and NAWEC, provided that its cost structure exhibits economies of scale, should be in position to increase output and to take up the demand that is increasingly offered by both the households and the industrial consumers.

LITERATURE REVIEW

Several studies have examined the characteristics and the determinants of electricity demand. The studies treat the demand as a function of income, own price and other variables assumed to be relevant. The other variables can range from household size to plasma display panel TV's, Yoo et al. (2007) and some include climate conditions, Hondroyannis (2004). Electricity is found to be a basic necessity of living, Walker (1979); Ubongu (1985); Silk and Joutz (1997); Narayan and Smyth (2005); Narayan, Smyth and Prasad (2007); Louw, Conradie, Howells and Dekenah (2008). Holtedahl and Joutz (2004) found the electricity demand to be unitary elastic in response to income changes; while in Greece electricity is a luxury, Hondroyannis (2004). Own price is found insignificant, Ubongu (1985) and Ziramba (2008), which could be due to the price distortions and price measurement error often prevailing in electricity market. The electricity demand is found to be price inelastic - Walker (1979); Holtedahl and Joutz (2004); Hondroyannis (2004); Narayan and Smyth (2005); Yoo et al. (2007); Narayan, Smyth and Prasad (2007) - which is typical for electricity, given the fact that it is has no close substitutes in short run.

Holtedahl and Joutz (2004); Hondroyannis (2004) find the demand to be inelastic in both the short and the long runs; while Narayan et al. (2007) has found it to be elastic in the long, which gives hope that in the long run consumers are able to adjust their consumption of electricity and switch to other energy alternatives. These studies have implicitly assumed the electricity supply constant, which can be understood in the cross sectional data, but questionable in the time series data. That is, they claim to observe identifiable and stable electricity demand, Hondroyannis (2004), or shifting electricity demand, Silk and Joutz (1997). Analyzing demand separately assuming away its interdependency with the supply could lead to biased results and conclusions. Other studies of electricity market focused on the supply side assuming the demand constant, McDonald and Schrattenhol (2001); Abott (2006) and Kahouli-Brahmi (2009).

The current paper attempts to fill in this gap by analyzing demand and supply of electricity simultaneously. The paper has presented the model, modifying that of Fischer and Kaysen (1962), in a way that both estimates the effects of learning and scale, and reduces the omitted variable bias that often arises when estimating the learning curves. Kamershen and Porter (2004) also use simultaneous equation approach, but their model does not incorporate learning effects. In addition, the paper pioneers this study in the context of the Gambia, where no such study has been undertaken. Thus, it provides evidence base, which is of high value to the policy makers in the country.

Modeling the demand for and the cost of electricity

Electricity demand function

Demand for electricity is a derived demand. This demand is for the services of electrical machines, and durable electrical appliances. This demand changes when the use of these machines and appliances changes or when the stocks of these machines and appliances vary through new purchases, retirements or retooling.

This paper uses Fischer and Kaysen (1962) model to estimate the household electricity demand. The household electrical appliances are named 'white goods'. The households demand electricity due to their demand for the services of the various stocks of the white goods. The stocks of the white goods are measured in terms of the total kilowatt hours that could be consumed if the appliances are employed at their normal rate, Fischer and Kaysen (1962). This entails knowing the kilowatts hour that could be normally consumed by each type of the white goods and then add up over the various white goods. The summation of the kilowatts hour consumption of the various White goods operated by household i gives us the stock of white goods operated by household i. Letting W_{it} to be the total appliance stock for household i at time t. Household i's demand for electricity will depend on the rates of use of the stock. This relationship is specified by Fischer and kaysen (1962) as follows:

$$q_{it} = u_{it} w_{it} \quad (1)$$

Where,

q_{it} = actual energy consumption of household i at time t,
u_{it} = rate of use of the white goods stocks by household I,

w_{it} = total stocks of the white goods and u_{it} is price of hypothesized to depend on per capita income, I_{it} and the the electricity, p_{it}.

