IMPACT OF ENERGY CONSUMPTION ON ECONOMIC GROWTH IN SUB-SAHARAN COUNTRIES

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ABSTRACT
The study examines the impact of energy consumption on economic growth in ten Sub-Saharan African Countries spanning 1990 to 2023. The novelty of the study is the utilization of the Driscoll and Kraay Estimation Technique, which adjusts for common problems in panel data, such as cross-sectional dependence, autocorrelation, and heteroscedasticity. The empirical evidence suggests that energy consumption stimulates economic growth. The positive influence of energy consumption on economic growth, confirms the energy-led growth hypothesis. Similarly, evidence indicates that foreign direct investment and capital stock enhance economic growth in the SSA countries. However, evidence suggests that labor force exerts a negative influence on economic growth. Therefore, the study recommends that policies should be developed to attract both domestic and foreign investment in the energy sector. Additionally, strategies should be implemented to create an enabling environment that fosters and supports investment.

Keywords: *Energy Consumption, Economic Growth, and Sub-Saharan African Countries*

1. Introduction

Economic growth and energy consumption, which are major contributors to environmental degradation, act as significant transmission channels. Industrialization, urbanization, and transport infrastructure, which depend heavily on energy sources like oil and coal, drive recent economic growth. These resources are utilized to produce electricity for industrial processes and transportation. While energy consumption is vital for rapid economic growth, industrialization, and urbanization, it also contributes to carbon emissions. The link between energy consumption and economic growth is deeply interconnected. Global energy consumption continues to rise, with wealthier nations consuming the most energy. The United Nations Development Programme (UNDP, 2015) highlights the importance of energy production and distribution for both economic and sustainable development. Academic perspectives on the relationship between energy consumption and economic performance are divided into orthodox and heterodox views. The orthodox view denies or minimizes any link between the two, suggesting that if such a relationship exists, it is economic performance that drives energy consumption. On the other hand, the heterodox view argues that the relationship is reciprocal, with energy consumption driving economic performance.

Despite the theoretical discourse, empirical studies face challenges in proving this relationship. Since Kraft & Kraft's (1978) foundational work, research findings have been varied, with four key perspectives emerging: growth, conservation, neutrality, and feedback. Percebois & Hansen (2011) suggest that economic structure and shifts in the behavior of economic actors play a role in this relationship. Indeed, the empirical literature on the energy consumption–growth nexus is mixed, as noted by Yu and Choi (1985), Ferguson et al. (2000), and Toman and Jemelkova (2003). The lack of consensus is often attributed to factors such as differing climate conditions, energy consumption patterns, stages of economic development, econometric methodologies, and the presence of omitted variable bias across varying study time horizons. The aim of this study is to expand upon the existing empirical literature regarding the impact of energy consumption on economic growth in Sub-Saharan Africa (SSA). Historically, SSA has comprised countries with the lowest gross domestic product (GDP) and minimal economic and financial development on a global scale. However, as noted in the World Economic Development (WED) report, these nations saw substantial growth in the 2000s, with GDP growth reaching 5.08% in 2008, while GDP per capita rose by 2.5%. In tandem, energy consumption in the region increased by 6%, and CO2 emissions surged by 20%. This backdrop sets the focus of the study, which is to evaluate the impact of energy consumption on economic growth in SSA countries. The study's key contribution is its examination of this effect across ten Sub-Saharan African nations. While various studies (e.g., Ozturk, 2010; Payne, 2010; Omri, 2013) have explored the relationship between economic growth and energy consumption, Mardani et al. (2019) also reviewed previous literature on economic growth and carbon emissions.

2. Literature Review

The literature on the relationship between energy consumption and economic growth presents two contrasting perspectives. On one side is the orthodox approach, which dismisses the role of energy consumption in driving economic growth, supporting two key hypotheses: the growth hypothesis and the neutrality hypothesis. On the other side is the heterodox approach, which acknowledges a connection between energy consumption and economic growth, basing its argument on two hypotheses: the conservation hypothesis and the feedback hypothesis. From the orthodox perspective, energy is not seen as a driver of economic growth; if any relationship exists, it is economic growth that influences energy consumption. This view is supported by proponents of traditional and endogenous economic growth theories, such as Stiglitz (1974), Lucas (1988), Barro (1990), and Mankiw et al. (1992), who do not consider energy as a growth factor. In contrast, heterodox economists, grounded in biophysical theory and the laws of thermodynamics, argue that energy is essential, and often the most critical factor, for explaining economic growth. This view is shared by Lékana (2018a), Percebois & Hansen (2011), Kane (2009), and Jumbe (2004). In summary, heterodox economists contend that any material transformation requires energy. These differing views have sparked numerous attempts at explanation, as discussed by Percebois & Hansen (2011), Stern (2012), and Lékana (2018a).

