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Determinants of Energy Consumption in Kenya: A Macroeconomic Perspective

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Abstract

To achieve reliable and sustainable energy access in Kenya, it is crucial to explore alternatives to traditional biomass and fossil fuels to address the challenges of limited electricity, affordable and clean cooking energy. Using the Autoregressive Distributed Lag (ARDL) technique, this study assessed macroeconomic factors affecting energy consumption in Kenya from 1980 to 2024. The results indicate that interest rates ($\beta = -0.034$, $p = 0.038$) and trade openness ($\beta = -0.015$, $p = 0.006$) negatively impact energy consumption, while foreign direct investment (FDI) has a positive effect ($\beta = 0.020$, $p = 0.029$). Economic growth and inflation were found to be statistically insignificant. Short-term energy consumption is characterised by inertia, driven by the immediate effects of interest rate fluctuations and trade liberalisation. Initially, FDI seems to reduce energy use due to project delays. The study concludes that structural and external factors—specifically FDI, interest rates, and trade openness—play a more significant role in energy consumption than economic growth or inflation. Recommendations include promoting energy-efficient investments through green FDI and aligning monetary policy with energy objectives.

Keywords: *Energy Consumption, Macroeconomy, ARDL*

1 Introduction

Energy consumption is a key driver of economic productivity and development worldwide. As global economies expand, energy demand continues to rise, shaping investment flows, industrial growth, and technological advancement. Access to energy power industries drives technological advancements and enhances the quality of life across various sectors, ultimately contributing to increased productivity, job creation, and improved healthcare and education (Stern, 2019; IEA, 2024). The International Energy Agency (IEA) reports that global energy consumption has more than doubled since 1980, from approximately 283 exajoules (EJ) in 1980 to over 620 EJ in 2022, with demand increasingly influenced by emerging economies, industrialisation, and shifts toward more energy-intensive production systems (IEA, 2024). This growth reflects rising incomes and access to modern energy, particularly in developing countries.

The dynamics of energy consumption are influenced not only by supply-side factors such as resource availability and technology but also by socioeconomic variables that determine demand conditions, affordability, and investment flows (Omri & Kahouli, 2018; Otieno, 2022). Excessive volatility in macroeconomic conditions, such as spikes in inflation, rising interest rates, or fluctuating trade flows, can introduce uncertainty, reduce affordability, and disrupt both consumption and investment in the energy sector (Maliketal., 2014; Mehrara & Rezaei, 2015). Conversely, favourable macroeconomic environments foster efficiency, access, and sustainability (Owiro *et al.*, 2021; Gajdzik et al., 2024).

In Kenya, energy consumption has steadily increased over the past four decades, reflecting the country's efforts toward industrialisation, urbanisation, and economic transformation (Waweru, 2022). The observed growth in energy consumption, rising from 0.084 BTU qn (1987) to 0.304 BTU qn (2023), signals an increasing reliance on electricity, petroleum products, and renewable sources to power industrial, infrastructural, and residential sectors (IEA, 2024). Petroleum products remain a dominant source of energy for transport and industry, accounting for nearly 25% of the national energy balance. Meanwhile, traditional biomass still contributes close to 55% of total final energy consumption, reflecting persistent energy poverty in rural and peri-urban areas (IEA, 2024). The increase is also mirrored by a surge in electricity generation capacity, major renewable energy projects such as geothermal plants in Olkaria and wind farms in Turkana, and broader access to off-grid solutions. Kenya's installed geothermal capacity is approximately 943.7 MW, and it is set to add 1,500 MW of green energy capacity by 2034 (including about 800 MW from geothermal sources) (World Bank, 2023). However, this growth faces challenges, including energy poverty, macroeconomic constraints, and infrastructural limitations (Smith & Jones, 2021). As Kenya strives to achieve SDG 7 (affordable and clean energy), understanding what drives this upward trend in energy demand is essential (Khan *et al.*, 2019).

