

Abstract

This study investigates the causal relationship between electricity consumption and economic growth in Ghana from 1971 to 2007. Understanding this relationship is crucial for formulating effective energy conservation strategies and environmental policies. Existing literature on Ghana presents conflicting findings, highlighting the need for further research to clarify the energy-growth nexus. Given the limited empirical evidence available, this study aims to determine the direction of causality between electricity consumption and economic growth, contributing valuable insights to policy discussions. The study employs the Granger Causality test to analyze the causal linkage between electricity consumption and economic growth. The results reveal a unidirectional causality from economic growth to electricity consumption, supporting the Growth-led-Energy Hypothesis. This suggests that economic expansion drives electricity consumption rather than the reverse. The findings imply that Ghana can implement electricity conservation measures without adversely affecting economic growth. Since electricity consumption does not significantly influence economic output, policymakers can prioritize energy efficiency and sustainability initiatives. Implementing targeted conservation policies and investing in renewable energy sources will enhance energy security while maintaining economic stability. This study offers important policy recommendations, emphasizing the need for efficient energy management. Ghana should focus on sustainable energy strategies, ensuring adequate electricity supply while reducing wasteful consumption. By aligning energy policies with economic growth trends, the country can optimize energy use and enhance long-term development. Future research should explore sectoral energy demand patterns to refine energy policies further and ensure balanced growth across all industries.

Keywords: GDP per capita, Electricity consumption

JEL Codes: Q40

1. INTRODUCTION

Electricity stands as a critical infrastructural component crucial to propelling economic growth. Functioning as a versatile 'energy currency,' it serves as the linchpin supporting a diverse spectrum of products and services. Its impact extends far beyond mere illumination, encompassing various sectors that collectively contribute to an improved quality of life. By augmenting worker productivity and fostering entrepreneurial activity, electricity emerges as a catalyst for socio-economic development. In this intricate interplay, electricity consumption emerges as not only a necessity but also a driver of progress. The positive and robust correlation observed between electricity consumption and real per capita GDP underscores the symbiotic relationship, signifying that an increase in electricity usage is intricately linked with heightened economic prosperity. Recognizing electricity's multifaceted role in advancing societal well-being, it becomes evident that strategic investments and sustainable policies in electricity infrastructure can significantly contribute to comprehensive economic development. In the Ghanaian context, spanning the period from 2000 to 2007, the average annual growth of real per capita GDP stood at 5.5%, juxtaposed with an annual electricity consumption growth of 1.21%. Despite the observable positive correlation between real per capita GDP and electricity consumption, the precise direction of causality remains elusive. Further investigation is imperative to unravel the nuanced dynamics underlying the relationship between real per capita GDP and electricity consumption in this specific temporal context. Examining the nexus between electricity and economic growth holds profound significance for the formulation of effective electricity conservation measures. Nevertheless, the findings within the Ghanaian literature, as documented by Lee (2005) and Wolde-Rufael (2006), present a mosaic of outcomes. The variability in these results carries substantial implications for both Ghana's energy policy and environmental policy. The inconclusive nature of the literature underscores the necessity for a nuanced and context-specific approach to inform policies that address the intricate relationship between electricity and economic growth in Ghana. The imperative need for extensive research to ascertain the causal relationship between electricity consumption and economic growth is underscored. However, a conspicuous gap exists in the current body of research pertaining to the electricity-economic growth nexus in Ghana. Against this backdrop, the present study endeavors to fill this void by employing the Granger Causality Test spanning the years 1971 to 2007. The objective is to systematically investigate the direction of causality between electricity consumption and economic growth, contributing valuable insights to the existing discourse in the literature.

2. LITERATURE REVIEW

The exploration of empirical investigations into the intricate causal relationships between energy consumption and economic growth unfolds through a comprehensive analysis, encompassing two distinct but interconnected lines of inquiry: the hypothesis criteria and the generation criteria, as elucidated by Guttormsen in 2004. Delving into these criteria offers a nuanced perspective on the multifaceted dynamics characterizing the symbiosis between energy utilization and economic advancement. On one hand, the hypothesis criteria delve into the conceptual underpinnings of causality, seeking to discern the directional influence between energy consumption and economic growth. This analytical approach scrutinizes whether energy consumption acts as a precursor, driving economic expansion, or if economic growth, in turn, propels heightened energy usage (Muhieddine, 2018). Unraveling this causative directionality is paramount for formulating informed energy policies and strategic economic planning (Ahmad, 2018). Simultaneously, the exploration extends to the generation criteria, which scrutinizes the generation patterns of energy and their correlation with economic growth. This involves an intricate examination of how energy generation mechanisms and patterns align with the dynamics of economic development. Such insights prove pivotal for designing sustainable energy infrastructures that not only meet the evolving demands of economic growth but also contribute to overall environmental sustainability (Iqbal, 2018). The hypothesis approach to analyzing the causal relationship between electricity consumption and economic growth involves a meticulous examination of studies to determine whether they assert that electricity consumption causes economic growth, the reverse, both, or neither. This categorization has led to the classification of empirical investigations into the energy-economic growth nexus into four distinct hypotheses, the Growth-led-Energy hypothesis, the Energy-led-Growth hypothesis, the Energy-led-Growth-led-Energy hypothesis, and the Neutrality hypothesis. Under the Growth-led-Energy hypothesis, studies posit that economic growth is the driving force behind increased electricity consumption. This perspective suggests that as economies expand, there is a

^a University of Ghana, Ghana

concomitant surge in the demand for electricity due to the proliferation of industrial and commercial activities. The Growth-led-Energy hypothesis posits that economic growth serves as the impetus for increased energy consumption. This implies that, even in the face of severe energy crises, economic growth remains unhindered (Okurut & Mbulawa, 2018). Consequently, this hypothesis suggests that implementing energy conservation measures remains a viable option, as economic growth continues unabated despite potential energy challenges.

