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Electricity Transmission Losses, Electricity Consumption, and Economic Growth in Ghana

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ABSTRACT: *An unsustainable power supply has dire consequences for every economy. Extant studies focused on the nexus of electricity consumption and economic growth to the neglect of electricity transmission losses (ETL). This paper argued that quantifying the effect of ETL on electricity consumption and understanding its implications on growth will incite actions to improve the electricity transmission system in Ghana. Using yearly data from 2000 to 2020 in an Autoregressive Distributed Lag (ARDL) model, the study concludes that ETL reduce the total amount of electric power consumed in Ghana by 34%. Again, a reduction in electricity consumption due to ETL reduces national income and Ghana's growth at large. Factors including electricity price, exchange rate, and inflation also influenced electricity consumption and economic growth in Ghana. The study suggests massive improvement in its electricity transmission system to reduce electricity losses, increase electricity consumption, and enhance economic growth.*

KEYWORDS: Electricity transmission losses, electricity consumption, growth, Ghana

INTRODUCTION

The importance of electricity consumption to economic growth can never be understated. It follows that changes in the consumption of electricity influences changes in the growth of an economy. An increase in electricity demand may be determined by factors such as industrialization, increased urbanization, and improved standard of living which are signs of economic growth (Osman et al., 2016). Environmental economists suggest that the positive effect of electricity utilization on economic growth is due to two main reasons. First, electricity is a factor that can substitute other productive factors in the production process (Zachariadis, 2007). Second, electricity complements other inputs which facilitate advancement in technology and increases the productivity of both labor and machines (Bhattacharyya, 2011).

The emphasis on electricity consumption as a driver of economic growth stems from the numerous benefits a country derives from the use of electricity. According to Torero (2015), electricity provides income-generating opportunities for individuals especially those in remote areas. Apart from farming which is their main occupation, the use of electricity allows them to engage in other economic activities such as barbering and sale of soft drinks among others. Electricity use also increases their working hours as they can work both day and night which increases their productivity. In the end, individuals benefit from income from farm and non-farm economic activities which improves their well-being (Torero, 2015). For the health and educational sectors, electricity consumption enhances the delivery of services as technological and sophisticated equipment like computers can be used (Blimpo, 2019). Electricity use allows certain medical operations to be conducted and improves ventilation at medical centers which are important for quality health care. The use of computers and projectors made possible by electricity enhances teaching and learning in schools which is effective for the transfer of knowledge. It is through these channels that electricity consumption work to affect economic growth.

Most developing countries are unable to fully benefit from electric power because of inadequate infrastructure in their energy sector. The reason is that shortages in electricity infrastructure lead to persistent fluctuations and outages in the supply of electric power which delimits its use. In addition, shortages in electricity supply represent huge losses to local firms. Mensah (2016) noted that outage-induced losses of firms as a percentage of their annual sales could be as high as 23%. Industries had to look for alternative sources of power to sustain their production which leads to a considerable increase in their cost of production. Firms operating under exorbitant cost due to infrastructure constraints is certainly unfavorable as they become uncompetitive in the international markets (Abdisa, 2019).

Electric power from the national grid is the main source for the majority of economic activities in Ghana. This implies that other measures such as self-generation adopted to mitigate the effects of outages do not help much. It rather added to total production cost as they incurred huge adjustments costs to acquire and operate a generator. Mensah (2016) noted that these adjustment costs due to self-generation reduced the productivity of firms and plunged them further into the path of collapse. Cissokho (2015) noted that the exporting sector of an economy greatly suffers when there is an unsustainable power supply. The reason is that the fall in productivity due to a reduction in production hours and the inability to use certain productive machines makes it impossible to meet foreign demand and reduce their performance.

One factor that is less mentioned in the discussion of growth and electricity consumption is an electricity transmission and distribution losses popularly referred to as ETL. ETL reduces the final amount of electric power available for consumption. Specifically, an average of 438 Gwh of electric power was lost during the transmission of electricity from generation plants to consumers between the years 2000 to 2020 in Ghana (Energy Commission Report, 2020). The benefits that have been cited to accrue to an economy will be reduced if the amount of electric power available for final consumption is limited. Apart from a reduction in firm performance, the work of the health and educational sectors of an economy is hampered when there is a limited supply of electricity (Torero, 2015).

