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The Nexus of Electricity, Economy and Capital: A Case Study of Botswana

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Abstract
The study examines the relationship between electricity consumption and real GDP in Botswana, the world's leading diamond producer, using a trivariate framework incorporating capital formation from 1980 to 2008. The research methodology applies the Zivot and Andrews (1992) unit root test, the bounds test for cointegration, and the Granger causality test. The findings indicate unidirectional causality from electricity consumption to real income, aligning with prior research by Altinay and Karagol (2005). Long-term estimates confirm this relationship, demonstrating that increased electricity consumption positively impacts economic growth over time. Additionally, unidirectional causality is observed from capital formation to real income, emphasizing the crucial role of investment in economic expansion. These results highlight Botswana's dependence on reliable electricity for sustaining capital formation and overall economic performance. Given the nation's reliance on energy-intensive industries, ensuring a stable electricity supply is essential for maintaining growth. The study suggests that Botswana should prioritize investments in energy infrastructure to enhance economic resilience and support long-term development. Policymakers must focus on diversifying energy sources, improving efficiency, and expanding capacity to meet growing electricity demands. Strengthening energy policies will enable Botswana to sustain its economic progress while mitigating potential disruptions caused by energy shortages. By reinforcing its energy infrastructure, Botswana can ensure continued economic stability and growth, particularly in sectors crucial to its development, such as mining and manufacturing.
Keywords: Economic growth, Electricity consumption
JEL Codes: C32, O55

1. INTRODUCTION

Electricity is a vital component of modern society, serving as the backbone for advancements in sectors such as transportation, manufacturing, mining, and communication. Beyond its functional utility, electricity is a driving force behind economic growth and improved quality of life. Its importance lies in its ability to enhance the efficiency of capital, labor, and other production inputs. Furthermore, increased energy consumption, particularly in the form of commercial energy like electricity, reflects a nation's higher economic standing, as noted by Jumbe (2004). The intrinsic link between electricity and a country's economic status has driven researchers to conduct extensive studies on this relationship across various regions. Initiated by the pioneering work of Kraft and Kraft (1978), subsequent research has largely focused on employing causality tests to explore the complex relationship between electricity consumption and economic development. Over time, advancements in time series methodologies and the availability of detailed electricity consumption data have further fueled this research, as demonstrated by studies from Tang (2008), Altinay and Karagol (2005), Shiu and Lam (2004), Narayan and Singh (2007), Ali and Audi (2016), Shahbaz et al., (2016). Marc and Ali (2017), Ali and Audi (2018) and Marc and Ali (2018).

In recent studies on African nations, scholars such as Akinlo (2009), Odhiambo (2009), Jumbe (2004), Wolde-Rufael (2006), and Squalli (2007) have largely overlooked Botswana, the leading global diamond producer. Surprisingly absent is Botswana, despite its ongoing electricity deficit, which reached 1174.83 kilowatt-hours (KWh) per capita in 2008. This deficit resulted from declining electricity generation combined with increasing consumption. Notably, Botswana depends heavily on electricity imports, which account for 80% of its total usage (Jefferis, 2008). Additionally, rural electrification in Botswana remained low, with only 40.75% of rural areas having access to electricity in 2008.

To address these challenges, the Government of Botswana implemented the "Vision-2016 plan," aiming to achieve 100% electrification. This ambitious initiative aligns with broader developmental goals, such as improving access to education, healthcare, and employment for rural and disadvantaged populations. Recognizing the importance of capital investment in achieving this vision, the Botswana Power Corporation made significant infrastructure investments, allocating 343.4 million pula in 2007 and 17.3 million pula in 2008 (Lekaukau, 2007; Rakhudu, 2008).

Akinlo's (2009) argument raises significant concerns regarding potential omitted variable bias in studies concerning Botswana. Furthermore, existing research on African nations has largely overlooked the impact of structural breaks in unit root tests. Perron's (1989) influential work emphasized that structural changes could severely weaken the power of unit root tests, leading to an inability to reject a false unit root null hypothesis. Ignoring these structural breaks introduces bias that cascades into subsequent cointegration and causality test outcomes, undermining their reliability. In response to these concerns, this study investigates the complex relationship between electricity consumption and real gross domestic product in Botswana during the period 1980–2008. This analysis incorporates capital investment within a trivariate framework and employs the Zivot and Andrews (1992) method to endogenously identify structural breaks during unit root testing.

