ENERGY-GROWTH DYNAMICS IN THE PRESENCE OF INCOME OF 5 OIL-EXPORTING AFRICAN COUNTRIES: A TIME SERIES APPROACH

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ABSTRACT

This study examines the relationship between economic growth and energy consumption in five African oil-exporting countries—Nigeria, Congo, Egypt, Algeria, and Gabon—from 1980 to 2021. Using Vector Autoregression (VAR), Vector Error Correction Model (VECM), and Granger causality tests, distinct causal patterns are identified. In Algeria, GDP and energy consumption show no significant interaction. In Egypt, energy consumption drives GDP growth. Gabon demonstrates strong short- and long-term causality between the variables. In Nigeria, energy consumption influences GDP in the short term, while in Congo, GDP has a significant long-term effect on energy consumption. These findings highlight varying policy implications for energy and economic planning in each country.

Keywords: Oil-exporting African countries, Causality analysis, Industrialization, Energy-led growth, Economic diversification

INTRODUCTION

In economic research, the relationship between energy consumption and economic growth has been a major interest, particularly in African nations that export oil. Developing policies promoting sustainable development requires understanding the interactions between these two elements.

Energy consumption is essential for industrial activities, transportation, and households. It often drives economic growth, but the role of income levels in this relationship is not well understood. Some studies suggest that higher income levels lead to increased energy use, while others argue that income growth can lead to more investments in energy efficiency and cleaner technologies, reducing overall energy demand (Gao et al., 2022). For example, in BRICS countries, Doğanalp et al. (2021) found that while income growth boosts employment and energy consumption, it also negatively affects education levels.

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In African oil-exporting countries, this relationship is further complicated by trade openness and energy intensity. Ogunsola and Tipoy (2022) found that while per capita income does not significantly affect energy consumption, trade openness does, showing the importance of international economic interactions. Similarly, Sulong and Farouq (2021) discovered a positive link between energy intensity, energy use, and financial development in key African oil-exporting nations, indicating that as these economies grow, their energy needs and financial systems become more complex. Environmental impacts are also a crucial part of this discussion. Adeleye et al. (2021) found that energy use significantly increases carbon emissions, with per capita income playing a moderating role. This emphasizes how difficult it is to balance environmental sustainability and economic growth, especially in areas that depend heavily on fossil fuels.

Despite significant research on the global relationship between energy consumption and economic growth, there is still a limited understanding of how income affects this relationship, particularly in oil-exporting African nations. Previous studies have yielded important insights but often focused on specific regions or isolated economic factors, primarily examining the direct impacts of energy use, oil prices, and the roles of investment and institutional quality. However, the influence of income levels on the dynamics between energy consumption and economic growth remains underexplored. This study aims to fill this gap by analyzing the interaction of energy consumption and economic growth in the context of income, specifically within five oil-exporting African nations.

Diverse conclusions have been drawn from research on the relationship between energy consumption and economic growth. Abbasian and Manochehri (2023) used a Bayesian vector autoregressive (BVAR) model to show how energy consumption in Iran significantly boosts economic growth, but carbon dioxide emissions have the opposite effect. Similarly, Uçan et al. (2022) employed the Dumitrescu-Hurlin causality test to identify a bidirectional relationship between economic growth and energy consumption in 15 developed countries, indicating mutual causation. Fraz (2022) utilized advanced panel cointegration techniques and pairwise panel causality tests to establish a long-run relationship between energy consumption and economic growth in both lower-middle-income and high-income countries, underscoring the positive impact of energy conservation policies. Ali et al. (2022) applied a non-linear panel autoregressive distributed lag (ARDL) framework to analyze the asymmetric effects of energy consumption on

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economic growth across 85 countries, finding that positive energy shocks enhance growth in some regions but lead to contractions in others. Topolewski (2021) used dynamic panel models to study 34 European countries, discovering that while economic growth significantly increases energy consumption both in the short and long term, energy consumption does not immediately affect economic growth. Umeji et al. (2023) conducted regression analysis in Nigeria, revealing a bi-directional relationship between renewable energy consumption and economic growth, emphasizing the importance of renewable energy for economic development. Gkergki (2020) employed econometric analysis to show that in Greece, economic growth does not significantly influence energy consumption, and the consumption of oil and coal negatively affects GDP per capita, highlighting the unique impact of the economic crisis and government regulation. Additionally, studies by Benali and Benabbou (2023) and Fuinhas et al. (2023) stress the importance of energy efficiency and reducing carbon emissions for sustainable growth, using varied econometric models to support their conclusions. These studies underscore the complex, context-specific dynamics between energy consumption and economic growth, emphasizing the need for tailored energy policies to promote sustainable development.

According to different analytical techniques, research on how Income affects economic growth and energy consumption yields varied results. Doğanalp et al. (2021) used PVAR, FMOLS, and DOLS analyses to study BRICS countries, finding that income growth positively impacts employment and energy consumption, supporting the growth hypothesis, but negatively affects education levels. Gao et al. (2022) examined China from 2000 to 2019 using multiple estimators and analyses, discovering that improving human capital reduces energy consumption through economic restructuring and technological innovation, with income equality enhancing this effect. Ehigiamusoe and Lea (2019) employed cointegration analysis across 122 countries, revealing that while energy consumption increases carbon emissions, economic growth and financial development reduce emissions in high-income countries but increase them in low and middle-income countries. Afia (2019), using panel data analysis, established that energy consumption directly and indirectly; through per capita income, increases happiness in 47 countries. These studies illustrate the varying impacts of income on economic growth and energy consumption across different contexts. Similarly, Fraz (2022) analyzed 31 countries from 1971 to 2014 using advanced panel cointegration techniques and pairwise panel causality tests, showing that energy

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consumption and economic growth are cointegrated for both lower-middle-income and high-income economies, with a Granger causality from GDP to energy consumption. The study highlighted the potential of energy conservation policies to boost economic growth, especially in lower-middle-income countries. In his review of the literature, Jakovac (2018) emphasized the complexity of the relationship and the need for customized policies. He noted that there was a lack of agreement in the literature because different econometric methodologies, datasets, and country characteristics were used. Utilizing panel data analysis for the E7 countries from 1990 to 2014, Doğan and Değer (2018) discovered that while there was no long-term correlation between carbon emissions and financial development, there was a significant correlation between energy consumption and economic growth and carbon emissions, with a 1% increase in energy consumption translating into a 1.840% increase in emissions and a 1% increase in economic growth into a 0.243% increase in emissions. All of these studies highlight how closely income, economic growth, and energy consumption are correlated, highlighting how crucial it is to take into account the unique circumstances of each nation and implement sustainable policies in order to effectively manage these relationships.