Thus Equation (1) is written as,

$$q_{it} = p^{\alpha}_{it} I^{\beta}_{it} w_{it} \quad (2)$$

This is a functional form of electricity demand proposed by Fischer and Kaysen (1962). α and β are price and income elasticity of demand, respectively, that is, the demand for electricity depends on the price of electricity, the household income and the stocks of white goods. It is a multiplicative demand function that shows that $p_{it}^{\alpha} y_{it}^{\beta}$ is an index which when multiplied by the total stocks w_{it} determines the level of actual electricity consumed by household i. The model is specified for cross-sectional data estimation; while this paper attempts to estimate the electricity demand in the Gambia over time. Taking this into account and taking the natural log of the variables we get Equation 3,

$$\ln q_t = \alpha \ln p_t + \beta \ln I_t + \ln w_t \quad (3)$$

The stocks of white goods grow over time, and Fischer and Kaysen postulate that they grow at a constant rate of γ per cent per year. That is $\frac{w_t}{w_{t-1}} = ex(\gamma)$, or

$$\ln w_t - \ln w_{t-1} = \gamma$$

Thus, lagging Equation (3) by one period, we get Equation 4;

$$\ln q_{t-1} = \alpha \ln p_{t-1} + \beta \ln I_{t-1} + \ln w_{t-1} \quad (4)$$

and subtracting it from Equation (3), we get,

$$\ln q_t - \ln q_{t-1} = \ln w_t - \ln w_{t-1} + \alpha(\ln p_t - \ln p_{t-1}) + \beta(\ln I_t - \ln I_{t-1})$$

or,

$$\ln q_t - \ln q_{t-1} = \gamma + \alpha(\ln p_t - \ln p_{t-1}) + \beta(\ln I_t - \ln I_{t-1})$$

or

$$\ln q_t = \gamma + \ln p_t + \ln I_t + \upsilon_t \quad (5)$$

Equation (5) is a first difference operator, and assuming υ_t is independently and identically distributed with mean zero and variance 1, the equation can be estimated using OLS. The price of electricity poses a measurement challenge. Price is often offered as price blocks to the consumers; no one price exists. The blocks are also fairly constant over time causing the price variable to be a constant, which can be confused with the intercept term of the equation. The study uses time series econometrics, the observations span over a long period; thus, prices changes are frequently observed. It also uses the average tariff, $\bar{P}$ for the sectors in the economy to replace p in the above equation.

Equation (6) can be estimated using OLS. It is a first difference operator that gives the short run multipliers of the household demand for electricity. Upholding the assumption on the price setting relation; then the actual electricity consumption q depends on the unit average cost and the per capita income y. in the long run, q is

$$\ln q = A_0 + A_1 \ln \bar{p}_t + A_2 \ln I_t + \upsilon_t \quad (6)$$

Using the Koyck approach of estimating a long run equation model and assuming that the adjustment process towards the equilibrium follows this form, $(\ln q_t - \ln q_{t-1}) = b(\ln y - \ln I_{t-1})$, where b is the adjustment coefficient; then both the short run and long run multipliers can be estimated and derived respectively as follows:

$$\ln q_t = bA_0 + (1 - b)\ln q_{t-1} + b\bar{A_1} \ln p_t + bA_2 \ln y_t + \varepsilon_t \quad (7)$$

or,

$$\ln q_t = \beta_0 + \beta_1 \ln q_{t-1} + \bar{\beta}_2 \ln p_t + \beta_3 \ln I_t + \varepsilon_t$$

Where $\beta_0 = BA_0$; $\beta_1 = (1-b)$; $\beta_2 = bA_1$; $\beta_3 = bA_2$

A's are the long run multipliers and bA's are the short run multipliers. As are derived after the estimation of Equation (7).

Learning and cost functions

Learning curve expresses the relationship between the unit average costs and the cumulative output. If a company innovates, and its workforce accumulates experiences, the output will expand more than before at the same given cost. The cumulative output, which captures advances in knowledge, technology and experiences, will have negative relationship with the unit average cost. This is specified, Berndt (1991), as follows:

$$\ln c_{it} = \ln c_1 + \alpha \ln n_{it} + u_{it} \quad (8)$$

Where u_t is assumed to be independently and identically distributed with mean zero and variance 1. c_{it} is the unit average cost for Company I, which is NAWEC in this case, t is time series observations, and c_1 is the initial unit average cost and n_{it} is the cumulative output up to but not including time t.