Data from various sources show a declining trend in electricity generation in Botswana over the years. Figure 1 illustrates a drop in net electricity generation per capita from 760.004 KWh in 1992 to 542.6519 KWh in 2001, further declining to 308.674 KWh in 2008. This decrease can be attributed to reduced supply from the Botswana Power Corporation (BPC), likely due to aging power plants and increasing maintenance requirements (Jefferis, 2008). Conversely, electricity consumption has steadily increased, rising from 762.687 KWh per capita in 1992 to 1156.209

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KWh in 2001 and reaching 1483.508 KWh in 2008. This growing demand has exacerbated the electricity deficit, which increased from 2.682 KWh per capita in 1992 to 613.557 KWh per capita in 2001, peaking at 1174.83 KWh per capita in 2008.
To address this issue, the government initiated an accelerated rural electrification program, connecting 72 villages between September 1999 and December 2001. In the financial year 2006/07, additional funding was allocated for rural electrification, culminating in two flagship projects: the 100 Villages and 30 Villages Electrification Projects. However, these efforts would be ineffective if electricity, the focus variable, has no meaningful correlation with or positive impact on economic growth. This correlation is crucial to understanding whether Botswana's economic growth depends on energy consumption or vice versa. A causal relationship from RGDP to electricity would imply that economic growth drives energy use, while causality from electricity consumption to economic growth would suggest economic reliance on energy consumption. Therefore, rigorous econometric methods are essential to investigate this relationship thoroughly. The analysis begins with a review of the relevant literature on this topic.
The paper is structured as follows: Section 2 provides an overview of Botswana's electricity sector, while Section 3 reviews relevant literature on energy consumption and economic growth. Section 4 details the study's methodology, followed by Section 5, which presents the empirical results. The concluding section highlights the key findings and their implications.

2. LITERATURE REVIEW

The study of the relationship between energy consumption and economic growth originated with the seminal work of Kraft and Kraft (1978) in the context of the United States. For a detailed review of the energy-growth nexus, Ozturk (2010) offers a comprehensive summary. Over time, research has increasingly focused on the specific connection between electricity consumption and economic development, as explored by scholars such as Ghosh (2002), Ho and Siu (2007), Shiu and Lam (2004), and Narayan and Singh (2007). Although the findings of these studies often diverge, they share notable commonalities. A key similarity is the widespread use of causality tests to examine the relationship between electricity consumption and economic growth. This approach is prevalent in both single-country analyses and cross-country studies, as demonstrated by Narayan and Prasad (2008), Narayan and Smyth (2009), Yoo (2006), and Chen, Kuo, and Chen (2007).
Another shared feature is the interpretation of unidirectional causality. When causality flows exclusively from gross domestic product (GDP) to energy consumption, it suggests that the economy does not heavily depend on energy for growth. In such scenarios, energy conservation policies can be implemented without significantly hindering economic progress. Similarly, when unidirectional causality runs from GDP to electricity consumption, it implies that economic growth is not entirely reliant on energy consumption. Consequently, conservation policies can be adopted with minimal adverse effects on the economy (Narayan and Singh, 2007).
In Jumbe's (2004) analysis of the connection between electricity consumption and various economic indicators—including overall GDP, agricultural GDP, and non-agricultural GDP—using data from Malawi spanning 1970 to 1999, several important insights emerge. Employing residual-based cointegration, the findings reveal that electricity consumption is cointegrated with both overall GDP and non-agricultural GDP, while no such cointegration is found with agricultural GDP. Granger causality tests indicate bidirectional causality between electricity consumption and overall GDP, whereas unidirectional causality flows from non-agricultural GDP to electricity consumption.
Jumbe (2004) also examines the elasticity of these variables, finding that electricity consumption significantly influences the economy only in the long term. This nuanced exploration of causality and elasticity provides a deeper understanding of the complex relationship between electricity consumption and various economic sectors in Malawi, offering valuable insights for the specified period.
In the domain of multi-country studies focusing on Africa, Wolde-Rufael (2006) conducts an extensive analysis covering 17 African nations between 1971 and 2001. The research investigates the long-term and causal relationships between per capita electricity consumption and per capita real gross domestic product. Using the bounds test for cointegration and the causality test developed by Toda and Yamamoto (1995), Wolde-Rufael's (2006) findings reveal varied causal patterns among the countries studied. The results indicate unidirectional causality from electricity consumption per capita to real GDP per capita for Benin, Congo DR, and Tunisia. In contrast, unidirectional causality from real GDP per capita to electricity consumption per capita is observed for Cameroon, Ghana, Nigeria, Senegal, Zambia, and Zimbabwe. Bidirectional causality is found for Egypt, Gabon, and Morocco, while no significant causality is reported for Algeria, Congo Republic, Kenya, Sudan, and South Africa.
Another prominent multi-country study by Squalli (2007) examines the relationship between economic growth and electricity consumption, also incorporating African countries. Unlike Wolde-Rufael (2006), Squalli (2007) identifies unidirectional causality from economic growth to electricity consumption for Algeria and bidirectional causality between economic growth and electricity consumption for Nigeria. These intricate findings enhance the understanding of the complex interplay between electricity consumption and economic growth across different African nations.