Ahmed and Azam (2016), Streimikiene and Kasperowicz (2016), and Mutascu (2016a, 2016b) are part of the growing literature dedicated to the electricity-growth nexus. The increasing focus of studies on the nexus of electricity consumption and growth has illicit the use of empirical methods and approaches that are similar as the same variables are mostly used in these estimations. A common feature of these studies is that they tend to focus solely on the influence of electricity consumption on economic growth and the direction of causality. Also, these studies have been criticized for the omission of important variables that might influence their conclusions (Sami, 2011). Again, bivariate analysis like that of Kraft and Kraft (1978) and Adom (2011) tend to produce feedback effects that might also affect results and conclusions. To avoid these issues, studies such as Sami (2011) used multivariate analysis to analyze cointegration and causality among electricity consumption, income, and other important variables like electricity transmission losses.

It is important to note that a huge chunk of generated electricity that could have been used for production is lost due to an inadequate transmission system in Ghana. Understanding electricity transmission losses, electricity consumption, and growth will help address power insecurity in Ghana by increasing the final volume of electricity for Ghanaians. The objective of this study is twofold. First, we quantified the effect of electricity transmission losses on electricity consumption in Ghana. Second, we analyzed how electricity transmission losses and electricity consumption work together to affect the country's growth.

Theoretical Framework

Until the oil price shocks of the 1970s, the role of energy was overlooked by traditional economists. They argued that the role of energy such as fossil fuel and electricity was captured in factor inputs such as land, labor, and capital. However, issues such as oil price shocks highlighted the need to capture the specific role of energy like electricity in an economy. The theoretical bedrock of this research is the theory of production. The traditional Cobb-Douglas production function is presented as;

$$Y = AK^{\alpha}L^{1-\alpha} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . [1]$$

where Y represents the economy's output, K as the stock of capital, L is the labor force, α is the factor share of capital, and A is technical progress. Electricity manifests within an economy mainly in two ways; first as a complementary factor to productive inputs and second as an input in itself that advances the production process and can replace other inputs (Bhattacharyya, 2011). This study limits its analysis to the role of electricity as a complementary input to labor and capital.
Equation 1 is modified as;

$$Y = A(KE)^{\alpha}(LE)^{1-\alpha} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. [2]$$

where E captures electricity as a complementary factor to labor and capital for the production of output. It must be noted that α is less than one. The modification of equation 1 into 2 stems from the idea of returns to scale. It seeks to ask how the output will change if the economy complements labor and capital with electricity. A log transformation of equation 2 gives;

$$lnY = lnA + \alpha(lnK) + (1-\alpha)lnL + (\alpha + 1 - \alpha)lnE \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. [3]$$
$$lnY = lnA + \alpha(lnK) + (1-\alpha)lnL + (1)lnE \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. [4]$$

Compared to labor and capital, the effect of electricity on the economy's output is unit elastic. This means electricity has a bigger impact on output than labor and capital because it complements them in the production process. Torero (2015) noted that the availability of electricity expands the working hours of the economy as individuals can work both day and night. Electricity also allows the use of sophisticated productive equipment which increases productivity.

It follows that any factor such as electricity transmission losses that reduces electricity consumption negatively affects the economy's output, holding all other factors constant. The fall in electricity consumption particularly causes the utilization of capital and the electricity efficiency of capital to fall which translates into a fall in the economy's output and economic growth at large (Bhattacharyya, 2011). The reverse is also true. If improvement in the electricity transmission system increases the consumption of electricity, the output will rise as utilization and efficiency of capital improves.

Empirical review

After the influential paper by Kraft and Kraft (1978) on the positive effect of electricity consumption on economic growth in the US, several studies have confirmed this finding in many jurisdictions (Aytac and Guran, 2011; Yoo, 2006; and Wolde-Rufael, 2004). A group of studies has also focused on electricity consumption and other indicators. Sami (2011) for example investigated the relationship between electricity consumption, exports, and national income per capita in Japan. The final group of empirical studies mostly on Ghana, have focused on different aspects of electricity supply and demand as well as the myriad of issues that comes with it

.