The surge has been exacerbated by various macroeconomic variables such as economic growth, inflation rate, interest rates, trade openness, and foreign direct investment, which significantly impact energy consumption patterns (IEA, 2024). Kenya's energy policies are guided by long-term national development frameworks such as Vision 2030 and the National Energy Policy, which emphasise universal access, diversification of energy sources, and expansion of renewable energy. Nevertheless, the sector continues to face challenges, including high system losses (above 20%), rising tariffs, inadequate financing for large projects, and heavy reliance on hydropower during dry periods (EPRA, 2025). The result has been a shift toward renewable energy sources, including solar, wind power, and hydroelectric power. Developed countries, driven by environmental policies and technological innovations, are increasingly investing in renewable energy, which impacts global energy markets and consumption trends (IRENA, 2023). Developing countries still lag in the transition to renewable energy due to economic constraints and infrastructural limitations (Smith & Jones, 2021).

The absence of thorough research and data-driven policies makes Kenya's efforts to achieve SDG 7 more challenging. While research on energy consumption is robust, prior analyses have often failed to address how macroeconomic factors specifically shape and determine long-term consumption patterns. Without understanding these factors, policymakers might struggle to create strategies that successfully strike a balance between sustainability and development. Therefore, an in-depth analysis is essential to bridge this knowledge gap and support effective energy management and policy planning. Thus, examining the effect of selected macroeconomic variables on energy consumption in Kenya is essential for informing policy interventions aimed at achieving sustainable energy development, economic resilience, and inclusive growth. The study answers the following questions: **(RQ1)** How do inflation rate and interest rate impact energy consumption in Kenya? **(RQ2)** How does economic growth influence Kenya's energy consumption? **(RQ3)** How do trade openness and foreign direct investment affect the country's energy use? This study makes several critical contributions to the literature on energy sustainability.

2. Literature Review

The study is framed by the Ecological Modernisation Theory (EMT), first introduced by Joseph Huber (early 1980s) and further elaborated upon by subsequent academics, notably Mol and Spaargaren. The theory posits that economic growth can influence sustainable energy consumption if modern institutions, markets, and technologies are leveraged effectively (Mol & Spaargaren, 2000). EMT suggests that macroeconomic progress like FDI and trade openness can drive cleaner energy consumption and energy efficiency, especially in developing countries, through innovation and regulatory reforms (Huber, 1982; Gajdzik et al., 2024). As economies grow and integrate into global markets, they adopt advanced technologies and environmental standards, leading to more sustainable energy consumption patterns. In the Kenyan context, EMT suggests that macroeconomic growth, if strategically managed, can stimulate a shift toward renewable energy sources and improve energy infrastructure through international collaboration and environmentally conscious investments. Thus, EMT supports the idea that when aligned with environmental policies, economic progress can drive a decoupling of energy consumption from environmental degradation, offering a viable pathway toward sustainable development. Dependency theory asserts that developing nations, including Kenya, are often in subordinate positions in the global economic system, which affects their access to affordable and sustainable energy solutions. For instance, the energy price in Kenya is primarily influenced by the worldwide energy market and foreign direct investments, with energy infrastructure and technological solutions often imported from more developed nations (Gessi, 2024). This creates a dependency cycle, where Kenya's energy consumption patterns are shaped by external economic forces rather than internal factors alone (Cardoso & Faletto, 2024).

At the regional level, the energy sector is subject to compounding stress due to the concurrent processes of accelerated urbanisation and sustained industrial growth. The UN projects that Sub-Saharan Africa's population will double by 2050, with urban areas absorbing most of this growth (UNCTAD, 2021; Berahab, 2022). Urbanisation often increases demand for modern energy sources such as electricity, petroleum, and natural gas, while industrialisation raises energy intensity. Yet weak institutions, high borrowing costs, and limited foreign direct investment constrain the financing of new infrastructure. Cross-country evidence suggests that energy access remains highly unequal: while electrification rates surpass 80% in countries such as South Africa and Egypt, they remain below 50% in Nigeria and Tanzania (IEA, 2024).