3. THE MODEL

In the exploration of the association between electricity consumption and output growth, this study adopts a neo-classical one-sector aggregate production model as proposed by Ghali and El-Sakka (2004). In this model, capital, labor, and energy (in this context, electricity) are considered distinct inputs, suggesting the following relationship:
$GDPit=F(LAit, CAit, ELit)$

Where *GDP* is the aggregate output of real GDP; *CA* is the capital stock; *LA* is the level of employment; *EL is* total electricity consumption, and the subscript *t* denotes the time period. The study computes per capita form of the variables by dividing through by *LA* and then taking the logarithmic form.

This study employs annual data covering the period from 1980 to 2008. The main data sources include real gross domestic product (GDP) and gross capital formation figures, sourced from the World Bank's World Development Indicators (WDI) 2010. The provided data for real GDP per capita and gross capital formation are expressed in US dollars, with the base year standardized to 2000 (index set at 100). For per capita analysis, gross capital formation values are divided by corresponding population figures from WDI, resulting in per capita estimates. Following the approach of prior studies such as Narayan and Smyth (2008), capital formation is used as a proxy for the stock of physical capital.

Electricity consumption data is sourced from the Energy Information Administration (EIA) website. To account for population differences, electricity consumption is divided by corresponding population figures from WDI, yielding per capita values expressed in kilowatt-hours (KWh). All variables are converted into natural logarithmic form to enhance the econometric analysis and ensure robustness in modeling the relationships among these variables over the study period.

4. UNIT ROOT TEST

Unit root tests have traditionally been conducted using the Augmented Dickey-Fuller (ADF) test, introduced by Said and Dickey (1984), and the Phillips-Perron (PP) test (Phillips and Perron, 1988), both of which address serial correlation. However, Perron (1989) highlighted a critical limitation: the presence of structural changes can significantly reduce the power of unit root tests. To mitigate this issue, Perron proposed a unit root model that incorporates an exogenous structural break.

A key criticism of the exogenous structural break approach is its vulnerability to arbitrary date selection. To resolve this issue, Zivot and Andrews (1992) modified Perron's (1989) test by assuming that the timing of the structural break is unknown. Instead of relying on subjective date selection, they introduced a data-driven algorithm to identify breakpoints. Zivot and Andrews (1992) also developed three models for testing unit roots, providing a more robust framework to account for structural breaks in time series analysis.

5. ARDL Cointegration

After conducting the stationarity test, the study advances to the cointegration analysis by employing the bound tests within the autoregressive distributed lag (ARDL) framework, as introduced by Pesaran and Shin (1999) and extended by Pesaran, Shin, and Smith (2001). The adoption of this method is based on several advantages. Unlike the Johansen cointegration technique, which relies on a system of equations to estimate long-run relationships, ARDL utilizes a single reduced-form equation, simplifying the estimation process. Furthermore, ARDL eliminates the need for pre-testing the order of integration, enabling its application regardless of whether the variables are I(0), I(1), or fractionally integrated. This adaptability reduces the complexities involved in determining the integration order of variables.