Various analytical techniques are used to show a range of conclusions from research on the relationship between income levels and economic growth in oil-exporting African countries. Babuga and Ahmad (2022) used the Pooled Mean Group (PMG) estimation method to analyze Sub-Saharan Africa's net oil-exporting countries, discovering an inverted U-shaped relationship between oil prices and economic growth, with a threshold level beyond which oil price increases negatively impact growth. Nkire et al. (2023) found that Foreign Direct Investment (FDI) did not significantly influence economic growth in eight oil-exporting African countries, while external debt and official development assistance had varying impacts across different nations, emphasizing the importance of institutional quality for sustainable development. Osintseva (2022) highlighted that economic growth in oil-exporting countries, including OPEC and non-OPEC members, is significantly influenced by oil prices, production rates, and structural shifts in oil exports, with larger economies benefiting more from positive oil price changes due to scale effects. Omojolaibi and Egwaikhide (2014) used vector autoregressive (VAR) analysis to show that gross investment is the main channel through which oil price volatility affects economic performance in five oil-exporting African countries, suggesting investment as crucial for mitigating volatility

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effects. Eagle (2017) employed SVAR, E(GARCH), and Granger Causality tests to examine Angola and Nigeria, finding that oil price volatility marginally impacts GDP growth but significantly affects exchange rates, with recommendations for economic diversification and enhancing crude oil refining capacity. These studies collectively underscore the complex interplay between oil prices, economic growth, and income levels, highlighting the need for tailored policies to manage the unique challenges faced by oil-exporting African nations.

Theoretical Framework

The energy-growth nexus is the main theory behind this research, proposing that energy consumption is essential for driving economic growth. This relationship can be unidirectional or bidirectional, depending on the specific context and characteristics of the economies involved. Previous studies, such as those by Doğanalp et al. (2021) and Osintseva (2022), have shown that energy consumption positively impacts economic growth, especially in oil-rich economies.

Understanding the link between energy consumption and economic growth necessitates knowledge of both the energy-growth nexus and the theory of income heterogeneity. This theory suggests that the effect of energy consumption on economic growth varies significantly based on income levels. For instance, Gao et al. (2022) and Ehigiamusoe and Lea (2019) found that higher income levels can enhance the benefits of energy consumption through improved technological adaptation and economic restructuring. In contrast, lower-income levels may struggle to harness these benefits due to limited resources and infrastructural constraints. This disparity highlights the need to involve the impact of income levels, as a contextual factor, when examining the energy-growth relationship, as different income contexts can lead to varied outcomes and policy requirements.

2.0 MATERIALS AND METHODS

The dataset utilized in this investigation encompasses three variables: energy consumption (ENC), economic growth (GDP), and income (INC). These variables were collected from five nations – Nigeria, Congo, Egypt, Algeria, and Gabon, constituting the cross-sectional data from 1980 to 2021. The GDP and INC data originated from the global economy and the World Development Indicators Databank (WDI), while the ENC data was obtained from the United States Energy

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Information Administration (EIA). The variables are expressed as natural logarithms as a statistical method to remove trends from time series data. Before embarking on the 2-step Engle-Granger cointegration test to establish potential long-term relationships, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were employed to assess the presence or absence of unit root.

2.1 Model Specification

The Vector Auto-Regressive (VAR) technique is a statistical method used to explore relationships among various influential factors (Suharsono et al., 2017). The VAR model, consisting of multiple autoregressive (AR) models, creates a vector that illustrates the interactions between these variables. It serves as a potent quantitative forecasting approach, specially designed for the analysis of multivariate time series data. This model captures the links between a variable's current observations, its past observations, and its relationships with other variables at previous time points.

The unit root test results indicate that most variables—energy consumption (Enc), income (Inc), and GDP—are non-stationary at their levels but become stationary after first differencing for all countries, implying they are integrated of order one, I(1). This finding suggests that, except for Egypt's energy consumption, where the ADF and PP tests indicate stationarity at level (I(0)) at the 5% significance level, other variables in Algeria, Gabon, Nigeria, and DR Congo exhibit time-series characteristics that only stabilize after differencing. The significance of stationarity at I(1) highlights that these variables share long-term trends, which is crucial for further cointegration analysis, allowing us to explore stable long-run relationships between energy consumption, income, and GDP in these oil-exporting African nations.

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Table 1: Unit Root tests

		Level		1st Difference		
Cross-section	**Variable**	**ADF**	**PP**	**ADF**	**PP**	**Integration Order**
Algeria	Enc	-0.9140	-0.8350	-3.704***	-7.941***	I(1)
	Inc	-0.9240	-1.2180	-5.321***	-5.501***	I(1)
	GDP	-0.6710	-0.8140	-5.688***	-5.797***	I(1)
Egypt	Enc	-3.550**	-3.158**	-5.444***	-5.438***	I(0)
	Inc	-1.1130	-0.9680	-4.274***	-4.257***	I(1)
	GDP	-0.6410	-0.4240	-4.434***	-4.478***	I(1)
Gabon	Enc	-1.3280	-1.7210	-7.601***	-7.895***	I(1)
	Inc	-1.1400	-1.0670	-7.165***	-7.201***	I(1)
	GDP	-0.0640	-0.0870	-5.802***	-5.778***	I(1)
Nigeria	Enc	-1.0340	-0.8540	-8.263***	-8.336***	I(1)
	Inc	-0.9970	-0.9970	-7.395***	-7.015***	I(1)
	GDP	-0.4430	-0.4430	-6.780***	-6.542***	I(1)
DR Congo	Enc	-1.4890	-1.4130	-6.166***	-6.699***	I(1)
	Inc	-1.1850	-1.4510	-4.699***	-23.391***	I(1)
	GDP	-0.2920	-0.1530	-10.405***	-10.580***	I(1)

*, **, *** denotes significance at 10%, 5%, and 1% levels respectively

The cointegration test results using the Engle-Granger method reveal evidence of long-term relationships between energy consumption, income, and GDP in the selected countries, though with varying levels of significance. For Algeria, both ADF and PP statistics are below critical values, suggesting a lack of cointegration. However, Egypt, Gabon, Nigeria, and DR Congo display significant cointegration at varying levels, evidenced by statistically significant ADF and PP statistics for different model specifications. Specifically, Gabon, Nigeria, and DR Congo show high significance in specific equations, indicating stable, long-term linkages among energy consumption, income, and GDP in these nations. This suggests that energy consumption policies

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targeting long-term economic growth can be effective when accounting for income, especially in contexts where cointegration exists, reinforcing the strategic role of income in economic planning.

The unit root and cointegration tests indicate no evidence of long-term causal relationship in the Algerian and Egyptian systems; therefore, a VAR model is appropriate for their dynamics. However, other cross-sections exhibit highly significant cointegration levels, suggesting the use of a Vector Error Correction (VEC) model.

Table 2: The 2-step Engle-Granger Cointegration test.