The empirical research highlights the complex interactions between energy consumption, economic growth, and various influencing factors in different contexts. Sifuna (2019), Gisore (2017), and Sekrafi and Sghaier (2018) confirmed a bidirectional relationship between energy and growth in Kenya, but its timeframe misses recent energy developments. Mehrara and Rezaei (2015) found that inflation negatively impacts energy consumption in oil-exporting developing countries, aligning with findings from Jamil and Ahmad (2010) in Pakistan and Shahbaz and Lean (2012) in Tunisia, which emphasized that inflation hampers energy sector growth. Further studies, such as those by Akinlo (2008) and Esso (2010), indicate that high interest rates can reduce energy consumption in African economies, a trend also observed in Kenya. In contrast, Lee and Chang (2007) reported that Asian economies experience weaker effects due to structural reforms. Shahbaz et al. (2014) found that trade openness in Pakistan boosts energy consumption, with differences noted compared to Kenya's experience. Moreover, Shahbaz and Lean (2012) studied Tunisia and showed that financial development, alongside FDI, significantly affects energy consumption in the long run. Unlike the Gulf Cooperation Council (GCC) findings, Tunisia's results suggest that the effectiveness of FDI in promoting sustainable growth is contingent on broader institutional contexts, a situation that could benefit Kenya's emerging renewable energy sector if supported by appropriate financial and regulatory frameworks.

3. Methods

3.1 Data and Sources

This primary objective of this study is the analysis of the impact of macroeconomic factors on Kenyan energy consumption, utilising time-series data from 1980 through 2024. The dependent variable was total energy consumption, encompassing electricity, petroleum products, biomass, and renewable energy sources. The independent variables under investigation included economic growth (measured by GDP), inflation rate, interest rate, trade openness, and foreign direct investment (FDI). The study was confined to Kenya, providing a country-specific analysis that reflected the local economic structure, energy policies, and consumption behaviour. Annual time-series secondary data were sourced from reputable institutions such as the Kenya National Bureau of Statistics (KNBS) and the World Bank (World Development Indicators). Table 1 outlines the variables, their definitions, the measurement methods, the sources of data, and the expected sign.

Table 1: *Variable description and data source*

Variable	Measurement	Source	Expected sign
Economic growth (GDP)	GDP per capita growth (%)	World Bank	+
Inflation rate (INF)	Consumer prices (%)	World Bank	-
Trade openness (TOP)	Trade (% of GDP)	KNBS	+
Interest rate (RI)	Real interest rate (%)	World Bank	-
Foreign direct investment (FDI)	FDI, net inflows (% of GDP)	World Bank	+
Energy consumption (ENC)	Total energy consumption (kWh)	KNBS	Dependent variable

***Source**: Authors' conceptualization*

3.2 Model Specification and Estimation

Informed by the empirical studies of Sifuna (2019) and Omri and Kahouli (2014), the study adopted the ARDL model to assess the influence of key macroeconomic indicators on Kenya's total energy consumption. Accordingly, the study specified the functional relationship as follows:

$$\text{ENC} = f\,(\,\text{GDP}, \text{INF}, \text{RI}, \text{TOP}, \text{FDI}\,) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

In this context, ENC stands for energy consumption, GDP refers to economic growth, INF denotes the inflation rate, RI represents the interest rate, TOP signifies trade openness, and FDI stands for foreign direct investment.
This functional form is expressed in the general linear model below:

$$\text{ENC}_t = \beta_0 + \beta_1\text{GDP}_t + \beta_2\text{INF}_t + \beta_3\text{RI}_t + \beta_4\text{TOP}_t + \beta_5\text{FDI}_t + \varepsilon t \ \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where:
ENC_trepresents the energy consumption at time t,
β_0 represents the intercept,
βi (for i=1,2,...,5) represents the coefficients of the respective independent variables at time t,
t denotes the period
εt represents the stochastic error term
The model, as specified by this equation, constituted the basis for the analysis of the dynamic and long-run interdependencies among macroeconomic factors and Kenyan energy consumption.

The study used the Autoregressive Distributed Lag (ARDL) model to analyse short-term and long-term correlations between macroeconomic factors and energy consumption patterns. Pesaran, Shin, and Smith (2001) developed the autoregressive distribution lag (ARDL), which illustrates the direction of causality between variables. The ARDL approach has the advantage of employing a single simplified equation. Time-series data can benefit from the ARDL model, especially if the variables show varying orders of integration, 1 (0), I (1), or a combination of both. The test of the current relationship between variables in levels will be relevant regardless of whether the underlying regressors are purely 1 (0), purely 1 (1), or a combination of both, as the ARDL model does not require pretexting (Pesaran, Shin, & Smith, 2001).

