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Finance, poverty-income inequality, energy consumption and the CO_2 emissions nexus in Africa

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Abstract

Purpose – This study provides the critical masses (thresholds) at which the positive incidence of finance and economic growth will be dampened by the negative effects of income inequality and poverty on energy consumption in Sub-Saharan Africa for policy direction.

Design/methodology/approach – The study employed the two steps systems GMM estimator for 41 countries in Africa from 2005–2020.

Findings – The study found that for finance to maintain a positive effect on energy consumption per capita, the critical thresholds for the income inequality indicators (Atkinson coefficient, Gini index and the Palma ratio) should not exceed 0.681, 0.582 and 5.991, respectively. Similarly, for economic growth (GDP per capita growth) to maintain a positive effect on energy consumption per capita, the critical thresholds for the income inequality indicators (Atkinson coefficient, Gini index and the Palma ratio) should not exceed 0.669, 0.568 and 6.110, respectively. On the poverty level in Sub-Saharan Africa, the study reports that the poverty headcount ratios (hc$144ppp2011, hc$186ppp2011 and hc$250ppp2005) should not exceed 7.342, 28.278 and 129.332, respectively for financial development to maintain a positive effect on energy consumption per capita. The study also confirms the positive nexus between access to finance (financial development) and energy consumption per capita, with the attending adverse effect on CO_2 emissions inescapable. The findings of this study make it evidently clear, for policy recommendation that finance is at the micro-foundation of economic growth, income inequality and poverty alleviation. However, a maximum threshold of income inequality and poverty headcount ratios as indicated in this study must be maintained to attain the full positive ramifications of financial development and economic growth on energy consumption in Sub-Saharan Africa.

JEL Classification — E21, D31, I14, I15, I18

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Originality/value – The originality of this study is found in the computation of the threshold and net effects of poverty and income inequality in economic growth through the conditional and unconditional effects of finance.

Keywords Finance, Income inequality, Poverty headcounts, Energy consumption, CO_2 emissions

Paper type Research paper

1. Introduction

Issues raised in the recent literature resonate with the positioning that the absence of inclusive and sustainable growth is a critical development challenge in Africa. Similarly, other crucial development goals relevant to environmental degradation and pollution, climate change, clean energy, low energy consumption per capita are akin to inadequate funding, income inequality, extreme levels of poverty and weak financial systems (Tamazian *et al.*, 2009; Piñeiro Chousa *et al.*, 2017; Akinyemi *et al.*, 2019; Asongu and Odhiambo, 2019a, b;Nathaniel and Iheonu, 2019; Asongu *et al.*, 2020; Joshua and Alola, 2020; Joshua *et al.*, 2020; Nathaniel and Bekun, 2021). Other researchers (Giglio *et al.*, 2021; Yang *et al.*, 2020; Zhang *et al.*, 2020) expound on these areas by assessing the impact of income inequality and financial instability on CO_2 emissions in the presence of fossil fuel energy, economic development and industrialization. There has been a growing concern for environmental degradation and energy shortage, mostly prevalent in developing countries. Asongu and Odhiambo (2021) contribute to this growing distress by assessing the troubling concern of environmental pollution across the world in general and Sub-Saharan Africa (SSA), especially because the sub-region is characterized by energy grid systems that are some of the worst in the world. Despite the extensive evidence about the relevance of finance in accelerating environmental sustainability and a green economy, the supporting evidence on how finance affects various development outcomes remains open.

Given the fact that majority of the adult population in Africa have no access to formal financial services (e.g. a formal bank account, insurance policy, among others) (Ayyagari *et al.*, 2011; Allen *et al.*, 2016; Demirgüç-Kunt and Singer, 2017), the attainment of sustainable development goals namely: (1) end poverty in all forms, (7) ensure access to affordable, reliable, sustainable and modern energy for all (10) reduce income inequality within and among countries, (13) take actions to combat climate change and its impact among others will be a mirage without universal access to finance, especially in developing and emerging economies in Africa. Earlier empirical studies on Africa (Asongu and Odhiambo, 2020a, b) have shared that the consequences of climate change will be worst felt in Africa than all else. Concerns are therefore high about environmental degradation and pollution in Africa. However, the debate on Africa's finance, energy consumption and environmental degradation nexus remains inconclusive due to poor data and inadequate research funding.

Nonetheless, inspired by the findings of Odhiambo (2020) and Asongu and Odhiambo (2021), who deployed the generalized method of moment (GMM) estimation technique to examine the nexus between inequality, renewable energy consumption and financial development in Africa, this study seeks to examine finance, poverty-income inequality, energy consumption and the CO_2 emissions nexus in Africa. Specifically, the paper complements the existing literature using energy consumption per capita in Africa, CO_2 emissions, income inequality, poverty headcount ratios, financial access and economic growth so that findings can be adopted for policy statements and reviews. This study contributes to the literature in two specific ways. First, it establishes the thresholds and net effect of economic growth and financial access on energy consumption per capita through the income inequality and poverty channel. This provides specific critical masses above which financial development (credit to the private sector) and economic growth will be negative or redundant in Africa, given the income inequality and poverty levels. Secondly, the study provides policy direction on how finance affects energy consumption and the interrelated effect on the economy. The study computes the net effect of finance (credit to the private sector) and the growth of the economy (GDP per capita growth) by adjusting for the pitfall in the interactive regression to calculate the net effect and adding all the slopes of variables to the model. This study further departs from the existing literature, which has predominantly used various measurements of GDP for economic progress. If access to and the use of energy (all power sources) is fundamental to production and productivity, then this study introduces energy consumption per capita as our main dependent variable.

The thresholds or critical masses guide policy to the point at which the positive unconditional effect of finance (or economic growth) on energy consumption per capita is no longer apparent in the presence of the high income inequality and extreme poverty levels in Africa. By interacting the financial access proxy (credit to the private sector by banks as a percentage of GDP) and income inequality measures (Atkinson index, Gini coefficient and Palma ratio) and poverty headcount ratios, this study establishes the thresholds and net effects at which the conditional effect (negative) of finance dominates the unconditional effect. The threshold analysis is consistent with Minlah *et al.*'s (2021) findings, which established critical income thresholds at which deforestation is initially negatively associated with economic growth but later increases with economic growth beyond the established income thresholds for policy direction in Ghana on the Environmental Kuznet Curve and deforestation.

Guided by the theoretical and empirical literature, access to finance and economic growth should positively affect energy consumption, whereas an increase in energy consumption should positively affect CO_2 emissions per capita. The literature also expects income inequality and poverty headcounts to dampen the positive effect of financial development and economic growth. This study found that access to finance and economic growth promotes energy consumption in Africa; however, the corresponding nexus is dampened by poverty and income inequality. High-income inequality and poverty rates cause lower demand for energy consumption. We also share that the corresponding effect of increased energy consumption through increased financial access and the economy's growth on CO_2 emissions is inescapable.