Conversely, the Energy-led-Growth hypothesis asserts that it is energy consumption that propels economic growth. In this scenario, a severe energy crisis is postulated to impede economic growth significantly. Consequently, under the Energy-led-Growth hypothesis, energy conservation measures are considered less viable, as any curtailment in energy consumption may hinder economic development. The Energy-led-Growth-led-Energy hypothesis introduces a bidirectional causality between energy consumption and economic growth. According to this hypothesis, not only does economic growth stimulate higher energy consumption, but increased energy availability and efficiency also contribute to further economic development. This dynamic interplay suggests that energy conservation measures and strategies for fostering economic growth should be approached in tandem (Muhieddine, 2018; Marc & Ali, 2018). Lastly, the Neutrality hypothesis asserts that there is no discernible causal relationship between energy consumption and economic growth. According to this perspective, changes in energy consumption have no significant impact on the trajectory of economic growth, and vice versa. This viewpoint challenges the need for direct policy interventions linking energy conservation measures with economic growth strategies.

In accordance with the framework introduced by Guttormsen (2004), empirical investigations into the relationship between energy and economic growth have been categorized into three distinct generations: the first generation studies, the second generation studies, and the third generation studies. The first generation studies primarily utilized traditional methodologies such as Vector Autoregressive Models (Sims, 1972) and the standard Granger causality test. These studies laid the foundation for exploring causal relationships between energy and economic growth, employing established statistical tools of their time. However, a notable limitation of this generation is its reliance on the assumption of series stationarity, which may not always hold true in real-world scenarios. This assumption oversimplifies the dynamics of the underlying data, potentially leading to biased results and hindering the comprehensive understanding of the intricate relationships between energy consumption and economic growth.

As the understanding of these relationships evolved, second generation studies emerged, seeking to address the limitations of their predecessors. These studies often incorporated more advanced econometric techniques and recognized the importance of non-stationary time series in capturing the complexities of real-world data. The progression to third generation studies signifies a continued refinement in methodology. These studies typically employ advanced techniques that account for issues such as endogeneity, nonlinearity, and structural breaks, aiming to provide more accurate and robust insights into the dynamic interplay between energy and economic growth. In essence, this classification scheme reflects the evolving sophistication in the empirical examination of the energy-economic growth nexus, highlighting the iterative nature of research as scholars adapt methodologies to better capture the intricacies of this complex relationship (Marc & Ali, 2016). Consequently, the second generation of studies introduced cointegration as a more sophisticated tool for analyzing the causal relationship between energy consumption and economic growth, building upon the works of Johansen and Juselius (1990). In this paradigm, pairs of variables were subjected to cointegration tests, and subsequently, an error correction model was employed to assess causality, drawing on the pioneering work of Engle and Granger (1987).

However, the second generation faced challenges when confronted with the possibility of multiple cointegrating vectors, making their approach less suitable. This limitation prompted the emergence of the third generation of studies, which advocated for a multivariate approach that accommodates more than two variables in the cointegrating relationship. This advancement in methodology reflected an acknowledgment of the intricate interdependencies among various factors influencing the energy-economic growth nexus. By embracing a multivariate perspective, the third generation of studies sought to enhance the analytical framework, providing a more nuanced understanding of the complex interactions between energy consumption, economic growth, and potentially other relevant variables. This evolution in methodology highlights the ongoing efforts within the academic community to refine tools and approaches, ensuring a more accurate depiction of the causal dynamics in the intricate relationship between energy and economic growth. This approach provides a framework for estimating systems in which restrictions on cointegrating relationships can be rigorously tested, allowing for the examination of short-run adjustment dynamics. Despite these advantages, the third-generation studies encounter two principal challenges. Firstly, these studies impose the requirement that the variables should be integrated of order one. Secondly, a precondition for conducting a test of causality in the third-generation framework is that the variables must already be cointegrated. These limitations have spurred the emergence of the fourth generation of studies, signifying a continued evolution in methodological sophistication. The fourth generation seeks to address the issues posed by its predecessors by relaxing some of the stringent assumptions. By doing so, this generation endeavors to enhance the applicability and robustness of empirical analyses, fostering a more accurate representation of the intricate relationships between energy consumption and economic growth. The fourth generation of studies represents a methodological shift by adopting the Toda and Yamamoto Granger Causality test, grounded in the Autoregressive Distributed Lag (ARDL) model. This innovative approach deviates from the constraints of its predecessors by not imposing restrictions on the integration order of the variables. Consequently, causality testing remains feasible irrespective of whether the variables are integrated of order zero, one, or both. In essence, this method allows for the examination of causality even when cointegration is not a prerequisite, providing greater flexibility in exploring the dynamic relationships between energy consumption and economic growth. This advancement reflects a commitment to refining empirical methodologies, ultimately contributing to a more nuanced understanding of the intricate dynamics within the energy-economic growth nexus.

The overarching observation derived from this study underscores the presence of contradictory outcomes within the realm of both multi-country studies and country-specific investigations concerning the causality between energy consumption and economic growth. Notably, the divergent findings suggest a nuanced and complex relationship that is influenced by a multitude of factors. Specifically, when scrutinizing country-specific studies on the causality between electricity consumption and economic growth, a consistent pattern emerges (Ali & Audi, 2016). These studies consistently indicate a positive causality, signifying a directional influence from electricity consumption to economic growth. In contrast, the results from multi-country studies on the causality between electricity consumption and economic growth present a less uniform picture, displaying inconsistencies and contradictions. This disparity in outcomes between country-specific and multi-country studies underscores the importance of considering unique national contexts and idiosyncrasies when investigating the intricate dynamics between electricity consumption and economic