The representation of the general ARDL (p, q) model is:

$\nabla Y_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \sum_{j=0}^{q} \gamma_j \Delta X_{t-j} + \phi Y_{t-1} + \lambda X_{t-1} + \varepsilon_t$……………………...………… (3)

In analysing the dependent variable Y over time, several important components are considered. The change in Y at time t is represented as ∇Y_t, with α as the intercept establishing a baseline. Coefficients β_i capture the effects of lagged differences ΔY_(t-i), while p denotes the maximum lag length. The symbol Δ highlights short-run changes, and Φ indicates the speed of adjustment to long-run equilibrium. The lagged level Y_(t-1) reflects the long-term relationship for Y, while ʎ represents the lagged level of the independent variable X_(t-1). Lastly, ε_t is the error term at time t, accounting for unmeasured factors influencing the model.

The specific model is as follows:

$ENC_t = \alpha + \Sigma(i = 1\ to\ p)\beta iENC_t(t-i) + \Sigma(j = 0\ to\ q)\delta jGDP_t(t-j) + \Sigma(i = 1\ to\ r)\beta iRI_t(t-k) + \Sigma(k = 0\ to\ s)\theta kINF_t(t-l) + \Sigma(l = 0\ to\ t)\gamma lTOP_t(t-m) + \Sigma(m = 0\ to\ u)\lambda mFDI_t(t-n) + \varepsilon_t$…………………………………………………………… (4)

Where:
α = Constant term
βi,δj= Short-run coefficients
θk,γl,λm=Long run coefficients
p,q = Optimal lag orders determined by AIC/BIC criteria
ϵt = Error term

The F-Bounds testing methodology advanced by Pesaran, Shin, and Smith (2001) incorporates both I (0) and I (1) variables to investigate the long-run relationship. The choice of lag length in this study was crucial because too few lags omit essential information, while too many lags lead to overfitting and inefficiency. Lag length selection is the process of determining the optimal number of lagged values to include in a time series model, such as in Autoregressive (AR) models, Vector Autoregressive (VAR) models, or Error Correction Models (ECM) (Leites, Cerqueira, & Soares, 2024). Where variables in the study are found to be cointegrated, a dynamic unrestricted error correction model (UECM) will be derived from the ARDL to integrate the short-run dynamics with the long-run equilibrium (equation 5) to help correct deviations from equilibrium in time series data.

$$\Delta InENC_t = \alpha_1 + \Sigma_{\{i=1\}}^{\{p\}} \beta_i \Delta InENC_{\{t-i\}} + \Sigma_{\{j=0\}}^{\{q\ \}} \beta_{\{k\}} \Delta InGDP_{\{t-j\}} + \Sigma_{\{k=0\}}^{\{r\ \}} \beta_{\{l\}} \Delta InRI_{\{t-k\}} + \Sigma_{\{l=0\}}^{\{s\}} \beta_{\{m\}} \Delta InINF_{\{t-l\}} + \Sigma_{\{m=0\}}^{\{t\}} \beta_{\{n\}} \Delta InTOP_{\{t-m\}} + \Sigma_{\{n=0\}}^{\{u\}} \beta_{\{o\}} \Delta InFDI_{\{t-n\}} + \epsilon_{1t} \quad \text{......} \quad (5)$$

Where Δ is the first difference Operator, and ϵ_{1t} is the error term or disturbances.

Given the equation above, the F-Bounds procedure, using either the Standard Walt test or the F-statistic, was used to test for cointegration under the null hypothesis that no cointegration vector exists (i.e., βenc= βgdp = βinf =βri =βtop =βfdi= a =0 against the alternative hypothesis (i.e., βenc ≠ βgdp ≠ βinf ≠βri ≠βtop ≠ βfdi

Pesaran, Shin, and Smith (2001) state that in the F-Bounds test, cointegration is confirmed when the calculated F-statistic is above the upper critical bound. If the statistic is below the lower bound, no cointegration exists. If the statistic lies between the bounds, the outcome is inconclusive. Hence, antecedent information on the integration order of the variables would be needed in decision-making.