Since the work of North (1990), many authors have sought to highlight the limitations of orthodox economic analysis (Hall & Jones, 1999; Acemoglu et al., 2001; Acemoglu et al., 2008; Kilishi et al., 2013). Kilishi et al. (2013) argue that it is nearly impossible to discuss the drivers of economic growth without considering the quality of governance. Acemoglu et al. (2008) suggest that institutions are the primary drivers of growth, while factors such as physical and human capital, technology, and energy are secondary contributors. Given the often-polluting nature of the link between energy consumption and economic growth, van der Bergh (2001) emphasizes that institutions play a crucial role in harmonizing this relationship to benefit future generations. Similarly, Mundial (2001) stresses that strong institutions are essential for economic development, as they help reduce market imperfections. Countries with robust institutions are better equipped to implement efficient regulations that promote economic development, while weak institutions hinder growth due to their limited regulatory capacity.

Numerous studies have examined the causal links between increasing carbon emissions, energy consumption, and economic growth using different time periods, variables, countries, and econometric techniques (e.g., Song et al., 2018; Rauf et al., 2018; Chaudhary & Bisai, 2018; Riti et al., 2017; Bildirici, 2017; Zhang et al., 2017; Zhao et al., 2017; Alam et al., 2016; Robaina-Alves et al., 2016; Ozcan, 2013; Jayanthakumaran et al., 2012; Ghosh, 2010; Apergis & Payne, 2010; Ang, 2008). The findings of these studies vary, with different policy implications based on the causal relationships identified between these variables. Payne (2010) confirmed the relationship between electricity use and economic growth, as well as between energy consumption and growth. Similarly, Yilanci (2013) investigated this relationship and found a unidirectional connection from economic growth to energy consumption in full sample estimates, while OECD countries demonstrated a direct relationship between energy consumption and economic growth. Sarwar et al. (2017) provided mixed evidence on the energy-growth link, with results varying by income groups, oil-importing and exporting countries, and regions. Shahbaz et al. (2017) corroborated these findings across 157 countries. In addition, Sarwar et al. (2018) analyzed the impact of energy consumption on economic growth, the stock market, and industrial sectors, showing a significant but industry-specific influence of energy consumption on growth.

Empirically, the literature can be divided into two groups: studies that do not consider institutional quality and those that do. In the first group, following the pioneering work of Kraft & Kraft (1978) on the United States, several papers have emerged. For example, Saidi et al. (2018) examine the asymmetric effects of the energy-growth relationship using data on per capita real GDP and per capita energy consumption for 12 African countries from 1971-2008. Their results show that conservation policies could negatively impact the growth rate in Gabon, Nigeria, and Côte d'Ivoire, while in Benin, Kenya, and Sudan, these policies could boost growth. Similarly, Streimikiene & Kasperowicz (2016) study the long-term relationship between energy consumption and economic growth in 18 European Union countries from 1995-2012, finding a positive correlation between the two. In the second group, which includes institutional quality, Edame & Okoi (2015) assess the effect of energy consumption and institutional quality on the performance of Nigeria's manufacturing sector from 1999-2013 using an ordinary least squares (OLS) approach. They measure institutional quality using the Economic Freedom Index, Corruption Perception Index, and Monetary Intensive Contract Index, and analyze energy consumption through indicators like industrial electricity consumption, total gas consumption, and total oil consumption. The study finds that the consumption of electricity, oil, and gas by the industrial sector does not significantly impact the performance of the manufacturing sector, but the perception of corruption does. The existing body of research has independently examined the determinants of economic growth, such as renewable energy (Qing et al., 2024; Hadj et al., 2023; Simionescu et al., 2023), internet usage (Ozpolat, 2021; Magazzino et al., 2021), and mineral rents (Aladejare, 2022). However, studies specifically investigating the impact of energy consumption on economic growth within the context of SSA countries remain largely unexplored

3. Methodology

3.1 Data Source and Description

The study examines the impact of energy consumption on economic growth in SSA countries from 1990 to 2023. The choice of SSA countries is due to the growing population and the increasing electricity demand. The region has abundant energy resources; however, these resources remain untapped. The study uses five variables such as GDP per capita, energy use, FDI, Labor, and Capital stock. All the data for GDP per capita, energy use, FDI, Labor, and Capital stock are sourced from the World Bank Development Indicators (WDI). GDP per capita is used to proxy economic growth by capturing the effect of the population, gross fixed capital formation is utilized to measure capital stock, and labor force total is used to proxy labor, energy use is utilized to proxy energy consumption.