		Engle-Granger Statistic	
Cross-Section	**Equation**	**ADF**	**PP**
Algeria	$\mu_{i,t} = lnenc_{i,t} - (0.9659 lngdp_{i,t} - 0.6929 lninc_{i,t} - 0.1521)$	-2.543	-2.490
	$\mu_{i,t} = lngdp_{i,t} - (0.7016 lnenc_{i,t} + 0.9135 lninc_{i,t} + 1.2157)$	-1.960	-1.944
Egypt	$\mu_{i,t} = lnenc_{i,t} - (1.0305 lngdp_{i,t} - 0.6257 lninc_{i,t} - 0.6374)$	-2.709*	-2.796*
	$\mu_{i,t} = lngdp_{i,t} - (0.3025 lnenc_{i,t} + 1.0847 lninc_{i,t} + 3.2353)$	-3.429**	-3.466**
Gabon	$\mu_{i,t} = lnenc_{i,t} - (0.4241 lngdp_{i,t} - 0.1289 lninc_{i,t} - 0.5588)$	3.967***	-4.053***
	$\mu_{i,t} = lngdp_{i,t} - (1.3867 lnenc_{i,t} + 0.7738 lninc_{i,t} + 0.9597)$	-3.228**	-3.374**
Nigeria	$\mu_{i,t} = lnenc_{i,t} - (1.0808 lngdp_{i,t} - 1.0368 lninc_{i,t} - 2.3223)$	-3.606***	-3.823***
	$\mu_{i,t} = lngdp_{i,t} - (0.7295 lnenc_{i,t} + 1.0125 lninc_{i,t} + 2.7692)$	3.399**	-3669***
DR Congo	$\mu_{i,t} = lnenc_{i,t} - (0.7870 lngdp_{i,t} - 0.6901 lninc_{i,t} - 2.4856)$	3.649**	3.554**
	$\mu_{i,t} = lngdp_{i,t} - (0.7715 lnenc_{i,t} + 0.9761 lninc_{i,t} + 3.8123)$	-4.255***	-3.868***
***, **, * represents significance at 1%, 5%, and 10% levels respectively.			

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It is crucial to take into account stationarity and the normality and independence of errors. Stationarity is examined using the unit root test, whereas the independence of errors can be observed through the residual plot.

$$Y_t = \Gamma_t X_{t-1} + \varepsilon_t \qquad (1)$$

If the residual plot shows a discernible pattern, it implies that the errors (ε_t) are not independent.

$$y_t = c + \emptyset(B) y_t + \varepsilon_t \qquad (2)$$

The adopted form of the VAR is as follows:

$$lngdp_t = \alpha_{01} + \sum_{i=1}^{p} \alpha_{i1} lngdp_{t-i} + \sum_{j=1}^{q_1} \alpha_{j1} lnenc_{t-j} + \sum_{k=1}^{q_2} \alpha_{k1} lninc_{t-k} + \varepsilon_{t1} \qquad (3)$$

$$lnenc_t = \alpha_{02} + \sum_{i=1}^{p} \alpha_{i2} lngdp_{t-i} + \sum_{j=1}^{q_1} \alpha_{j2} lnenc_{t-j} + \sum_{k=1}^{q_2} \alpha_{k2} lninc_{t-k} + \varepsilon_{t2} \qquad (4)$$

A Vector Error Correction Model (VECM) is a restricted VAR developed for use with cointegrated non-stationary series. The VECM illustrates how the studied model adjusts in each time period towards its long-run equilibrium state once the equilibrium constraints are implemented.

The adopted form of the VECM is as follows:

$$\triangle lngdp_t = \alpha_{01} + \sum_{i=1}^{p-1} \alpha_{i1} \triangle lngdp_{t-i} + \sum_{j=1}^{q_1-1} \alpha_{j1} \triangle lnenc_{t-j} + \sum_{k=1}^{q_2-1} \alpha_{k1} \triangle lninc_{t-k} + \lambda_1 EC_{t-1} + \varepsilon_{t1} \qquad (5)$$

$$\triangle lnenc_t = \alpha_{01} + \sum_{i=1}^{p-1} \alpha_{i2} \triangle lngdp_{t-i} + \sum_{j=1}^{q_1-1} \alpha_{j2} \triangle lnenc_{t-j} + \sum_{k=1}^{q_2-1} \alpha_{k2} \triangle lninc_{t-k} + \lambda_2 EC_{t-1} + \varepsilon_{t2} \qquad (6)$$

The formal definition of Granger causality asks if previous values of *x* help in the prediction of y_t , assuming that the effects of past values of *y* on y_t have already been accounted for (and perhaps of past values of other variables). If they do, *x* is considered to be the "cause" of *y*.

Testing for Granger causality in a dataset amounts to testing the joint blocks of coefficients $\beta_{yxs}$and β_{xys} to see if they are zero. The null hypothesis $x \nRightarrow y$ (*x* does not Granger cause *y*) in this VAR is. This can be tested using a standard Wald F or chi square test. Similarly, the null hypothesis $y \nRightarrow x$ can be expressed in the VAR as

$$H_0: \beta_{yx1} = \beta_{yx2} = \cdots = \beta_{yxp} = 0, \qquad (7)$$

$$H_0: \beta_{xy1} = \beta_{xy2} = \cdots = \beta_{xyp} = 0 \qquad (8)$$

The Jarque-Bera test was used to determine the normality of the error terms and serial correlation test was also carried out as diagnostics on the resulting models to establish that the results are not spurious.

3.0 RESULTS AND COMPARATIVE DISCUSSION OF RESEARCH FINDINGS

The visual representation of the series—Economic Growth (GDP), Energy Consumption (ENC), and Income per capita (INC)—shown in Fig. 1 provides an overview of the detrended data used in this research. The integration order is crucial for determining the appropriate model, either VAR or VEC, for this study. A series with an integration order of zero, indicating trend stationarity at the level form, is best represented by a VAR model. For the formulation of a VECM, the detrended series must show trend stationarity after the first difference, indicating an integration order of one. Unit root tests in Table 1 present the results for the series in both their level and first difference states.

