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Income Inequality and Energy Consumption in Africa: A Nonlinear Dynamic Panel Threshold Analysis of Financial and Governance Moderation Effects

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Abstract

This study investigates the intricate relationships among energy consumption, income inequality, financial development, and governance quality in the African region. Focusing on African countries characterized by prevalent energy poverty, weak governance, and underdeveloped financial systems, the moderating role of income inequality on energy consumption is examined using a dynamic panel threshold model. The primary objective is to elucidate the nonlinear nature of these relationships and identify how their effects vary depending on income inequality thresholds. The analysis encompasses 21 sub-Saharan and 5 North African countries over the period 1985–2021, utilizing indicators sourced from various databases. Following preliminary tests, the study employs the dynamic panel threshold method developed by Diallo (2020), which builds on Hansen's (1999) threshold modelling framework. Below the income inequality threshold, financial development and government quality exhibit a positive relationship with energy consumption. Above this threshold, the relationship turns negative due to heightened inequality. This study enhances the literature on how fragile financial systems and inadequate governance, influenced by income inequality, obstruct Africa's sustainable energy transition, advocates for cohesive policies to tackle inequality, implements institutional reforms, and promotes financial inclusion, while providing substantial, regime-dependent insights into energy consumption dynamics.

Keywords: Income inequality, energy consumption, financial development, governance, institutional quality, dynamic panel threshold analysis

JEL Classification: C23, O13, O15

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1. Introduction

Energy poverty remains one of the most pressing challenges in Southern African countries. These nations are characterized by high energy demand, heavy dependence on fossil fuels, and persistent difficulties in transitioning to renewable energy sources (Todd and McCauley, 2021, pp. 5–7; Mirzania *et al*., 2023, p. 8; Masuku, 2024, p. 3). These challenges are further exacerbated by underdeveloped financial systems and weak institutional frameworks, making the region an important case for examining the interplay between energy consumption, institutional quality, and financial development. In particular, South Africa presents a dual dynamic: while financial and institutional advancements have driven energy consumption and offer potential for supporting a renewable energy transition, the country's dependence on coal and persistent governance deficiencies continue to impede sustainable progress. Conversely, in less developed countries across the region, inadequate financial infrastructure and institutional weaknesses perpetuate fossil fuel reliance and constrain access to cleaner energy sources. Recent empirical studies – such as those by Smarte Anekwe *et al*. (2024), Cai *et al*. (2024), Diallo and Ouba (2024), Odhiambo (2023), and Okere and Fasanya (2024) – have emphasized the critical roles of transparency, corruption control, the rule of law, political stability, robust institutional frameworks, and deep financial markets in shaping both the quantity and quality of energy consumption in Sub-Saharan Africa. These findings underscore the importance of a holistic, governance-centred approach to energy policy and sustainable development.

From a political economic perspective, income inequality plays a pivotal role in shaping patterns of energy use. Wan *et al*. (2022) argue that inequality leads to power asymmetries in society, where wealthier individuals tend to favour cheap fossil fuels to minimize costs and show less willingness to support environmental improvements, thereby increasing aggregate energy consumption. At the same time, lower-income groups often rely on inefficient energy sources for survival, while environmentally conscious voices among the poor are frequently ignored due to systemic inequities (Chen *et al*., 2020). Mallick *et al*. (2019) further suggest that income equalization can enhance the enforcement of environmental regulations, thus improving energy sustainability outcomes. Economically, income inequality intensifies the unequal distribution of social benefits, provokes social conflict, and fuels short-term, individualistic consumer behaviour. This dynamic leads to increased demand for low-cost, energy-intensive products driven by private benefit maximization (Wan *et al*., 2022). Communities marked by income inequality tend to exhibit diminished social trust and lower levels of environmental awareness, which in turn undermines collective responsibility and encourages environmentally harmful consumption patterns (Tan and Uprasen,

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2021). Ahlborg *et al*. (2015) found that residents in unequal African communities show significantly lower interest in environmentally friendly products. Additionally, inequality is viewed as a barrier to technological innovation and productivity growth, further reinforcing high energy dependency (Sahu and Patnaik, 2020).

The energy–growth nexus has long been studied in the literature through four main hypotheses: the growth hypothesis, which sees energy as a driver of economic growth; the conservation hypothesis, which views energy demand as a consequence of investment-led growth; the feedback hypothesis, which posits bidirectional causality; and the neutrality hypothesis, which assumes no significant relationship between the two (Atsu *et al*., 2021; Fatima *et al*., 2021; Lu *et al*., 2021). Moreover, recent contributions have examined how financial and institutional development, trade openness, and technological progress affect energy demand (Yao *et al*., 2019; Hanif *et al*., 2020). Emerging findings highlight income inequality as a critical determinant of energy access, where growing disparities constrain energy use among low-income groups and suppress aggregate consumption (Sehrawat, 2021; Nkomo, 2007). The energy ladder hypothesis offers an important lens here, suggesting that as household income rises, energy preferences shift from traditional biomass to coal, and eventually to electricity or cleaner energy forms (Asongu and Odhiambo, 2024; Nar, 2021). This dynamic reflects how energy consumption can stimulate economic growth by improving labour market outcomes and household income, which in turn enhances access to education and healthcare services, potentially reducing inequality over time. Conversely, persistent energy deprivation hinders educational and employment opportunities, thereby reinforcing poverty and inequality (Nkomo, 2007; Asongu and Odhiambo, 2021).

Despite the expanding body of literature on energy transitions and inequality, several important gaps remain that this study seeks to address. First, while considerable research has examined the relationship between income inequality and environmental degradation, the direct link between income inequality and energy consumption, particularly within the African context, remains underexplored. Second, the nonlinear nature of this relationship – especially the existence of threshold effects – has largely been overlooked, despite theoretical support for such dynamics. Third, there is limited empirical evidence on the moderating roles of financial development and governance quality, even though these institutional factors are widely recognized as critical to energy access and policy efficiency. Finally, most existing studies do not account for regime-dependent effects, thus failing to capture how income inequality may condition or reverse the influence of financial and institutional variables on energy consumption. This study addresses these gaps by applying a dynamic panel threshold model to a panel of 26 African countries from 1985 to 2021. The paper

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contributes to the literature by identifying inequality thresholds that alter the direction and magnitude of institutional and financial impacts on energy use, treating income inequality as a threshold variable rather than a simple control. By accounting for cross-sectional dependence, endogeneity, and dynamic persistence, the study offers a more nuanced understanding of how equitable and efficient energy systems can be promoted in highly unequal settings. In doing so, it provides policy-relevant insights for overcoming energy poverty and advancing sustainable development in Africa.

2. Literature review

The existing literature primarily addresses the relationship between income inequality and various environmental issues such as environmental degradation, the Environmental Kuznets Curve (EKC), energy poverty, and carbon emissions. However, the link between income inequality and energy consumption has received comparatively less attention, despite its critical importance for the formulation of effective economic and environmental policies. This relationship becomes even more complex when mediated by financial development and the quality of governance. In this context, understanding how financial systems, institutional structures, and governance quality influence both income distribution and energy consumption is essential for achieving the United Nations' Sustainable Development Goals (SDGs). Several recent studies provide valuable insights into this multifaceted relationship. Baloch *et al*. (2020) examined the interplay among income inequality, poverty, and carbon emissions across 40 sub-Saharan African (SSA) countries between 2010 and 2016. Their findings revealed that rising income inequality contributes to increased carbon emissions, while escalating poverty further aggravates environmental degradation. Similarly, Uzar (2020), using panel data from 43 countries, found that income inequality has a significant negative impact on renewable energy consumption. Arı (2022), focusing on the Turkish economy over the period 1989–2018, identified no long-term relationship between income inequality and energy consumption but reported a short-term effect, underscoring the role of country-specific institutional and structural dynamics.