4 Empirical Results

4.1 Stationarity Test Results

In this study, the Phillips-Perron test was conducted at both levels, and the first difference is presented in Table 2.

Table 2: *Unit root test results*
Source: Authors' Compilation from E-Views

Level						
			Critical Values			
Variables	Mackinnon p-values	Test Statistic	1%	5%	10%	*Conclusion*
ENC	0.9389	-0.1356	-3.5885	-2.9297	-2.6030	*Unit root*
GDP	0.0003	-4.7886	-3.5885	-2.9297	-2.6030	*Stationary*
FDI	0.0001	-5.1573	-3.5885	-2.9297	-2.6030	*Stationary*
INF	0.0126	-3.4984	-3.5885	-2.9297	-2.6030	*Stationary*
RI	0.0002	-4.8709	-3.5885	-2.9297	-2.6030	*Stationary*
TOP	0.5608	-1.4129	-3.5885	-2.9297	-2.6030	*Unit root*
Difference						
ENC	0.0003	-4.8235	-3.5924	-2.9314	-2.6039	*Stationary*
GDP	0.0001	-18.5861	-3.5924	-2.9314	-2.6039	*Stationary*
FDI	0.0001	-22.9534	-3.5924	-2.9314	-2.6039	*Stationary*
INF	0.0000	-8.6849	-3.5924	-2.9314	-2.6039	*Stationary*
RI	0.0000	-10.7198	-3.5924	-2.9314	-2.6039	*Stationary*
TOP	0.0000	-7.1109	-3.5924	-2.9314	-2.6039	*Stationary*

Table 2 reports the results of the Phillips–Perron test, providing crucial information regarding the order of integration (stationarity) for the variables utilised in the study. At the level form, a mixed outcome is observed. Energy consumption (ENC) produced a MacKinnon p-value of 0.9389, which is well above the 5% significance threshold. In addition, its test statistic (−0.1356) is less negative than all the critical values at the 1%, 5%, and 10% levels. This indicates failure to reject the null hypothesis of a unit root, thereby confirming that ENC is non-stationary at the level. Similarly, trade openness (TOP) registered a p-value of 0.5608, also greater than the 5% significance level, and a test statistic (−1.4130) that is higher than the critical values. These results similarly suggest that TOP contains a unit root and is therefore non-stationary at the level. By contrast, gross domestic product (GDP), foreign direct investment (FDI), inflation (INF), and interest rate (RI) all demonstrated stationarity in their level forms. Once first differencing was applied, all variables, including ENC and TOP, became stationary. Hence, the dataset comprises a combination of I(0) and I(1) variables.

4.3 Selection of Optimal Lag Length

The procedural integrity of estimating ARDL models in time series econometrics fundamentally depends on accurately determining the optimal lag length. The choice of lag length significantly affects the explanatory power and validity of model results.

Table 3: *Lag selection criteria*

Lag	LL	LR	Df	P	FPE	AIC	HQIC	SBIC
0	-727.247				1.4e+08	35.7682	35.8595	36.0189
1	-630.527	193.44	36	0.000	7.3e+06*	32.8062	33.4454*	34.5616*
2	-593.665	92.248*	36	0.000	7.8e+06	32.237*	33.9513	36.0241

***Source**: Authors' Compilation from E-Views*

The optimal lag length for the ARDL model was determined using the Akaike Information Criterion (AIC), which minimises information loss while balancing model fit and complexity. As shown in Table 3, the AIC reached its lowest value at lag 2 (AIC = 32.237), which means that this is the most suitable lag for the analysis. Although other criteria, such as FPE, suggested shorter lag lengths (lag 1), the study prioritises AIC due to its ability to capture the dynamics of macroeconomic time series more flexibly, especially in moderate-sized samples (n < 60) (Liew, 2021).

4.4 Result of Cointegration Test

The ARDL F-Bounds Test was applied to determine the existence of a stable long-run relationship across the sample of macroeconomic variables.