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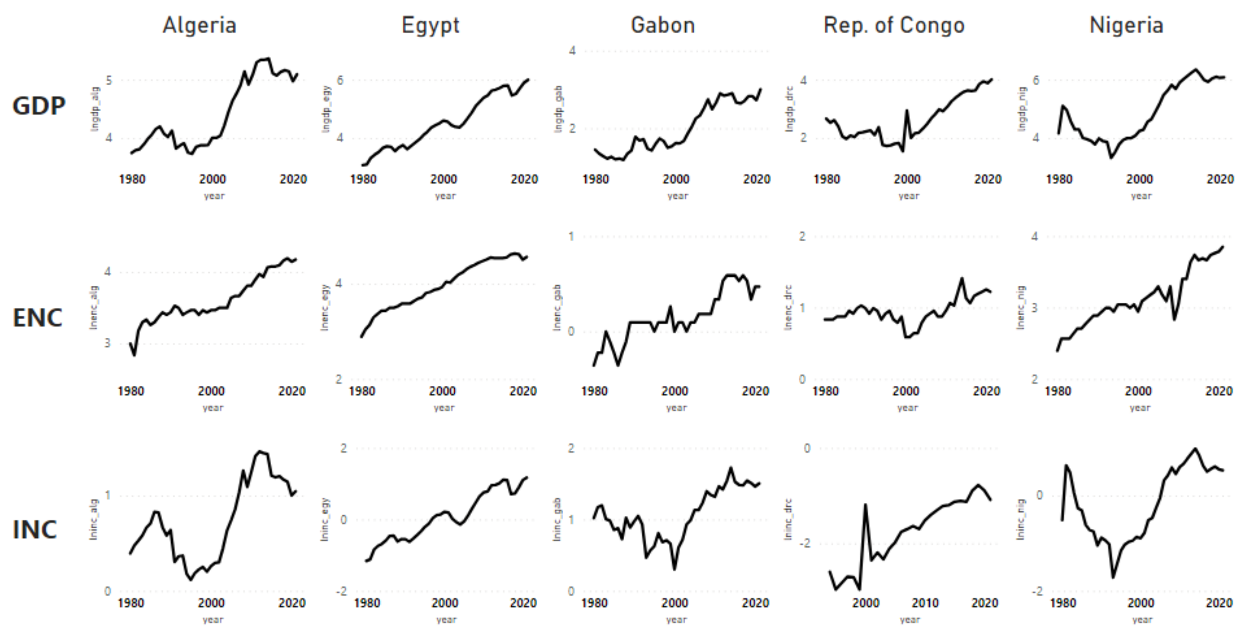

Figure 1: Visual overview of the series

The optimal lag orders (4, 6, 2, 8, and 4 lags) for Algeria, Egypt, Gabon, Nigeria, and DR Congo were determined using the Akaike's Information Criterion (AIC), Schwarz's Bayesian Information Criterion (SBIC), and Hannan and Quinn's Information Criterion (HQIC).

3.1 The Vector Auto-Regressive (VAR) and Vector Error Correction (VEC) models

In the Algerian model (refer to Appendix 1 for details), the lnenc equation is mainly influenced by the previous year's ENC, ENC from two years ago, and income (INC), with effects of +37.93%, -60.81%, and +66.75%, respectively. In contrast, the lngdp equation relies heavily on the previous year's ENC, GDP from four years ago, and INC, showing effects of -71.96%, +54.51%, and +86.94%.

In the Egyptian model, the lnenc equation is primarily influenced by the recent past ENC, GDP from three years ago, and INC, with impacts of +90.99%, -57.28%, and +82.05%, respectively. Meanwhile, the lngdp equation is mainly influenced by GDP from six years ago, ENC from six years ago, and INC from five years ago, with effects of +87.67%, -122.52%, and -134.36%.

In the Gabonese model, previous deviations from long-term equilibrium are swiftly corrected in the current period, with adjustment speeds of 41.75% for lnenc and 15.75% for lngdp.

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Similarly, in the Nigerian model, disparities from equilibrium in previous periods are efficiently addressed in the current period, with adjustment rates of 224.42% for lnenc and 7.39% for lngdp.

The Congolese model demonstrates a similar tendency to resolve deviations from long-term equilibrium in earlier periods, with adjustment speeds of 194.82% for lnenc and 200.52% for lngdp.

Furthermore, findings from serial correlation assessments, conducted using Lagrange Residual Error (LRE) statistics and Rao F-tests (refer to appendix 2 for details), indicate that residual patterns in most models do not exhibit significant serial correlation. It is noteworthy that weak serial correlation at the 0.1 level was observed in the first lag of the Algerian VAR model, while a significant instance at the 0.1 level emerged in the seventh lag of the Nigerian system. Overall, all models exhibit error distributions consistent with a normal distribution.

3.2 Granger Causality Test

The Algerian and Egyptian systems can only be evaluated for short-run and joint causal relationships as the VAR model was specified for them. The Gabonese, Nigerian, and DR Congo systems are however evaluated for short-run, joint, and long-run causal relationships.

Examining the causal relationships between energy consumption, economic growth, and income across different economies provides valuable insights. This study compares five oil-exporting countries—Algeria, Egypt, Gabon, Nigeria, and Congo—to reveal complex causal dynamics and their implications.

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Table 3: Granger Causality Tests

Cross-Section	Causation Source	Dependent Variable lnenc	Dependent Variable lngdp
Short-run			
Algeria	lnenc		6.022
	lngdp	8.299*	
	lninc	4.42	6.53
Egypt	lnenc		6.454
	lngdp	8.687	
	lninc	10.064	9.329
Gabon	lnenc		5.755**
	lngdp	2.592	
	lninc	1.431	0.253
Nigeria	lnenc		3.513**
	lngdp	12.228*	
	lninc	12.808*	3.456
DR Congo	lnenc		2.654
	lngdp	6.321*	
	lninc	7.515*	6.463*
Joint			
Algeria	lnenc/lninc		1.034
	lngdp/lninc	0.646	
Egypt	lnenc/lninc		0.504
	lngdp/lninc	0.386	
Gabon	lnenc/lninc		5.764*
	lngdp/lninc	2.856	
Nigeria	lnenc/lninc		5.973
	lngdp/lninc	20.805	
DR Congo	lnenc/lninc		7.544
	lngdp/lninc	16.529**	
Long-run			
Gabon	ECT	-3.074***	-0.791
Nigeria	ECT	-3.262***	-0.058
DR Congo	ECT	-4.762***	1.62

***, **, * represents significance at 1%, 5%, and 10% levels respectively.

The analysis of the Algerian model reveals that ENC is significantly influenced by lagged ENC, ENC from two years prior, and INC, demonstrating varying positive and negative effects. Similarly, GDP shows strong dependencies on previous ENC, GDP from four years ago, and INC. They align with previous research indicating a one-way causal relationship from GDP to ENC, emphasizing the impact of economic growth on energy use (Elbadri et al., 2023; Chekouri et al., 2021). However, the short-term perspective shows no significant causal effects, diverging from the findings of Hassoun et al. (2018) which shows a bidirectional causality between carbon emission and GDP. This highlights a modest yet noticeable one-way causal link from GDP to ENC, suggesting a relatively independent relationship when considering INC. Additionally, the unidirectional link from ENC to GDP in the long run aligns with the findings of Amri (2017).