Further contributions to this line of inquiry come from Asongu and Odhiambo (2024), who investigated the effect of income inequality on renewable energy use by employing three inequality indices (Atkinson Index, Palma Ratio, and Gini Coefficient). Their results demonstrated that only the Atkinson Index shows a clear positive association with renewable energy consumption, particularly when it exceeds a threshold value of 0.6180. Below this threshold, a negative relationship – referred to as the "equality hypothesis" – was observed. This nuanced finding highlights the importance of considering non-linear threshold effects

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and the limitations of generalizing such results across different SSA countries. Sarkodie and Adams (2020) analysed the relationship between income inequality and energy poverty in 45 SSA countries over the period 1990–2017, using access to electricity as a key proxy. Their findings indicated that increasing income inequality significantly reduces electricity access. Similarly, Boyce (1994) argued that high-income groups influence policymaking through institutional corruption and political instability, sustaining fossil fuel-based policies and hindering the shift toward renewable energy. Berthe and Elie (2015) further noted that societies with widening income disparities tend to show reduced public support for environmental policies, as inequality weakens collective concern for environmental sustainability.

Trotter (2016) examined the effect of democratization on rural electrification using panel data from 46 SSA countries (1990–2010) and in-depth case studies. The study concluded that democratization, competitive elections, effective policy implementation, and increased national savings promote rural electrification, while high dependence on foreign aid and large rural populations hinder equitable electricity access. In another significant contribution, Asongu and Odhiambo (2021) used Generalized Method of Moments (GMM) and Quantile Regression techniques to explore the impact of financial development and income inequality on renewable energy consumption in 39 SSA countries. Their findings suggest that financial development positively influences renewable energy use, but its effect is offset by rising income inequality. Acheampong (2022) employed a two-step GMM estimator to assess the influence of income inequality and governance quality on electricity access in 43 SSA countries from 1990 to 2017. The study revealed that while income inequality severely restricts electricity availability, governance quality shows only a limited capacity to mitigate energy poverty. This suggests that governance reforms alone may not be sufficient unless combined with income redistribution policies. Guo, You and Lee (2022) further explored how income inequality and country risk affect CO_2 emissions in 73 countries, including selected African nations, over the period 1995–2014. Their results support an inverted U-shaped relationship between GDP and emissions and highlight that country risk can diminish the negative impact of inequality on emissions, especially in low- and upper-income countries.

Nawaz and Rahman (2023), using data from 31 countries between 2002 and 2019, examined how financial development, institutional quality, and human capital interact to influence renewable energy consumption. The findings highlight a U-shaped GDP–energy consumption nexus and underscore the complementary role of human capital in driving the energy transition. Their study emphasizes the need for integrated policies that simultaneously enhance institutional quality, financial systems, and educational outcomes. Mawutor *et al*.

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(2024) investigated the threshold effects of governance quality on the relationship between cost of living and energy poverty across 40 African countries using a two-step system GMM approach. Their results suggest that governance quality mitigates the adverse effect of inflation on energy poverty, but only after surpassing certain threshold levels (0.03, 0.02, and 0.07). These findings stress the importance of surpassing minimal governance quality benchmarks to make meaningful progress in reducing energy poverty. Finally, Ogede, Oduola and Tiamiyu (2024) analysed the relationship between income inequality and CO_2 emissions in SSA, focusing on the moderating roles of financial inclusion and institutional quality. By employing robust econometric techniques that account for cross-sectional dependence and heterogeneity, the study finds that institutional quality can significantly weaken the positive link between income inequality and environmental degradation.

In sum, the literature underscores the pivotal role of financial development, institutional quality, and governance structures in shaping the relationship between income inequality and energy-related outcomes. Yet, these dynamics are highly context-dependent, structurally heterogeneous, and often governed by nonlinear mechanisms that remain underexplored – particularly in African economies marked by deep structural inequality and institutional fragility. Motivated by the need to better understand these complex interactions, this study investigates how financial development and government quality influence energy consumption across different regimes of income inequality. Specifically, it seeks to empirically identify whether threshold effects exist within this nexus and how these effects vary depending on inequality levels. In doing so, the study offers policy-relevant insights into balancing inclusive growth with environmental sustainability in the African context. To guide the empirical analysis, the study tests the following hypotheses:

H_1: There is a nonlinear relationship between income inequality and energy consumption.

H_2: Below the threshold level of inequality, financial and government quality affect energy consumption in the same direction, whereas above the threshold – that is, as inequality increases – their effects on energy consumption become inverse.

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3. Data and estimation methodology

3.1 Description of data

This study examines how financial development (*fdi*) and government quality (*qog*) influence energy consumption (*enc*) in selected African countries, particularly under varying levels of income inequality (*gini*). To ensure robust estimations and avoid omitted variable bias, the model incorporates key control variables – real GDP (*gdp*), CO_2 emissions (*co2*), population size (*pop*), and gross fixed capital formation (*inv*) – all chosen for their theoretical and empirical relevance to energy demand, as established in previous studies (Boyce, 1994; Nkomo, 2007; Berthe and Elie, 2015; Lu *et al*., 2021; Sehrawat, 2021; Odhiambo, 2021; Guo *et al*., 2022; Wan *et al*., 2022; Nawaz and Rahman, 2023; Cai *et al*., 2024; Mawutor *et al*., 2024; Ogede *et al*., 2024; Okere and Fasanya, 2024). While (*fdi*) reflects financial inflows that can boost energy-intensive activities, (*qog*) captures institutional quality – such as rule of law, bureaucratic efficiency, and corruption control – that shapes energy governance, (*gdp*) represents economic expansion linked to rising energy demand, (*co2*) serves as both a cause and consequence of energy use, especially in fossil fuel-dependent contexts, (*pop*) reflects demand scale, and (*inv*) captures the effect of capital accumulation on energy-intensive industrialization. Table 1 details variable definitions, sources, and units, reinforcing transparency and replicability.

The dataset comprises a balanced panel of 26 African countries – 21 from Sub-Saharan Africa and 5 from North Africa – spanning the period 1985 to 2021, selected to ensure temporal breadth and regional diversity for robust empirical investigation. The starting year of 1985 reflects optimal data availability across the sample, while the end year aligns with the latest update of the IMF Financial Development Index (August 15, 2023), guaranteeing consistency and harmonization across variables. To address issues of scale and non-linearity commonly encountered in panel data analysis, all variables – except for the inequality measure – are expressed in natural logarithms, facilitating coefficient interpretation as elasticities. This transformation also enhances model stability and comparability. Tables 2 and 3 present the sample composition and descriptive statistics, respectively, offering a comprehensive overview of variable distributions, central tendencies, and underlying heterogeneity across countries. The deliberate construction of a well-balanced dataset and adherence to established econometric practices reinforce the methodological rigour of the study and lay the groundwork for sound empirical estimation.