For instance, Ackah et al. (2014) explored the exogenous and endogenous factors of electricity demand and found increases in the level of education of consumers to reduce their electricity consumption because such consumers are energy efficient. Sarkodie (2017) forecast the consumption of electricity in Ghana by the year 2030 and revealed the country's consumption will grow from 8.52 billion kWh in 2012 to 9.56 billion kWh by the year 2030. While Kumi (2017) reviewed the electricity situation in Ghana, Kemausuor and Ackom (2017) revealed that the disparity between rural and urban access to electricity, inadequate electricity supply, and the low generation capacity are some of the shortfalls obstructing Ghana's goal of universal electrification. Kwakwa (2018) found education, electricity price, income, and population to be some of the factors that determine electricity power losses in Ghana. Yakubu et al. (2018) also examined the influence of electricity theft on the income generation capacity of utility companies in Ghana. Twerefou and Abeney (2020) investigated the efficiency of electricity consumption for households in Ghana and found low educational levels of some consumers and power outages to reduce efficiency. This finding confirmed the conclusion of Ackah et al. (2014) and Kwakwa (2018) who found that high levels of education improve the efficiency of electricity use. Other factors such as appliance use, location, load, and regional zones were found to influence electricity demand in Ghana. Most recently, Abeberese et al. (2021) examined how Ghanaian firms respond to electricity outages and how it influence their productivity. Their paper concluded that changing the production mix to less electricity intensive ones can help firms to mitigate the effects of electricity outages.

The review of empirical literature shows no work has analyzed the specific effect of ETL on the consumption of electricity and how they combine to affect economic growth in Ghana. The huge amount of electricity transmission losses that occur as a result of inadequate electricity infrastructure have the potential to partly account for the inefficiencies experienced in the supply of electricity and its attendant effects on the Ghanaian economy. This study extends the discussion on the electricity-growth nexus by examining how ETL affects the consumption of electric power and how their interplay influences economic growth in Ghana.

METHODOLOGY

Model Specification

The motive of this research is to find out how losses from the transmission of electricity have affected the total consumption of electricity in Ghana for the past 20 years. Against that background, the study expresses the total consumption of electricity as a function of electricity transmission losses plus other relevant determinants like electricity price, national income, inflation, and official exchange rate. The functional form of the model is given as;

$$EC_t = f(ETL_t, EP_t, GDP_t, ER_t INF_t) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots [5]$$

The econometric form of equation 5 can be written as;

$$lnEC_t = \beta_0 + \beta_1 ETL_t + \beta_2 EP_t + \beta_3 lnGDP_t + \beta_4 ER_t + \beta_5 lnINF_t + \mu_t \ldots \ldots \ldots [6]$$

where EC_t is defined as electricity consumption for each year, ETL_t as electricity transmission losses, EP_t as electricity price, GDP_t as a gross domestic product, ER_t as the official exchange rate

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and INF_t as the level of inflation. β_0 is the intercept, μ_t as the stochastic error term and β_1 to β_5 as coefficients of the independent variables.
The importance of electricity consumption to economic growth suggests that negative influences from electricity transmission losses on electricity consumption will have a detrimental effect on economic growth. The second target of this study is to examine the combined effect of electricity transmission losses and electricity consumption on economic growth in Ghana. This second aim is specified as;

$$lnGDP_t = \gamma_0 + \gamma_1 ln(ETL_t * EC_t) + \gamma_2 EP_t + \gamma_3 ER_t + \gamma_4 lnINF_t + w_t \ldots\ldots [7]$$

where γ_1 is the elasticity of national income to changes in the interactive variable of electricity transmission losses and the consumption of electricity. w_t is the error term whiles all other variables remained as before.

Type and sources of data plus variable description
The National Energy Statistics of Ghana Energy Commission and the World Bank Development Indicators (WDI, 2020) are the main sources of data for this study. Variables such as electricity consumption, electricity transmission losses, and electricity prices were acquired from the National Energy Statistics (2000-2020) whereas gross domestic product (GDP), official exchange rate, and inflation were obtained from WDI (2020). In all, the study employed yearly data spanning from 2000 to 2020 to find out the exact influence of electricity transmission losses on the consumption of electricity in Ghana and their combined effect on growth. The variables used in the study are described as follows.

Electricity consumption is defined as the total amount of electricity used by an economy for its various economic activities. This includes electricity used by the industrial, transport, residential, and agricultural sectors of Ghana. Electricity consumption is measured as total electricity used in gigawatt per hour (GWh). Electricity consumption is important for the growth of every economy as it enhances productive economic activities and improves economic efficiency (Kraft and Kraft, 1978).