Assuming the production of electricity follows a Cobb-Douglas function, following Berndt (1991), the study derives the unit average cost function that contains information on advances in technology, economies of scale and returns to scale as follows:

i. National Water and Electricity Company (NAWEC) employs only two inputs, labor and capital, which are denoted here as X_1 and X_2 respectively. Labor inputs consist of all human resources that go into producing and facilitating the production of electricity. Capital inputs consist of all non-human resources that go into the production of electricity output.

ii. Y is the electricity output, which is produced using the technology A^{α} for combining X_1 and X_2. α is the technology elasticity of output.

iii. The production function is,

$$Y_t = A^{\alpha} X_{1t}^{\alpha_1} X_{2t}^{\alpha_2} \quad (9)$$

where; α_1 and α_2 are input elasticity of output, and $\alpha_1 + \alpha_2 = r$ indicates the returns to scale. For NAWEC to have economies of scale, it should have increasing returns to scale, $r > 1$.

iv. The input prices are P_1 and P_2 for X_1 and X_2 respectively; then budget constraint of NAWEC with C as the total budget is,

$$C_t = P_1 X_{1t} + P_2 X_{2t} \quad (10)$$

The problem of NAWEC is to maximize Equation (9) subject to Equation (10). That is,

$$Max \quad Y_t = A^{\alpha} X_{1t}^{\alpha_1} X_{2t}^{\alpha_2}$$

Subject to:

$$C_t = P_1 X_{1t} + P_2 X_{2t}$$

Suppressing time subscripts for simplicity, the problem is reduced to maximizing a Langrage function of;

$$Max \quad L(X_1, X_2, \lambda) = A^{\alpha} X_1^{\alpha_1} X_2^{\alpha_2} - \lambda[P_1 X_1 + P_2 X_2 - C]$$

Assuming the solution is unique, the first conditions are,

$$L_{x1} = \alpha_1 A^{\alpha} X_1^{\alpha_1 - 1} X_2^{\alpha_2} - \lambda P_1 = 0 \quad (11)$$

$$L_{x2} = \alpha_2 A^{\alpha} X_1^{\alpha_1} X_2^{\alpha_2 - 1} - \lambda P_2 = 0 \quad (12)$$

$$L_{\lambda} = P_1 X_1 + P_2 X_2 - C = 0 \quad (13)$$

Dividing Equation (11) by Equation (12), the study obtains,

$$\frac{\alpha_1}{\alpha_2} \cdot \frac{X_2}{X_1} = \frac{P_1}{P_2} \quad (14)$$

or

$$X_1 = \frac{\alpha_1}{\alpha_2} \cdot \frac{P_2}{P_1} \cdot X_2$$

Substituting Equation (14) in the output function, Equation (9), the study obtains,

$$X_2^{r} = A^{-\alpha} \alpha_1^{-\alpha_1} \alpha_2^{\alpha_1} P_1^{-\alpha_1} P_2^{\alpha_1} Y$$

or $\quad (15)$

$$X_2 = A^{-\alpha/r} Y^{1/r} \alpha_1^{-\alpha_1/r} \alpha_2^{\alpha_1/r} P_1^{-\alpha_1/r} P_2^{\alpha_1/r}$$

Substituting the value for X_2 in equation (15) into equation (14), the study obtains the value for X_1,

$$X_1 = A^{-\alpha/r} Y^{1/r} \alpha_1^{\alpha_2/r} \alpha_2^{-\alpha_2/r} P_1^{-\alpha_2/r} P_2^{\alpha_2/r} \quad (16)$$

And substituting the values for X_2 and X_1 in Equations (15) and (16) respectively into the budget Equation (13), the study obtains the following cost function:

$$C = KA^{-\alpha/r} Y^{1/r} P_1^{\alpha_1/r} P_2^{\alpha_2/r} \quad (17)$$

Where; $K = \alpha_1^{-\alpha_2/r} \alpha_2^{\alpha/r} + \alpha_1^{-\alpha_1/r} \alpha_2^{\alpha_1/r}$

Taking the natural log of equation (17) and adding the error term u, then the cost function to be estimated using OSL is,

$$\ln C_t = \beta_0 + \beta_1 \ln A_t + \beta_2 \ln Y_t + \beta_3 \ln P_{1t} + \beta_4 \ln P_{2t} + u_t \quad (18)$$