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Table 1: Basic knowledge of variables

Variable	Definition	Source
Dependent Variable		
Energy Consumption (*enc*)	Total energy use refers to per capita primary energy consumption, measured in kilowatt-hours per year, including energy from combustible renewables and waste such as biomass, biogas, and municipal waste, before conversion into end-use fuels.	Our World in Data – Carbon Brief
Threshold Variable		
Income Inequality (*gini*)	The Gini coefficient measures pre-tax income inequality on a scale from 0 (perfect equality) to 1 (perfect inequality).	World Inequality Database (WID)
Threshold Regime-Dependent Variables		
Financial Development (*fdi*)	The Financial Development Index (FDI) is a composite measure based on normalized and aggregated sub-indices capturing various dimensions of financial development.	International Monetary Fund (IMF) Financial Development Index
Government Quality (*qog*)	Government quality is similarly assessed through a standardized index (0–1 scale) combining corruption, law and order, and bureaucratic quality indicators from the ICRG dataset.	University of Gothenburg Quality of Government Institute
Threshold Regime-Independent Variables		
CO_2 Emission (co_2)	Annual CO_2 emissions, measured in metric tonnes, capture releases from fossil fuel combustion and industrial processes, excluding land-use changes.	Global Carbon Budget
Economic Growth (*gdp*)	Gross domestic product (current US$)	World Bank Database
Population (*pop*)	Total population	World Bank Database
Investment (*inv*)	Gross fixed capital formation (current US$)	World Bank Database

Source: Author's own elaboration

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Table 2: Sample countries

Angola	Mauritius	Zimbabwe	Nigeria	Ghana	Libya
Botswana	Namibia	Seychelles	Niger	Algeria	
Lesotho	Malawi	Kenya	Togo	Morocco	
South Africa	Mozambique	Tanzania	Ethiopia	Egypt	
Madagascar	Zambia	Republic of the Congo	Liberia	Tunisia	

Source: Author's own elaboration

Table 3: Description of statistics

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
gini	962	0.6226485	0.0663308	0.4879854	0.7813728
log *fdi*	962	–1.921451	0.5870514	–3.506558	0.5276327
log *qog*	962	–0.9310434	0.4277737	–3.178054	–0.1074203
log *enc*	962	7.997824	1.379671	5.256297	10.96625
log co₂	962	0.673523	1.785474	–2.282783	4.927767
log *gdp*	962	7.062009	1.173346	4.130451	9.859614
log *pop*	962	16.15076	1.591232	11.08589	19.17868
log *inv*	962	4.067412	1.372953	2.045284	6.274901

Source: Author's own calculations by using Stata/MP 17.0

Table 3 presents the descriptive statistics for the primary variables, offering a comprehensive summary of their central tendencies and dispersion. Key measures such as mean and standard deviation elucidate the typical values and variability within the dataset. The core variables of interest – financial development (log *fdi*) and government quality (log *qog*) – exhibit mean values of approximately –1.921 and –0.931, respectively, suggesting generally low levels of financial inflows and governance quality across the sample, likely influenced by structural institutional constraints in many Southern African economies. Among the control variables, population (log *pop*) displays the highest mean at 16.150, highlighting the

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substantial demographic scale and corresponding energy demand across the continent. Notably, the Gini coefficient peaks at around 0.78, reflecting marked income disparities within the region. These statistics underscore the economic, institutional, and demographic heterogeneity of the sample countries, establishing a critical empirical foundation for the subsequent threshold analysis.

3.2 Cross-sectional dependence estimation methodology

Before selecting the appropriate analytical method, the study first tested for cross-sectional dependence, a critical concern in panel data models where countries may exhibit interrelated economic, social, or environmental characteristics (Chudik and Pesaran, 2013). Ignoring such dependencies can yield biased and inconsistent estimates, particularly in highly integrated economies with trade and institutional spillovers (Menyah *et al*., 2014). To address this, the Cross-Sectional Dependence (CD) test developed by Pesaran (2015) was employed, as it offers robustness across various panel configurations regardless of the N/T ratio. Its methodological flexibility makes it especially suitable for heterogeneous datasets like the African sample analysed in this study.

$$\mathrm{CD} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right. \tag{1}$$

In Equation 1, T and i represent the time and cross-sectional dimensions, respectively, while $\hat{\rho}_{ij}$ denotes the correlation of the error terms derived from individual ordinary least squares estimations. If the CD statistic exceeds the critical value, the null hypothesis of weak cross-sectional dependence is rejected, indicating the presence of strong cross-sectional dependence.

3.3 Unit root estimation methodology

To ensure the reliability of the estimations, this study employs the Cross-sectionally Augmented Dickey–Fuller (CADF) panel unit root test developed by Pesaran (2007), which accounts for cross-sectional dependence often present in macro-panel datasets. Unlike traditional tests such as Im–Pesaran–Shin (IPS), the CADF test offers robust results regardless of the panel's N/T ratio by incorporating cross-sectional averages of lagged levels and first differences. This methodological flexibility renders it especially suitable for heterogeneous country panels like the one analysed here.

$$\Delta y_{it} = \alpha_i + \rho_i^* y_{i,t-1} + d_0 \bar{y}_{t-1} + d_1 \Delta \bar{y}_t + \varepsilon_{it} \tag{2}$$

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where y_{it} is the variable of interest for unit i at time t, $\bar{y}_{t-1}$ and $\Delta\bar{y}_t$ are the cross-sectional averages of the lagged level and first difference of the series, respectively, α_i is the unit-specific intercept, and ε_{it} is the error term. The CADF test statistic for each unit is derived from the t-ratio of ρ_i^* testing the null hypothesis of a unit root (non-stationarity) against the alternative of stationarity for that unit. To assess the stationarity of the panel, the Cross-sectionally Augmented IPS (CIPS) test statistic is computed by taking the arithmetic average of the individual CADF test statistics across all units:

$$\text{CIPS} = \frac{1}{N}\sum_{i=1}^{N} \text{CADF}_i \tag{3}$$

3.4 Panel cointegration estimation methodology

To examine the presence of a long-run equilibrium relationship among the variables, the Westerlund (2007) panel cointegration test has been employed. This test is well-suited for heterogeneous panels with cross-sectional dependence, as it is based on structural error-correction models rather than residual-based approaches and provides robust inference through bootstrapped critical values. The test is based on the following panel error-correction model:

$$\Delta_{y_{it}} = \alpha_i + \delta_i t + \phi_i(y_{it-1} - \beta_i' \boldsymbol{x}_{it-1}) + \sum_{j=1}^{p_i} \gamma_{ij}\Delta y_{it-j} + \sum_{j=0}^{q_i} \theta_{ij}\Delta \boldsymbol{x}_{it-j} + \varepsilon_{it} \tag{4}$$

where y_{it} is the dependent variable, $\boldsymbol{x}$ is a vector of explanatory variables, ϕ_i is the error-correction coefficient, α_i and $\delta_i t$ capture the individual-specific intercept and deterministic trend, ε_{it} is the error term. The null hypothesis of no cointegration is defined as H_0: $\phi_i = 0 \forall i$, meaning that there is no error-correction and thus no long-run relationship. The alternative hypothesis differs by test type:

For group mean tests (G_t, G_a): H_1: $\phi_i < 0$ for at least some i.

For panel tests (P_t, P_a): H_1: $\phi_i < 0$ for all i.

Rejecting the null implies the presence of cointegration among the panel variables. Given the evidence of cross-sectional dependence, bootstrapped p-values are used to ensure the robustness of inference.