3.2 Model Specification

The study examines the impact of energy consumption on economic growth in SSA countries spanning 1990 to 2023. The study adopts the Warsame et al. (2024) model with few modifications, which is based on the neoclassical economic growth and Cobb Douglas production function. The empirical model is specified as follows:

$$logGDPper_{it} = \beta_0 + \beta_1 logFDI_{it} + \beta_2 logEU_{it} + \beta_3 logGFCF_{it} + \beta_4 logLABOR_{it} + \mu_{it}$$

Where $logGDPper_{it}$ is the gross domestic product per capita as a proxy for economic growth, $logFDI_{it}$ is the foreign direct investment net inflows, $logEU_{it}$ stands for energy consumption proxy by energy use, $logGFCF_{it}$ denotes gross fixed capital formation as a proxy for capital stock, $logLABOR_{it}$ stands for labor force total. log represents the natural logarithm, and μ_{it} is the disturbance term.

***3.3 Panel Unit Root Test* –** The study utilized the Breitung robust unit root test is a statistical test used in panel data analysis to determine whether a series is stationary or contains a unit root, which would indicate that the data follows a stochastic trend. It is specifically designed for panel data, where multiple time series are observed across different cross-sectional units (like countries or firms) over time. Breitung and Das (2005) utilized a different technique, modifying the data before fitting a regression model. The data are generated by an $AR(1)$ process so that we can express $y_{it}\ as$:

$$y_{it} = z'_{it}\gamma_i + \mathcal{X}_{it} \qquad [3]$$

where

$$\mathcal{X}_{it} = \alpha_1 \mathcal{X}_{i,t-1} + \alpha_2 \mathcal{X}_{i,t-2} + \varepsilon_{it} \qquad [4]$$

The Breitung test eliminates the need for bias adjustments and allows pre-whitening to address serial correlation. It assumes uncorrelated error terms across time (t) and individuals (i), though a robust version permits contemporaneous correlation. The null hypothesis is non-stationarity, while the alternative is stationarity.

Also, the study utilized the Pesaran 2007 unit root technique, the technique is a method for testing unit roots in panel data. It extends traditional unit root tests by accounting for cross-sectional dependence among the units (such as countries or firms), which is often present in panel data but ignored by many earlier tests. This feature makes it more robust in cases where entities in the panel are influenced by common shocks or unobserved factors that may cause correlations across units. The asymptotic null distribution of the individual $CADF_i$ and the associated technique statistics is defined as:

$$CIPS\ (N,T) = N^{-1} \sum_{i=1}^{N} t_1\ (N,T) \qquad (5)$$

where $t_i(N,T)$is the cross-sectionally augmented Dickey-Fuller statistic for the i_{th} cross-section unit given by the *t-ratio* of the coefficient of$y_{i,t-1}$in the CADF regression indicates the i_{th} cross-section unit of CADF statistics. The statistics are examined as $N \to \infty$ followed by $T \to \infty$, also in a joint situation with N and T heading to infinity such that $\frac{N}{T} \to k$, k is considered to have fixed finite non-zero positive constant.

3.4 Panel Cointegration Technique - The Westerlund (2007) panel cointegration technique is a widely-used method for testing the presence of cointegration in panel data, which refers to a long-run equilibrium relationship between two or more time series. Westerlund's method is an improvement over earlier panel cointegration tests (such as Pedroni's or Kao's tests) because it accounts for cross-sectional dependence and does not impose common factor restrictions across cross-sectional units. The Westerlund calculation criteria are written as:

$$\Delta y_{it} = \delta_{it}' d_i + \alpha_i (y_{i(t-i)} - \beta_i' \mathcal{X}_{i(t-1)}) + \sum_{j=1}^{\rho i} \alpha_{ij} \Delta y_{i(t-j)} + \sum_{j=0}^{\rho i} \theta_{ij} \Delta \mathcal{X}_{i(t-j)} + \varepsilon_{it} \quad (6)$$

where the deterministic composition, vector parameter, and error are shown by $d_{t,}\delta', \alpha_i$ respectively. The error correction model could be estimated by:

$$(y_{i,t-1} - \beta_i' X_{i,t-1})$$

3.5 Driscoll and Kraay Technique - The Driscoll-Kraay fixed effect technique is an econometric method used to address specific issues in panel data analysis, particularly when dealing with time series data across different entities (like countries or firms) over a fixed time period (Hoechle, 2007). This technique adjusts for common problems in panel data, such as cross-sectional dependence, autocorrelation, and heteroscedasticity, while maintaining the advantages of using fixed effects to control for unobserved heterogeneity.