growth. The divergent results also emphasize the need for a more nuanced approach that recognizes the heterogeneity across nations, shedding light on the complexities inherent in drawing overarching conclusions in the field of energy-economic growth causality. The author, therefore, recommends adopting more contemporary approaches in current studies investigating the causality between energy (specifically electricity) consumption and economic growth. To mitigate conflicting and unreliable results, the suggested methodologies include the use of advanced techniques such as the ARDL Bounds cointegration test proposed by Pesaran et al. (2001), threshold cointegration models as proposed by Hansen and Seo (2002), and the application of panel data models. The conclusion drawn by the author underscores the significance of avoiding studies that merely alter the data period while utilizing identical methods and variables. Such practices contribute to the conflicting results present in the existing literature on energy (electricity)-growth causality. The author asserts that such duplicative efforts lack meaningful contributions to the field. Therefore, researchers are advised to refrain from replicating studies without introducing novel elements, as this does not enrich the existing body of literature on the subject. For further clarity and reference, a summary table of works pertaining to the causality between energy (electricity) consumption and economic growth is provided below. This compilation aims to offer a succinct overview of the diverse studies conducted in this domain, serving as a valuable resource for researchers and scholars in the energy-growth literature.

3. OVERVIEW OF THE ELECTRICITY SUB-SECTOR AND ECONOMIC GROWTH

The electricity delivery process typically unfolds in three sequential phases as it traverses from generation to the end-user. Initially, power is generated at remote locations using generators. Subsequently, the generated power is conveyed through the transmission grid, which consists of transmission lines, transformers, and associated components, en route to the bulk load distribution substations. Finally, from these substations, the power is disseminated to individual customer sites through distribution lines. This intricate journey involves a systematic and interconnected network, ensuring the efficient and reliable supply of electricity to end-users.

In Ghana, the intricate three-step process of electricity delivery is overseen by three distinct utility companies, each entrusted with specific responsibilities. The Volta River Authority, a state-owned enterprise, assumes the crucial role of bulk power generation within the country. Presently, Volta River Authority operates the Akosombo and Kpong hydro stations, serving as the primary sources of power generation for Ghana. The Ghana Grid Company is tasked with the vital responsibility of transmitting power from bulk power plants to the distribution lines. Acting as the intermediary link in the electricity delivery chain, Ghana Grid Company ensures the efficient and reliable transfer of power across the transmission grid. The final leg of the process involves the distribution of power to end consumers, a task assigned to two entities, the Electricity Company of Ghana and the Northern Electrical Department, a subsidiary of VRA. ECG is responsible for serving the southern half of the country, while the Northern Electrical Department is dedicated to supplying power to the northern region. Through this strategic division of responsibilities, these utility companies collectively contribute to the comprehensive and organized delivery of electricity across the nation. The electricity sector has undergone substantial growth over the past decade. In 1992, the electricity and water sector achieved a notable growth rate of 12.02%, marking a 5.43% increase compared to the preceding year. The impetus behind this growth was prominently outlined in the budget statement and economic policy for 1993. Key contributing factors included expansive initiatives within the national electricity grid, particularly through the rural electrification programme. Additionally, efforts were directed towards the expansion and enhancement of urban electricity distribution networks. These strategic measures were instrumental in fostering the sector's growth, underscoring a commitment to both rural electrification goals and the improvement of urban electricity infrastructure. In the year 2000, the electricity sector experienced a growth rate of 4.5%, representing a decrease from the 1992 figure. Analyzing its relative contribution to the overall industrial growth in the country, the electricity sector accounted for 10.21% of the total industrial Gross Domestic Product (GDP) in 2000. Moving forward to 2005, there was a notable upswing in the growth rate of the electricity sector, reaching 12.4%. This substantial increase translated into an augmented relative contribution to the total industrial GDP, which rose to 11.9%. This positive growth trajectory underscored the sector's increasing significance within the broader industrial landscape, reflecting ongoing efforts to enhance its efficiency and capacity during this period.

Nevertheless, in 2007, the electricity sector faced a significant setback with a contraction in growth rate, recording a notable decline of -17.4%. This downturn had repercussions on the sector's relative contribution to the total industrial Gross Domestic Product (GDP), causing it to decrease to 10.2%. The primary factor contributing to this diminished contribution was the severe drought that afflicted the Ghanaian economy in 2007. The adverse weather conditions led to a substantial reduction in the water level of Akosombo, the primary powerhouse for the country's electricity generation. This environmental challenge severely impacted the sector's capacity to generate power, resulting in a temporary setback in both growth and its overall contribution to the industrial landscape.

4. DATA AND METHODOLOGY

Preceding from the discussion of the empirical literature on energy-growth nexus, the long-run relationship between electricity consumption and economic growth may be specified as below:

$$E_t = (Y_t)$$

Where EC_t is the log of electricity consumption, Y_t is the log of real per capita GDP (constant 2000 US\$). Annual time series data from 1971 to 2007 on electricity consumption and real per capita GDP were sourced from the EnerData Global Energy and CO₂ Data Research Services and Africa Development Indicators correspondingly.

Although it has been argued in the literature that the ARDL Bounds cointegration tests does not require the pre-testing of series for their order of integration, the need for series to pass two conditions necessitates the need to test for the order of integration of the series. First, the ARDL Bounds cointegration requires that the series in a model should be integrated of an order of either zero or one but not two or more. Secondly, the dependent variable should be integrated of order one. In this study the Augment-Dickey Fuller unit root test (ADF) and the Phillip-Perron (PP) unit root test are used to ascertain the order of integration of the series.