Where, $\beta_0 = \ln K$, $\beta_1 = \alpha / r$, $\beta_2 = 1 / r$, $\beta_3 = \alpha_1 / r$, $\beta_4 = \alpha_2 / r$

lnK is the constant term, and A is the technology. Time variable can be used to proxy for the technology, or from the learning curve A is the cumulative output variable and thus n can replace A in Equation (18). But the appearance of input prices as regressors can complicate the estimation results. Output is a regressor in the cost function; cost functions are traditionally defined to be a function of output. To make the cost function as a function of only output variables, following Berndt (1991), who assumes that some price index is a function of the input prices. Here, the study assumes that the consumer price index is a function of the input prices; thus,

$$\ln CPI_t = \alpha_1 / r \ln P_{1t} + \alpha_2 / r \ln P_{2t}$$

So that real cost of the electricity $C_t^r = \frac{C_t}{CPI_t}$,and $\ln C_t^r = \ln C_t - \ln CPI_t$; thus, by substituting the values for lnC and lnCPI, the study obtains the real cost to be,

$$\ln C_t^r = \ln K + \alpha / r \ln A_t + 1/r \ln Y_t + \alpha_1 / r \ln P_{1t} + \alpha_2 / r \ln P_{2t} + u_t - \alpha_1 / r \ln P_{1t} - \alpha_{2t} / r \ln P_{2t}$$

The price variables will cancel out. The variable A which represents advances in knowledge and technology can be replaced with the variable n from the learning curve, where n represents the cumulative output and captures the learning, experiences and advances in technology. A and n are different measures of the same variable, and the study assumes that A = n; and the above real cost variable will look as below:

$$\ln C_t^r = \ln K + \alpha / r \ln n_t + 1/r \ln Y_t + u_t \quad (19)$$

From the total real cost equation (19), the real average cost of the electricity is derived as the total real cost divided by the output:

$c_t = \frac{C_t^r}{Y_t}$, and $\ln c_t = \ln C_t^r - \ln Y_t$, which means, from Equation (19) that the real average cost is,

$\ln c_t = \ln K + \alpha / r \ln n_t + (1 - r)/r \ln Y_t + u_t$, and OLS can be used to estimate this equation as,

$$\ln c_t = \ln K + A_1 \ln n_t + A_2 \ln Y_t + u_t \quad (20)$$

The study could not find data on total costs of electricity production, which are often mixed with that of the water and sewerage, since the same company provides the three services, and there are no clear separate cost accountings for each service. Since it is a regulated monopolist company, its price will be proportional to its average cost, specifically, $\overline{p_t} = \rho C_t$, Where, $\overline{p}$ is the average price for all the consumers at time t, and ρ is the constant of proportionality. Taking the natural log of this relation and solving for average cost, the study obtains $\ln C_t = \ln p_t - \ln \rho$, and by substituting in Equation (20), the study obtains the following model:

$$\ln \overline{p}_t = A_0 + A_1 \ln n_t + A_2 \ln Y_t + u_t$$

Where,

$$A_0 = \ln K + \ln \rho, \quad A_1 = \alpha / r, \quad A_2 = \frac{1 - r}{r}$$

If returns to scale are increasing, r will be greater than 1; if returns to scale are decreasing, r will be lower than 1, and if the returns to scale are constant, r will be 1 and A_2 will not be significantly different from zero. After estimating Equation (21), the returns to scale and economies of scale can be computed as follows:

Returns to scale, r, $r = \frac{1}{A_2 + 1}$, while the economies of scale, ES, $ES = \frac{-A_2}{A_2 + 1}$.

This completes the mathematical modeling of the cost of and the demand for the electricity. In the next section, the paper discusses the nature and the sources of data for the estimation of Equation (7), the demand function, and Equation (21), the supply function. These two functions form a 2 × 2 system of equations,

$$\ln q_t = \beta_0 + \beta_1 \ln q_{t-1} + \beta_2 \overline{\ln} p_t + \beta_3 \ln I_t + \varepsilon_t \quad (7)$$

Quantity demanded of electricity = f (last period quantity demanded, price, income)

$$\ln \overline{p}_t = A_0 + A_1 \ln n_t + A_2 \ln Y_t + u_t \quad (21)$$

Price of electricity = f (cumulative output, current output). Spanos (1990) states that “the identification and simultaneity problems associated with supply-demand model arises because available data refer to quantities transacted and corresponding prices over time". But in Equation (21) y is not the quantity transacted, the quantity transacted is q, which is actually produced and purchased. Whereas y is the total output produced that includes the quantity purchased and the unmetered output loss including own consumption. Thus, to treat the identification and simultaneity problems in the model, Equation (21)’s current output, y, is replaced with q, the actual transacted quantity plus the unmetered production. This modifies Equation (21) as:

$$\ln \overline{p}_t = A_0 + A_1 \ln n_t + A_2 \ln(q_t + um_t) + u_t \quad (21)$$

The reduced forms that result after solving Equations (21) and (7) together for p and q values are estimated and examined for the identification of the structural parameters. Then, it employs the VEC method to complement the reduced form method (Spanos, 1990).