2. Empirical review

Earlier studies on economic growth-energy nexus include (Kraft and Kraft, 1978), who established unidirectional causality running from gross national product (GNP) for postwar periods but no causality from energy to GNP. They concluded that economic growth caused an increase in energy demand in the US economy during 1947–1974. However, rising income levels are a recipe for a significant rise in energy consumption for a growing economy (Apergis and Payne, 2009a, b, 2010; Wolde-Rufael, 2009). Furthermore, Wolde-Rufael (2009) shared that energy was no more than a growth factor in 11 out of 17 African countries. Recent arguments by Jarrett (2017), Asongu and Odhiambo (2021) and Shobande and Asongu (2021) pointed out that countries in Africa are characterized by the worse energy and power grid systems in the world. This phenomenon poses significant environmental risks and concerns and a poor energy supply in the sub-region.

A significant proportion of the literature on energy has focused on the output-energy nexus and mostly on developed economies. This phenomenon has only portrayed a partial description of the nexus. However, according to Boulila and Trabelsi (2004), financial development stimulates economic growth, which may further cause an increase in energy consumption in Tunisia. Some studies (Jalil and Feridun, 2011; Shahbaz *et al.*, 2013; Dogan and Seker, 2016; Piñeiro Chousa *et al.*, 2017; Xing *et al.*, 2017; Xiong and Qi, 2018) have documented that financial development promotes a green and sustainable environment by mitigating CO_2 emissions while other studies have reported that finance can cause environmental sustainability to deteriorate through an increase in CO_2 emissions (Zhang, 2011; Boutabba, 2014; Al-Mulali *et al.*, 2015; Shahbaz *et al.*, 2016; Bekhet *et al.*, 2017; Lu, 2018; Khan *et al.*, 2019). Atsu and Adams (2021) found that renewable energy, bureaucratic quality and financial development moderate CO_2 emissions in BRICS (Brazil Russia India China and South Africa) countries over 1984–2017, but fossil fuel consumption and policy uncertainty positively contribute to CO_2 emissions.

Other studies on the finance and energy nexus include (Gungor and Simon, 2017), who established long-run causality between energy consumption and financial development in South Africa. They also showed that energy consumption is a positive function of economic growth. Similar studies on the finance-energy consumption nexus by Sadorsky (2010, 2011) showed positive causality. Studies on the long-run relationship of energy consumption, finance and economic policy uncertainty (Atsu and Adams, 2021) showed that financial development, renewable energy and bureaucratic quality mitigates CO_2 emission in BRICS countries. Ramaano (2021) found that the weak application of development policies and low education on tourism practices in the Musina Municipality of South Africa accounts for the deterioration of the ecosystem and the enormous adverse environmental effects of tourism activities.

Ahmad *et al.* (2019) found the impact of financial development on energy consumption and CO_2 emissions to be mixed. While they found the development of the banking sector to advance energy consumption and CO_2 emissions, the development of the stock market reduced energy consumption and mitigated CO_2 emissions. Mahi *et al.* (2020) also examined the causal relationship between energy consumption, finance and economic growth in five ASEAN countries. They established that financial crisis does not affect energy consumption in these countries. Kassi *et al.* (2020) found bidirectional financial development and improved governance quality as key drivers of economic growth in the Americas, Europe and Central Asia from 1900 to 2017. However, a battery of empirical estimations (Saini and Neog, 2018) recorded no long-run causal relationship between financial development and energy consumption in India but established a bi-directional short-run causal relation. Kovacic *et al.* (2018) also explained how economic growth does not affect energy consumption in European economies over 18 years. They showed that energy consumption per hour of labor has been constant over time. Their finding provides insight that no significant progress in technology has been observed in the productive sectors of the economy.

In Malaysia, Tang and Tan (2014) reported economic growth and energy consumption to granger cause each other. Sustained economic growth in a buoyant financial sector stimulated energy consumption in Malaysia. Shahbaz and Lean (2012) confirmed a long-run causal relationship among energy consumption, financial development and economic growth in Tunisia. They argued that a robust financial system is bait to attract investors, stimulate the stock market and improve the country's overall economic outlook. Jamel and Derbali (2016) also confirmed the presence of a long-run causal relationship between financial development, economic growth, energy consumption and environmental degradation in ASEAN countries.

Following the literature, we justify the problem statement of this study since most of the studies have often concentrated on the mere establishment of the causal relationship between (among) finance, energy consumption and CO_2 emissions which is not sufficient since policymakers need more policy tools on how to influence the relationship. By examining the nexuses among finance, inequality, poverty and energy consumption, the present study also improves the policy relevance of the associated findings by establishing poverty headcounts and income inequality thresholds at which financial development increases or decreases energy consumption in Africa. The findings of this study add to the existing literature by strengthening or conflicting the results of Asongu and Odhiambo (2021) in assessing how financial access and economic growth moderates poverty alleviation (poverty headcount ratios) and income inequality (Atkinson coefficient, Gini coefficient and the Palma ratio) on energy consumption in Africa. The study further examines the effect of energy consumption on CO_2 emissions.

2.1 Data sources and variable definition

The study employed annual data sourced from the World Development indicators database and the Global Income and Consumption Project (GICP). The key variables of the study are energy use per capita, CO_2 emissions per capita, credit to the private sector as a percentage of GDP and GDP_{PC} growth. The study employed credit to the private sector to GDP as the amount of credit provided by financial institutions to the private sector expressed a percentage of GDP. This variable represents the amount of credit channeled from savers through financial intermediation to private firms. Many studies that have employed this variable as a measure of financial access, sometimes financial depth/development include (Asongu *et al.*, 2020a; Beck *et al.*, 2007; Demirgüç-Kunt and Klapper, 2012; Sadorsky, 2010, 2011; Tchamyou, 2020). The study expects a positive relationship between finance and energy consumption per capita and the positive effect on CO_2 emissions in Africa.

The study also employed bank credits to deposits ratio. The bank credit to deposits ratio refers to the ratio of a bank's assets to liabilities. This ratio helps measure a bank's liquidity. It indicates how much of a bank's funds are for lending. This ratio helps assess a bank's liquidity and serves as an indicator of its financial health. This ratio is also a mark of intermediation efficiency. A higher ratio means that more loans are disbursed than deposits. This ratio, in effect, represents the health and intermediation efficiency of the financial sector. Consequently, the study avers that a healthy financial sector will be robust enough to extend to all segments of society and reduce income inequality and poverty (Hodgman, 1961; Van den End, 2016; Boďa and Zimková, 2021). The study expects a positive relationship between finance and energy consumption per capita and the positive effect on CO_2 emissions in Africa.