Electricity transmission losses clearly explain the total amount of electricity that is lost as electric power is transmitted from power plants to consumers, especially over long distances. According to the United States, Energy Information Administration (EIA, 2020), electricity transmission losses amounted to 5 percent of total transmitted electricity from 2015 to 2019. In Ghana, 438 Gwh of electric power were lost due to transmission and distribution from 200 to 2020.

Electricity price is precisely explained as the price end users pay for using electricity and this is highly subsidized in Ghana. Consumers normally pay the price of electricity in the form of tariffs based on a particular type of pricing policy. It can be a uniform system of pricing or a peak pricing

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system where consumers pay based on their level of demand. Electricity prices recorded by the Energy Commission of Ghana for various years as GHS per kilowatts hour (GHS\Kwh) were used for this analysis.

Gross domestic product (GDP) is the monetary value of final goods and services produced in a country at a given time frame usually a year (Sloman & Wride, 2009). It is synonymous with the total income spent on all final goods and services in the country; in the absence of any leakages and injections, the total income must equal the total value of output produced. The study measured national income as the local currency value of the total amount of goods and services as given in the WDI (2020) datasets.

The exchange rate in this study is defined as the price of Ghana's currency (cedi) in terms of another currency like the US dollar. Increases in it represent depreciation whiles a fall in it means an increase in the value of the home currency. The exchange rate was measured by the real effective exchange rate in Ghana over the study period.

Inflation specifically refers to a sustained rise in the overall price level in an economy for a given time (Mishkin, 2008). It is also described as a period of sustained increases in the general price level in an economy which may emanate either from the demand or supply side mainly witnessed during the boom stage of the business cycle. The study measured inflation by the growth in consumer prices reported by the World Bank Development Indicators (WDI, 2019).

Table 1: Summary of variables and their expected signs

Variable	Explanation	Expected Sign
Electricity transmission losses	Amount of electricity lost through transmission	Negative (-)
Electricity price	Price consumers' pay for electricity	Negative (-)
National Income	Total income for the country	Positive (+)
Rate of exchange	Price of the cedi in terms of another currency	Positive (+)
Inflation	The persistent rise in the general price level	Negative (-)

Source: Author's Construction

ECETL is the interacted variable of electricity consumption (EC) and electricity transmission losses (ETL) which captures the combined effect of the two variables on economic growth. This variable will enable an examination of how the interplay of EC and ETL impact national income and by extension economic growth in Ghana. Electricity transmission losses shrink the volume of electric power consumed which consequently impacts negatively on economic growth. The study, therefore, expects the combined effect of EC and ETL to have a negative effect on national income. Mathematically, ECETL is derived as;

$$ECETL_t = f(EC_t, ETL_t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [8]$$

$$ECETL_t = \sum_{t=1}^{n}(EC_t)(ETL_t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [9]$$

where n is the total number of study periods and *t* is the period being considered. All variables are as already defined.

Estimation strategy

The need for valid estimates for time-series data requires that the series be stationary. ARDL model requires that the series be integrated into orders one and zero. Stationarity tests are performed to ensure the series satisfies the stationarity conditions for an ARDL estimation. The Bounds test of cointegration is then performed to check if a long-run relationship exists among the variables. Confirmation of a long-run relationship among the variables will pave way for the estimation of an Error Correction (EC) model. Otherwise, the simple ARDL model will be estimated.

Stationarity tests

The testing of the stationarity properties had become necessary when using time series data. Most macroeconomic variables are trends and thus there is the possibility of estimating a wrong model when a correct model is not specified using the information on the order of integration. Because this is very important in econometric model specification, the study performs two different tests of stationarity; the Augmented Dickey-Fuller and the Philip-Perron tests for unit root tests.

The ADF test may be expressed by the following equation:

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \alpha_3 Y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots [10]$$

where Y_t is the time series variable, t is the time/trend variable, α_1 and α_2 are the estimated parameters, Δ is the first difference operator, β_i is the various estimated parameters of the differenced values of the lagged variables and ε_t is the white noise error term. Based on equation 10, the hypothesis that there exists a unit root or the time series is non-stationary; $\alpha_3 = 0$, is tested. If the null hypothesis is rejected, then the series is stationary. The series is non-stationary and as such possesses unit root if we fail to reject the null hypothesis. Philips and Perron (1988) developed a more robust test for stationarity in time series which makes a non-parametric correction to test statistics by correcting for autocorrelation and heteroscedasticity in the error terms. The test can provide mechanisms to deal with deviations for having white noise in the estimated regression. The PP test regression is specified as;

$$\Delta Y_{t-1} = \alpha_0 + \beta Y_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [11]$$

Based on equation 11, we test the null hypothesis that $\beta = 0$, which proves the existence of unit root against the alternative hypothesis of the non-existence of unit root. If we do not reject the null hypothesis, then, the series is non - stationary and as such possesses a unit root. If, however, the null hypothesis is rejected, then the series is stationary.