3.5 Dynamic panel threshold estimation methodology

Threshold effects imply that the relationship between independent and dependent variables may vary across different levels of an explanatory variable, particularly in heterogeneous contexts such as Sub-Saharan Africa. The choice of a dynamic panel threshold model is the-

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oretically grounded in the notion that the relationship between institutional and financial factors and energy consumption is nonlinear and regime-dependent, especially in settings marked by structural inequality. According to political economy theory, income inequality can distort policy implementation, alter access to financial and energy resources, and weaken institutional effectiveness, thereby influencing energy consumption paths. Development economics further suggests that inequality affects the distributional efficiency of financial development and governance quality, particularly in low- and middle-income economies. The threshold model captures these asymmetries by allowing for endogenous estimation of inequality levels at which the influence of financial and institutional variables shifts, offering a more realistic and policy-relevant framework than conventional linear approaches. When a variable crosses a critical value – *i.e.*, the threshold – its impact can shift in magnitude or direction due to underlying nonlinear dynamics and structural asymmetries. To capture such complexities, Hansen (1999) proposed a panel threshold regression model that endogenously estimates threshold values while accounting for unobserved heterogeneity and avoiding arbitrary regime classification. This method improves the realism and reliability of inference compared to traditional linear models by allowing regime-dependent behaviours to emerge directly from the data.

$$y_{it} = \eta_i + \vartheta_1' I(\rho_{it} \leq \gamma) x_{it} + \vartheta_2' I(\rho_{it} > \gamma) x_{it} + u_i + \varepsilon_{it} \tag{5}$$

In the threshold regression model, y_{it} denotes the dependent variable, while η_i captures the unobserved individual-specific effects. The term x_{it} represents the main explanatory (independent) variable, and ρ_{it} is the threshold variable, which determines the regime classification based on its value relative to the threshold level γ. The parameters ϑ_1 and ϑ_2 denote the slope coefficients corresponding to the two regimes. The function $I(.)$ is an indicator function that takes the value 1 when the condition in parentheses is satisfied, and 0 otherwise. Specifically, the panel observations are divided into two regimes based on whether the threshold variable ρ_{it} is less than or equal to, or greater than, the estimated threshold value γ. Control variables are denoted by u_i and ε_{it} represents the idiosyncratic error term. The subscripts i and t refer to the cross-sectional unit and time period, respectively.

$$y_{it} = \begin{cases} \eta_i + \vartheta_1' x_{it} + \varepsilon_{it} & (\rho_{it} \leq \gamma), \\ \eta_i + \vartheta_2' x_{it} + \varepsilon_{it} & (\rho_{it} > \gamma). \end{cases} \tag{6}$$

Equation 6 can also be written as figured in Equation 7:

$$y_{it} = \vartheta' x_{it}(\gamma) + \eta_i + \varepsilon_{it} \tag{7}$$

To address potential endogeneity – especially from lagged dependent variables – this study employs the dynamic panel threshold model proposed by Caner and Hansen (2004)

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and extended by Kremer *et al*. (2013), which builds on Hansen's (1999) threshold framework. A key methodological refinement involves using the forward orthogonal deviations transformation by Arellano and Bover (1995) to eliminate country-specific fixed effects while avoiding serial correlation. This approach improves estimation efficiency and consistency in dynamic settings involving endogenous regressors and nonlinear threshold effects.

$$Var(\varepsilon_i) = \sigma^2 I_T \text{ and } Var(\varepsilon_i^*) = \sigma^2 I_{T-1}. \quad (8)$$

The transformation applied to the error term is formally presented in Equation (9), which highlights the correction procedure used to eliminate individual-specific effects and address potential autocorrelation.

$$\varepsilon_{it}^* = \sqrt{\frac{T-t}{T-t+1}} \left[\varepsilon_{it} - \frac{1}{T-t}(\varepsilon_{i(t+1)} + \cdots + \varepsilon_{iT}\right] \quad (9)$$

The threshold value $\hat{\Upsilon}$ is selected as the estimate associated with the smallest sum of squared residuals (SSR). The corresponding threshold estimate is denoted by Υ, and its precision is assessed using a confidence interval constructed to reflect the level of statistical confidence, as specified below. To evaluate the statistical significance and precision of the estimated threshold value $\hat{\Upsilon}$, the likelihood ratio (LR) statistic is employed. Following Hansen (1999), the confidence interval for $\hat{\Upsilon}$, is constructed based on the no-rejection region of the LR statistic, rather than relying on standard asymptotic theory, as the threshold parameter does not follow a conventional distribution. The LR statistics are defined as:

$$LR_{(\Upsilon)} = \frac{S_{(\Upsilon)} - S_{(\hat{\Upsilon})}}{\sigma^2} \quad (10)$$

where $S_{(\Upsilon)}$ denotes the residual sum of squares for a given candidate threshold Υ, $S_{(\hat{\Upsilon})}$ is the minimal residual sum of squares obtained at the estimated threshold $\hat{\Upsilon}$ and σ^2 represents the estimated variance of the error term.

Under the null hypothesis of no threshold effect, the distribution of the LR statistic is non-standard. Therefore, bootstrap methods are used to derive asymptotic critical values and construct confidence intervals for $\hat{\Upsilon}$. The 95% confidence interval includes all values of Υ for which the LR statistic does not exceed the critical value obtained from the bootstrap distribution. This procedure ensures robust inference regarding the threshold value, accounting for the complexities introduced by nonlinearity, fixed effects, and endogenous regressors in panel data settings.

$$z_{it} = \alpha_i + \partial z_{it-1} + \gamma_1 X_{it-1} + \phi_1 f_{it-1} + I(q_{it-1} \leq c) + + \phi_1 f_{it-1} + I(q_{it-1} > c) + v_{it} \quad (11)$$

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In the model specification, primary energy consumption (z) is regressed on its lag (∂), financial development and institutional quality indicators (α), a set of control variables (X), and the threshold variable (q), representing income inequality with an estimated threshold level (c) determining regime shifts.

4. Analysis findings and discussion

The CD test results, reported in Table 4 due to character constraints, confirm the presence of cross-sectional dependence among the series. This finding aligns with expectations, given the high degree of economic and regional integration among African countries, which facilitates spill overs through trade, investment, and policy coordination (Menyah *et al*., 2014). The results of these tests indicate that most variables in the dataset are stationary in levels, suggesting that they do not contain a unit root. However, two exceptions are the logarithmic energy consumption log *enc* and logarithmic carbon dioxide emissions log *co2* series, which are found to be non-stationary in levels. To address this, the first differences of these series were taken, and subsequent tests confirmed that both Δlog *enc* and Δlog *co2* are stationary, indicating that they are integrated of order one, I(1).

Table 4: Cross-sectional dependence (CSD) and CADF unit root test results

	CSD	CIPS Statistics		
		Level	1st difference	Result
gini	17.22*	–2.374*	–	I_0
log *fdi*	14.05*	–3.042*	–	I_0
log *qog*	35.64*	–3.582*	–	I_0
log *enc*	43.85*	–4.063	–3.284*	I_1
log co_2	37.02*	–1.739	–3.482*	I_1
log *gdp*	107.16*	–2.048*	–	I_0
log *pop*	68.54*	–2.648*	–	I_0
log *inv*	25.73*	–2.562*	–	I_0
CV		1%	5%	
Constant and trend		–2.57	–2.43	
Constant		–2.44	–2.21	

Note: * denotes statistical significance at the 1% level

Source: Author's own calculations by using Stata MP/17.0

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Westerlund (2007) test results presented in Table 5 provide strong evidence against the null hypothesis of no cointegration in both models. For Model 1, where financial development (log *fdi*) is the regime-dependent variable, all four test statistics (G_t, G_a, P_t, P_a) are statistically significant at the 1% level based on bootstrap p-values. Similar findings are observed for Model 2 with government quality (log *qog*) as the threshold-dependent regressor. These results confirm the existence of a long-run cointegrating relationship among energy consumption, inequality, financial development, and governance quality in the panel of African countries analyzed. This justifies the application of the dynamic panel threshold model and supports the inference of regime-dependent long-term effects.