Following through with the empirical and theoretical literature including (Asongu and Odhiambo, 2018; Aterido *et al.*, 2013; Beck *et al.*, 2003, 2007; Besley and Burgess, 2003; Dabla-Norris *et al.*, 2021; Dabla-Norris *et al.*, 2015; Tchamyou, 2020; Tchamyou and Asongu, 2017; Uduji *et al.*, 2019; Van den End, 2016), the study develops and examines the relationship between finance (independent variables) and consumption inequality variables. The study employed the Gini coefficient, the Atkinson coefficient, and the Palma ratio on the income inequality front. The Gini index is defined as the ratio of the area between the Lorenz curve and the 45° line. The range of the Gini coefficient is between 0 and 1. A Gini coefficient of 1 is interpreted as perfect inequality, and 0 means perfect equality. The study employed other income inequality indicators (the Atkinson coefficient and the Palma ratio) for a robustness check.

Another set of dependent variables the study employed are poverty headcount ratios following the finance-poverty alleviation literature (Beck *et al.*, 2004, 2007; Castleman *et al.*, 2015). The study employed three sets of poverty headcount ratios from the GICP database from 2005 to 2020, namely, hc144ppp2011, hc186ppp2011 and hc250ppp2005. These ratios represent a poverty headcount ratio of \$1.44 at 2011 purchasing power parity, \$1.86 at 2011 purchasing power parity and \$2.50 at 2005 purchasing power parity. These poverty headcount ratios describe the percentage of the population in Africa living below the poverty lines.

The study applied a set of control variables proven to influence financial access and credit. These control variables are inflation, trade as a percentage of GDP, personal remittances as a percentage of GDP, net foreign direct investment (FDI) inflow as a percentage of GDP, percentage of the rural population with access to electricity and tertiary education enrollment. Energy use refers to the use of primary energy before transformation to other end-use fuels.

2.2 Descriptive statistics

The summary statistics allow the study to synthesize the main trends (mean, standard deviation, maximum value, minimum value and number of observations) of the variables, which presents an overview of the characteristics of the sample. Table 1 reports the summary statistics of energy use per capita, CO_2 emissions per capita, credit to the private sector as a percentage of GDP, GDP_{PC} growth and income inequality indicators (Atkinson coefficient, Gini index and the Palma ratio). The sample size consists of 41 countries in Africa over a period of 15 years, summing up 615 observations. The study employed different measures of income inequality and poverty headcount ratios for robustness checks as they capture different tendencies of the population. The mean value of energy use per capita is 691.22, and the standard deviation is 712.75. This suggests a significant variation or dispersion between the mean value of energy use per capita and the individual observations. The study also finds a significant variation in CO_2 emissions per capita values from their mean value. The standard deviation of 1.601 shows a significant dispersion from the mean of 1.001. The wide variations among the variables indicate the large differences in development among countries in Africa.

2.3 Pairwise correlation matrix

Table 2 shows the Pearson correlation analysis between determinants of energy use per capita, credit to the private sector as a percentage of GDP, CO_2 emissions, income inequality (Atkinson coefficient, Gini index and the Palma ratio), and economic growth. The correlation matrix showed vital evidence of the relationship between the determinants of energy use per capita, CO_2 emissions, credit to the private sector as a percentage of GDP, income inequality indicators (Atkinson, Gini and the Palma ratio) and economic growth variables by providing the direction and strength of the relationship among variables of the study of this section. The size of the correlation coefficient ranges from a negative one (−1) to a positive one (+1). A correlation coefficient of positive or minus one (±1) represents a perfect correlation between the variables. If such a condition persists, it raises the problem of multi-collinearity. However,

Variable	Obs	Mean	Std. Dev.	Min	Max
Energy consumption	615	691.22	712.75	9.548	3353.526
CO_2 emissions	615	1.001	1.601	0.022	8.747
Credit	615	22.22	25.311	0.544	160.125
GDP_{PC} growth	615	2.16	4.139	−36.557	18.053
Inflation	615	7.874	11.596	−21.165	100.658
Trade % of GDP	615	81.818	55.225	19.101	347.997
Remittances % GDP	615	4.122	7.377	0	53.826
Net FDI % of GDP	615	4.407	5.812	−4.846	65.167
Tertiary enrollment	615	6.48	6.932	0.269	35.028
Access to electricity	612	25.531	29.85	−7.684	100
GINPC	615	4134.992	4239.352	460	25,470
Income inequality					
Atkinson coefficient	615	0.577	0.173	0.17	0.833
Gini index	615	0.506	0.112	0.245	0.852
Palma ratio	615	4.525	2.335	0.835	14.435
Poverty headcount ratios					
hc186ppp2011	615	8.827	43.335	0	556.296
hc250ppp2005	615	20.861	91.412	0	932.88
hc144ppp2011	615	5.981	30.103	0	412.809

Table 1. Descriptive statistics

Table 2.
Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) Energy use per capita	1.000													
(2) CO2 emissions per capita	0.150*	1.000												
	(0.000)													
(3) Credit	0.374*	0.023	1.000											
	(0.000)	(0.571)												
(4) GDP_{PC} growth	–0.025	–0.013	0.013	1.000										
	(0.530)	(0.748)	(0.755)											
(5) Inflation	–0.045	–0.001	–0.112*	0.032	1.000									
	(0.265)	(0.977)	(0.006)	(0.430)										
(6) Trade % GDP	0.203*	0.242*	0.083*	0.179*	–0.101*	1.000								
	(0.000)	(0.000)	(0.039)	(0.000)	(0.012)									
(7) Remittances % GDP	0.075	–0.090*	–0.063	0.047	–0.079*	0.195*	1.000							
	(0.061)	(0.026)	(0.120)	(0.242)	(0.050)	(0.000)								
(8) Net FDI % GDP	0.073	0.123*	–0.021	0.187*	–0.025	0.324*	–0.029	1.000						
	(0.071)	(0.002)	(0.609)	(0.000)	(0.543)	(0.000)	(0.474)							
(9) Atkinson index	0.050	0.004	–0.029	–0.018	0.093*	–0.252*	–0.185*	0.065	1.000					
	(0.217)	(0.924)	(0.474)	(0.648)	(0.022)	(0.000)	(0.000)	(0.107)						
(10) Gini index	0.082*	0.030	–0.005	–0.010	0.091*	–0.211*	–0.167*	0.063	0.983*	1.000				
	(0.043)	(0.451)	(0.899)	(0.803)	(0.024)	(0.000)	(0.000)	(0.119)	(0.000)					
(11) Palma ratio	0.036	0.071	–0.018	0.011	0.072	–0.137*	–0.165*	0.051	0.919*	0.936*	1.000			
	(0.367)	(0.078)	(0.649)	(0.792)	(0.073)	(0.001)	(0.000)	(0.210)	(0.000)	(0.000)				
(12) Tertiary Enrollment	0.244*	0.168*	0.283*	0.036	–0.009	0.004	0.111*	–0.038	–0.047	–0.029	–0.063	1.000		
	(0.000)	(0.000)	(0.000)	(0.370)	(0.815)	(0.912)	(0.006)	(0.348)	(0.242)	(0.472)	(0.117)			
(13) GNI per capita	–0.168*	0.151*	0.030	–0.037	0.004	–0.088*	0.041	–0.004	–0.076	–0.068	–0.010	–0.001	1.000	
	(0.000)	(0.000)	(0.460)	(0.358)	(0.920)	(0.029)	(0.314)	(0.925)	(0.059)	(0.091)	(0.814)	(0.974)		
(14) Access to electricity	–0.089*	0.036	–0.106*	–0.053	0.099*	–0.113*	–0.141*	–0.085*	0.116*	0.119*	0.162*	0.051	0.106*	1.000
	(0.027)	(0.368)	(0.009)	(0.189)	(0.014)	(0.005)	(0.000)	(0.036)	(0.004)	(0.003)	(0.000)	(0.206)	(0.009)	