The findings in the Egyptian system indicate no causal relationship between ENC and GDP, supporting the neutrality hypothesis. This aligns with Sharaf (2016), who found no causality between total primary energy consumption and economic growth from 1980 to 2012 but contrasts with Sharaf's findings of unidirectional causality from economic growth to electricity and oil consumption, supporting the conservation hypothesis. Additionally, this result contrasts with Sadraoui et al. (2019), who indicated a positive impact of energy consumption on economic growth in the MENA region. Furthermore, the findings differ from Ibrahiem (2018), who provided evidence of bidirectional short-run causality between road energy consumption and economic growth in Egypt, highlighting the mixed findings in this area.

In contrast, the Gabonese context presents a different scenario. A significant causal effect emerges from ENC on the GDP equation, which aligns with previous research suggesting a positive impact of energy consumption on economic growth, known as the growth hypothesis (Zerbo, 2017; Khobai & Le Roux, 2018; Awodumi & Adewuyi, 2020). Specifically, the Granger causality test results indicate a unidirectional causality flowing from energy consumption to economic growth in the long run, supporting the notion that energy consumption boosts economic growth in Gabon (Zerbo, 2017). Additionally, a weak joint causal effect is observed from ENC and income (INC) on the GDP equation, emphasizing a robust long-term impact of ENC on GDP (Awodumi & Adewuyi, 2020). This dynamic suggests a short-term influence of ENC on GDP, with the long-term indicating a more substantial effect on economic growth in Gabon.

In the Nigerian context, the short-term analysis reveals weak causal effects from GDP and income on energy consumption (ENC), alongside a significant causal effect from ENC on GDP. This finding aligns with previous research suggesting a one-way causality from ENC to GDP (Birnintsaba et al., 2021; Ekeocha et al., 2020; Chinedu et al., 2019; Nathaniel & Bekun, 2021).

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However, the long-term analysis shows a strong causal effect from economic growth on ENC, highlighting the enduring impact of GDP on energy consumption in Nigeria. This supports findings by Umeji et al. (2023), who identified a bi-directional relationship between renewable energy consumption and economic growth. Additionally, the findings align with Tijani et al. (2023), who noted that energy consumption, particularly from fossil fuels, contributes to increased energy-related emissions, negatively impacting environmental quality and sustainable economic growth. The finding also aligns with Olayungbo et al. (2022) who demonstrated a causal relationship between energy consumption and economic growth, supporting the environmental Kuznets curve hypothesis in Nigeria, where emissions decrease as the economy grows.

In the Congolese context, the short-term analysis reveals no significant causal effects, indicating a complex interaction of factors that do not immediately show causal connections. This finding aligns with Sunde (2020), where weak causal effects from GDP and income (INC) on energy consumption (ENC) and a minor causal relationship from ENC on GDP were observed. However, the robust joint and long-term causal effect on the ENC equation observed in this study is consistent with earlier research by Merlin and Chen (2021). Additionally, Félix et al. (2022) confirm a Granger causal relationship between economic growth and energy consumption, suggesting economic growth significantly increases energy consumption in the CEMAC zone, including DR Congo. This finding aligns with the unidirectional causality from economic growth to energy consumption in DR Congo, as identified by Sunde (2020) and Omaye et al. (2022).

4.0 CONCLUSION AND RECOMMENDATIONS

This study highlights the relationship between energy consumption and economic growth in the presence of income in African oil-exporting countries. The findings reveal varying causal relationships across the countries, showing how energy availability, economic growth, and income levels interact differently. Technological innovation, energy-intensive industries, and sustainable development are identified as key drivers of economic growth, alongside industrialization's role in job creation, poverty reduction, and sustainable progress. Effective management of energy resources, diversification of energy sources, and sound political policies are crucial for balancing economic goals. In Algeria and Egypt, no significant causal relationship exists between GDP and energy consumption. Gabon displays a notable causal effect of energy consumption on GDP in

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both the short and long term. In Nigeria, energy consumption significantly affects GDP in the short term, while GDP influences energy consumption in the long term. Congo shows no short-term causal effects, but a significant long-term effect of GDP on energy consumption is evident, with income and GDP jointly influencing energy consumption.

Future research should focus on further exploring the complex relationships between energy consumption, economic growth, and income in African oil-exporting countries, particularly over extended periods and under varying economic conditions. It would be valuable to investigate the role of renewable energy sources and their potential long-term impact on economic growth, as well as to assess how technological advancements and energy efficiency improvements affect this dynamic. Additionally, future studies could benefit from incorporating more advanced econometric techniques to capture the nuances of energy-economy interactions in different sectors. Cross-country comparisons, taking into account differences in energy policies, infrastructure, and development stages, could also provide deeper insights into the factors influencing energy-led growth in these economies. Lastly, future research should examine the socio-environmental impacts of energy consumption, particularly in the context of climate change and sustainable development.

5.0 LIMITATION OF THE STUDY

The findings of the study are subject to certain limitations. Primarily, the analysis is constrained by the quality of data on energy consumption, income, and GDP for the oil-exporting African nations. Additionally, while the study focuses on key economic variables, other potential factors—such as political stability, environmental impacts, and technological advancements—are not included in this analysis but may influence the relationship between energy use and economic growth. Future research could address these aspects to provide a more comprehensive understanding of the dynamics in this context.

REFERENCES

Abbasian, E. & Manochehri, S., 2023. The Nexus between Energy Consumption Shocks and Economic Growth: Using BVAR Approach. *Tehnički glasnik,* 17(1), pp. 14-19.

Adeleye, B., Osabohien, R., Lawal, A. & De Alwis, T., 2021. Energy use and the role of per capita income on carbon emissions in African countries. *Plos one,* 16(11), p. e0259488.

ISSN NUMBER: 1116-249X

Afia, N., 2019. The relationship between energy consumption, economic growth and happiness. *Journal of Economic Development,* 44(3), pp. 41-57.

Ali, W., Nathaniel, S., Adekunle, I. & Kumar, B., 2022. Energy consumption and economic growth linkage: global evidence from symmetric and asymmetric simulations. *Quaestiones Geographicae,* 41(2), pp. 67-82.

Amri, F., 2017. The relationship amongst energy consumption (renewable and non-renewable), and GDP in Algeria. *Renewable and Sustainable Energy Reviews,* Volume 76, pp. 62-71.

Awodumi, O. & Adewuyi, A., 2020. The role of non-renewable energy consumption in economic growth and carbon emission: Evidence from oil producing economies in Africa. *Energy Strategy Reviews,* Volume 27, p. 100434.

Babuga, U. & Ahmad, M., 2022. Oil price change and economic growth: evidence from net Sub-Saharan Africa oil exporting countries. *International Journal of Energy Economics and Policy,* 12(2), pp. 369-378.

Benali, M. & Benabbou, L., 2023. Carbon emissions, energy consumption, and economic growth in Morocco. *International Journal of Energy Economics and Policy,* 13(4), pp. 61-67.