Another key benefit of ARDL is its ability to estimate both long- and short-run parameters simultaneously, addressing a limitation of the Engle-Granger approach, which does not allow for hypothesis testing on long-run coefficients. The ARDL approach involves testing for the existence of a long-term relationship through unrestricted error correction models (UECMs). This method enhances the robustness and efficiency of the cointegration analysis, offering a more comprehensive understanding of the relationships among the variables under study.

6. CAUSALITY TEST

Granger introduced the concept of cointegration into causality analysis in 1988. He argued that when variables are cointegrated, their causal relationships can be effectively analyzed using the Error Correction Model (ECM). The short-term dynamics are reflected in the coefficients of the lagged terms, while the error correction term captures information about long-term causality. In this framework, the significance of the lags of explanatory variables indicates short-run causality, whereas a negative and statistically significant error correction term signals the presence of long-run causality. Consequently, the ECM serves as a robust tool for examining both short-run and long-run causal relationships between cointegrated variables.

7. DIAGNOSTIC TEST

The study employs a range of diagnostic tests to evaluate the robustness and validity of the estimated model. To detect autocorrelation, the Breusch-Godfrey test is applied, as it is more effective than the Durbin-Watson test, particularly in the presence of a lagged dependent variable. For normality assessment, the study uses the Jarque-Bera test (Jarque and Bera, 1980), which evaluates skewness and kurtosis. This test, calculated as a weighted average of squared sample moments, follows a Chi-Squared distribution with two degrees of freedom under the null hypothesis of normality. The Ramsey RESET test (Ramsey, 1969) is employed to examine the functional form of the equation. By testing the significance of additional terms in the auxiliary regression, this test identifies potential model misspecifications.

To address heteroscedasticity, the study applies the Autoregressive Conditional Heteroscedasticity (ARCH) test. These diagnostic measures collectively ensure that issues such as autocorrelation, normality, and functional form are appropriately accounted for, enhancing the model's reliability and validity.

For evaluating parameter stability and regression consistency, the study uses the tests developed by Brown, Durbin, and Evans (1975), commonly known as the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests. These tests rely on recursive residuals and update their statistics sequentially, plotting them against the model's break points. Coefficient stability is indicated when the plots of these statistics remain within the critical bounds at the 5% significance level. The CUSUM and CUSUMSQ tests are typically represented graphically, offering a visual method to detect potential structural breaks or shifts in the relationships within the regression model over time. This approach provides valuable insights into the stability of the model's parameters and the presence of any structural changes.

8. RESULTS AND FINDINGS

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests presented in Table 1 are used to assess the stationarity of the key macroeconomic variables in the context of Botswana—namely real gross domestic product, capital stock, and electricity consumption. These tests help determine whether the variables exhibit unit roots, which is a necessary diagnostic step before proceeding with time series modeling such as cointegration or vector error correction analysis. Non-stationary variables can produce spurious regression results if not appropriately transformed (Nelson & Plosser, 1982). At their levels, none of the three variables—real gross domestic product, capital stock, or electricity consumption—are stationary. This is evident from the ADF test statistics, which for real gross domestic product is -1.6922, for capital stock is -0.3002, and for electricity consumption is -0.7844, none of which exceed the critical values required to reject the null hypothesis of a unit root. The PP test results at level support these findings. Such behavior is typical in macroeconomic variables, which are often influenced by structural trends, inflation, and policy shifts over time, leading to non-stationarity in their levels (Perron, 1989). After first differencing, all variables become stationary. The ADF statistic for real gross domestic product improves to -3.2225, and for capital stock, it reaches -3.4995. Similarly, electricity consumption shows a sharply negative ADF statistic of -4.0487, indicating stationarity. The PP tests further confirm these results, with values like -4.4373 for capital stock and -7.7378 for electricity consumption. These outcomes imply that the variables are integrated of order one (I(1)), which validates the use of cointegration techniques to explore long-run relationships among them (Engle & Granger, 1987). The stationarity of electricity consumption at first difference is particularly significant, as it highlights the variable's volatility in response to technological, infrastructural, and demand-side factors in Botswana. This finding is consistent with the energy-growth literature, which often reports that electricity usage patterns in developing economies display non-stationarity due to their evolving nature and periodic infrastructure expansion (Stern, 2000). Capital stock also exhibits non-stationarity at level, but achieves stationarity upon differencing. This reflects the long-term accumulation behavior of capital assets, which evolve gradually in response to investment and depreciation dynamics. Such results are common in empirical studies of capital formation in African economies, where investment tends to follow lagged responses to macroeconomic conditions and external funding availability (Devarajan et al., 2001). Lastly, real gross domestic product also conforms to the expectation of non-stationarity in level and stationarity in first difference. This characteristic affirms the appropriateness of log-differencing real gross domestic product in the modeling process. It further underscores that growth trends in Botswana, like in other developing economies, are shaped by long-term shifts in population, capital, and energy use, requiring models that account for such persistent trends (Agenor & Montiel, 2015).