Table 5: Panel cointegration test results

Test statistic	Value	*Z*-value	*p*-value (bootstrap)	Decision
Model 1: log *fdi* as regime-dependent variable				
G_t	−3.512	−4.231	0.000	Reject H_0
G_a	−12.245	−5.034	0.002	Reject H_0
P_t	−10.654	−3.912	0.001	Reject H_0
P_a	−8.384	−4.026	0.001	Reject H_0
Model 2: log qog as regime-dependent variable				
G_t	−2.971	−3.764	0.004	Reject H_0
G_a	−10.842	−4.512	0.006	Reject H_0
P_t	−9.437	−3.506	0.005	Reject H_0
P_a	−7.889	−3.922	0.003	Reject H_0

Notes: Null hypothesis (H_0): No cointegration. The results are reported with both constant and trend specifications. Bootstrap p-values are obtained from 10,000 replications, while asymptotic *p*-values are derived from the standard normal distribution. The lag and lead lengths are set to 1.

Source: Author's own calculations by using Stata MP/17.0

The dynamic panel threshold estimation procedure begins with a preliminary assessment of nonlinearity using a suite of statistical tests, including the likelihood ratio (LR) test, Wald test, and Fisher test. These tests evaluate the null hypothesis of a linear relationship against the alternative of a threshold effect, with bootstrap p-values employed to ensure robust inference, particularly in the presence of small sample sizes or cross-sectional depend-

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ence. The results, reported in Tables 6 and 7, indicate that the null hypothesis of linearity is strongly rejected, confirming the presence of a nonlinear relationship among energy consumption, financial development, and government quality. This finding underscores the importance of modelling threshold effects to accurately capture the complex dynamics at play.

Table 6: Dynamic panel threshold estimation results with financial development regime-dependent indicator

Variables	Dependent Variable: log *enc*
L. log *enc*	0.7856 (0.0197)*
Regime-dependent regressors: The effect of financial development on energy consumption under income inequality threshold	
log *fdi* (***g****ini* ≤ 0.7002)	0.0524 (0.0254)**
log *fdi* (*gini* ≤ 0.7002)	−0.0255 (0.0287)**
Regime-independent regressors: The effect of control variables on energy consumption	
log co_2	0.1176 (0.0210)*
ln *gdp*	0.0516 (0.0124)*
log *pop*	−0.0968 (0.0372)*
log *inv*	0.0362 (0.0137)*
Constant	2.7603 (0.6126)*
Threshold Regime	0.7002
90% Confidence Interval of Threshold Regime	0.6901–0.7003
Bootstrap *p*-value for linearity test	0.0000
Wald test	292.95
Fisher test	241.327
Observations	936
Number of instruments	14

Notes: One-step GMM findings are displayed. Coefficients are reported outside parentheses, with their corresponding standard errors enclosed within parentheses. *, ** denote statistical significance at the 1%, and 5% levels, respectively. The notation "L. log *enc*" refers to the first lag of the logarithmic energy consumption variable (log *enc*).

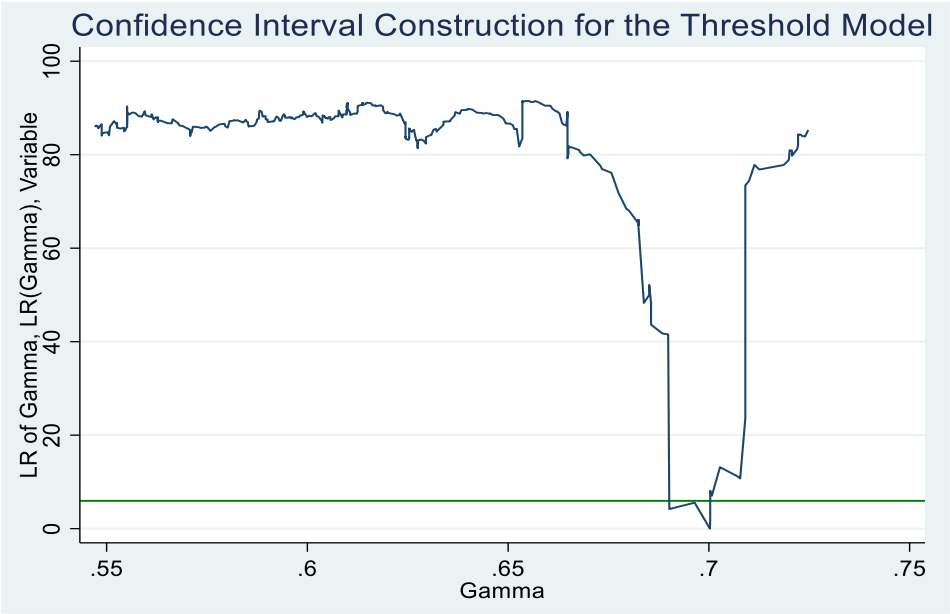
Source: Author's own calculations by using Stata MP/17.0

The dynamic panel threshold estimation reveals that the lagged value of energy consumption (L. log *enc*) is statistically significant and positive in both threshold regimes. This result suggests that changes in energy consumption exhibit a persistent, lagged effect, influencing consumption levels in subsequent periods in 26 selected African countries. For

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instance, an increase in energy use in one period is likely to perpetuate higher consumption in the following period, reflecting inertia in energy demand driven by economic, infrastructural, or behavioural factors. Similarly, reductions in energy consumption may have lasting impacts, highlighting the importance of sustained policy interventions to achieve long-term energy efficiency. These findings align with the theoretical expectations of Diallo (2020) and Kremer *et al*. (2013) who emphasize the role of nonlinear dynamics in economic relationships. The persistence of energy consumption, coupled with the nonlinear influence of financial development and government quality under the inequality threshold, suggests that policy interventions must account for threshold-specific effects and lagged responses to be effective. By employing the dynamic panel threshold method, this study provides a robust framework for understanding how institutional and financial factors shape energy consumption in African contexts, offering valuable insights for policymakers aiming to promote sustainable energy transitions consistent with the previous research. The detailed results of the threshold estimation, including coefficient estimates, threshold values, and test statistics, are presented in Tables 5 and 6. These findings set the stage for the subsequent discussion of policy implications, which will explore how threshold effects and lagged dynamics can inform strategies for balancing energy access with environmental sustainability.

Figure 1: Likelihood ratio statistics graph of confidence interval (log *fdi*)



Source: Author's own elaboration

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The analysis identifies a statistically significant threshold level of income inequality (*gini*) at 0.7002, with a 90% confidence interval, delineating two distinct regimes of influence. The Gini coefficient, which measures income inequality before taxes and transfers, ranges between 0.48 and 0.78 across 26 African countries during the selected period (see Table 3). Africa stands out as the region with the highest level of income inequality globally. Therefore, it is essential to acknowledge that the countries included in the analysis are subject to high levels of income inequality, and the threshold value appears to be high. The likelihood ratio (LR) statistics, as depicted in Figures 1 and 2, exceed the critical threshold value, confirming the robustness and statistical significance of the estimated threshold. This finding validates the presence of a nonlinear relationship, highlighting the importance of modelling regime-specific effects to capture the complex interplay among the variables. Below the threshold inequality level of 0.7002, the coefficients for financial development (log *fdi*) and government quality (log *qog*) are 0.0524 and 0.0132, respectively, both significant at the 5% level. These positive coefficients indicate that increases in financial development and government quality are associated with higher energy consumption in this regime. This relationship suggests that, in contexts with relatively lower income inequality, enhanced financial systems and stronger governance structures facilitate greater energy use, likely by supporting energy-intensive economic activities and improving the implementation of energy policies. Conversely, above the threshold inequality level, the coefficients for (log *fdi*) and (log *qog*) are −0.0255 and −0.1097, respectively, also significant at the 5% and 1% levels, revealing a negative relationship with energy consumption. This finding implies that when income inequality exceeds the threshold, improvements in financial development and government quality may lead to reduced energy consumption. Such a pattern could reflect diminished energy access for lower-income groups or a shift toward energy-efficient practices in high-inequality settings, potentially driven by institutional reforms or targeted financial investments.