Data

There are four variables in this paper on which annual time series data are collected from 1982 to 2007. These are consumer price index which is used to find real per capita income of GDP. Real per capita GDP is used as a proxy for the income variable in the electricity demand function. The study also collects data on the actual total consumption of electricity (electricity consumption by households, government and firms). NAWEC often has three main sale prices, residential price, business price and hotel price; the study averaged these prices to find the mean price, $\overline{p}$. The data are sourced from IMF country statistical appendices of the Gambia and the annual reports 1983/1984 and 1984/1985 of the Gambia Utilities Corporation.

RESULTS AND ANALYSES

Table 1 presents the estimation output of the reduced form for the quantity demanded, and the Table 2 presents that of the price variable. The reduced form estimates, which are derived as the result of simultaneous solution of the Equations (21) and (7), do not fit the underlying data

Table 1. Reduced form estimates for the dependent variable: LQ.

Variable	Coefficient	Std. Error	t-Statistic	Probability
C	3.862744	1.387471	2.784018	0.0115
LQ(-1)	0.327832	0.222825	1.471251	0.1568
LI	0.141164	0.191739	0.736229	0.4701
LN	0.099893	0.149004	0.670403	0.5103
LUM	0.105535	0.140839	0.749333	0.4624
R^2	0.907548	Mean dependent var		11.02614
Adjusted R^2	0.889058	S.D. dependent var		0.401828
Log likelihood	17.59339	F-statistic		49.08215
Durbin-Watson stat	1.822412	Prob(F-statistic)		0.000000
White Hetero Test nR	12.31812	Probability		0.137564
Ramsey RESET Test	2.052448	Probability		0.168210
BG Serial correlation LM test nR	1.511511	Probability		0.679616

Table 2. Reduced form estimates for the dependent variable: LP.

Variable	Coefficient	Std. error	t-statistic	Prob.
C	-4.537343	2.917809	-1.555051	0.1356
LQ(-1)	-0.833779	0.468594	-1.779320	0.0904
LI	1.299208	0.403222	3.222070	0.0043
LN	0.095276	0.313352	0.304054	0.7642
LUM	0.246855	0.296180	0.833465	0.4144
R^2	0.909725	Mean dependent var		0.628190
Adjusted R^2	0.891670	S.D. dependent var		0.855160
Log likelihood	-0.990371	F-statistic		50.38613
Durbin-Watson stat	1.249079	Prob (F-statistic)		0.000000
Ramsey RESET Test	0.433817	Probability		0.518025
White Hetero Test nR	9.767581	Probability		0.281719
BG Serial correlation LM test nR	5.509260	Probability		0.138086

on the electricity demand and supply in the Gambia. The coefficients are mostly insignificant, though there appear no serial correlation or heteroscdastcity problems to render the t-ratios unreliable. The structural slope coefficient parameters are over identified, whereas the structural constant parameters cannot be identified. Three explanations can be given for the results of the two tables. The explanatory variables have been found to be highly correlated; the correlation coefficients exceed 90% between the variables. No variable can be dropped as explained in earlier, the explanatory variables have been theoretically introduced, and hence they are relevant for the model, and limited data constraint as often is the case in the developing countries could not allow us to expand the observations. Another explanation lies in the presence of the lagged quantity demanded variable as an explanatory variable, which came about as a result of electricity demand modeling following Fischer and Kaysen (1962) leading to the fact that not all the explanatory variables in the reduced forms are exogenous, which violate the assumptions of reduced form regressions. Finally, the reduced form regressions in Tables 2 and 3 uses the level of variables in the estimation, it can be seen in Table 1 that the variables of the model are mostly first difference stationary; thus, the relationships estimated in the reduced form regressions are spurious.

The latter two explanations cannot be avoided when estimating demand and supply functions with the learning effects, and they have rendered the reduced form estimation unreliable. Thus, a system of simultaneous equations can be easily reduced to some regression equations and then estimated and solved for the structural parameters, when actually some exogenous variables are theoretically irrelevant for some endogenous variables, such as the case in this paper. The cumulative production is irrelevant for the electricity demand; likewise, the income does not have to appear in the estimation of the supply

Table 3. Error correction results for demand and cost functions of electricity.