The ARDL bounds testing approach compared to the other approaches of cointegration has several distinct advantages. One of the main advantages of the ARDL approach in contrast to the Engle and Granger (1987) and Johansen approach (1990) is that the ARDL Bounds cointegration approach permits to test for cointegration regardless of whether the variables are all I (1) or I (0) or a mixture of the two. Secondly, the ARDL Bounds approach is not sensitive to the size of the sample, therefore, making its small sample properties more superior to the multivariate cointegration approach. Lastly, the ARDL approach is known to provide unbiased long-run estimates even when some of the variables are endogenous. Narayan (2005) demonstrates that even when some of the

independent variables are endogenous, the bounds testing approach generally provides unbiased long-run estimates and valid t-statistics. Since it is difficult to a priori tell the direction of cointegration between variables, the study in testing for long-run relationships in the variables using the Bounds cointegration test, normalised each variable as a dependent variable. Thus, the following ARDL equations were estimated using OLS and a test of significance on the parameters of the lag level variables were conducted. The resulting F-statistic were then compared to the Pesaran et al asymptotic critical bounds to determine whether there exists a long-run relationship between the variables.

The study of causality has widely been analysed using the vector error correction model (VECM) and error correction model (ECM). However, Toda and Yomamoto (1995) have shown that the asymptotic distribution of the test in the unrestricted VAR has nuisance parameter and nonstandard distribution. Also, Toda and Yomamoto (1995), Zapata and Rambaldi (1997) and Rambaldi and Doran (1996) have all reported that approaches such as VECM and ECM used to analyse causality are sensitive to the values of the nuisance parameters in finite samples making the results a bit unreliable. As a result, Toda and Yomamoto (1995) proposed a modification of the Granger causality approach. This approach requires estimating a VAR model in their levels by augmenting the VAR model with the maximum order of integration, d , of the variables in the model. The method then applies the Wald test statistic for linear restrictions to the resulting VAR (K) model. As shown by Toda and Yomamoto (1995), the Wald statistic for restrictions on the parameters of VAR (K) has an asymptotic χ^2 distribution when a VAR (K+d) is estimated (Zapata and Rambaldi, 1997). Thus, the main idea is to intentionally over-fit the causality test underlying model with additional d lags so that the VAR order becomes (K+d) with K representing the optimal order of the VAR determined by Akaike Information Criterion.

That is when one is uncertain about the order of integration of the variables, augmenting the VAR model with an extra lag usually ensures that the Wald statistic possesses the necessary power properties. Thus, in applying the Toda and Yomamoto method, all that is required of one is the maximum order of integration of the variables in the model and the optimal lag order of the VAR (K) model. This method in contrast to the methods of ECM and VECM does not require pre-testing for cointegration and unit root properties and thus, overcomes the pre-test biased associated with the unit root and cointegration test. Also, this approach minimises the risk associated with possibly wrongly identifying the order of integration of the series and the presence of cointegration relation (Giles, 1997; Mavrotas and Kelly, 2001).

4. EMPIRICAL RESULTS

The study first tested for unit root in variables using the Augmented Dickey Fuller Test and Phillip-Perron Test. The results of the test are shown in table 1. Table 1 presents the results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests for two key variables: the natural logarithm of electricity consumption and the natural logarithm of real per capita gross domestic product in Ghana, using annual data from 1971 to 2007. The tests are conducted under three specifications: intercept with no trend, intercept with trend, and no intercept or trend. The presence or absence of a unit root determines whether a variable is stationary or requires differencing for statistical modeling, which is crucial for avoiding spurious regression results in time series econometrics (Nelson & Plosser, 1982). Starting with electricity consumption, the ADF test with a trend reports a value of -3.510253, which exceeds the 5 percent critical value, indicating stationarity at level under this specification. However, the ADF test without trend and the PP tests across all specifications do not provide sufficient evidence to reject the null hypothesis of a unit root at level. This mixed evidence suggests caution and supports confirming stationarity at the first difference. When first differenced, electricity consumption shows strong evidence of stationarity across all test types and specifications (e.g., ADF = -6.1046 and PP = -7.030818). This confirms that electricity consumption is integrated of order one, consistent with global empirical literature on energy variables that exhibit persistent trends over time (Perron, 1989).

Table 1: unit root test

Variable/test statistic	Intercept and no trend	Intercept and trend	None
E-ADF	-1.819619**	-3.510253***	0.207093
E-PP	-1.618351	-1.924609	1.529186
D(E)-ADF	-6.1046***	-5.101561***	-6.10703***
D(E)-PP	-7.030818***	-8.086952***	-6.661058***
Y-ADF	-0.295843	-0.310855	1.023481
Y-PP	-0.030965	-0.693311	0.745731
D(Y)-ADF	-4.946368***	-1.407076	-4.72704***
D(Y)-PP	-4.231615***	-7.403595***	-4.428853***

Real per capita gross domestic product appears non-stationary in all level forms across both ADF and PP tests, regardless of trend specifications. For example, under the intercept and trend specification, ADF = -0.310855 and PP = -0.693311, both above the 10 percent critical value. However, after first differencing, the ADF test under the intercept-only model reports a statistic of -4.946368, and the PP test reports -4.231615—both significant at the 1 percent level. This result implies that real per capita gross domestic product, like electricity consumption, is integrated of order one. The I(1) nature of both series allows the use of cointegration techniques to examine long-run relationships between electricity use and economic growth (Engle & Granger, 1987). The finding that both electricity consumption and economic growth become stationary after first differencing aligns with typical macroeconomic dynamics in developing countries. These economies often experience long-term growth trends and evolving energy demands due to population growth, infrastructure development, and policy reforms (Stern, 2000). Hence, their energy-output relationships are better modeled using difference-stationary frameworks. In Ghana's context, where substantial reforms such as market liberalization and energy sector restructuring have occurred since the 1980s, non-stationarity in levels may also reflect the underlying structural evolution of the economy. Recognizing this pattern is important before conducting any long-run estimation such as Johansen cointegration or error correction models, which assume variables are integrated of the same order (Narayan & Smyth, 2005).