Bounds test of cointegration

A long-run association among the variables is a requirement for the estimation of an error correction model. The ARDL Bounds test for co-integration was conducted to verify if a long-run relationship exists among the variables. The hypothesis for the Bounds test of cointegration is given as;

$$H_O : \beta_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 \dots\dots\dots [12]$$

$$H_1 : \beta_0 \neq \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \dots\dots\dots [13]$$

The null hypothesis of no co-integration is rejected if the F-statistics exceed the lower bound critical values at a 5% significance level. In that case, a long-run relationship is said to exist among the variables.

Estimation of long-run coefficients and the Error Correction model

Confirmation of a long-run relationship among the series leads to an estimation of coefficients for the long run using ARDL $(p, q_1, q_2, q_3, q_4, q_5)$ as:

$$\ln EC_t = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \ln EC_{t-i} + \sum_{i=0}^{q_1} \alpha_2 \ln \mathrm{ETL}_{t-i} + \sum_{i=0}^{q_2} \alpha_3 \ln \mathrm{EP}_{t-i} + \sum_{i=0}^{q_3} \alpha_4 \ln \mathrm{GDP}_{t-i} + \sum_{i=0}^{q_4} \alpha_5 \ln \mathrm{ER}_{t-i} + \sum_{i=0}^{q_5} \alpha_6 \ln \mathrm{INFL}_{t-i} + v_t \dots\dots\dots [14]$$

where $p, q_1, q_2, q_3, q_4, q_5$ are the optimal lag selection criteria, v_t as the stochastic error term, α_1 to α_6 represents the long-run coefficients of electricity consumption, electricity transmission losses, electricity price, income, exchange rate, and inflation. All variables remained the same.

The short-run coefficient is also obtained by estimating the error correction version of ARDL. Once established, the speed of Adjustment to long-run equilibrium is determined. ECT_{t-1} is the first leg of the error correction term, the residual of the cointegration equation.

$$lnEC_t = \alpha_0 + \sum_{i=1}^{p} \emptyset_{1i} \, \Delta lnEC_{t-i} + \sum_{i=1}^{q_1} \emptyset_{2i} \, \Delta ln\mathrm{ETL}_{t-i} + \sum_{i=1}^{q_2} \emptyset_{3i} \, \Delta ln\mathrm{EP}_{t-i} + \sum_{i=1}^{q_3} \emptyset_{4i} \, \Delta ln\mathrm{GDP}_{t-i} + \sum_{i=1}^{q_4} \emptyset_{5i} \, \Delta lnER_{t-i} + \sum_{i=1}^{q_5} \emptyset_{6i} \, \Delta lnINFL_{t-i} + \delta ECT_{t-1} + e_t \dots\dots\dots [15]$$

where e_t is the stochastic error term. All other variables are as already defined.

Diagnostic tests

The study further conducts various diagnostics tests to ensure the estimates obtained by the model are consistent. This is because it's common to fit a skewed model which might bias the outcome of the study as research software like STATA is built for normally distributed models. The study hence employs various tests such as Cameron & Trivedi's decomposition of IM-test of Heteroskedasticity, skewness, and kurtosis to ensure the estimated ECM model is normally distributed.

Time series estimations are characterized by issues of autocorrelation where variations in the dependent variable are due more to its lags. This makes results biased and leads to inconsistent conclusions. The Breusch-Godfrey LM test for autocorrelation was therefore employed to ensure the model is free from autocorrelation.

RESULTS

Descriptive statistics of variables

Descriptive statistics reveal an understanding of the variables used in the study. Section 4.1 presents specific statistics such as the mean, standard deviation, maximum and minimum values of the variable. The statistics are presented in Table 2.