Cointegration restrictions:					
B(1, 1)=1, B(2, 2)=1,B(1, 5)=0, B(2, 1)=B(2, 5) B(1, 4)=0,					
B(2, 3)=0, A(5, 1)=0, A(4, 1)=0, A(3, 1)=0					
Restrictions identify all cointegrating vectors					
LR test for binding restrictions (rank = 2):					
Chi^2 (5)	14.58877				
Probability	0.012272				
Standard errors in ( ) and t- statistics in [ ]					
Cointegrating Eq:	**CointEq1**	**CointEq2**			
LQ(-1)	1.000000	11.33709			
		(0.96434)			
		[11.7564]			
LP(-1)	32.14728	1.000000			
	(5.13545)				
	[6.25987]				
LI(-1)	-39.58564	0.000000			
	(6.61161)				
	[-5.98729]				
LN(-1)	0.000000	-17.13213			
		(1.36419)			
		[-12.5585]			
LUM(-1)	0.000000	11.33709			
		(0.96434)			
		[11.7564]			
C	287.3139	-3.509722			
	(51.3582)	(5.75811)			
	[5.59432]	[-0.60953]			
Error correction:	**D(LQ)**	**D(LP)**	**D(LI)**	**D(LN)**	**D(LUM)**
CointEq1	0.008025	-0.028386	0.000000	0.000000	0.000000
	(0.00417)	(0.00533)	(0.00000)	(0.00000)	(0.00000)
	[1.92520]	[-5.32876]	[NA]	[NA]	[NA]
CointEq2	-0.010411	-0.042057	-0.023631	0.020827	-0.033762
	(0.01685)	(0.02163)	(0.00922)	(0.00216)	(0.02245)
	[-0.61780]	[-1.94418]	[-2.56215]	[9.62399]	[-1.50370]

function of the electricity, the reduced form regressions ignore these facts. To remedy this situation, the study introduces VAR for the model and then incorporate the restrictions that in the demand estimation cumulative output and the unmetered output are irrelevant, and in the estimation of the supply function the income variable does have to appear, and further restricting that the co-\efficient estimate of quantity variable and that of the unmetered output are equal in the supply function, which comes about as a result of replacing the total production, y, with actual quantity purchased, q, plus the unmetered out-\put, um. The model is expected to produce two co-integrating equations, one to be identified as the demand function and the other to be identified as the cost function of the electricity. The following restrictions are imposed to identify these equations:

1. In the co-integration equation for the demand function, the co-integrating vectors are normalized by the co-integrating coefficient of the quantity purchased; the per

capita GDP is treated an exogenous variable, while the cumulative electricity output and the unmetered electricity output are treated irrelevant.

2. To identify the second co-integrating equation as the cost function of the electricity, the co-integrating vectors are normalized by the coefficient of the average price; the per capita GDP is treated irrelevant, and coefficient of the quantity purchased is equated to the coefficient of the unmetered output to fit the Equation (21) modeling.

These restrictions produce two co-integrating equations, on with no trend and intercept and the other has intercept but not trend. The restrictions in the model with no trend and no intercept are rejected at 1% significance level, its estimation output are reported in Annex Table 1. The restrictions of the model with intercept and no trend cannot be rejected at 5% significance level. Thus, the study reproduces in Table 3 the estimation results of this model:

Demand function

$$\ln \hat{q}_t = -287.314 - 32.45 \ln \bar{p}_t + 39.59 \ln I_t \quad (7)$$

Cost function:

$$\ln \hat{p}_t = 3.51 + 17.132 \ln n_t - 11.337 \ln q_t - 11.337 lum_t \quad (21)$$