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

if the correlation coefficient is close to zero (0), it suggests that the variables are linearly independent, and multi-collinearity will not be an issue. In addition, a correlation coefficient less than 0.5, is generally considered acceptable.

The table reports that all the correlation coefficients are weakly correlated showing correlation coefficients below 0.5 in most cases. The study also shows that most of the correlation coefficients are statistically significant 10%. Theoretically, the study expects a positive relationship of energy use per capita, credit to the private sector as a percentage of GDP and CO_2 emissions per capita; the results meet this expectation. Similarly, the study expects energy consumption per capita to be positively correlated with a net inflow of FDI, remittances % GDP and trade % GDP. A negative relationship runs from the inequality variables to energy consumption per capita. The weak correlation between the variables indicates that the study is insulated from the problem of multi-collinearity.

2.4 Methodology

The study adopted the two-step GMM estimation strategy of Roodman (2009a, b), an extension of Arellano and Bover (1995). The choice of the GMM estimator is premised on four main justifying arguments. First, as a baseline requirement, the GMM estimation technique requires the number of cross-sections ($N = 41$) to be greater than the number of time series ($T = 15$). The correlation coefficients between the dependent variables and their corresponding first lags exceed the threshold that is critical for the establishment of persistence. The GMM estimation technique is also robust to the extent that it accounts for endogeneity by controlling simultaneity through instrumentation and time-invariant omitted variables. The GMM method also controls for cross-sectional dependence and restricts the proliferation of instruments (Love and Zicchino, 2006; Baltagi, 2008; Asongu *et al.*, 2020b; Tchamyou, 2020). Moreover, in accordance with Brambor *et al.* (2006), all the necessary elements have been incorporated in the specification. Finally, applying a panel data structure is consistent with the GMM technique, which does not eliminate cross-country variations. The preference of the two-step is supported by the fact that it controls for heteroscedasticity while the one-step only controls for homoscedasticity.

Baseline model:

$$ECPC_{i,t} = \delta_0 + \delta_1 ECPC_{i,t-\tau} + \delta_2 GDPPC_{i,t} + \delta_3 CO2_{i,t} + \delta_4 IEQxCREDIT_{i,t} + \sum_{n=1}^{n} \theta_j W_{n,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (1)$$

$$\begin{aligned} ECPC_{i,t} - ECPC_{i,t-\tau} = {} & \delta_1 (ECPC_{i,t-\tau} - ECPC_{i,t-2\tau}) + \delta_2 (GDPPC_{i,t} - GDPPC_{i,t-\tau}) \\ & + \delta_3 (CO2_{i,t} - CO2_{i,t-\tau}) + \delta_4 (IEQxCREDIT_{i,t} \\ & - IEQxCREDIT_{i,t-\tau}) + \sum_{n=1}^{n} \theta_j (W_{n,i,t-\tau} - W_{n,i,t-2\tau}) \\ & + (\xi_t - \xi_{t-\tau}) + \varepsilon_{i,t-\tau} \end{aligned} \quad (2)$$

Where $ECPC_{i,t}$ is energy consumption per capita of country I at period t. $GDPPC_{i,t}$ is GDP per capita of country I at period t. $CO2_{i,t}$ is CO_2 emissions per capita of country I at period t. $IEQxCREDIT_{i,t}$ is the interactive term between income inequality indicators (poverty headcount ratios) of country I at period t. δ_0 is a constant and τ is the autoregression coefficient; W is also a vector of independent control variables (Net FDI as a percentage of GDP, remittances as a percentage of GDP, size of rural population with access to electricity and tertiary education enrollment). η_i represents country-specific effect, ξ_t is also the time-specific effect and $\varepsilon_{i,t}$ is the error term.

3. Empirical results and discussion

The study opens the empirical discussion by examining the causal relationship between CO_2 emissions and energy consumption, credit to the private sector and economic growth. In column (1) of Table 3, the study documented how the lags of CO_2 emissions affect the present, while in column 2; the study reports how CO_2 emission is affected by the growth in the economy, credit to the private sector and energy consumption per capita in Africa. The study found that increasing energy consumption positively and significantly affects CO_2 emissions. Similarly, an increase in credit to the private sector (at 5% significance level) and growth in national income (at 10% significance level) also causes CO_2 emissions to increase. These findings contradict the findings of Acheampong (2018), who reported that energy consumption causes CO_2 emissions in the Middle East and North Africa but negatively causes CO_2 emissions in Africa. These findings also firmly collaborate earlier findings by Ma *et al.* (2019) of the positive influence of rapid economic development and accelerated urbanization on energy production consumption and, consequently, its attending adverse effect on CO_2 emissions in China. Similar results were documented by Ahmad *et al.* (2016) in India. They established a positive long-run causal relationship between energy consumption and CO_2 emissions and reverse causality between economic growth and CO_2 emissions.