Table 2: Summary statistics of variables

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Electricity consumption (Gwh)	8855.179	2645.038	5187	13943	21
Electricity transmission losses (Gwh)	438.012	173.560	205	844	21
Electricity price	0.313	0.286	0.017	0.817	21
National Income (mill. GHS)	38.9	8.7	27.4	51.9	21
Rate of exchange (GHS/$)	2.071	1.446	0.545	4.587	21
Inflation (%)	15.41	6.312	7.126	32.91	21

Source: Based on data from WDI (2019) and National Energy Statistics of Ghana.

Table 2 shows electricity consumption over the study period averaged 8,855.179 Gwh with a standard deviation of 2645.03 Gwh. Overall, electricity consumption in Ghana ranged from the lowest of 5,187 Gwh to a peak of 13,943 Gwh from the year 2000 to 2020. The severity of electricity transmission losses is highlighted as 438.012 Gwh of electric power was lost on average for the same period. This implies consumers are deprived of 438.012 GWh worth of power which is awful for a country whose electricity demand trails its supply. Ghana's national income averaged 38.9 million GHS and a standard deviation of 8.7 million GHS which shows income has fairly been stable from 2000 to 2020. The exchange rate of Ghana over the study period also had an average of 2.07 while inflation had a mean of 15.4%. These statistics show that exchange rate and inflation have not been particularly the best. Ghana gives up more domestic currency units to get a unit of the dollar and the price level has also been high which signals a higher cost of living in the country, holding all other factors constant.

Effect of electricity transmission losses on electricity consumption in Ghana

It is generally known that electricity transmission losses reduce the final amount of electricity available for consumption but the exact amount of reduction is unknown. This study fills the gap by quantifying the exact difference in electricity consumption attributed to electricity transmission losses in Ghana. The log-log model also allows a description of the responsiveness of electricity consumption to changes in electricity transmission losses. In doing so, the results of pre-estimation tests of stationarity and cointegration are first presented.

Stationarity tests

The variables employed in the study must be stable to yield robust and consistent results. This section, therefore, presents the results and explanation of the stationarity test using the Augmented Dickey-fuller (ADF) and Philips-Perron (PP) tests for unit root.

Table 3: Results of Stationarity tests

Variable	ADF test		Philip-Perron Test		Order of Integration
	CONST	CONST + T	CONST	CONST + T	
Panel A: Levels					
EC	-0.576	-2.782	-0.523	-2.703	-
ETL	-1.662	-3.401	-1.529	-3.372	-
GDP	-0.594	-1.448	-0.610	-1.726	-
EP	-0.135	-1.798	-0.190	-1.862	-
RER	0.017	-1.460	-0.234	-1.673	-
INF	-3.211**	-3.415	-3.155**	-3.389	-
Panel B: First Difference					
Δ**EC**	-3.954***	-3.839***	-3.896***	-3.714***	I(1)
Δ **ETL**	-5.447***	-5.219***	-5.653***	-5.388 ***	I(1)
Δ**GDP**	-3.287***	-3.930**	-3.246***	-3.930***	I(1)
Δ**EP**	-3.870***	-3.783***	-3.881***	-3.793***	I(1)
Δ**ER**	-4.521***	-4.518***	-4.514***	-4.518***	I(1)
Δ**INF**	-8.338***	-8.940***	-7.948***	-8.671***	I(1)

Source: Based on data from WDI

According to Table 3, only inflation was stationary at the level while the rest of the variables required a first difference for them to be stationary. This is shown by both the ADF and the PP test for both constant and with trend. Stationarity of variables at order zero I(0) and order one I(1) meets the requirement for the estimation of an ARDL model but there is the need for a cointegration test to see if a long-run association exists among the variables.

Bounds test of Cointegration

It is a requirement to verify if a long-run association exists among the variables to determine whether the short-run ARDL model will be estimated or the error correction model. The reason is that the short-run ARDL is estimated if the series are not cointegrated. Otherwise, the error correction model is estimated. The results of the Bounds test of Cointegration are presented in Table 4.

Table 4: Results from Bounds test

Dependent variable	AIC lags	F-statistic	Decision
F_{EC} (EC\ETL, EP, GDP, ER, INFL)	2	10.365	Cointegration
Lower-bound critical value at 5%	2.62		
Upper-bound critical value at 5%	3.35		

Lower and Upper-bound critical values from Pesaran et al. (2001), Table CI (iii) Case III

The prime objective of the study is to find the effect of electricity transmission losses on electricity consumption in Ghana. The study, therefore, considered electricity consumption as its dependent variable in the ARDL-OLS regression. At a maximum lag order of 2, the results indicate that the series are cointegrated when electricity consumption is used as the dependent variable. This is because the F-statistic exceeds the 5 percent critical value at the upper bound and hence fails to reject the null hypothesis of a long-run association between the variables.