Birnintsaba, D., Ozdeser, H. & Saliminezhad, A., 2021. Impact analysis on the effective synergy between climate change, ecological degradation and energy consumption on economic growth in Nigeria. *SAGE Open,* 11(4), p. 21582440211061361.

Chekouri, S., Chibi, A. & Benbouziane, M., 2021. Economic growth, carbon dioxide emissions and energy consumption in Algeria: a wavelet coherence approach. *World Journal of Science, Technology and Sustainable Development,* 18(2), pp. 172-189.

Chinedu, U. A., Daniel, O. C. & Ezekwe, U. C., 2019. Impact of Energy Consumption on Economic Growth in Nigeria: An Approach of Time Series Econometric Model. *International Journal of Academic Research in Economics and Managment and Sciences,* 8(2), p. 65–77.

Doğanalp, N., Ozsolak, B. & Aslan, A., 2021. The effects of energy poverty on economic growth: a panel data analysis for BRICS countries. *Environmental Science and Pollution Research,* 28(36), pp. 50167-50178.

Doğan, B. & Değer, O., 2018. The role of economic growth and energy consumption on CO 2 emissions in E7 countries. *Theoretical & Applied Economics,* 25(2).

Eagle, B., 2017. Oil price volatility and macroeconomy: Tales from top two oil producing economies in Africa. *Journal of Economic & Financial Studies,* 5(4), pp. 45-55.

ISSN NUMBER: 1116-249X

Ehigiamusoe, K. & Lean, H., 2019. Effects of energy consumption, economic growth, and financial development on carbon emissions: evidence from heterogeneous income groups. *Environmental Science and Pollution Research,* 26(22), pp. 22611-22624.

Ekeocha, P., Penzin, D. & Ogbuabor, J., 2020. Energy consumption and economic growth in nigeria: A test of alternative specifications. *International Journal of Energy Economics and Policy,* 10(3), pp. 369-379.

Elbadri, M., Bsikre, S., Alamari, O. & Balcilar, M., 2023. Nexus between renewable energy consumption, economic growth, and CO2 emissions in Algeria: New evidence from the Fourier-Bootstrap ARDL approach. *Natural Resources Forum,Oxford, UK: Blackwell Publishing Ltd,* 47(3), pp. 393-412.

Félix, M., Nziengui, M. & Didier, M., 2022. Economic Growth and Energy Consumption in the CEMAC Zone. *Theoretical Economics Letters*, 12(6), pp. 1693-1709.

Fraz, T., 2022. Exploring the relationship between energy consumption and economic growth in lower middle and high income economies using panel data techniques. *International Journal of Energy Economics and Policy,* 12(3), pp. 50-56.

Fuinhas, J., Koengkan, M. & de Barros Santiago, R., 2023. Renewable Energy Consumption and Economic Growth. *Sustainability,* 15(6), p. 5260.

Gao, Y., Yuan, R. & Zheng, S., 2022. Effects of Human Capital on Energy Consumption: The Role of Income Inequality. *International Journal of Environmental Research and Public Health,* 19(24), p. 17005.

Gkergki, A., 2020. The relationship between energy consumption and economic growth: New evidence from Greece. *Economics and Policy of Energy and Environment,* Issue 2, pp. 131-153.

Hassoun, S., Mékidiche, M. & Guellil, M., 2018. Examining the connection amongst renewable energy, economic growth and carbon dioxide emissions in Algeria. *EKOIST Journal of Econometrics and Statistics,* 14(29), pp. 199-223.

Ibrahiem, D., 2018. Road energy consumption, economic growth, population and urbanization in Egypt: cointegration and causality analysis. *Environment, Development and Sustainability,* Volume 20, pp. 1053-1066.

Jakovac, P., 2018. *Causality between energy consumption and economic growth: Literature review.* Istanbul, 5th International Conference on Education and Social Sciences.

Khobai, H. & Le Roux, P., 2018. Does renewable energy consumption drive economic growth: Evidence from granger-causality technique. *International Journal of Energy Economics and Policy,* 8(2), pp. 205-212.

ISSN NUMBER: 1116-249X

Merlin, M. & Chen, Y., 2021. Analysis of the factors affecting electricity consumption in DR Congo using fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS) and canonical cointegrating regression (CCR) estimation approach. *Energy,* p. doi.org/10.1016/j.energy.2021.121025.

Nathaniel, S. & Bekun, F., 2021. Electricity consumption, urbanization, and economic growth in Nigeria: New insights from combined cointegration amidst structural breaks. *Journal of Public Affairs,* 21(1), p. e2102.

Nkire, N., Akomolafe, J. & Aiyegbusi, O., 2023. *Capital Inflows, Institutional Quality and Economic Growth: Empirical Evidence From Oil Exporting African Countries.* [Online] Available at: https://www.researchsquare.com/article/rs-1962016/v1 [Accessed 24 June 2024].

Ogunsola, A. & Tipoy, C., 2022. Determinants of energy consumption: The case of African oil exporting countries. *Cogent Economics & Finance,* 10(1), p. 2058157.

Olayungbo, D. O., Faiyetole, A. A. & Olayungbo, A. A., 2022. Economic Growth, Energy Consumption, and Carbon Emissions: The Case of Nigeria. In: *Handbook of Research on Energy and Environmental Finance 4.0.* s.l.:IGI Global, p. 18.

Omaye, S., Sa'ad, S., Hamma Adama, A. & Dotti, R., 2022. Energy consumption, economic growth and energy transition in Africa: A cross-sectional dependence analysis. *OPEC Energy Review,* 46(4), pp. 502-514.

Omojolaibi, J. & Egwaikhide, F., 2014. Oil price volatility, fiscal policy and economic growth: a panel vector autoregressive (PVAR) analysis of some selected oil-exporting A frican countries. *OPEC Energy Review,* 38(2), pp. 127-148.

Osintseva, M., 2022. Influence of oil factor on economic growth in oil-exporting countries. *International Journal of Energy Economics and Policy,* 12(1), pp. 217-224.

Sadraoui, T., Hamlaoui, H., Youness, Z. & Sadok, B., 2019. A dynamic panel data analysis for relationship between energy consumption, financial development and economic growth. *International Journal of Econometrics and Financial Management,* 7(1), p. 2.

Sharaf, M., 2016. Energy consumption and economic growth in Egypt: A disaggregated causality analysis with structural breaks. *Energy,* Volume 9, pp. 1-2016.

Sulong, Z. & Farouq, I., 2021. Energy-Finance Nexus: Evidence from African Oil Exporting Countries. *International Energy Journal,* Volume 21, pp. 171-181.

Sunde, T., 2020. Energy Consumption and Economic Growth Modelling in SADC Countries: An Application of the VAR Granger Causality Analysis. *International Journal of Energy Technology and Policy,* p. doi.org/10.1504/ijetp.2020.103846.