In Table 4, the study showed the results of the causal relationship between energy consumption per capita, economic growth and a set of control variables. In column 1 of

	The dependent variable is CO_2 emission per capita	
Variables	Model (1)	Model (2)
L. CO_2 emissions	0.898*** (0.0185)	0.904*** (0.0226)
Energy consumption per capita		0.00513** (0.00211)
Gross national income per capita		0.0230* (0.0161)
Inflation		0.000132 (0.00193)
Remittances % GDP		0.000721* (0.00038)
Net FDI % of GDP		−0.00423 (0.00427)
Credit		0.000143** (0.00007)
Tertiary enrollment		0.00294 (0.00323)
Access to electricity rural		−0.00164 (0.00303)
Constant	0.0958*** (0.0319)	0.134*** (0.015)
Observations	574	571
Number of id	41	41
AR (1)	−0.166	−1.67
p-value	0.096	0.095
AR (2)	−1.07	−1.09
p-value	0.287	0.275
Sargan test	130.39	70.75
p-value	0.000	0.000
Hanson test	19.92	17.19
p-value	0.338	0.308

Note(s): Standard errors in parentheses
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 3.
CO_2 emission per capita and energy consumption per capita

The dependent variable is energy consumption per capita Variables	Model (1)	Model (2)	Model (3)
L. Energy consumption per capita	0.994*** (0.00822)	1.015*** (0.00830)	1.012*** (0.00948)
GDP_{PC} growth		0.00284* (0.00136)	
Net FDI % GDP		1.592* (0.933)	1.729 (1.185)
Trade % of GDP		−0.844*** (0.276)	−0.792*** (0.269)
Remittances % of GDP		1.098 (0.681)	1.191** (0.559)
Inflation		−0.635* (0.320)	−0.634 (0.403)
Tertiary enrollment		−0.734 (0.748)	−0.635 (0.657)
Intermediation efficiency		0.0734** (0.0263)	0.218* (0.160)
Constant	12.11*** (4.470)	46.92 (31.17)	47.08 (29.63)
Observations	574	574	574
Number of id	41	41	41
AR (1)	−0.166	−1.67	−1.88
p-value	0.097	0.098	0.060
AR (2)	−1.07	−1.09	−0.48
p-value	0.287	0.265	0.633
Sargan test	131.39	71.74	5.62
p-value	0.000	0.000	0.691
Hanson test	19.82	17.29	4.59
p-value	0.337	0.306	0.792

Note(s): Standard errors in parentheses; where $***p < 0.01$, $**p < 0.05$, $*p < 0.1$

Table 4. Energy consumption per capita and national income per capita

Table 4, the study documented how past values energy consumption per capita positively and significantly affects the present; whiles in column 2, the study reported how energy consumption per capita is affected by the growth in the economy (GNI per capita), financial intermediation efficiency (banks credit to banks deposits ratio) and other macro-variables that influence finance and consumption (inflation, personal, remittances and FDI) in Africa. The study found in Model 2 that economic growth (GNI per capita) positively and significantly affects energy consumption per capita. Similarly, increasing net FDI % of GDP (at 10% significance level) and intermediation efficiency (at 10% significance level) also stimulate energy consumption (Model 2). The study also found that trade openness and inflation negatively affect energy consumption per capita. The results agree with the findings of Vidyarthi (2013), who found unidirectional causality running from energy consumption and CO_2 emissions to economic growth in the long run in India. Similar results are also attributed to Akadiri *et al.* (2019), who found a unidirectional causality from economic growth to energy consumption and from CO_2 emissions to energy consumption in the long run in Iraq. These findings also firmly collaborate earlier findings by Ma *et al.* (2019) of the positive influence of rapid economic development and accelerated urbanization on energy production, consumption and, consequently, its attending adverse effect on CO_2 emissions in China. Similar results are shared by Ahmad *et al.* (2016) in India, where they established a positive long-run causal relationship between energy consumption and CO_2 emissions and reverse causality between economic growth and CO_2 emissions.

Following recent threshold literature (Asongu and Nwachukwu, 2018; Asongu and Odhiambo, 2018, 2020a; Boateng *et al.*, 2018; Asongu *et al.*, 2019) and also contingent on the problem statement underlying this study, thresholds or critical masses at which income inequality completely wipes-outs the expected positive incidence of finance (credit to the private sector) on energy consumption per capita and GDP per capita growth is established. Accordingly, the intuition for this research is consistent with positive unconditional effects of finance (credit to the private sector) and GDP per capita growth on energy consumption per capita and negative conditional impacts (i.e. from the interaction between finance (credit to the private sector) and GDP per capita growth and income inequality (Atkinson, Gini and Palma)) on energy consumption per capita. It follows that the study expects access to finance (credit to the private sector) and GDP per capita growth to promote energy consumption per capita, while income inequality should dampen the underlying positive nexus. Hence, with positive unconditional effects and the corresponding negative conditional or interactive effects, at certain thresholds of income inequality (Atkinson, Gini and Palma), the positive incidence of finance (credit to the private sector) and GDP per capita growth on energy consumption per capita is no longer apparent. This study aims to establish such thresholds of income inequality (Atkinson, Gini and Palma) above which finance (credit to the private sector) and GDP per capita growth no longer promotes energy consumption per capita GDP per capita growth in Africa.

The threshold represents the point at which further income inequality (Atkinson, Gini and Palma) compromises development by yielding a net negative effect on energy consumption per capita and per capita growth. The concept of threshold is consistent with the literature, notably: minimum conditions for desired impacts (Cummins, 2000), critical masses for appealing results (Roller and Waverman, 2001; Batuo, 2015) and requirements for inverted U-shaped and U-shaped patterns (Ashraf and Galor, 2013). The relevance of the thresholds from a policy-making perspective, is only attained when they are within the corresponding statistical range reported in the summary statistics.

Table 5 presents thresholds at which income inequality (Atkinson, Gini and Palma) negatively affect energy consumption per capita. Hence, only thresholds corresponding to negative marginal effects are computed. Moreover, negative marginal effects overwhelmingly dominate positive marginal effects. For instance, in Model (3) of Table 5, the 0.680 threshold corresponding income inequality (Atkinson coefficient) established for African countries is the quotient of "4.565/6.708". This implies that when income inequality (Atkinson coefficient) is 0.681, the net effect of finance (credit to the private sector) on energy consumption per capita is 0.00356 ([-6.708×0.680] + [4.565]). Hence, income inequality (Atkinson coefficient) beyond 0.680 corresponds to a net negative effect on energy consumption per capita. However, the established threshold has little practical relevance unless it is consistent with the range of income inequality provided by the summary statistics. The minimum and maximum values respectively corresponding to income inequality (Atkinson coefficient) are 0.17 and 0.833.

In the light of the above, thresholds for policy relevance are highlighted in bold in Table 5. For brevity; the thresholds are emboldened since they are self-evident from Table 5. It is essential to articulate the thresholds from the regressions, which are apparent from the results of the regressions in the panels for all the representative income inequality variables and finance (credit to the private sector). They are 0.582 (5.749/9.876) for Gini and credit to the private sector; 5.991 (2.678/0.447) Palma coefficient and credit to the private sector. All the thresholds are within policy range because they are within the minimum and maximum ranges provided by the summary statistics.