Moreover, the stronger evidence of stationarity for electricity consumption relative to economic growth could indicate that energy policy reforms were more decisive or consistent than broad-based economic reforms. This interpretation finds support in previous studies suggesting that energy markets in Sub-Saharan Africa tend to respond more rapidly to external aid, infrastructure projects, or privatization than broader macroeconomic indicators (Kraft & Kraft, 1978).

Table 2 reports the results of an OLS-based variable addition test in which the dependent variable is the first difference of the natural logarithm of real per capita gross domestic product ($\Delta \log \text{GDP}$). The model tests for dynamic relationships by including lagged values of both the dependent variable and the first differences and lag levels of electricity consumption and gross domestic product. This method provides insight into the short-term causal influence of electricity consumption on economic growth within a dynamic autoregressive framework (Granger, 1969). The lagged value of the dependent variable, the first difference of real per capita gross domestic product ($\Delta \log \text{GDP}(-1)$), is statistically significant with a coefficient of 1.10799 and a p-value of 0.043. This indicates a strong autoregressive component in Ghana's short-run economic growth, suggesting that past economic performance is a significant determinant of current growth levels. This autoregressive effect is consistent with empirical findings across developing countries, where inertia in growth processes is common due to capital accumulation lags and adjustment frictions (Nelson & Plosser, 1982). The coefficient of the lagged first difference of electricity consumption ($\Delta \log \text{EC}(-1)$) is -0.18645 with a p-value of 0.552, indicating that short-term changes in electricity consumption do not have a statistically significant effect on short-term economic growth. This finding implies that short-run electricity consumption volatility is not immediately growth-inducing and supports the view that energy-growth linkages are typically long-term in nature (Stern, 2000). The lack of a significant short-run effect may also reflect inefficiencies or supply constraints within Ghana's electricity sector during the period under analysis. The inclusion of the lagged level of real per capita gross domestic product ($\log \text{GDP}(-1)$) yields a coefficient of 0.151101, but this estimate is statistically insignificant ($p = 0.368$). Although the positive sign aligns with economic theory, which expects a reinforcing effect of prior output levels on current economic activity, the insignificance suggests limited explanatory power from past output in this static form. This may indicate that Ghana's economic growth is more influenced by structural breaks or shocks than by smooth, level-based dynamics (Zivot & Andrews, 1992).

The lagged level of electricity consumption ($\log \text{EC}(-1)$) has a coefficient of -0.46467 with a standard error of 0.164428 and is also statistically insignificant ($p = 0.411$). Despite being negative, the insignificance of this coefficient implies that electricity consumption in its lagged level does not exert a contemporaneous or delayed impact on growth within the short-run model. This again may point to structural deficiencies in energy distribution or productivity bottlenecks, where electricity use is not efficiently transformed into economic value in the immediate term (Kraft & Kraft, 1978). The constant term in the regression (CON) has a coefficient of 0.80738 but is statistically insignificant ($p = 0.647$), indicating that when all variables are held at zero, the intercept has no substantive effect on the model's explanatory capacity. In the context of a differenced model, this is expected, as intercepts often lose interpretability when differencing is applied to remove unit roots (Engle & Granger, 1987). The variable addition test confirms that short-run economic growth in Ghana exhibits significant autoregressive behavior but is not significantly influenced by electricity consumption in the short term. These findings reinforce the importance of using cointegration frameworks to capture long-run equilibrium relationships where the full effect of electricity use on growth may manifest over time, as established in several energy-growth empirical models (Narayan & Smyth, 2005).

Table 2: Variable Addition Test OLS
Dependent variable is DY

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CON	0.80738	-0.20268	.46285[.647]
DY(-1)	1.10799	0.07204	2.1217[.043]
DE(-1)	-0.18645	0.446698	-.60191[.552]
LY(-1)	0.151101	-0.58587	-.91539[.368]
LE(-1)	-0.46467	0.164428	.83453[.411]

Table 3

Statistic	Result
Lagrange Multiplier	CHSQ(2)= 1.2410[.538]
Likelihood Ratio	CHSQ(2)= 1.2635[.532]
F Statistic	F(2, 28)= .51465[.603]

Table 3 presents the results of diagnostic tests for model adequacy, specifically focusing on the detection of residual autocorrelation and overall model fit using three different statistical approaches: the Lagrange Multiplier test, the Likelihood Ratio test, and the F-statistic. The Lagrange Multiplier test yields a chi-square statistic of 1.2410 with a p-value of 0.538, while the Likelihood Ratio test produces a very similar result with a chi-square statistic of 1.2635 and a p-value of 0.532. Both tests evaluate the null hypothesis that there is no serial correlation in the residuals. Given the high p-values, the null hypothesis cannot be rejected, indicating that the residuals are not autocorrelated, and the model does not suffer from serial correlation problems. The F-statistic result is 0.51465 with degrees of freedom (2, 28) and a corresponding p-value of 0.603. This test provides an additional check on the overall model specification and confirms the absence of significant misspecification. The high p-value again supports the conclusion that the residuals are well-behaved and that the model structure is statistically sound. In summary, all three diagnostic tests suggest that the regression model is free from residual autocorrelation and is properly specified. The residuals appear random and independent, which is a desirable outcome in regression analysis, as it ensures the reliability of statistical inference and the validity of the estimated coefficients.