These results indicate that, over the study period, financial development and government quality enhance energy consumption in African countries when income inequality is at or below the threshold of 0.7002. However, above this threshold, high inequality appears to counteract these positive effects, leading to a decline in energy consumption despite advancements in financial and institutional frameworks. These findings are consistent with prior studies, including Baloch *et al*. (2020), Sarkodie and Adams (2020), Asongu and Odhiambo (2021), Atsu *et al*. (2021), Diallo and Ouba (2024), Mawutor *et al*. (2024), and Okere and Fasanya (2024), which highlight the interplay between institutional quality, financial development, and energy outcomes.

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Table 7: Dynamic panel threshold estimation results with government quality regime-dependent indicator

Variables	**Dependent Variable: log *enc***
L. log *enc*	0.1662 (0.0084)*
Regime-dependent regressors: The effect of government quality on energy consumption under income inequality threshold	
log *qog* (*gini* ≤ 0.7002)	0.0132 (0.0206)**
log *qog* (*gini* ≤ 0.7002)	−0.1097 (0.0288)*
Regime-independent regressors: The effect of control variables on energy consumption	
log co_2	0.1120 (0.0208)*
ln *gdp*	0.0459 (0.0124)*
log *pop*	−0.0867 (0.0361)**
log *inv*	0.0452 (0.0687)***
Constant	2.7557 (0.5674)*
Threshold Regime	0.7002
90% Confidence Interval of Threshold Regime	0.6964–0.7077
Bootstrap *p*-value for linearity test	0.0000
Wald test	278.37
Fisher test	252.046
Observations	936
Number of instruments	14

Notes: One-step GMM findings are displayed. Coefficients are reported outside parentheses, with their corresponding standard errors enclosed within parentheses. *, **, *** denote statistical significance at the 1%, 5%, and 10% levels, respectively. The notation "L. log *enc*" refers to the first lag of the logarithmic energy consumption variable (log *enc*).

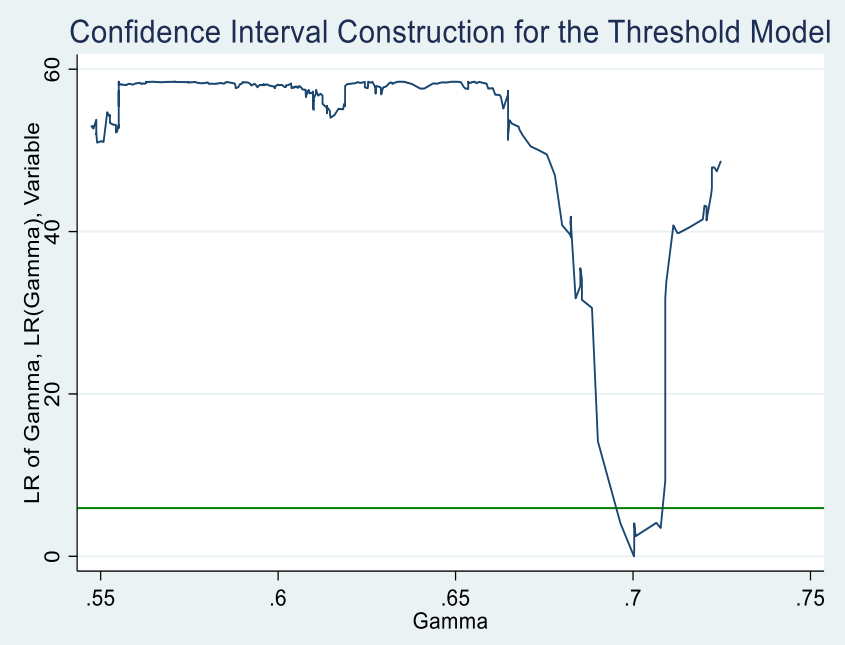
Source: Author's own calculations by using Stata MP/17.0

However, this study provides novelty to the literature in two keyways: 1) Regime-Dependent Threshold Analysis: Unlike previous studies that rarely estimate thresholds based solely on financial development, governance, or energy consumption, this study introduces

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income inequality as the threshold variable. This approach allows for a nuanced examination of how financial and institutional factors influence energy consumption under different inequality regimes, capturing context-specific dynamics. 2) Dynamic Effects and Heterogeneity: By incorporating the lagged value of energy consumption and employing a dynamic panel threshold model, the study accounts for persistence in energy use and the heterogeneous institutional and economic characteristics of African countries. This contemporary econometric approach offers methodological superiority, providing more robust insights into the direction and magnitude of these effects across regimes. Among the threshold regime-independent control variables, investment (log *inv*), carbon dioxide emissions (log *co2*), and economic growth (log *gdp*) exhibit positive and statistically significant effects on energy consumption, consistent with expectations. Higher levels of investment and economic growth drive energy demand by fuelling industrial and infrastructural activities, while CO_2 emissions reflect the environmental footprint of energy-intensive processes and more energy consumption. In contrast, population (log *pop*) hurts energy consumption, a finding that aligns with prior research suggesting that larger populations may face energy access constraints in resource-scarce settings such as African countries (Nkomo, 2007; Menyah *et al*., 2014; Chen *et al*., 2020; Guo *et al*., 2022; Nawaz and Rahman, 2023; Odhiambo, 2023; Ogede *et al*., 2024). These control variables ensure that the model accounts for macroeconomic and environmental factors, enhancing the robustness of the threshold estimation.

Figure 2: Likelihood ratio statistics graph of confidence interval (log *qog*)



Source: Author's own elaboration

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5. Conclusions and policy implications

The results of the analysis, detailed in Tables 6 and 7, examining how financial development and government quality influence energy consumption under income inequality thresholds for 26 African countries over the period 1985–2021, provide a comprehensive understanding of how this interaction is moderated. Figures 1 and 2 further illustrate the statistical significance of the threshold, reinforcing the reliability of the findings. These insights underscore the need for tailored policy interventions that consider inequality thresholds to optimize energy consumption and promote sustainable development in African contexts. The subsequent discussion may explore these findings in greater depth, drawing implications for policymakers aiming to balance energy access with environmental and economic objectives. In contexts where income inequality is below a critical threshold (*e.g.*, a logarithmic Gini coefficient of 0.7002), financial development – manifested through expanded credit access and foreign direct investment – stimulates energy consumption by channelling resources into energy-intensive sectors such as industry and infrastructure. High government quality, characterized by bureaucratic quality, rule of law, and low corruption, *etc*. may boost the efficiency of energy policies, further amplifying demand. However, these effects often rely on fossil fuels, particularly in countries with established energy systems like South Africa, posing challenges for environmental sustainability. Conversely, in high-inequality regimes, where disparities exceed the threshold, financial development and government quality may reduce energy consumption due to inequitable resource allocation, which restricts energy access for lower-income households and exacerbates energy poverty. This dynamic panel threshold analysis, employing advanced econometric techniques to account for cross-sectional dependence and stationarity, underscores the persistence of energy consumption through lagged effects and the heterogeneous institutional landscapes of African nations.