Or

$$\ln \hat{p}_t = 3.51 + 17.132 \ln n_t - 11.337 \ln y_t \quad (21)$$

As the results in Table 3 illustrate, the electricity demand is price inelastic and income elastic. A 1% increase in the electricity price leads, holding other things constant, on average, to a 32.45% fall in the quantity demanded of electricity; whereas, a 1% increase in the income, holding other things constant, on average, leads to 39.59% increase in the quantity demanded of electricity. Thus, the electricity demand in the Gambia is price elastic; the revenue will fall if the average price increases. It is income elastic and it is a luxury for the average Gambian. The total electricity demand will be expansive and profit generating as long as the percentage price increase is less than 1.3 times of the per capita GDP growth rate. With a projected per capita GDP growth of 5% next year, the electricity company can increase its average electricity price by 6.5% and a positive increase in the revenue. The company should be however able to satisfy the expansion of demand. It should be able to expand its supply, innovate and consequently reduce its average unit cost. The income growth is a major constraint on profitable price increase; the projected maximum price increase of 6.5% cannot land the company in profit if it continues to lose more than 30% of its production to inefficiency. This inefficiency is clearly captured by the estimated supply function. The estimated factor of returns to scale, r, is 0.097, which also gives a factor of economies of scale of minus 1.097.

Thus, the company's operation exhibits decreasing returns to scale and diseconomies of scale. This implies that over this period of study, on average, the company has not innovated and learnt from experience; it has not be able to accumulate any useful knowledge to enable it to expand output over time and nationwide; the little that has been expanded has been at corresponding increasing average costs, as the coefficient of the cumulative output clearly illustrates. Charging increasingly high electricity prices to recover the inefficient average costs cannot be sustained as percentage price increase exceeding 1.3 times of the per capita GDP growth rate will result in shrinking electricity demand. In fact, the current estimated demand function shows that the company's operation is the price elastic region, where price increases can only reduce the revenue; it can only increase now by charging lower electricity prices. The company should re-structure its operations and modernize its systems to minimize the unmetered production, which currently stands at 44% of its total production.

CONCLUSIONS AND POLICY RECOMMENDATIONS

This paper has found out that systems of simultaneous equations cannot be simply solved into reduced form regressions for estimation purposes; the theoretical modeling should define the statistical modeling. The vector error correction method incorporating the theoretical restrictions has better fit the data than the reduced form regressions. The study finds the electricity demand to price elastic and income elastic. The paper finds that for the electricity demand not to shrink, the company should not charge an average price higher than 1.3 times of the per capita GDP growth rate. The demand is elastic, which implies that company cannot increase its revenue by further increasing the electricity price; only reducing the price can result in increased revenue. These are constraints on the demand side, but the major constraint of the electricity industry lies on the production side, which is found to exhibit diseconomies of scale. Due to this inefficiency in the electricity production, the output expansion can be done only with increasing average costs and hence prices. Policy makers should take drastic actions to re-structure and re-engineer the company to hold and reverse its inefficient operations, which is currently responsible for 44 % output wastage.

ACKNOWLEDGEMENT

The author thanks the anonymous reviewers for their valuable comments and suggestions.

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ANNEX

Table 1. Vector error correction results for demand and supply functions of electricity (no trend and no intercept).

Vector error correction estimates	
Standard errors in ( ) and t-statistics in [ ]	
Cointegration Restrictions:	
B(1, 1)=1, B(2, 2)=1, B(1, 4)=0, B(1, 5)=0	
B(2, 3)=0, A(3, 1)=0, A(4, 1)=0, A(5, 1)=0	
B(2, 1)=B(2, 5)	
Convergence achieved after 99 iterations.	
Restrictions identify all cointegrating vectors	
LR test for binding restrictions (rank = 2):	
Chi-square(5)	24.46296
Probability	0.000177

Cointegrating Eq:	**CointEq1**	**CointEq2**
LQ(-1)	1.000000	10.00814
		(0.83818)
		[11.9403]
LP(-1)	0.699347	1.000000
	(0.11059)	
	[6.32404]	
LI(-1)	-1.431111	0.000000
	(0.02124)	
	[-67.3872]	
LN(-1)	0.000000	-15.33292
		(1.27495)
		[-12.0263]
LUM(-1)	0.000000	10.00814
		(0.83818)
		[11.9403]

Error correction:	**D(LQ)**	**D(LP)**	**D(LI)**	**D(LN)**	**D(LUM)**
CointEq1	0.010803	-0.946103	0.000000	0.000000	0.000000
	(0.17042)	(0.23338)	(0.00000)	(0.00000)	(0.00000)
	[0.06339]	[-4.05396]	[NA]	[NA]	[NA]
CointEq2	-0.002504	-0.051409	-0.026054	0.023640	-0.032295
	(0.01967)	(0.02602)	(0.01045)	(0.00230)	(0.02571)
	[-0.12728]	[-1.97554]	[-2.49369]	[10.2610]	[-1.25629]