Table 4 reports the variable addition test where the dependent variable is the first difference of the natural logarithm of electricity consumption in Ghana. The model includes lagged values of both electricity and economic indicators to assess short-run determinants of changes in electricity consumption. This model structure helps evaluate the responsiveness of electricity demand to past economic and energy patterns—a critical consideration in energy demand forecasting (Narayan & Smyth, 2005). The constant term has a coefficient of 2.0327 with a p-value of 0.300, indicating statistical insignificance. While the positive sign suggests an upward trend in electricity consumption, its lack of significance implies that, when controlling for other explanatory factors, there is no strong inherent drift in electricity consumption. This is often the case in models where differencing has removed long-term trends or deterministic drift components (Nelson & Plosser, 1982). The lagged value of the dependent variable (first difference of electricity consumption) has a coefficient of 0.08833 and is statistically insignificant ($p = 0.112$). Although it shows some inertia in electricity consumption growth, the effect is weak. This finding implies that changes in electricity consumption are not strongly autoregressive in the short run, potentially due to seasonal, weather-related, or policy-driven consumption shifts that override momentum from previous periods (Fatai et al., 2004).

More notably, the lagged value of the first difference of real per capita gross domestic product is positive and statistically significant with a coefficient of 2.205 and a p-value of 0.018. This indicates that short-term increases in economic activity directly lead to increases in electricity consumption. The elasticity captured here suggests that economic growth in Ghana strongly and positively influences short-term electricity demand, validating the growth-led electricity consumption hypothesis commonly found in emerging economies (Stern, 2000). Interestingly, the lagged level of the natural logarithm of electricity consumption is negative and statistically significant (coefficient = -0.6082; $p = 0.004$). This suggests a correction effect in which higher past electricity consumption levels may suppress short-run consumption growth—possibly due to capacity constraints, saturation effects, or policy-imposed demand management. This behavior reflects the nonlinearities in electricity usage where infrastructure limits or conservation measures affect responsiveness (Ghosh, 2002). The lagged level of real per capita gross domestic product has a very small and statistically insignificant coefficient (-0.03442, $p = 0.319$). This indicates that past income levels do not independently explain short-run changes in electricity consumption, once differenced income is accounted for. It reinforces the idea that electricity demand is more responsive to changes in income than to income levels, a result supported in other African energy demand studies (Kambu & Aboagye, 2020). Together, the results suggest that electricity consumption in Ghana is influenced by recent economic activity and past consumption levels, but not strongly by income or electricity use levels alone. These dynamics highlight the importance of electricity infrastructure investment and demand elasticity management in supporting economic growth.

Table 4: Variable Addition Test OLS
Dependent variable is DE

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CON	2.0327	2.2652	1.0569[.300]
DE(-1)	0.08833	0.87389	1.6431[.112]
DY(-1)	2.205	1.33765	2.5126[.018]
LE(-1)	-0.6082	-0.31041	-3.1097[.004]
LY(-1)	-0.03442	0.02309	1.0139[.319]

Table 5 presents the results of the bounds cointegration test to determine whether long-run relationships exist among the variables under consideration. The model labeled as Fec, which likely has electricity consumption as the dependent variable, produces an F-statistic of 5.0226. This value is compared against the critical values at the ten percent and five percent significance levels. At the five percent level, the lower bound ($I(0)$) is 2.81, and the upper bound ($I(1)$) is 3.76. Since the F-statistic of 5.0226 exceeds the upper bound, the null hypothesis of no cointegration is rejected, indicating that a long-run cointegrating relationship exists between electricity consumption and its explanatory variables. In contrast, the second model labeled as Fy yields an F-statistic of 0.51465, which falls well below even the ten percent lower bound of 2.49. This result clearly suggests that there is no evidence of cointegration in this model, and thus, no long-run relationship can be confirmed between the dependent variable and its regressors.

Table 5: Bounds cointegration test

F-statistics	10% $I(0)$	10% $I(1)$	5% $I(0)$	5% $I(1)$
Fec = 5.0226	2.49	3.38	2.81	3.76
Fy = 0.51465				

Table 6 provides the outcomes of several test statistics and selection criteria used for determining the optimal lag length in a vector autoregression (VAR) model. The statistics include the log-likelihood (LL), Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC), and the likelihood ratio (LR) test along with its adjusted version. Among all the tested lag orders, order 4 provides the highest log-likelihood value of 86.0247 and the lowest AIC score, which suggests it as a preferred model in terms of explanatory power. However, this order lacks an associated LR test result, possibly because it serves as the baseline in the sequential testing procedure. The likelihood ratio tests compare the model fit as the lag length is reduced. For example, reducing from lag 4 to lag 3 yields a chi-square statistic of 9.1325 with a p-value of 0.058, which is just above the five percent threshold. The adjusted LR test for this change gives a p-value of 0.168, reinforcing that the reduction does not significantly worsen the model. Similarly, the test between lag 3 and lag 2 produces a chi-square statistic of 14.8322 with a p-value of 0.062, and the adjusted p-value is 0.234, also indicating that lag 2 could be sufficient. However, dropping to lag 1 results in a highly significant chi-square value of 28.7655 ($p = 0.004$), and even the adjusted LR p-value is 0.062, suggesting a significant loss of model fit. Moving to lag 0 causes a drastic reduction in performance, as seen in the extremely high LR test value of 122.1912 with a p-value of 0.000, confirming the inadequacy of this minimal specification. In short, while the AIC suggests that lag 4 is optimal, the LR test results indicate that lag 2

is a statistically justifiable choice, balancing model complexity and fit. Therefore, for further analysis or estimation using the VAR model, lag order 2 may be considered both efficient and parsimonious.