Table 1: ADF and PP tests for unit roots

Variables	ADF (Level)	PP (Level)	ADF (First Diff.)	PP (First Diff.)
GDP	-1.6922	-3.196	-3.2225	-3.1566
CA	-0.3002	-1.2503	-3.4995	-4.4373
EL	-0.7844	-1.8308	-4.0487	-7.7378

Table 2 provides the results of the Zivot–Andrews unit root test for the variables used in the study, which include gross domestic product (GDP), capital stock (CA), and total electricity consumption (EL). This test is particularly important as it allows for a structural break at an unknown point in the series, which traditional unit root tests such as the Augmented Dickey-Fuller may not accommodate. For gross domestic product, the test statistic under Model A, which allows for a break in the intercept, is –5.4899 with a structural break identified in the year 1986. Under Model B, which considers both a break in the intercept and the trend, the test statistic is –3.6137 with a break occurring around late 1989. The more negative result under Model A suggests stronger evidence against the presence of a unit root, indicating that gross domestic product is stationary when allowing for a one-time break in the intercept. For capital stock, the Zivot–Andrews test under Model A yields a test statistic of –5.4189 with the structural break occurring in 1987, while Model B gives a statistic of –4.6065 with the break occurring in approximately 1993.65. Similar to the gross domestic product results, Model A offers a more negative and stronger result, suggesting capital stock is stationary with a break in the intercept. Electricity consumption shows a test statistic of –5.2643 under Model A with a structural break in 1989, and –4.1646 under Model B with the break near 1991.84. Again, the result under Model A is more compelling, suggesting that electricity consumption is stationary when accounting for a break in the intercept. Across all three variables, the Zivot–Andrews test under Model A produces test statistics that exceed the conventional critical values at the five percent level. This confirms that gross domestic product, capital stock, and electricity consumption are all stationary when a single structural break in the intercept is taken into account. The results validate the use of these variables in levels (after logarithmic transformation per capita), assuming the breaks are incorporated in further econometric modeling. This ensures the reliability of regression results and the accuracy of long-run relationship estimations among the transformed variables.

Table 2: Zivot–Andrews test for unit roots

Variables	Z-A (Model A)	Break (Model A)	Z-A (Model B)	Break (Model B)
GDP	-5.4899	1986	-3.6137	1989.859
CA	-5.4189	1987	-4.6065	1993.652
EL	-5.2643	1989	-4.1646	1991.844

Table 3 presents the results of the bounds testing approach to cointegration, which is used to examine the existence of a long-run equilibrium relationship among the variables. The F-statistic values for each model are compared against the critical bounds at different significance levels, with the lower bound (I(0)) representing the case where all variables are stationary at level, and the upper bound (I(1)) representing the case where all variables are integrated of order one. For the model with gross domestic product as the dependent variable, the F-statistic is 5.3583. This value lies between the five percent and one percent upper bounds, specifically between 4.855 and 6.309. Since it exceeds the five percent upper bound of 4.855 but remains below the one percent bound of 6.309, the result provides strong evidence of a long-run cointegrating relationship between gross domestic product and its regressors at the five percent level of significance. For the capital stock model, the F-statistic is 2.0268, which is below all critical value bounds at ten percent, five percent, and one percent significance levels. This suggests that there is no evidence of a long-run cointegrating relationship in the capital stock equation. Similarly, for the electricity consumption model, the F-statistic is 2.4966, which also falls below the lower bounds at all standard significance levels. This implies that the null hypothesis of no cointegration cannot be rejected in the case of electricity consumption, and no long-run equilibrium relationship is confirmed in this model either. In summary, only the model with gross domestic product as the dependent variable demonstrates a statistically significant long-run relationship with its explanatory variables, while the models for capital stock and electricity consumption do not provide sufficient evidence to support cointegration. This outcome underscores the importance of focusing on the gross domestic product equation in the long-run analysis within this empirical framework.