The results of the critical masses are summarily consistent with the findings of earlier studies, including Asongu and Odhiambo (2021), who established that financial development unconditionally impacts renewable energy consumption in Africa, whiles income inequality dampens the underlying positive effects. Komal and Abbas (2015) also found a positive synergy between economic growth and energy consumption, while financial development positively and significantly promotes energy consumption through the economic growth channel in Pakistan. Saini and Neog (2018) also found a bi-directional causality between financial development and energy consumption in India.

Table 5. Finance, Income inequality and Energy consumption per capita

Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
	The dependent variable is energy consumption per capita				
L. Energy consumption per capita	0.994*** (0.00822)	0.991*** (0.00894)	1.008*** (0.00844)	1.013*** (0.00878)	1.009*** (0.00895)
Atkinson index		−86.46 (81.23)	−294.0** (143.8)		
Credit		1.224* (0.610)	4.565** (1.682)	2.678*** (0.881)	5.749** (2.551)
Atkinson *x* credit		−1.702* (0.854)	−6.708** (2.730)		
GDP_{pc} growth			−1.448 (3.383)	−1.382 (3.008)	−1.681 (3.192)
Net FDI % GDP			1.722 (1.417)	1.476 (1.159)	1.704 (1.317)
Trade			−0.884*** (0.218)	−0.911*** (0.187)	−0.973*** (0.225)
Remittances % GDP			1.839** (0.857)	1.749** (0.763)	1.855* (0.923)
Inflation			−0.970** (0.389)	−0.813* (0.424)	−0.950* (0.524)
Tertiary enrollment			−1.627** (0.754)	−1.121 (0.774)	−1.504* (0.849)
Intermediation efficiency			−0.206 (0.587)	−0.277 (0.637)	−0.361 (0.539)
Palma ratio				−18.28** (8.192)	
Palma ratio *x* credit				−0.447** (0.173)	
Gini coefficient					−488.8 (290.7)
Gini coefficient *x* credit					−9.876** (4.660)
Constant	12.11*** (4.470)	−41.48 (49.53)	−88.89 (101.1)	−1.777 (65.75)	−149.6 (149.9)
Threshold		0.719	0.681	5.991	0.582
Net effect		0.242	0.694	0.655	0.771
Observations	574	574	574	574	574
Number of id	41	41	41	41	41
AR (1)	-0.157	−1.68	−1.88	−1.83	−1.83
p-value	0.094	0.098	0.060	0.067	0.067
AR (2)	−1.05	−1.08	−0.48	−0.51	−0.34
p-value	0.287	0.274	0.632	0.618	0.741
Sargan test	133.39	71.75	5.61	5.09	3.92
p-value	0.000	0.000	0.691	0.737	0.874
Hanson test	19.92	17.19	4.68	5.11	5.69
p-value	0.328	0.318	0.781	0.746	0.681

Note(s): Standard errors in parentheses; where, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

The study also achieves the net effect by adjusting for the pitfall in the interactive regression by calculating the net effect and adding all the slopes of variables to the model. The net effect of credit to the private sector in moderating the impact of income inequality (Atkinson coefficient) on energy consumption per capita in Model 3 is 0.694, i.e. $[(-6.708 \times 0.577) + (4.565)]$. The net effect calculation is done based on the mean value of the income inequality (Atkinson) 0.577 as provided in the summary statistic. The unconditional effect of finance (credit to the private sector) is 4.565, and the conditional effect from the interaction between credit to the private sector and the Gini coefficient is −6.708. The net effect is only computed when both the conditional and unconditional effects are statistically significant. Consistent with the thresholds, and as interpreted above, mean values of the income inequality indicators (supplied in the summary statistics) above the thresholds provide negative net effects, and the mean values of the income inequality indicators (supplied in the summary statistics) below the thresholds provides positive net effects. These are critical findings for policy direction.

Table 6 further demonstrates the causal relationship among income inequality indicators (Atkinson, Gini and Palma), economic growth (GDP per capita growth) and energy consumption per capita. It is reported that the income inequality indicators (Atkinson, Gini and Palma) exhibited negative effects on energy consumption, while economic growth (GDP per capita growth) showed a positive effect on energy consumption. The interaction between income inequality indicators (Atkinson, Gini and Palma) and economic growth (GDP per capita growth) also negatively affected energy consumption. These findings are summarily consistent with the theory and the expectations of this study, such that a growing and robust economy will stimulate and yield a positive net effect on energy consumption while high poverty levels downplay the positive effect.

In Model (3) of Table 6, the 0.669 threshold corresponding income inequality (Atkinson coefficient) established is the quotient of "22.45/33.55". This implies that when income inequality (Atkinson coefficient) is 0.669, the net effect of GDP per capita growth on energy consumption per capita is 0.00505 $([-33.55 \times 0.669] + [22.45])$. Hence, income inequality (Atkinson coefficient) beyond 0.669 corresponds to a net negative effect on energy consumption per capita and per capita growth. However, the established thresholds have little practical relevance unless they are consistent with the range of income inequality provided by the summary statistics. The minimum and maximum values respectively corresponding to income inequality (Atkinson coefficient) are 0.17 and 0.833.

In the light of the above, thresholds of policy relevance are highlighted in bold in Table 6. It is essential to articulate the thresholds from the regressions, which are apparent from the regressions outputs in the panels for all the representative income inequality variables and finance (credit to the private sector). They are 0.568 (31.92/56.19) for Gini and GDP per capita growth; 6.110 (9.397/1.538) Palma coefficient and GDP per capita growth. All the thresholds are within policy range because they are within the minimum and maximum ranges provided by the summary statistics.

The results of the critical masses are summarily consistent with the findings of earlier studies, including Asongu and Odhiambo (2021), who reported that financial development unconditionally impacts renewable energy consumption in Africa, whiles income inequality dampens the underlying positive effects. Komal and Abbas (2015) also found a positive synergy between economic growth and energy consumption, while financial development positively and significantly promotes energy consumption through the economic growth channel in Pakistan. Saini and Neog (2018) also found a bi-directional causality between financial development and energy consumption in India.