4. Estimation Results and Interpretation

4.1 Descriptive Statistics

The descriptive statistics provides the summary of the data through the mean value, standard deviation, and minimum and maximum values.

Table 1
Descriptive Summary

Variable	Obs	Mean	Std. Dev.	Min	Max
GDPper	340	3288.454	2731.51	558.4883	11318.6
FDI	340	9.78E+08	2.76E+09	-3.19E+08	4.07E+10
GFCF	340	7.00E+09	1.35E+10	500070.8	6.24E+10
EU	340	916.8497	764.4829	209.2126	3519.243
LABOR	340	1.06E+07	1.56E+07	284784	7.57E+07

Note: GDPper is the gross domestic product per capita. FDI is the foreign direct investment net inflows. GFCF is the gross fixed capital formation. EU is the energy use per capita. LABOR is the labor force total.

Source: Author's computation. 2024

The observed in Table 1. Variable GDPper as the dependent variable, has a standard of 2731.51 and a mean of 3288.45. This implies a high deviation from the average mean. Similarly, the variable FDI indicates a standard deviation of 2.76E and a mean of 9.78E. This implies a higher deviation from the average mean. Also, the variable LABOR has a standard deviation of 1.56E and a mean of 1.06E. This means a high deviation from the average mean. Similarly, GFCF indicates a high deviation from the mean, with a mean of 7.00E and a standard deviation of 1.35E. Similarly, the variable of the EU has a standard deviation of 760.48 and a mean of 916.85. This implies a lower deviation from the mean.

4.2 Correlation Analysis

Table 2
Correlation Estimates

Variable	**GDPper**	**FDI**	**GFCF**	**EU**	**LABOR**
GDPper	1				
FDI	0.1207	1			
GFCF	0.2546	4.69E-01	1.00E+00		
EU	0.6836	0.3955	0.7298	1	
LABOR	-0.1744	0.3932	0.1978	0.0948	1

Source: Author's computation. 2024

Table 2 presents the correlation coefficients. Variable GFCF has a positive and lower correlation coefficient with GDPper at 0.25, and a moderate correlation coefficient with FDI at 4.69. Similarly, the variable EU has a high and positive correlation coefficient with GDPper and GFCF, which are 0.68 and 0.72 respectively. Also, the EU has a positive and lower correlation with FDI at 0.39. Similarly, the variable LABOR has a negative and lower correlation coefficient with GDPper at -0.17. Also, LABOR has a positive and lower correlation coefficient with FDI, GFCF, and EU, which stood at 0.39, 0.19, and 0.09 respectively.

4.3 Panel Unit Root Test

The study utilizes two-unit root approaches in testing the level of stationarity of the variables. The study used Breitung and Pesaran 2007 which are second-generation unit root techniques robust to cross-sectional dependence.

Table 3
Panel Unit Root Test

Second Generation Breitung				**Pesaran 2007**		
	Level	First Difference	Order of Integration	Level	First Difference	Order of Integration
Variable	Zt-bar	Zt-bar	0 or I	Zt-bar	Zt-bar	0 or I
GDPper	2.6035	-6.1646***	I(1)	-0.053	-4.278***	I(1)
FDI	-3.1306***	-7.9158***	I(0)	-0.194	-8.464***	I(1)
GFCF	1.0701	-2.9679***	I(1)	2.313	-2.037**	I(1)
EU	0.1962	-5.4707***	I(1)	0.310	-6.297***	I(1)

LABOR	13.8275	-5.4707***	I(1)	0.546	-2.643***	I(1)

***, **, * denotes the level of significance at 1%, 5% & 10% respectively.

Source: Author's computation

As presented in Table 3. The variable FDI is stationary at level, and GDPper, GFCF, EU, and LABOR are all stationary at the first difference using the second generation Breitung. Also, all variables are stationary at the first difference using the Pesaran 2007-unit root technique. All the two techniques are robust to cross-sectional difference.

4.4 Panel Cointegration

The estimation results in Table 5 suggest the presence of cross-sectional dependence in the series. This implies that only the second generation of estimation techniques should be used for the analysis. Based on this, the study utilized the Westerlund panel cointegration approach which is robust to cross-sectional dependence.