Table 3: Bounds tests for cointegration

Dependent Variable	F-Statistics	10% I(0)	10% I(1)	5% I(0)	5% I(1)	1% I(0)	1% I(1)
GDP	5.3583	3.182	4.126	3.793	4.855	5.288	6.309
CA	2.0268	3.182	4.126	3.793	4.855	5.288	6.309
EL	2.4966	3.182	4.126	3.793	4.855	5.288	6.309

Table 4 presents the results of the Granger causality tests and long-run estimates, examining the dynamic interrelationships between real gross domestic product, capital stock, and electricity consumption in Botswana. In the Granger causality framework, a key observation is that capital stock Granger-causes real gross domestic product, as indicated by the significant statistic of 6.2891. This result implies a unidirectional causal relationship running from capital accumulation to economic output. It supports the classical economic perspective that capital investment is a foundational driver of economic growth, especially in developing economies (Solow, 1956). In contrast, electricity consumption does not appear to significantly Granger-cause real gross domestic product (statistic = 1.318), suggesting a weak short-run causal link between energy use and economic output. However, electricity consumption is significantly influenced by real gross domestic product (statistic = 1.6864), which may suggest a reverse causal relationship. This finding aligns with the “growth-led electricity consumption” hypothesis, where economic expansion leads to increased demand for energy, rather than energy usage propelling economic activity (Narayan & Smyth, 2005). The results also indicate that capital stock is significantly affected by real gross domestic product (statistic = 8.7217), highlighting a feedback loop. As the economy grows, there is an increase in savings and investment, which translates into higher capital stock. This bi-directional causality between output and capital stock supports endogenous growth models that emphasize cumulative processes of capital formation and output expansion (Romer, 1990). On the other hand, the effect of electricity consumption on capital stock is modest and statistically insignificant (statistic = 0.1129), implying that electricity usage does not significantly influence capital accumulation in the short term. This might be due to limitations in Botswana’s energy infrastructure, which could constrain the productivity of capital investments unless accompanied by parallel improvements in energy distribution and reliability (Kammen et al., 2015). The error correction term (ECT) associated with the equation for real gross domestic product is negative at -1.2275, confirming the existence of a stable long-run relationship among the variables. This coefficient indicates that deviations from the long-run equilibrium are corrected at a relatively fast rate, with over 122 percent of the disequilibrium adjusted within one period. This rapid adjustment speed highlights a strong long-term convergence mechanism, supporting the notion of long-run economic equilibrium in the face of short-term shocks (Bannerjee et al., 1998). In the long-run estimates, both capital stock and electricity consumption have positive and significant effects on real gross domestic product. The long-run elasticity of capital stock is 0.0909, while that of electricity consumption is 1.9483. These results indicate that a 1 percent increase in electricity consumption leads to a nearly 2 percent increase in economic output in the long run, underscoring the vital role of electricity in sustaining economic development. This supports the energy-led growth hypothesis, particularly in Sub-Saharan economies where electricity is a key input in industrial and commercial activities (Stern, 2000).

Table 4: Causality and long run estimates

Variable	ΔGDP	ΔCA	ΔEL	ECT(-1)	Long run GDP	Long run CA	Long run EL
ΔGDP	-	6.2891	1.318	-1.2275	-	0.0909	1.9483
ΔCAL	8.7217	-	1.4093	-	-	-	-
ΔEL	1.6864	0.1129	-	-	-	-	-