Table 5: Effect of electricity transmission losses on electricity consumption in Ghana

Electricity consumption (ln)	Short-run	Long run
Speed of Adjustment	-0.934***	-
	(0.186)	
Electricity transmission losses	-0.337**	-0.189
	(0.089)	(0.158)
Electricity Price (ln)	0.158	-0.208
	(0.148)	(0.182)
National Income (ln)	-1.703*	3.13**
	(0.746)	(1.100)
Real Exchange rate (ln)	0.298*	-0.100
	(0.141)	(0.340)
Inflation (ln)	-0.232**	0.302
	(0.096)	(0.187)
Constant	-15.55	
	(0.072)	

Source: Based on data from WDI, ***, ** & * represents 1%, 5% & 10% significance level

Table 5 confirms the long-run relationship among the variables as the speed of adjustment was negative, significant, and below one. The results show that losses due to electricity transmission have a negative effect on the total amount of electricity consumed in Ghana from 2000 to 2020. This finding is in line with the a-priori expectation and confirms the fact that these transmission losses deprive customers of some gigawatts of electric power that would have been employed in productive use. One percentage increase in electricity transmission losses reduces electricity consumption by 0.34 percent which is quite substantial and underscores why efforts must be made to reduce losses incurred during the transmission of electric power. It must be said that while electricity transmission losses reduce electricity consumption in both the long-run and short-run, it is only significant in the later period. This is explained by the fact that it is only the present demand and supply of electricity that is essential as electric power cannot be stored in large quantities (Bhattacharyya, 2011). It follows those losses from electricity transmission have an immediate impact on the total amount consumed. It can further be argued that infrastructure shortages from the past may increase transmission losses which will impact negatively on current electricity consumption.

National income influenced electricity consumption in both the short-run and the long-run. One percentage rise in national income reduces electricity consumption by 1.7 percent in the short run but raises it by 3.13 percent in the long run. Essentially, a lot of income increases committed to electrification projects crowd out other economic investments and activities which reduces the total amount of electricity consumed in the meantime. However, this infrastructure investment in electrification pays off in the future and ensures a constant and uninterrupted power supply which ultimately increases the amount of electricity consumed. In all, the result shows electricity consumption is sensitive to changes in national income which confirms findings such as that of Kraft and Kraft (1978) in the US as well as by Adom (2011) in Ghana.

Again, the results revealed that exchange rate and inflation only influenced electricity consumption in the short run. While a one percent increase in exchange rate raises electricity consumption by 0.298 percent, the same percentage change in inflation reduces it by 0.232 percent. The reason is that increase in the exchange rate signifies depreciation of the Ghanaian cedi which encourages domestic production for exports (Chiang, 2020). This ultimately increases the total consumption of electricity as the energy resource enters into the production function of almost every commodity. For inflation, increases in it reduce consumer's real income, reduces aggregate demand, and discourage production (Slowman and Wride, 2009). The contraction of the economy, therefore, reduces electricity consumption in the country as general economic activity reduces.

Combined effect of electricity transmission losses and electricity consumption on Ghana's economic growth

Objective two of the study analyzed how electricity consumption and electricity transmission losses play out to influence national income in Ghana. The ARDL result for model two is presented in Table 6.

Table 6: Combined effect of electricity transmission losses and electricity consumption on economic growth in Ghana.

National income (ln)	Short-run	Long run
Speed of Adjustment	-0.651**	-
	(0.275)	
ECETL (ln)	-0.0018	-0.014**
	(0.0032)	(0.0072)
Electricity Price (ln)	-0.132**	0.229*
	(0.0485)	(0.1158
Real Exchange rate (ln)	0.267***	-0.172
	(0.0716)	(0.2153)
Inflation (ln)	0.0475	-0.2459**
	(0.037)	(0.0685)
Constant	5.601**	
	(2.273)	

Source: Based on data from WDI, ***, ** & * represents 1%, 5% & 10% significance level

Table 6 also confirmed the long-run association between the series used for the study. This is evidenced by the fact that the speed of adjustment was once again negative, less than one, and significant. This implies that the variables are cointegrated.