Table 6: Test Statistics and Choice Criteria for Selecting the Order of the VAR Model

Order	LL	AIC	SBC	LR test	Adj LR test
4	86.0247	66.0247	50.7611	-----	-----
3	81.4585	65.4585	53.2476	CHSQ(4)= 9.1325[.058]	6.4465[.168]
2	78.6086	66.6086	57.4505	CHSQ(8)= 14.8322[.062]	10.4698[.234]
1	71.642	63.642	57.5365	CHSQ(12)= 28.7655[.004]	20.3051[.062]
0	24.9291	20.9291	17.8764	CHSQ(16)= 122.1912[.000]	86.2526[.000]

Table 7 evaluates the statistical relevance of deterministic or exogenous variables—specifically the intercept and time trend—in the vector autoregression (VAR) model. The Likelihood Ratio (LR) test is used to determine whether these components significantly contribute to the VAR's explanatory power. This step is critical because over-parameterization can distort VAR estimation, while under-specification may result in omitted variable bias (Lütkepohl, 2005). In the first row, the null hypothesis tests the inclusion of an intercept without a trend. The LR statistic of 10.3154, with a p-value of 0.4237, fails to reject the null, suggesting that the intercept-only model does not significantly improve the fit of the VAR. This outcome implies that while the system may include a level term, the effect is not strong enough to be retained for model parsimony. The second test evaluates a model with a deterministic trend but no intercept. Here, the LR statistic is 2.8395, with a negative p-value likely reflecting an invalid or non-applicable result due to numerical rounding or overidentification. This suggests that a trend-only specification is statistically less justified, echoing similar findings in macroeconomic VAR modeling where trends alone rarely capture structural dynamics (Enders, 2015). The third specification includes both an intercept and a linear trend. The LR test yields a statistic of 10.5769 and a p-value of 0.581, again failing to reject the null hypothesis. This result implies that including both deterministic components does not significantly enhance model fit. Therefore, the optimal VAR specification may exclude trend components, focusing instead on endogenous dynamics between electricity consumption and gross domestic product (Toda & Yamamoto, 1995).

Table 7: LR Test of Deletion of Deterministic/Exogenous Variables in the VAR

Null hypothesis	LR test of restrictions	Max log-likelihood	P-value
Intercept but no trend	10.3154	73.958	0.4237
No intercept but trend	2.8395	77.5273	-0.329
Intercept and trend	10.5769	74.6524	0.581

Table 8 presents the results of the block Granger non-causality test, which evaluates whether one variable can predict the future values of another within the VAR framework. This test helps determine the direction of causality between electricity consumption and real per capita gross domestic product in Ghana. The null hypothesis that electricity consumption does not Granger-cause real per capita gross domestic product yields an LR statistic of 2.3158, leading to a failure to reject the null. This result suggests that, in the Ghanaian context, past values of electricity consumption do not significantly improve forecasts of economic output. This aligns with the “growth-led electricity consumption” hypothesis, where energy usage responds to rather than drives economic growth in the short term (Narayan & Smyth, 2005). In contrast, the test rejects the null hypothesis that real per capita gross domestic product does not Granger-cause electricity consumption, with an LR statistic of 9.7764, significant at the 1 percent level. This finding implies that economic growth has predictive power for electricity consumption in Ghana. As income increases, electricity demand rises, possibly due to greater industrial activity, expanding services, and higher household energy use—consistent with the growth-driven energy demand theory (Stern, 2000). These asymmetric causality results reinforce policy implications that Ghana's electricity sector should focus on demand forecasting tied to economic expansion, rather than treating energy infrastructure investment as a direct tool for triggering growth. In developing economies with evolving supply chains and electricity access gaps, demand tends to follow macroeconomic expansion, not lead it (Apergis & Payne, 2010).

Table 8: LR Test of Block Granger Non-causality in the VAR

Null Hypothesis	LR statistic	Decision
Electricity consumption does not cause GDP	2.3158	Do not reject the null
Real per capita GDP does not cause consumption	9.7764***	Fail to accept the null

5. CONCLUSION

The study delved into the examination of the causal relationship between electricity consumption and economic growth, employing the Granger Causality test spanning the years 1971 to 2007. This rigorous investigation sought to discern the directional influence between these two pivotal variables, shedding light on the dynamic interplay within the electricity-economic growth nexus over the specified period. The ARDL Bounds test of cointegration yielded significant results, indicating the presence of a long-run relationship between electricity consumption and real per capita GDP. Furthermore, it was discerned that real per capita GDP can be considered the 'long-run forcing' variable, elucidating its role as a fundamental determinant explaining variations in electricity consumption over an extended timeframe. This finding contributes valuable insights into the sustained and interconnected dynamics between economic prosperity and electricity usage. The Granger Causality test conducted to explore the causal relationship between electricity consumption and real per capita GDP in Ghana unveiled supportive evidence for the Growth-led-Electricity Hypothesis. This result suggests that, in the Ghanaian context, economic growth significantly influences electricity

consumption, aligning with the notion that expanding economic activities drive an increased demand for electricity. This finding contributes to a nuanced understanding of the causal dynamics within the electricity-economic growth relationship in Ghana, reinforcing the idea that economic development plays a pivotal role in shaping electricity consumption patterns. The findings presented in this study suggest that implementing electricity conservation measures is a feasible and prudent option for Ghana. Given the supportive evidence for the Growth-led-Electricity Hypothesis, indicating that economic growth propels electricity consumption, there is an opportunity to develop and intensify targeted electricity conservation measures in the Ghanaian economy. Importantly, this approach is envisioned to coexist harmoniously with economic growth, dispelling concerns about potential impediments to the overall economic advancement. The implication is that the pursuit of energy efficiency and conservation initiatives can be integrated into the national strategy without compromising the trajectory of economic growth in Ghana.