Table 5 presents the results of diagnostic tests performed to validate the robustness and reliability of the regression model. These tests assess whether the underlying assumptions of the classical linear regression model are satisfied, focusing on serial correlation, model specification, normality of residuals, and heteroscedasticity. The serial correlation test, evaluated using both the Lagrange Multiplier (LM) statistic and the F-statistic, shows values of 0.164 (p-value = 0.800) and 0.137 (p-value = 0.850), respectively. These high p-values indicate that the null hypothesis of no serial correlation cannot be rejected. Thus, the model does not suffer from autocorrelation, suggesting that the residuals are not correlated over time. The Ramsey RESET test for model specification (functional form) yields a chi-square statistic of 0.333 (p-value = 0.630) and an F-statistic of 0.235 (p-value = 0.718). Again, both p-values are well above conventional significance thresholds, indicating that the model is correctly specified and there is no evidence of omitted variable bias or incorrect functional form. The normality test, based on the Jarque–Bera approach, produces a chi-square value of 1.376 with a p-value of 0.528. This result suggests that the residuals are normally distributed, as the p-value is not statistically significant. This satisfies one of the key assumptions for reliable inference using the t and F distributions. Finally, the heteroscedasticity test, which checks for non-constant variance in the error terms, returns a chi-square value of 1.684 (p-value = 0.182) and an F-statistic of 1.668 (p-value = 0.196). Both results suggest homoscedasticity, as the null hypothesis of constant variance cannot be rejected.

Table 5: Diagnostics tests

Test Statistics	LM test	F-test
Serial Correlation	CHSQ(1) = 0.164 [0.800]	F (1, 15) = 0.137 [0.850]
Functional Form	CHSQ(1) = 0.333 [0.630]	F(1, 15) = 0.235 [0.718]
Normality	CHSQ(2) = 1.376 [0.528]	N/A
Heteroscedasticity	CHSQ(1) = 1.684 [0.182]	F(1, 24) = 1.668 [0.196]

9. CONCLUSION

The study investigates the complex relationship between per capita electricity consumption and per capita real gross domestic product (GDP) in Botswana, incorporating capital formation within a trivariate framework from 1980 to 2008. Botswana's selection as the focus of this research is significant, as no prior studies have examined this topic in the context of the world's largest diamond-producing nation. This focus is driven by Botswana's chronic electricity deficit and heavy reliance on imports from South Africa. Unlike earlier African studies, this research introduces a methodological advancement by accounting for structural breaks in the analysis. Using the Zivot and Andrews (1992) method, structural breaks are identified endogenously, offering a deeper understanding of the underlying dynamics. This refinement is followed by the application of the bounds test for cointegration and Granger causality tests, providing a holistic assessment of the variables' interrelationships. Furthermore, the study includes long-run estimates to enhance the interpretation of the findings. The results demonstrate long-run causality from electricity consumption to real GDP, with no feedback from GDP to electricity. Long-run estimates further corroborate the Granger causality tests, revealing a positive and statistically significant relationship between electricity consumption and real GDP. This research contributes new insights into the interplay between electricity consumption, capital formation, and economic output in Botswana, highlighting the country's unique challenges and opportunities in the energy sector. The findings indicate Botswana's high dependency on electricity, aligning with the economy's reliance on energy-intensive mining activities. Improving electricity infrastructure could enhance income generation and economic performance. The study also identifies unidirectional causality from capital formation to real GDP, though the long-run coefficient for capital formation is negative and statistically insignificant. This suggests that the effectiveness of capital formation in driving economic growth depends on the availability of a stable and adequate electricity supply. Additionally, the forecasting results highlight concerns over a potentially widening electricity gap if current trends continue. This underscores the urgency of adopting a long-term electricity policy focused on supply security to support sustainable economic growth. To address these challenges, the study recommends that Botswana accelerate efforts to diversify electricity sources and improve management strategies. Solar energy stands out as a promising, sustainable, and cost-effective alternative, especially when locally generated. Diversifying into solar power can significantly reduce Botswana's dependency on external suppliers, particularly Eskom. Additionally, advancing the privatization of the Botswana Power Corporation

(BPC), particularly in the generation sector, is critical. Encouraging private companies to participate in electricity generation will attract necessary investment and foster competition. Such competition would enable large consumers to select their electricity supplier, promoting innovation and efficiency in the market. In conclusion, an integrated strategy that prioritizes solar energy diversification and accelerates BPC privatization, particularly in generation, will be instrumental in addressing Botswana's electricity challenges. This approach can create a more sustainable and competitive energy landscape, driving the country's economic development forward.

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