The results indicate that ECETL which is the combined variable for electricity transmission losses and electricity consumption has a negative effect on national income in the long run. A percentage increase in ECETL leads to a 0.014 percent decline in national income, holding all other factors fixed. This supports the findings of Adams et al. (2020) who found a negative effect of electricity transmission losses on the economic growth of South Africa. The reduction in the consumption of electric power necessitated by losses from its transmission reduces national income in the future. It makes sense that the combined effect is not significant in the short run because the interplay of these two variables will take time for it to influence national income.

Electricity price had a short-run negative effect but a long-run positive effect on national income. A percentage increase in electricity price reduces income by 0.132 percent in the short-run but increases it by 0.229 percent in the long run. This implies immediately reacting to increases in electricity price by reducing the use of power which reduces income. However, since electricity is a necessity good, individuals eventually have to make use of it despite an increase in its price. It also shows that national income is less sensitive to changes in electricity piece as the correspondent change in it was less than one percent.

The real exchange rate influenced national income only in the short run. A percentage increase in the real exchange rate increases national income by 0.267 percent. The depreciation of the exchange rate encourages exports of goods and services which increases national income (Slowman and Wride, 2009). This effect is enhanced if the country can produce to meet its foreign demand.

Inflation also influenced national income only in the long run as a percentage rise in it reduces national income by 0.246 percent. This effect is expected because increases in inflation reduce the real income of consumers, discourage consumption, and reduce aggregate demand. This explains why monetary authorities in Ghana have price stability as their primary objective.

Results of Diagnostic tests

Results from post-ARDL estimation tests have been presented and explained. These diagnostic tests validate the results of the study and repose confidence in its conclusions and policy recommendations. These results are presented in Table 7.

Table 7: Results of Diagnostic tests

	Model 1			**Model 2**		
Equation	**Chi2**	**Df**	**Prob>chi2**	**Chi2**	**Df**	**Prob>chi2**
Heteroskedasticity	19.00	18	0.3918	19.00	18	0.3918
Autocorrelation	9.141	1	0.2305	0.478	1	0.4895
Skewness	13.55	13	0.4066	12.68	12	0.3928
Kurtosis	0.69	1	0.4054	2.35	1	0.1254

Note: Reject the null hypothesis if the P-value is greater than 0.05

Table 7 presents test results of heteroscedasticity, autocorrelation, skewness, and kurtosis for models 1 and 2. It shows that all the p-values are not significant which confirms the null of homoscedasticity and no serial autocorrelation cannot be rejected for both models. This means the series employed in the model are normally distributed and do not suffer from the econometric issues of autocorrelation and heteroscedasticity. Consequently, the findings of the study and its conclusions can be relied on for policy recommendations.

CONCLUSION

An unsustainable power supply has dire consequences for every economy, especially for firms that produce for exports and the country at large. Losses incurred during the transmission of power have become prominent, especially with Ghana's aging electricity infrastructure. Extant studies focused on the nexus of electricity consumption and economic growth to the neglect of electricity transmission losses. This paper argued that quantifying the effect of transmission losses on electricity consumption and understanding its implications on growth will prompt actions to improve the electricity transmission system in Ghana.

Yearly data spanning 2000 to 2020 was employed in an Autoregressive Distributed Lag (ARDL) model to achieve the goals of the study. The study concludes that electricity transmission losses reduce the total amount of electric power consumed in Ghana over the study period. It further concludes that a reduction in electricity consumption due to transmission losses reduces national income and Ghana's growth at large.

It is also concluded that electricity price affects national income negatively in the short run but positively in the long run. However, the study concludes that electricity price does not influence electricity consumption in Ghana as the energy resource has become price inelastic. While increases in exchange rate improved both electricity consumption and national income, the conclusion is that inflation reduces them both in Ghana. Another conclusion is that national income has a negative effect on electricity consumption in the short run but this effect turns positive in the long run.

The study suggests massive improvement in the electricity infrastructure of Ghana, especially in its electricity transmission system to reduce electricity losses and enhance electricity consumption. It is also recommended that government create a conducive environment for productive economic activities to flourish and improve electricity consumption. Finally, the research recommends improvements in the generation of electricity to increase the volume of electric power and reduce the price of electricity. This will go a long way to improve national income and economic growth in the long run.

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