Table 4: *F-bounds test*

	Critical Values (0.1-0.01), F-statistic, Case 3			F = 5.785, t = -2.527
	[I_0] [I_1] L_1 L_1	[I_0] [I_1] L_05 L_05	[I_0] [I_1] L_025 L_025	[I_0] [I_1] L_01 L_01
k_5	2.26 3.35	2.62 3.79	2.96 4.18	3.41 4.68

***Source**: Authors' Compilation from E-Views*

Table 4 presents the results of the F-Bounds test. The calculated F-statistic value was 5.785, the number of regressors in the long-run model was k = 5, and the model is estimated under Case 3 (unrestricted intercept and no trend), as specified in Bertsatos *et al.* (2022). Since the computed F-statistic of 5.785 exceeds the upper bound critical values at the 10%, 5%, 2.5%, and 1% levels, the study rejected the null hypothesis of no level relationship. Evidence of cointegration was detected, confirming a long-run relationship between the variables specified in the econometric framework.

4.5 ARDL Long- and Short-Run Results with Diagnostics

The cointegration analysis confirmed the presence of a long-run relationship among the selected variables and hence the use of the ARDL F-Bounds testing framework to estimate both short-run and long-run dynamics affecting energy consumption in Kenya over the period 1980–2024.

Table 5: *Long-run and short-run estimates*

Sample 1980 – 2024 Log likelihood = 96.7646				R-squared=0.7632 Adj R-squared = 0.5821 Root MSE= 0.0144	
	D.ENC	Coef.	Std. Err	T	P > |t|
ADJ	ENC				
	L1	-.2949	.1167	-2.53	0.022
LR	GDP	.0113	.0078	1.45	0.166
	FDI	.0557	.0234	2.38	0.029
	INF	-.0342	.0255	-1.34	0.197
	RI	-.0711	.0316	-2.25	0.038
	TOP	-.0046	.0015	-3.17	0.006
SR					
	ENC				
	LD	.5537	.1869	2.96	0.009
	FDI				
	D1	-.0100	.0036	-2.82	0.012
	LD	-.0041	.0026	-1.58	0.132
	RI				
	D1	-.0119	.0075	-1.58	0.132
	LD	.0207	.0084	2.47	0.025
	TOP				
	D1	.0033	.0011	3.09	0.007
	LD	.0018	.0009	1.92	0.072
	Cons	1.9570	.7662	2.55	0.021

Source*: Authors' Compilation from E-Views*

In the long-run estimates, Foreign Direct Investment (FDI) recorded a positive and significant coefficient of 0.0557 ($p = 0.029$), suggesting that increased FDI inflows stimulate energy demand in Kenya. This result implies that a 1% increase in net FDI inflows, expressed as a share of GDP, leads to a 5.57% rise in energy consumption, holding all other factors constant. This relationship can be explained by the role of FDI in expanding industrial activity, infrastructure development, and modernisation of energy-intensive sectors. Capital inflows from foreign investors boost production capacity, facilitate technology transfers, and enhance demand for energy in manufacturing, transport, and services. Consequently, FDI operates as both a direct and indirect catalyst for energy consumption as the intensity of economic activity increases. These findings align with Kahouli and Omri (2017), who found that in MENA and BRICS countries, FDI increased energy consumption by between 3%

and 7%, depending on the sectoral distribution of investments. Similarly, Shahbaz (2024) observed a statistically significant long-run elasticity of 0.061 for FDI with respect to energy consumption in developing economies, reinforcing the argument that FDI stimulates energy-intensive growth. In the Kenyan context, this relationship is plausible given that FDI during the 1980s and 1990s often targeted infrastructure, telecommunications, and extractive industries, which are energy-intensive. The short-run results reveal that the first difference of Foreign Direct Investment (D1.FDI) negatively and significantly affects energy consumption (–0.0100, $p = 0.012$). This indicates that a short-run increase in FDI inflows results in an immediate contraction of domestic energy consumption. This could be due to the time lag between the inflow of foreign capital and the actual operationalisation of investment projects.

