Journal of Economics, Entrepreneurship, Management Business and Accounting, 2026, 4(5),415-450.
https://doi.org/10.61255/jeemba.v4i5.1475

Africa's Energy Security and Influence on Inclusive Human Development: Examining the Role Played by Governance

Marilyn Edoh Ofeh, Ibrahim Ngouhouo, and Salomon Leroy*
Faculty of Economics and Management, University of Dschang, Dschang, 00000, Cameroon

ABSTRACT

Purpose – Looking at how a shift from dirty energies to clean advanced energies would affect livelihood and the fight against the long-aged poverty and inequality plight especially in Africa, has topped academic discourse. This study examines the effect of energy security on inclusive human development in Africa.

Design/methodology/approach – The study adopts a quantitative approach by using the panel regressions like the GMM, quantile regression, and mediation analysis as estimation strategies adopting data from 2010 to 2022 for 34 African countries. Secondary data were obtained from the WDI, WGI, OPEC, and UNDP.

Finding/Results – Firstly, a unit increase in energy security will lead to an increase in inclusive human development in Africa, by unit increases between 0.42 to 4.25. Secondly, those in the upper inclusive human development quantile (Q90) have a better gain from energy security when compared to the lowest quantile (Q10) [0.073 and 0.018 respectively]. Thirdly, lower middle income countries have a better output than lower income countries, with respect to an increase in inclusive human development (0.049 and 0.039 respectively). Lastly, governance acts as a good mediator in the energy security – inclusive human development nexus. This shows that energy security positively influences inclusive human development, through improvement in health, livelihood earnings, and education.

Originality/Value – Energy security delivers the greatest growth dividends where institutions strengthen infrastructure and absorptive capacity—reminding policymakers that reliable energy alone cannot close development gaps without these complementary foundations.

ARTICLE INFO

Keywords:
Africa,
Energy Security,
Inclusive Human Development,
Sustainable Development,
Quantile Regression

Article Information:
Received: 30/06/2026
Revise: 26/07/2026
Accepted: 07/08/2026

ISSN:
2985-3168 (Online)
2985-3222 (Print)

*Corresponding Author at:
Department of Public Economic and human resources, Faculty of Economics and Management, University of Dschang, Dschang, 00000, Cameroon
E-mail address: lavoidef@gmail.com (Salomon Leroy Deffo Ghamsi) marilynedoh@gmail.com (author#1), ibrahimngouhouo59@gmail.com (author#2)

1. Introduction

Energy security has received wide attention in the last few couple of years, given its importance in spurring the sustainable development goals, economic development, and overall wellbeing. The growth in the literature about inclusive human development has equally received much attention, as it has been found to be a more realistic measure for human development considering that it accounts for inequality. Apart from immediately enhancing livelihoods, it is widely believed that having access to contemporary, sustainable energy services is a prerequisite for attaining most of the SDGs (Pondie et al., 2023). Lack of access to these modern energy sources disproportionately affects overall livelihoods, consequently exacerbating inequality and worsening living standards (KfW Development Bank et al., 2020; WEF, 2025).

Many economies in Africa struggle with limited electricity producing capacity, which is frequently exacerbated by inadequate and badly maintained transmission and distribution networks. Important social and economic activities are as a result hampered by the erratic electrical supply that follows from this. A sufficient and reliable energy supply not only allows for the generation of value through productive use, but it also frees up time that would otherwise be spent on home work for other profitable economic activities (KfW Development Bank et al., 2020). Notwithstanding the many advantages that robust energy systems can offer inclusive human development, Africa continues to lag behind in terms of achieving social equity and energy security standards (WEF, 2025; KfW Development Bank et al., 2020).

Looking from a closer range at the energy system in Africa, biomass, primarily firewood and charcoal for cooking, accounted for 45% of Africa's primary energy demand in 2018 (IEA, 2019). This has detrimental effects that are rather severe. In Sub-Saharan Africa (SSA), indoor air pollution results in 490,000 premature deaths annually (WHO, 2018). Women and young children are especially exposed since they spend the most time around the home fireplace. This puts energy security and clean energy at the centre of the literature on inclusive human development, considering all the advantages it would bring for well-being, as opposed to the consequences from biomass use and other dirty energies.

In this current era, amidst significant pressure regarding Agenda 2063 and the achievement of the SDGs by 2030, Africa is still a long way from the attainment of these goals as it continues to experience severe inequality due to a predominance of exclusive development over inclusive development on the continent (Asongu and Nnana, 2020). The governments of economies in the region must give inclusive development special attention if poverty is to be lowered to a threshold of less than 3% by 2030.

It is as a result of all the above that the following question emerges: what role does energy security play on inclusive human development in the African region? In answering this question, the study's contribution is seen in three perspectives. Firstly, the study comes in to fill the gap in the literature by providing evidence from the effect of energy security on inequality adjusted inclusive human development, as opposed to previous studies that simply studied the effect of energy and its types on human development. Secondly, the study uses a policy exposing methodology (Quantile regression) which accounts for existing levels of inclusive human development, thus permitting concise policy frameworks, as opposed to generalized policies. Lastly, we use a mediation analysis to show channels through which energy security enhances inclusive human development in Africa. The study therefore seeks to examine the effect of energy security on inclusive human development in Africa.