ISSN NUMBER: 1116-249X

Tijani, D., Adeyinka, O. & Michael, D., 2023. Nexus of energy efficiency, carbon emission and economic growth in Nigeria. *Jurnal Perspektif Pembiayaan Dan Pembangunan Daerah,* 10(6), pp. 363-378.

Topolewski, Ł., 2021. Relationship between energy consumption and economic growth in European countries: Evidence from dynamic panel data analysis. *Energies,* 14(12), p. 3565.

Uçan, O., Budak, H. & Aktekin, E., 2022. Analysis of relationship between economic growth and energy consumption in developed countries. *Journal of Human, Earth, and Future,* 3(1), pp. 82-89.

Umeji, G. et al., 2023. Renewable Energy Consumption and Economic Growth in Nigeria. *African Journal of Social Sciences and Humanities Research,* 6(1), pp. 34-48.

Zerbo, E., 2017. Energy consumption and economic growth in Sub-Saharan African countries: Further evidence. *Economics Bulletin,* 37(3), pp. 1720-1744.

APPENDICES

Appendix 1: Model Equations

Algeria (VAR):

$$lnenc_{i,t} = 0.2906 + 0.3793lnenc_{i,t-1} + 0.1225lnenc_{i,t-2} - 0.0591lnenc_{i,t-3} + 0.2388lnenc_{i,t-4}$$

(0.1438) (0.1716) (0.1754) (0.1149)
(0.0990)

$$+0.4782lngdp_{i,t-1} - 0.6081lngdp_{i,t-2} + 0.4714lngdp_{i,t-3} + 0.1300lngdp_{i,t-4}$$

(0.2311) (0.3106) (0.3117)
(0.2202)

$$-0.3826lninc_{i,t-1} + 0.6675lninc_{i,t-2} - 0.5396lninc_{i,t-3} + 0.2193lninc_{i,t-4}$$

(0.2559) (0.3403) (0.3350)
(0.2363)

$$lngdp_{i,t} = -0.6739 - 0.7196lnenc_{i,t-1} + 1.0049lnenc_{i,t-2} - 0.3170lnenc_{i,t-3} - 0.2598lnenc_{i,t-4}$$

(0.4504) (0.5374) (0.5491) (0.3597)
(0.3098)

$$+1.0419lngdp_{i,t-1} - 0.0468lngdp_{i,t-2} - 0.0441lngdp_{i,t-3} + 0.5451lngdp_{i,t-4}$$

(0.7235) (0.9725) (0.9760) (0.6897)

$$-0.2149lninc_{i,t-1} + 0.1104lninc_{i,t-2} + 0.3907lninc_{i,t-3} - 0.8694lninc_{i,t-4}$$

(0.8014) (1.0656) (1.0489) (0.7398)

Egypt (VAR):

$$lnenc_{i,t} = 2.1296 + 0.9099lnenc_{i,t-1} + 0.0731lnenc_{i,t-2} + 0.2673lnenc_{i,t-3} + 0.3147lnenc_{i,t-4}$$

(0.9987) (0.2667) (0.3633) (0.3725) (0.3595)

$$-0.0804lnenc_{i,t-5} - 0.1751lnenc_{i,t-6} - 0.0697lngdp_{i,t-1} - 0.3455lngdp_{i,t-2}$$

(0.3087) (0.2364) (0.3622) (0.3329)

$$-0.5728lngdp_{i,t-3} + 0.2919lngdp_{i,t-4} - 0.4591lngdp_{i,t-5} + 0.4051lngdp_{i,t-6}$$

(0.3524) (0.3537) (0.3779) (0.3662)

$$+0.1445lninc_{i,t-1} + 0.1870lninc_{i,t-2} + 0.8205lninc_{i,t-3} - 0.5522lninc_{i,t-4}$$

(0.3662) (0.3246) (0.3632) (0.3901)

$$+0.4190lninc_{i,t-5} - 0.2490lninc_{i,t-6}$$

(0.3920) (0.3446)

$$lngdp_{i,t} = -4.4151 - 0.7624lnenc_{i,t-1} + 2.0421lnenc_{i,t-2} - 0.7684lnenc_{i,t-3} - 0.7847lnenc_{i,t-4}$$

(2.4938) (0.6660) (0.9072) (0.9302) (0.8978)

$$-0.4985lnenc_{i,t-5} + 0.8767lnenc_{i,t-6} + 1.1851lngdp_{i,t-1} + 0.8483lngdp_{i,t-2}$$

(0.7708) (0.5904) (0.9044) (0.8313)

$$-0.6989lngdp_{i,t-3} + 0.7628lngdp_{i,t-4} - 1.0481lngdp_{i,t-5} - 1.2252lngdp_{i,t-6}$$

(0.8800) (0.8831) (0.9437) (0.9145)

$$-0.2477lninc_{i,t-1} - 1.0242lninc_{i,t-2} + 0.6646lninc_{i,t-3} - 0.6358lninc_{i,t-4}$$

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(0.9146) (0.8106) (0.9070)
(0.9742)

$$-1.3436 lninc_{i,t-5} + 1.2456 lninc_{i,t-6}$$

(0.9789) (0.8605)

Gabon (VEC):

$$\Delta lnenc_{i,t} = 0.0235 - 0.4175 ECT_{i,t-1} - 0.0345 \Delta \text{lnenc}_{i,t-1} - 0.2168 \Delta \text{lngdp}_{i,t-1} + 0.1340 \Delta \text{lninc}_{i,t-1}$$

(0.0158) (0.1992) (0.1572) (0.1347)
(0.1120)

$$\Delta lngdp_{i,t} = 0.0293 - 0.1575 ECT_{i,t-1} + 0.5531 \Delta \text{lnenc}_{i,t-1} + 0.0502 \Delta \text{lngdp}_{i,t-1} - 0.0826 \Delta \text{lninc}_{i,t-1}$$

(0.0232) (0.1992) (0.2305) (0.1975)
(0.1643)

$$ECT_{i,t-1} = \Delta \text{lnenc}_{i,t-1} - 0.5292 \Delta \text{lngdp}_{i,t-1} + 0.2990 lninc_{i,t-1} + 0.5784$$

Nigeria (VEC):

$$\Delta lnenc_{i,t} = 0.1661 - 2.2442 ECT_{i,t-1} + 1.2063 \Delta \text{lnenc}_{i,t-1} + 1.1060 \Delta \text{lnenc}_{i,t-2} + 1.3425 \Delta \text{lnenc}_{i,t-3}$$

(0.0671) (0.6879) (0.5512) (0.4362)
(0.3832)

$$+1.0886 \Delta \text{lnenc}_{i,t-4} + 0.7623 \Delta \text{lnenc}_{i,t-5} + 0.5695 \Delta \text{lnenc}_{i,t-6} + 0.2563 \Delta \text{lnenc}_{i,t-7}$$