The long-run analysis reveals that interest rate (RI) had a negative and statistically significant coefficient of –0.0711 ($p = 0.038$), implying that rising interest rates are associated with reduced energy consumption in Kenya. This suggests that a 1% increase in the real interest rate leads to a 7.11% decline in energy consumption, holding other factors constant. The relationship can be explained by the fact that higher interest rates raise borrowing costs, discouraging both households and firms from taking credit for energy-intensive investments in sectors such as manufacturing, transport, and real estate. This result is consistent with research by Wu *et al.* (2023), which studied dynamic energy efficiency in OECD countries and found that a 1% increase in interest rates reduced industrial energy consumption by approximately 5–6% during the COVID-19 pandemic. The most significant contractionary impulse was registered in capital-intensive industries, as financing costs directly influence investment and subsequent energy use. Conversely, some studies report differing results. Chen *et al.* (2021), analysing a panel of emerging economies between 1995 and 2018, found a positive elasticity of 0.03 between interest rates and energy consumption. The study argued that in financially open economies, higher interest rates attract foreign capital inflows, which stimulate investment activity and ultimately raise energy demand. The short-run estimates show that the lagged difference of interest rate (LD.RI) had a positive and statistically significant effect on energy consumption (0.0207, p = 0.025). This finding indicates that recent increases in interest rates are associated with a temporary rise in energy use. One possible explanation is the presence of policy and behavioural lags, where investment and consumption decisions that were initiated before interest rate adjustments continue to drive energy demand.

The ARDL long-run results show that trade openness (TOP) has a negative and statistically significant effect on energy consumption (–0.0047, p = 0.006). This suggests that greater integration into international markets reduces domestic energy demand in Kenya. Specifically, a 1% increase in trade openness leads to a 0.47% decline in energy consumption, holding other variables constant. The decline can be attributed to two main channels: technological transfer and efficiency improvements. Increased openness allows local industries to access modern production technologies, often embedded in imported machinery and processes, which are more energy-efficient than traditional methods. This finding aligns with a study by Akbar *et al.* (2020), which reported that trade liberalisation in Southeast Asian countries enhanced energy efficiency and reduced energy intensity over time. Their panel estimates showed that a 1% rise in trade openness reduced energy consumption by approximately 0.32%, primarily through the adoption of modern technologies and restructuring toward less energy-intensive sectors. However, not all studies support this negative relationship. Rafindadi and Usman (2019), using the Maki cointegration test for South Africa, found a positive and significant relationship between trade openness and energy consumption, suggesting that trade expansion can intensify energy use, particularly when exports are concentrated in energy-intensive sectors such as mining and heavy manufacturing. In the short run, trade openness (D1.TOP) exhibited a positive and statistically significant effect on energy consumption (0.0033, p = 0.007). This result suggests that increased trade activity stimulates short-term energy demand, particularly in export-oriented and import-intensive industries.

The ARDL long-run and short-run estimates revealed that GDP had no statistically significant impact on energy consumption in Kenya. This suggests that while GDP growth may signal economic expansion, it does not directly translate into higher energy use. The insignificance is consistent with Kenya's structural transformation toward less energy-intensive sectors such as ICT, services, and finance, coupled with improvements in energy efficiency and renewable energy integration. Further, inflation had no significant effect on energy consumption in Kenya. This suggests that, although inflationary pressures can temporarily affect the costs of energy production and access, they are insufficient to alter the fundamental, long-term structure of energy consumption. Kenya's resilience may be explained by its structural composition and rapid adoption of renewable energy, which reduces exposure to price fluctuations.

In the short run, the lagged difference of energy consumption (LD.ENC) was positive and statistically significant (0.5537, p = 0.009), indicating strong inertia or persistence in energy use patterns. This suggests that past energy consumption levels continue to influence current consumption behaviour, due to fixed infrastructure or habits that do not adjust immediately to economic shocks. The coefficient of the lagged error correction term (L1.ENC) is –0.2949, indicating that approximately 29.5% of the disequilibrium from the previous period is corrected within the current period.