REFERENCES

- Ahmad, S. (2018). Analyzing the relationship between GDP and CO₂ emissions in Malaysia: A time series evidence. *Journal of Energy and Environmental Policy Options*, 1(1), 1–4.
- Ali, A., & Audi, M. (2016). The Impact of Income Inequality, Environmental Degradation and Globalization on Life Expectancy in Pakistan: An Empirical Analysis. *International Journal of Economics and Empirical Research (IJEER)*, 4(4), 182-193.
- Apergis, N., & Payne, J. E. (2010). Energy consumption and economic growth: Evidence from the Commonwealth of Independent States. *Energy Economics*, 32(6), 1374–1380.
- Enders, W. (2015). *Applied econometric time series* (4th ed.). Wiley.
- Engle, R. F., & Granger, C. W. J. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica*, 55(2), 251–276.
- Fatai, K., Oxley, L., & Scrimgeour, F. G. (2004). Modelling the causal relationship between energy consumption and GDP in New Zealand, Australia, India, Indonesia, The Philippines and Thailand. *Mathematics and Computers in Simulation*, 64(3–4), 431–445.
- Ghosh, S. (2002). Electricity consumption and economic growth in India. *Energy Policy*, 30(2), 125–129.
- Giles, J. A., Mizra S. (1998). Some pre-testing issues on testing for Granger non-causality: Econometric working papers, EWP9914. Department of Economics, University of Victoria, Canada.
- Granger G.W.J., (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica* 37. 424-438
- Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*, 37(3), 424–438.
- Guttormsen, A.G. (2004). Causality between Energy Consumption and Economic Growth: Department of Economics and Resource Management, Agriculture University of Norway. Norway.
- Hansen, B.E., Seo, B., (2002). Testing for two-regime threshold cointegration in vector error-correction models. *Journal of Econometrics* 110, 293–318.
- Iqbal, S. (2018). Electricity consumption and economic growth in Pakistan: An empirical analysis. *Journal of Energy and Environmental Policy Options*, 1(1), 5–8.
- Johansen S, and Juselius K. (1990). Maximum likelihood estimation and inference on cointegration with applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, 52, 169–210.
- Johansen, S., (1996). Likelihood-Based Inference in Cointegrated Vector Autoregressive Models, second ed: Oxford University Press, Oxford. Johansen,
- Kambu, A. K., & Aboagye, F. F. (2020). Energy consumption and economic growth nexus in Sub-Saharan Africa: A panel causality approach. *Energy Economics*, 86, 104670.
- Kraft, J., & Kraft, A. (1978). On the relationship between energy and GNP. *The Journal of Energy and Development*, 3(2), 401–403.
- Lee, C. C. (2005). Energy consumption and GDP in developing countries: a cointegrated panel analysis. *Energy Economics*, 27, 415–27.
- Lütkepohl, H. (2005). *New introduction to multiple time series analysis*. Springer.
- Marc, A., & Ali, A. (2016). *Environmental Degradation, Energy consumption, Population Density and Economic Development in Lebanon: A time series Analysis (1971-2014)* (No. 74286). University Library of Munich, Germany.
- Marc, A., & Ali, A. (2018). *Determinants of Environmental Degradation under the Perspective of Globalization: A Panel Analysis of Selected MENA Nations* (No. 85776). University Library of Munich, Germany.
- Mavrotas G. and Kelly R. (2001). Old wine in New bottles>testing causality between savings and growth. *The Manchester School*. Vol. 69. 97-105.
- Morimoto, R., Hope, C., (2004). The impact of electricity supply on economic growth in Sri Lanka. *Energy Economics* 26, 77–85.
- Muhieddine, M. (2018). The nexus between oil prices and current account deficit: An empirical analysis for Lebanon. *Journal of Energy and Environmental Policy Options*, 1(1), 9–13.
- Narayan, P. K., & Smyth, R. (2005). Electricity consumption, employment and real income in Australia: Evidence from multivariate Granger causality tests. *Energy Policy*, 33(9), 1109–1116.
- Narayan, P.K., (2005). The saving and investment nexus for China. evidence from cointegration tests. *Applied Economics* 37, 1979–1990.
- Nelson, C. R., & Plosser, C. R. (1982). Trends and random walks in macroeconomic time series: Some evidence and implications. *Journal of Monetary Economics*, 10(2), 139–162.
- Okurut, F. N., & Mbulawa, S. (2018). The nexus of electricity, economy, and capital: A case study of Botswana. *Journal of Energy and Environmental Policy Options*, 1(1), 14–21.
- Perron, P. (1989). The great crash, the oil price shock, and the unit root hypothesis. *Econometrica*, 57(6), 1361–1401.
- Pesaran, M.H., and Pesaran, B., (1997). Working with Microfit 4.0. Interactive Econometric analysis. Oxford University Press, Oxford.
- Pesaran, M.H., and Shin, Y., (1992). An Autoregressive Distributed Lag Modeling Approach to Cointegration Analysis, in Strom S. (Ed) *Econometrics and Economic theory in the 20th century*. Cambridge University Press, Cambridge.

Journal of Energy and Environmental Policy Options

Vol. 1(2), 37-45

- Pesaran, M.H., Shin, Y.C., and Smith, R., (2001). Bound testing approaches to the analysis of level relationships. *Journal of Applied Econometrics* 16, 289–326.
- Rambaldi, A.N. and H.E. Doran (1996). Testing for Granger non-causality in cointegrated systems made easy. Working Papers in Econometrics and Applied Statistics 88, Department of Econometrics.
- Sims C. (1972). Money, Income and Causality. *American Economic Review*, 62, 540-552.
- Stern, D. I. (2000). A multivariate cointegration analysis of the role of energy in the U.S. macroeconomy. *Energy Economics*, 22(2), 267–283.
- Stern, D. I. (2000). A multivariate cointegration analysis of the role of energy in the U.S. macroeconomy. *Energy Economics*, 22(2), 267–283.
- Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics*, 66(1–2), 225–250.
- Wolde-Rufael, Y., (2006). Electricity consumption and economic growth: a time series experience for African countries: *Energy Policy* 34, 1106-1114.
- Zapata, H. O., and A. N. Rambaldi (1997). Monte Carlo evidence on cointegration and causation: *Oxford Bulletin of Economics and Statistics* 52, 285-298.
- Zivot, E., & Andrews, D. W. K. (1992). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business & Economic Statistics*, 10(3), 251–270.