The study also achieves the net effect by adjusting for the pitfall in the interactive regression by calculating the net effect and adding all the slopes of variables to the model. The net effect of GDP per capita growth in moderating the impact of income inequality (Atkinson coefficient) on

Table 6. GDP per capita growth, income inequality and energy consumption per capita

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
	The dependent variable is energy consumption per capita				
L. Energy consumption	0.994*** (0.00822)	0.994*** (0.00702)	1.010*** (0.0112)	1.009*** (0.0115)	1.008*** (0.0126)
AQ		−11.83 (103.2)	−29.68 (75.24)		
GDP per capita growth		13.55** (5.42)	22.45** (10.23)	9.397** (3.911)	31.92** (11.90)
Atkinson X GDP_{PC} growth		−16.77** (6.32)	−33.55** (13.23)		
Credit			0.108 (0.482)	0.363 (0.427)	0.0850 (0.408)
Net FDI % of GDP			2.031 (1.667)	2.164 (1.420)	2.629 (1.594)
Trade % of GDP			−0.801*** (0.260)	−0.824*** (0.264)	−0.825*** (0.263)
Remittances % of GDP			2.136** (0.864)	1.792** (0.691)	1.835** (0.866)
Inflation			−0.749* (0.421)	−0.677* (0.385)	−0.703 (0.468)
Tertiary enrollment			−0.895 (1.027)	−0.661 (0.819)	−0.753 (1.141)
Intermediation efficiency			0.260 (0.650)	−0.0781 (0.557)	0.314 (0.505)
Palma ratio				−1.997* (0899)	
Palma ratio X GDP_{PC} growth				−1.538** (0.606)	
Gini index					−47.46* (23.008)
Gini index X GDP_{PC} growth					−56.19*** (7.90)
Constant	12.11*** (4.470)	13.68** (6.89)	29.03** (9.68)	56.41*** (5.52)	20.05** (1.28)
Threshold		0.808	0.669	6.110	0.568
Net effect		4.450	3.092	2.438	3.600
Observations	574	574	574	574	574
Number of id	41	41	41	41	41
AR (1)	−0.167	−1.67	−1.88	−1.83	−1.83
p-value	0.096	0.095	0.060	0.067	0.067
AR (2)	−1.07	−1.09	−0.48	−0.50	−0.33
p-value	0.287	0.275	0.633	0.618	0.741
Sargan test	130.39	70.75	5.61	5.09	3.92
p-value	0.000	0.000	0.691	0.747	0.864
Hanson test	19.92	17.19	4.68	5.11	5.69
p-value	0.338	0.308	0.791	0.746	0.682

Note(s): Standard errors in parentheses; where, $***p < 0.01$, $**p < 0.05$, $*p < 0.1$

energy consumption per capita in Model 3 is 3.092, i.e. [(−33.55 × 0.577) + (22.45)]. The net effect calculation is done based on the mean value of the income inequality (Atkinson) 0.577 as provided in the summary statistic. The unconditional effect of GDP per capita growth is 22.45, and the conditional effect from the interaction between credit to the private sector and the Gini coefficient is −33.55. The net effect is only computed when both the conditional and unconditional effects are statistically significant. Consistent with the thresholds and as interpreted above, mean values of the income inequality indicators (supplied in the summary statistics) above the thresholds provide negative net effects and mean values of the income inequality indicators (supplied in the summary statistics) below the thresholds provides positive net effects.

Similar arguments are advanced in computing the critical masses (thresholds) and net effects of the interaction between poverty headcounts and credit to the private sector (financial access). In Model (3) of Table 7, the 7.069 threshold corresponding to poverty headcount (hc$144ppp2011) established is the quotient of "1.718/0.243". This implies that when poverty headcount (hc$144ppp2011) is 7.070, the net effect on energy consumption per capita and per capita growth is 0.000233 ([−0.243 × 7.069] + [1.718]). Hence, poverty headcount (hc$144ppp2011) beyond 7.070 corresponds to a net negative effect on energy consumption per capita and per capita growth. However, the established threshold has little practical relevance unless it is consistent with the range of poverty headcount by the summary statistics. The minimum and maximum values, respectively corresponding to poverty headcount (hc$144ppp2011) are 0.00 and 556.296.

In the light of the above, thresholds of policy relevance are highlighted in bold in Table 7. It is essential to articulate the thresholds from the regressions, which are reported from the regressions estimates in the panels for all the representative poverty headcount ratios and finance (credit to the private sector). They are 28.278 (1.872/0.0662) for hc$186ppp2011 and credit to the private sector in panel 5; 129.332 (1.239/0.00958) hc$250ppp2005 and credit to the private sector in Panel 7. All the thresholds are within policy range because they are within the minimum and maximum ranges provided by the summary statistics.

The study achieved the net effect by adjusting for the pitfall in the interactive regression by summing all the slopes of variables to the model. The net effect of finance (credit to the private sector) in moderating the impact of poverty headcount (hc144ppp2011) on energy consumption per capita in Model 3 is 0.265, i.e. [(−0.243 × 5.981) + (1.718)]. The net effect calculation is done based on the mean value of the headcount (hc144ppp2011) 5.981 as provided in the summary statistic. The unconditional effect of finance (credit to the private sector) is 1.718, and the conditional effect from the interaction between credit to the private sector and headcount (hc144ppp2011) is −0.243. The net effect is only computed when both the conditional and unconditional effects are statistically significant. Consistent with the thresholds, and as interpreted above, mean values of the poverty headcount ratios (supplied in the summary statistics) above the thresholds provide negative net effects and mean values of the income inequality indicators (supplied in the summary statistics) below the thresholds provides the positive net effect.

The study demonstrated the causal relationship between poverty headcounts (hc$1.44ppp2011, hc$1.86ppp2011 and hc250ppp2005) and financial access (credit to the private sector as a percentage of GDP), and energy consumption per capita. It is reported that the poverty indicators exhibit negative effects on energy consumption whiles credit the private sector showed a positive effect on energy consumption. The interaction between poverty headcounts and financial access also produced a negative effect on energy consumption. These findings are summarily consistent with the theory and the expectations of the study. Improvement in access to finance will stimulate and yield a positive net effect on energy consumption while high poverty levels downplay the positive effect. The results of the critical masses are summarily consistent with the findings of earlier studies, including