The model demonstrates a good fit with an R-squared of 0.7632, suggesting that approximately 76.3% of the variation in energy consumption (ENC) is explained by the set of explanatory variables. The table summarises key diagnostic tests conducted to validate the regression model results. The Jacque-Bera Test confirmed that the residuals of all variables are approximately normally distributed, as p-values exceeded 0.05. The Variance Inflation Factor (VIF) analysis showed all values below the threshold of 10, with a mean VIF of 1.70, indicating no significant multicollinearity among explanatory variables. Finally, the Breusch–Godfrey Lagrange Multiplier (LM) test assessed for serial correlation in residuals, which is vital for maintaining unbiased standard errors and ensuring reliable coefficient interpretations. Overall, the results from these diagnostic tests validate the econometric model, reinforcing the robustness and statistical reliability of the regression analysis for examining the specified economic factors.

Conclusion and Recommendations

The study investigated the effect of macroeconomic variables on energy consumption in Kenya for the period 1980–2024 using the ARDL model with an error correction framework. In the long run, foreign direct investment positively and significantly affected energy consumption, suggesting that external capital inflows stimulate industrial expansion, infrastructure development, and business activity that raise energy demand. In contrast, both the interest rate and trade openness exerted negative and significant effects, indicating that higher borrowing costs limit access to credit for energy-intensive investment, while greater trade integration reduces reliance on domestic energy consumption through efficiency improvements and adoption of imported technologies. In the short run, energy consumption showed persistence, as reflected in the significant and positive coefficient of its lagged value, indicating that past energy consumption strongly influences current levels. Additionally, FDI exhibited a negative short-run effect, which may reflect transitional inefficiencies or the time lag before foreign investments translate into higher energy demand. The analysis revealed that the contemporaneous difference in interest rates had no significant effect; conversely, the coefficient on the lagged term was both positive and significant, suggesting a time-lagged stimulative impact of financial conditions on energy use. Similarly, trade openness displayed both a positive and significant effect and a marginally significant lagged effect, underscoring its dynamic role in shaping energy consumption patterns in the short run. Moreover, GDP and inflation remained insignificant across short-run and long-run estimations, confirming their limited role in influencing energy demand in Kenya.

The findings are relevant to policies intended to enhance the efficacy of strategies that integrate robust economic growth with long-term energy sustainability. As economic expansion drives energy demand, the government of Kenya should prioritise investment in renewable energy infrastructure and promote energy efficiency in industries and households. Policies that encourage the adoption of modern technologies, coupled with incentives for clean energy use, will ensure that growth is not accompanied by disproportionate increases in energy demand and environmental degradation.

In addition, the findings underscore the importance of inflation management for stable energy consumption patterns. Since inflationary pressures can erode household purchasing power and undermine investment in energy infrastructure, the Central Bank of Kenya should adopt proactive inflation-targeting frameworks. Further, policies that protect vulnerable households from price shocks, such as targeted subsidies or energy efficiency programmes, would help stabilise demand for essential energy services during periods of inflation.

Moreover, the findings highlight the significance of monetary policy in shaping energy demand through interest rates. Monetary authorities should consider the implications of interest rate adjustments for energy-intensive investments, particularly in manufacturing and infrastructure. Implementing preferential credit schemes or interest rate incentives to reduce the borrowing costs associated with green energy projects can effectively stimulate private investment in sustainable energy systems, thereby reinforcing the the nexus between finance and energy sustainability.

Further, findings emphasise the role of trade openness in influencing energy consumption. Policymakers should leverage trade policies to promote access to energy-efficient technologies and cleaner energy systems. By negotiating trade agreements that prioritise low-carbon technologies and supporting sectors that are less energy-intensive, Kenya can benefit from globalisation while minimising excessive energy demand. Strengthening export competitiveness in green industries can further reduce energy intensity while boosting foreign earnings.

Finally, the findings have implications for foreign direct investment policies. Attracting FDI into renewable energy and energy-efficient sectors should be a central policy priority. The government should create an enabling environment through investor protection frameworks, tax incentives, and reduced bureaucratic hurdles for energy-related FDI. Successful projects such as the Lake Turkana Wind Power Plant illustrate the potential of foreign capital in driving large-scale renewable energy adoption. The promotion of FDI serves as a vital policy mechanism to enable Kenya to reconcile its national economic growth ambitions with the imperatives of environmental sustainability.

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