(0.4415) (0.4570) (0.3797) (0.2375)

$$-2.3114 \Delta \text{lngdp}_{i,t-1} - 1.5796 \Delta \text{lngdp}_{i,t-2} - 0.8883 \Delta \text{lngdp}_{i,t-3} - 1.2324 \Delta \text{lngdp}_{i,t-4}$$

(0.8074) (0.6541) (0.6070) (0.6336)

$$-1.9105 \Delta \text{lngdp}_{i,t-5} - 2.2793 \Delta \text{lngdp}_{i,t-6} - 1.9192 \Delta \text{lngdp}_{i,t-7} + 2.2978 \Delta \text{lninc}_{i,t-1}$$

(0.7862) (0.8521) (0.6627) (0.8013)

$$+1.4509 \Delta \text{lninc}_{i,t-2} + 0.5816 \Delta \text{lninc}_{i,t-3} + 0.9863 \Delta \text{lninc}_{i,t-4} + 1.6565 \Delta \text{lninc}_{i,t-5}$$

(0.6098) (0.5427) (0.5562) (0.6610)

$$+1.8324 \Delta \text{lninc}_{i,t-6} + 1.6288 \Delta \text{lninc}_{i,t-7}$$

(0.6716) (0.5568)

$$\Delta lngdp_{i,t} = 0.0639 - 0.0739 ECT_{i,t-1} - 0.2152 \Delta \text{lnenc}_{i,t-1} - 0.0920 \Delta \text{lnenc}_{i,t-2} + 0.3270 \Delta \text{lnenc}_{i,t-3}$$

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(0.1240) (1.2719) (1.0190) (0.8064)
(0.7084)

$$-0.4091\Delta\text{lnenc}_{i,t-4} - 0.4903\Delta\text{lnenc}_{i,t-5} - 0.2588\Delta\text{lnenc}_{i,t-6} + 0.2157\Delta\text{lnenc}_{i,t-7}$$

(0.8162) (0.8449) (0.7019) (0.4392)

$$+0.6646\Delta\text{lngdp}_{i,t-1} + 0.3166\Delta\text{lngdp}_{i,t-2} - 0.7425\Delta\text{lngdp}_{i,t-3} - 0.9773\Delta\text{lngdp}_{i,t-4}$$

(1.4927) (1.2093) (1.1223) (1.1714)

$$+0.8597\Delta\text{lngdp}_{i,t-5} + 0.1099\Delta\text{lngdp}_{i,t-6} + 0.6287\Delta\text{lngdp}_{i,t-7} - 0.4487\Delta\text{lninc}_{i,t-1}$$

(1.4536) (1.5753) (1.2252) (1.4814)

$$-0.1141\Delta\text{lninc}_{i,t-2} + 0.3780\Delta\text{lninc}_{i,t-3} + 0.9713\Delta\text{lninc}_{i,t-4} - 0.5705\Delta\text{lninc}_{i,t-5}$$

(1.1274) (1.0033) (1.0282) (1.2220)

$$-0.1496\Delta\text{lninc}_{i,t-6} - 0.5339\Delta\text{lninc}_{i,t-7}$$

(1.2417) (1.0294)

$$ECT_{i,t-1} = \Delta\text{lnenc}_{i,t-1} - 1.4752\Delta\text{lngdp}_{i,t-1} + 1.5320 lninc_{i,t-1} + 4.3688$$

DR Congo (VEC):

$$\Delta lnenc_{i,t} = 0.0015 - 1.9482 ECT_{i,t-1} + 1.2145\Delta\text{lnenc}_{i,t-1} + 0.3678\Delta\text{lnenc}_{i,t-2} + 0.7796\Delta\text{lnenc}_{i,t-3}$$

(0.0279) (0.4091) (0.3043) (0.2809)
(0.2398)

$$-0.7988\Delta\text{lngdp}_{i,t-1} - 1.1461\Delta\text{lngdp}_{i,t-2} - 0.1203\Delta\text{lngdp}_{i,t-3} + 0.8260\Delta\text{lninc}_{i,t-1}$$

(0.5048) (0.4907) (0.2759) (0.4131)

$$+0.9942\Delta\text{lninc}_{i,t-2} + 0.1844\Delta\text{lninc}_{i,t-3}$$

(0.3930) (0.2183)

$$\Delta lngdp_{i,t} = 0.2644 + 2.0051 ECT_{i,t-1} - 0.3468\Delta\text{lnenc}_{i,t-1} - 0.1687\Delta\text{lnenc}_{i,t-2} - 1.0613\Delta\text{lnenc}_{i,t-3}$$

(0.0845) (1.2376) (0.9205) (0.8498)
(0.7254)

$$-1.8244\Delta\text{lngdp}_{i,t-1} + 2.1470\Delta\text{lngdp}_{i,t-2} - 0.4278\Delta\text{lngdp}_{i,t-3} + 0.6837\Delta\text{lninc}_{i,t-1}$$

(1.5271) (1.4844) (0.8347) (1.2496)

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$$-2.1787\Delta \text{lninc}_{i,t-2} - 0.0674\Delta \text{lninc}_{i,t-3}$$

(1.1887) (0.6603)

$$ECT_{i,t-1} = \Delta \text{lnenc}_{i,t-1} - 0.9951\Delta \text{lngdp}_{i,t-1} + 0.8890 inc_{i,t-1} + 3.4255$$

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Appendix 2: Model Diagnostics

Serial Correlation Test

Cross-Section	Lag	LRE Stat	Rao F-test
Algeria	1	16.151*	1.962*
	2	12.035	1.403
	3	9.859	1.125
	4	10.754	1.238
Egypt	1	14.067	1.743
	2	12.709	1.541
	3	5.718	0.620
	4	6.249	0.683
	5	8.498	0.963
	6	10.388	1.213
Gabon	1	6.472	0.716
Nigeria	1	6.245	0.669
	2	9.936	1.186
	3	14.571	2.002
	4	11.667	1.467
	5	4.239	0.429
	6	9.139	1.065
	7	18.602*	2.903*
DR Congo	1	4.323	0.448
	2	9.687	1.135
	3	8.976	1.034
	4	4.133	0.427

Jarque-Bera Normality Test

Cross-Section	Equation	Chi-Square	df
Algeria	ENC	0.009(0.923)	1
	GDP	2.338(0.126)	1
Egypt	ENC	0.001(0.979)	1
	GDP	2.420(0.120)	1
Gabon	ENC	0.071(0.790)	1
	GDP	1.628(0.202)	1
Nigeria	ENC	0.514(0.473)	1
	GDP	0.030(0.654)	1
DR Congo	ENC	0.034(0.853)	1
	GDP	0.000(0.997)	1

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