Table 7. Finance, poverty headcounts and energy consumption per capita

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	The dependent variable is energy consumption per capita						
L. Energy consumption	0.989*** (0.0149)	0.915*** (0.0476)	0.862*** (0.110)	0.930*** (0.0364)	0.863*** (0.130)	0.916*** (0.0456)	0.763** (0.284)
hc144ppp2011		−0.610** (0.272)	−6.635** (2.67)				
Credit		1.791** (0.733)	1.718** (0.805)	1.134*** (0.008)	1.872** (0.722)	1.814** (0.679)	1.239* (0.612)
hc144ppp2011 X credit		−0.0553** (0.026)	−0.243** (0.011)				
GDP_{PC} growth			2.997* (1.451)		3.396* (1.566)		3.484* (1.728)
Net FDI % GDP			9.625* (4.812)		8.322* (4.190)		9.484* (4.301)
Trade % GDP			−1.393* (0.698)		−0.622 (2.718)		−0.848 (3.293)
Remittances % GDP			−0.361 (6.525)		−1.596 (6.212)		−2.434 (6.407)
Inflation			2.969 (3.448)		3.234** (1.245)		2.708 (3.994)
Tertiary enrollment			0.339 (4.153)		1.379 (4.223)		2.744 (4.367)
Intermediation efficiency			6.515 (4.353)		6.845* (3.964)		8.461* (4.607)
hc186ppp2011				−1.597** (0.794)	−2.535** (0.854)		
hc186ppp2011 X credit				−0.0885*** (0.024)	−0.0662** (0.030)		
hc250ppp2005						0.969 (1.065)	−1.004 (9.816)
hc250ppp2005 X credit						−0.0978** (0.026)	−0.00958** (0.0041)
Constant	10.04** (4.744)	13.15** (5.76)	−312.1** (135.9)	14.50** (6.31)	−397.9** (159.1)	23.75** (8.65)	−430.2** (206.2)
Threshold		32.387	7.070	12.814	28.278	18.548	129.332
Net effect		1.460	0.265	0.352	−3.971	−0.226	1.039
Observations	574	574	574	574	574	574	574
Number of id	41	41	41	41	41	41	41
AR (1)	-0.177	−1.77	−1.89	−1.60	−1.85	−1.63	−1.80
p-value	0.097	0.097	0.061	0.087	0.064	0.095	0.069
AR (2)	−1.06	−1.08	−0.46	−1.08	−0.40	−1.13	−0.34
p-value	0.286	0.275	0.631	0.284	0.608	0.247	0.740
Sargan test	132.38	70.79	5.60	69.82	5.09	76.25	3.93
p-value	0.000	0.000	0.689	0.000	0.748	0.000	0.865
Hanson test	18.93	16.18	4.69	13.49	5.10	18.86	5.71
p-value	0.349	0.306	0.792	0.547	0.745	0.227	0.673

Note(s): Standard errors in parentheses, where *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Asongu and Odhiambo (2021), who reported that financial development unconditionally impacts renewable energy consumption in Africa, whiles income inequality dampens the underlying positive effects. Komal and Abbas (2015) also found a positive synergy between economic growth and energy consumption, while financial development positively and significantly promotes energy consumption through the economic growth channel in Pakistan. Similarly, Saini and Neog (2018) also found a bi-directional causality between financial development and energy consumption in India.

4. Conclusion and recommendations

This study departed from the conventional energy-growth-finance nexus by examining how the negative effect of income inequality and poverty on access and consumption of energy in Africa can be dampened by financial development (credit to the private sector) and economic growth. The study provided the critical masses (thresholds) at which the positive incidence of finance and economic growth will be dampened by the negative effects of income inequality and poverty on energy consumption in Africa for policy direction. Using the GMM estimator for 41 countries from 2005–2020, the study found that for credit to the private sector to maintain a positive effect on energy consumption per capita, then the critical thresholds for the income inequality indicators (Atkinson coefficient, Gini index and the Palma ratio) should not exceed 0.681, 0.582 and 5.991, respectively. Similarly, for economic growth (GDP per capita growth) to maintain a positive effect on energy consumption per capita, the critical thresholds for the income inequality indicators (Atkinson coefficient, Gini index and the Palma ratio) should not exceed 0.669, 0.568 and 6.110, respectively. On the poverty level in Africa, the study reports that the poverty headcount ratios (hc$144ppp2011, hc186ppp2011 and hc$250ppp2005) should not exceed 7.342, 28.278 and 129.332, respectively for financial development to maintain a positive effect on energy consumption per capita.

We provide vital evidence that access to finance and economic growth are vital in stimulating the demand for energy in Africa, where only 25.531% of the rural population has access to electricity for policymakers and the real managers of the economy. We also confirmed the positive nexus between access to finance (financial development) and energy consumption per capita, with the attending adverse effect on CO_2 emissions inescapable. Higher energy consumption occasioned by improved financial development contributes to the deterioration of the environment through CO_2 emissions.

It is evident, for policy recommendation, that finance is at the micro-foundation of economic growth, income inequality and poverty alleviation. However, a maximum threshold of income inequality and poverty headcount ratios as indicated in this study must be maintained by policymakers and governments to attain the full positive ramifications of financial development and economic growth on energy consumption in Africa. The study also advocates for strong efforts to improve financial access through inclusive finance programs to elevate persons and groups living below the poverty line for increased energy consumption. Conclusively, the study recommends that further studies focus on country-specific characteristics to establish the thresholds and net effects of financial development and economic growth in modulating income inequality and poverty alleviation on energy consumption in Africa. Such will supply policymaker's country-specific policy designs that would be more flexible and executable given the dynamics and resource constraints of the country.

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Appendix

Country	Freq.	Percent	Cum.
Benin	15	2.44	2.44
Botswana	15	2.44	4.88
Burkina Faso	15	2.44	7.32
Burundi	15	2.44	9.76
Cabo Verde	15	2.44	12.20
Cameroon	15	2.44	14.63
Central African Republic	15	2.44	17.07
Chad	15	2.44	19.51
Comoros	15	2.44	21.95
Congo, Dem. Rep.	15	2.44	24.39
Congo, Rep.	15	2.44	26.83
Cote D'ivoire	15	2.44	29.27
Djibouti	15	2.44	31.71
Egypt, Arab Rep.	15	2.44	34.15
Eswatini	15	2.44	36.59
Gabon	15	2.44	39.02
Gambia, The	15	2.44	41.46
Ghana	15	2.44	43.90
Guinea	15	2.44	46.34
Guinea-Bissau	15	2.44	48.78
Kenya	15	2.44	51.22
Lesotho	15	2.44	53.66
Liberia	15	2.44	56.10
Madagascar	15	2.44	58.54
Malawi	15	2.44	60.98
Mali	15	2.44	63.41
Mauritania	15	2.44	65.85
Mauritius	15	2.44	68.29
Mozambique	15	2.44	70.73
Niger	15	2.44	73.17
Nigeria	15	2.44	75.61
Senegal	15	2.44	78.05
Seychelles	15	2.44	80.49
Sierra Leone	15	2.44	82.93
South Africa	15	2.44	85.37
Sudan	15	2.44	87.80
Sao Tome and Principe	15	2.44	90.24
Tanzania	15	2.44	92.68
Togo	15	2.44	95.12
Tunisia	15	2.44	97.56
Zimbabwe	15	2.44	100.00
Total	615	100.00	

Table A1.
List of countries