To address these findings, a multifaceted and regime-sensitive policy framework is essential. In low-inequality contexts, governments should scale up green finance tools such as concessional loans, green bonds, and blended finance schemes to mobilize investment in renewable infrastructure. At the same time, strengthening institutional transparency through open bidding systems, digital monitoring platforms, and anti-corruption reforms in energy procurement can enhance the impact of high-quality governance on sustainable energy delivery. In high-inequality regimes, targeted and inclusive instruments are needed. These may include direct subsidies or voucher programs for low-income households to afford clean energy technologies; community-based solar micro-grids to provide off-grid rural populations with decentralized access; and the integration of energy access objectives into social assistance programs such as conditional cash transfers. Furthermore, promoting dig-

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ital financial inclusion (*e.g.*, mobile money-enabled energy payments), energy literacy campaigns, and cross-border cooperation on renewable energy corridors can reinforce equitable access and institutional effectiveness across both regime types. These practical policy tools, tailored to varying inequality conditions, can help African governments align energy access goals with inclusive growth and long-term environmental sustainability.

For future academic studies, researchers could employ several analytical methods to capture exogenous variations in inequality, endogeneity, and relevant dynamic interactions. Additionally, a quantile regression panel model could be utilized to explore how these relationships vary across different quantiles of energy consumption, providing insights into the distributional impacts of financial and institutional factors, particularly in extremely high- or low-consumption contexts. Incorporating alternative measures of inequality, financial, and institutional indicators – such as the Atkinson index, Theil index, Palma ratio, wage and wealth inequality indicators, financial access, and financial depth indexes – along with diverse databases like the Standardized World Income Inequality Database (SWIID), Heritage Foundation, Freedom House, and others, would significantly enrich the contribution of this research to the field. These methodological advancements would enhance the robustness of findings and offer deeper insights into the complex interplay of inequality, institutions, and energy dynamics in African economies.

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References

Acheampong, A. O., Shahbaz, M., Dzator, J., & Jiao, Z. (2022). Effects of Income Inequality and Governance on Energy Poverty Alleviation: Implications for Sustainable Development Policy. *Utilities Policy*, *78*(C), 1-30. https://doi.org/10.1016/j.jup.2022.101403

Ahlborg, H., Boräng, F., Jagers, S. C., & Söderholm, P. (2015). Provision of Electricity to African Households: The Importance of Democracy and Institutional Quality. *Energy Policy*, *87*(C), 125-135. https://doi.org/10.1016/j.enpol.2015.09.002

Final version of the article before editorial processing

Arellano, M., & Bover, O. (1995). Another Look at the Instrumental Variable Estimation of Error-Components Models. *Journal of Econometrics*, *68*(1), 29-51. https://doi.org/10.1016/0304-4076(94)01642-D

Arı, A. (2022). The Relationship Between Income Inequality and Energy Consumption: Evidence from Turkey. *Manisa Celal Bayar University Journal of Social Sciences*, *20*(2), 236-244. https://doi.org/10.18026/cbayarsos.1056051

Asongu, S. A., & Odhiambo, N. M. (2021). Inequality, Finance and Renewable Energy Consumption in Sub-Saharan Africa. *Renewable Energy*, *165*(Part 1), 678-688. https://doi.org/10.1016/j.renene.2020.11.062

Asongu, S. A., & Odhiambo, N. M. (2024). Inequality and Renewable Energy Consumption in Sub-Saharan Africa: Implication for High Income Countries. *Innovation: The European Journal of Social Science Research*, *37*(2), 1-22. https://doi.org/10.1080/13511610.2020.1861442

Atsu, F., Adams, S., & Adjei, J. (2021). ICT, Energy Consumption, Financial Development, and Environmental Degradation in South Africa. *Heliyon*, *7*(7), 1-10. https://doi.org/10.1016/j.heliyon.2021.e07328

Baloch, M. A., Danish, Khan, S. U., Ulucak, Z. Ş., & Ahmad, A. (2020). Analyzing the Relationship Between Poverty, Income Inequality, and CO_2 Emission in Sub-Saharan African Countries. *Science of the Total Environment*, *740*(C), 1-7. https://doi.org/10.1016/j.scitotenv.2020.139867

Berthe, A., & Elie, L. (2015). Mechanisms Explaining the Impact of Economic Inequality on Environmental Deterioration. *Ecological Economics*, *116*(C), 191-200. https://doi.org/10.1016/j.ecolecon.2015.04.026

Boyce, J. K. (1994). Inequality as a Cause of Environmental Degradation. *Ecological Economics*, *11*(3), 169-178. https://doi.org/10.1016/0921-8009(94)90198-8

Cai, K., Lemaire, T., Medici, A., Melina, G., Schwerhoff, G., & Thube, S. D. (2024). Harnessing Renewables in Sub-Saharan Africa – Barriers, Reforms, and Economic Prospects. *Staff Climate Notes*, *2024*(005), 1-42. https://doi.org/10.5089/9798400290107.066.A001

Caner, M., & Hansen, B. E. (2004). Instrumental Variable Estimation of a Threshold Model. *Econometric Theory*, *20*(5), 813-843. https://doi.org/10.1017/S0266466604205011

Chen, J., Xian, Q., Zhou, J., & Li, D. (2020). Impact of Income Inequality on CO_2 Emissions in G20 Countries. *Journal of Environmental Management*, *271*(C), 1-8. https://doi.org/10.1016/j.jenvman.2020.110987

Chudik, A., & Pesaran, M. H. (2013). *Large Panel Data Models with Cross-Sectional Dependence: A Survey* Working Paper No. 13/153. Federal Reserve Bank of Dallas Globalization and Monetary Policy Institute. https://doi.org/10.2139/ssrn.2316333

Diallo, I. A. (2020). *XTENDOTHRESDPD: Stata Module to Estimate a Dynamic Panel Data Threshold Effects Model with Endogenous Regressors* (Statistical Software Components S458745). Boston College Department of Economics. https://econpapers.repec.org/RePEc:boc:bocode:s458745

Final version of the article before editorial processing

Diallo, S., & Ouoba, Y. (2024). Financial Development and Renewable Energy Deployment in Sub-Saharan African Countries. *International Journal of Energy Sector Management*, *18*(6), 1305-1327. https://doi.org/10.1108/IJESM-06-2023-0012

Fatima, N., Li, Y., Ahmad, M., Jabeen, G., & Li, X. (2019). Analyzing Long-Term Empirical Interactions Between Renewable Energy Generation, Energy Use, Human Capital, and Economic Performance in Pakistan. *Energy, Sustainability and Society*, *9*(42), 1-14. https://doi.org/10.1186/s13705-019-0228-x

Guo, Y., You, W., & Lee, C. C. (2022). CO_2 Emissions, Income Inequality, and Country Risk: Some International Evidence. *Environmental Science and Pollution Research*, *29*(C), 12756-12776. https://doi.org/10.1007/s11356-020-09501-w

Hanif, N., Arshed, N., & Aziz, O. (2020). On Interaction of the Energy: Human Capital Kuznets Curve? A Case for Technology Innovation. *Environment, Development and Sustainability*, *22*(C), 7559-7586. https://doi.org/10.1007/s10668-019-00536-9