Table 4

Westerlund ECM Panel Cointegration Tests

Statistic	**Value**	**P-value**
Variance ratio	2.5573	0.0053

***, **, * denotes the level of significance at 1%, 5% & 10% respectively.

Source: Author's computation. 2024

As observed in Table 4. The results presented indicate a variance ratio of 2.5573 and a P-value of 0.0053. this implies the existence of a long-run association in the model.

4.5 Driscoll and Kraay Estimation Technique

The study utilized the Driscoll and Kraay estimation technique to examine the impact of energy consumption on economic growth in SSA countries. The Driscoll and Kraay are robust to cross-sectional dependence problems.

Table 5

Estimation Coefficients (Driscoll and Kraay Method)

Variable logGDPper	**Coefficient**	**Drisc/Kraay Std. Err.**	**t-Statistics**	**Prob-value**
logFDI	0.014629	0.00507	2.89	0.018
logEU	0.17867	0.067172	2.66	0.026
logLABOR	-0.33046	0.120735	-2.74	0.023
logGFCF	0.273645	0.047426	5.77	0.000
_cons	5.499543	0.703139	7.82	0.000
R-squared	*0.5633*			
Breusch-Pagan for heteroskedasticity		*2.96*		*0.0855*
Wooldridge test for autocorrelation		*22.314*		*0.0011*
Mean VIF		*1.51*		
Breusch-Pagan LM test		*91.552*		*0.0001*

Note: GDPper is the gross domestic product per capita. FDI is the foreign direct investment net inflows. GFCF is the gross fixed capital formation. EU is the energy use per capita. LABOR is the labor force total.

***, **, * denotes the level of significance at 1%, 5% & 10% respectively.

Source: Author's computation. 2024

As observed in Table 5 above, the estimation results of FDI indicate a positive and significant coefficient. This means that a one percent increase in FDI leads to a 0.014 increase in economic growth. This implies that foreign direct investment stimulates economic growth. This result lends support to studies by Sunde (2023), Ennin and Wiafe (2023), Banday, Murugan, and Maryam (2021), and Wondimu (2023) who found a positive effect of foreign direct investment on economic growth. Similarly, the results of the EU suggest a significant and positive coefficient. This indicates that a one percent increase in the EU results in a 0.178 increase in economic growth. This implies that energy consumption enhances economic growth in SSA countries. The result is in agreement with studies such as Pegkas (2020), Polat (2021), and Warsame et al., (2024) who reported a positive effect of energy consumption on economic growth. These results confirmed the energy-led growth hypothesis, which states that energy consumption encourages economic growth.

The estimation results of LABOR suggest a negative and significant coefficient. This means that a one percent increase in LABOR leads to a -0.330 percent decrease in economic growth. This implies that the labor force total discourages economic growth. These results show the unskilled and poor condition of the labor force total in SSA countries. The result is supported by studies such as Amna Intisar et al. (2020), and Wondimu (2023) who found labor to hurt economic growth. Furthermore, the results of logGFCF suggest a positive and significant coefficient. This means that a one percent rise in GFCF results in a 0.273 percent increase in economic growth. This implies that capital stock enhances economic growth in SSA countries. The result is supported by Warsame et al. (2023), and Warsame et al. (2024) who reported capital stock to significantly contribute to economic growth.

5. Conclusion and Policy Implications

The ability of countries to harness energy resources contributes to their economic growth and development. Economies that can access a huge amount of energy often achieve increased productivity and economic growth. The Sub-Saharan African Countries which believe to have a shortage of energy supply. these have become a bottleneck in achieving economic growth. Hence, examining the impact of energy consumption in achieving economic growth is critical to resolve in SSA countries. To this end, the study aims to examine the impact of energy consumption on economic growth in SSA economies for the period of 1990 to 2023. Furthermore, FDI, LABOR, and Capital stock were included as control variables. The study utilized second-generation methods, which are robust to cross-sectional dependence, heteroskedasticity, and autocorrelation in a model.

Evidence supported the energy-led growth hypothesis, the results suggest that energy consumption, foreign direct investment, and capital stock are vital for economic growth in the SSA economies. However, labor retards economic growth. The estimation results indicate that energy consumption is essential for achieving economic growth. However, the supply of energy in the SSA economies is not sufficient to provide for the increasing energy demand in the region. Therefore, the study recommends that policymakers should formulate and provide policies toward attracting both domestic and foreign investment in the energy sectors. Also, policies toward the provision of an enabling environment for investment should be devised. Furthermore, more efforts be tailored to providing and encouraging clean energy to achieve sustainable economic growth

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