Hansen, B. E. (1999). Threshold Effects in Non-Dynamic Panels: Estimating, Testing and Inference. *Journal of Econometrics*, *93*(2), 345-368. https://doi.org/10.1016/S0304-4076(99)00025-1

Kremer, S., Bick, A., & Nautz, D. (2013). Inflation and Growth: New Evidence from a Dynamic Panel Threshold Analysis. *Empirical Economics*, *44*(2), 861-878. https://doi.org/10.1007/s00181-012-0553-9

Lu, J., Imran, M., Haseeb, A., Saud, S., Wu, M., Siddiqui, F., & Khan, M. J. (2021). Nexus Between Financial Development, FDI, Globalization, Energy Consumption and Environment: Evidence from BRI Countries. *Frontiers in Energy Research*, *9*(C), 1-12. https://doi.org/10.3389/fenrg.2021.707590

Mallick, H., Padhan, H., & Mahalik, M. K. (2019). Does Skewed Pattern of Income Distribution Matter for the Environmental Quality? Evidence from Selected BRICS Economies with an Application of Quantile-on-Quantile Regression (QQR) Approach. *Energy Policy*, *129*(C), 120-131. https://doi.org/10.1016/j.enpol.2019.02.021

Mawutor, J. K. M., Gborse, F. C., Agbanyo, R., & Sogah, E. (2024). Inflation and Energy Poverty: Threshold Effect of Governance Quality in Africa. *Journal of Economic Studies*, *51*(1), 222-237. https://doi.org/10.1108/JES-12-2022-0620

Masuku, B. (2024). Rethinking South Africa's household energy poverty through the lens of off-grid energy transition. *Development Southern Africa*, *41*(3), 467-489. https://doi.org/10.1080/0376835X.2023.2300411

Menyah, K., Nazlioglu, S., & Wolde-Rufael, Y. (2014). Financial Development, Trade Openness and Economic Growth in African Countries: New Insights from a Panel Causality Approach. *Economic Modelling*, *37*(2), 386-394. https://doi.org/10.1016/j.econmod.2013.11.044

Mirzania, P., Gordon, J. A., Balta-Ozkan, N., Sayan, R. C., & Marais, L. (2023). Barriers to powering past coal: Implications for a just energy transition in South Africa. *Energy Research & Social Science*, *101*(103122), 1-24. https://doi.org/10.1016/j.erss.2023.103122

Final version of the article before editorial processing

Nar, M. (2021). The Relationship Between Income Inequality and Energy Consumption: A Pareto Optimal Approach. *Journal of Asian Finance, Economics and Business*, *8*(4), 613-624. https://doi.org/10.13106/jafeb.2021.vol8.no4.0613

Nawaz, A., & Rahman, M. M. (2023). Renewable Energy Consumption in Sub-Saharan Africa: The Role of Human Capital, Foreign Direct Investment, Financial Development, and Institutional Quality. *Energy Reports*, *10*(C), 3383-3393. https://doi.org/10.1016/j.egyr.2023.10.025

Nkomo, J. C. (2007). Energy Use, Poverty and Development in the SADC. *Journal of Energy in Southern Africa*, *18*(3), 10-17. https://doi.org/10.17159/2413-3051/2007/v18i3a3385

Odhiambo, N. M. (2023). A Symmetric Impact of Energy Consumption on Economic Growth in South Africa: New Evidence from Disaggregated Data. *Energy Nexus*, *9*(C), 1-9. https://doi.org/10.1016/j.nexus.2023.100174

Ogede, J. S., Oduola, M. O., & Tiamiyu, H. O. (2024). Income Inequality and Carbon Dioxide (CO_2) in Sub-Saharan Africa Countries: The Moderating Role of Financial Inclusion and Institutional Quality. *Environment, Development and Sustainability*, *26*(C), 18385-18409. https://doi.org/10.1007/s10668-023-03393-9

Okere, K. I., & Fasanya, I. O. (2024). Technological Progress in Achieving Environmental Sustainability in Central and Southern Africa: The Role of Fossil Fuels and Institutional Quality. *Energy Sources, Part B: Economics, Planning, and Policy*, *19*(1), 1-23. https://doi.org/10.1080/15567249.2024.2361746

Pesaran, M. H. (2007). A Simple Panel Unit Root Test in the Presence of Cross-Sectional Dependence. *Journal of Applied Econometrics*, *22*(2), 265-312. https://doi.org/10.1002/jae.951

Pesaran, M. H. (2015). Testing Weak Cross-Sectional Dependence in Large Panels. *Econometric Reviews*, *34*(6–10), 1089-1117. https://doi.org/10.1080/07474938.2014.956623

Sahu, S. K., & Patnaik, U. (2020). The Trade-Offs Between GHGs Emissions, Income Inequality and Productivity. *Energy and Climate Change*, *1*(C), 1-8. https://doi.org/10.1016/j.egycc.2020.100014

Sarkodie, S. A., & Adams, S. (2020). Electricity Access, Human Development Index, Governance and Income Inequality in Sub-Saharan Africa. *Energy Reports*, *6*(C), 455–466. https://doi.org/10.1016/j.egyr.2020.02.009

Sehrawat, M. (2021). Modelling the Nexus Between Human Capital, Income Inequality, and Energy Demand in India: New Evidences From Asymmetric and Non-Linear Analysis. *Environmental Science and Pollution Research*, *28*(C), 3632-3643. https://doi.org/10.1007/s11356-020-10733-z

Smarte Anekwe, I. M., Akpasi, S. O., Mkhize, M. M., Zhou, H., Moyo, R. T., & Gaza, L. (2024). Renewable Energy Investments in South Africa: Potentials and Challenges for a Sustainable Transition - A Review. *Science Progress*, *107*(2), 1-16. https://doi.org/10.1177/00368504241237347

Tan, Y., & Uprasen, U. (2021). Carbon Neutrality Potential of the ASEAN-5 Countries: Implications from Asymmetric Effects of Income Inequality on Renewable Energy Consumption. *Journal of Environmental Management*, *299*(C), 1-14. https://doi.org/10.1016/j.jenvman.2021.113635

Final version of the article before editorial processing

Todd, I., & McCauley, D. (2021). An inter-disciplinary approach to the energy transition in South Africa. *Discover Sustainability*, *2*(33), 1-15. https://doi.org/10.1007/s43621-021-00043-w

Trotter, P. A. (2016). Rural Electrification, Electrification Inequality and Democratic Institutions in Sub-Saharan Africa. *Energy for Sustainable Development*, *34*(C), 111-129. https://doi.org/10.1016/j.esd.2016.07.008

Uzar, U. (2020). Is Income Inequality a Driver for Renewable Energy Consumption? *Journal of Cleaner Production*, *255*(C), 1-11. https://doi.org/10.1016/j.jclepro.2020.120287

Wan, G. H., Wang, C., Wang, J. X., & Zhang, X. (2022). The Income Inequality-CO_2 Emissions Nexus: Transmission Mechanisms. *Ecological Economics*, *195*(3), 1-10. https://doi.org/10.1016/j.ecolecon.2022.107360

Westerlund, J. (2007). Testing for error correction in panel data *. *Oxford Bulletin of Economics and Statistics*, *69*(6), 709-748. https://doi.org/10.1111/j.1468-0084.2007.00477.x

Yao, Y., Ivanovski, K., Inekwe, J., & Smyth, R. (2019). Human Capital and Energy Consumption: Evidence from OECD Countries. *Energy Economics*, *84*(C), 1-14. https://doi.org/10.1016/j.eneco.2019.104534

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