2. Literature Review & Hypothesis Development

This section comprises two subsections theoretical backings and the empirical review. The main theories captured include the Sustainable Livelihood Approach, and Sen's Capability Approach, which concretize the relationship between energy security and inclusive human development. The empirical literature exposes existing studies, methodologies and findings in a bit to carve out the existing gap this study seeks to fill in the literature.

2.1 Theoretical review

According to Chambers (1988) and Conway (1983), the fundamental concept of the sustainable livelihood approach is based on five pillars that are regarded as livelihood assets. The pillars encompass social, human, physical, natural, and, financial capital. To them, the reason why people continue to live in poverty is due to their incapacity to change the resources at their disposal in order to live better lives. Thus, the term "livelihood" in this context refers to the resources (financial, material, and social), and capabilities that people can engage in to support their living. Accordingly, human development is influenced by all five pillars since it is a component of livelihood. In accordance with the assertion of the Sustainable Livelihood Framework, this study classifies physical and natural capital as capital related to energy sources, water, forests, land quality, and others. We then draw a hypothesis that inclusive human development (henceforth, IHD) is influenced by energy security.

On the other hand, Sen's Capability Approach argued that while designing policies and conducting social evaluations, the emphasis should be on people's capabilities, their quality of life, and the removal of barriers to provide them greater freedom to pursue the kind of life that they ultimately find valuable (Sen 1980; 1987; Drèze and Sen 2002). Given variations in needs and subject to the research topic, we introduce energy security component into Sen's capabilities, since everyone would love to have access to clean energy at affordable prices because it will improve their living conditions (storage, lighting, health services, studying at night, and so on). However, not everyone actually has the ability to achieve that functionality and as a result inequality issues emerge. Thus, energy security enhances IHD.

2.2 Empirical literature review

Every country aims at improving its human development index because it is the ultimate objective of economic development. Determinants of human development have drawn a lot of attention from academics in recent years. Some of these studies have shown the impact of economic growth (Smith, 2016), industrialisation (Klafke, et al., 2018), foreign direct investment (Orbes, 2019), trade openness (Mustafa et al., 2017), population (Costa et al., 2011), urbanisation (Eren et al., 2019; Tran et al., 2019) terrorism (Khan et al., 2018), education (Khodabakhshi, 2011), tourism (Rivera, 2017), natural resource rents (Sinha and Sengupta, 2019), information and communication technology (Khan et al., 2019), and carbon emissions (Smith, 2016; Costa et al., 2011) on human development.

Focusing on Pakistan from 1990 to 2016, Khan et al. (2018) used the ARDL bound testing approach and confirmed an insignificant impact of electricity utilization on HDI. The impact of fossil fuels and renewable energy on the course of human development (henceforth, HD) was estimated by Pîrlogea (2012), and findings indicate that renewable energy significantly improves human growth, while fossil fuel worsens it. Satrovic (2018) used the Granger causality analysis and the Johansen cointegration analysis to examine the connection between human development and renewable energy in Turkey from 1992 to 2015. Results show that renewable energy has a one-way effect on HD.

Human development could be used interchangeably with concepts such as development and socio-economic development, therefore, the literature related to these concepts is included in the study. Bello (2015) examined the relationship between socioeconomic growth and renewable energy in SSA. According to the study, when used properly, renewable energy resources could support socioeconomic activity. Sasmaz et al. (2020) results concur with that of Bello (2015). In contrast to the studies mentioned previously, Tran et al. (2019) looked at the relationship for 93 countries using data from 1990–2014 by using the system GMM approach. Results demonstrated that energy use does not improve HD in either developed nor developing nations.

Wang et al. (2020) examined how the BRICS countries' use of biomass affected HD between 1990 and 2015. Results show that biomass consumption increases HD in BRICS countries and that there is bidirectional causality between these two variables. Elsewhere, Wang et al. (2018) used the 2SLS approach to investigate the association between Pakistan's HDI, economic growth, and renewable energy use from 1990–2014. Results show that the use of renewable energy does not boost Pakistan's HD process. Sule et al. (2022) found that energy poverty has a significant impact on health and education in Africa.

Nchofoung et al. (2022) on the linear and nonlinear effects of infrastructure development on inclusive human development in Africa, used the GMM estimation and the results showed that infrastructure development had a positive effect on inclusive development across all infrastructure development indexes, with the exception of the ICT infrastructural composite index, which showed an insignificant negative effect. Specifically, the electricity index had a clear positive threshold. Therefore, in order to produce overall beneficial effects on IHD, the electricity index should both surpass crucial values of 49.79%. The aforementioned illustrates how IHD is enhanced by having access to electricity, which is one of the elements of energy security. Therefore, considering all of what has been examined in this sub-section we can hypothesize that:

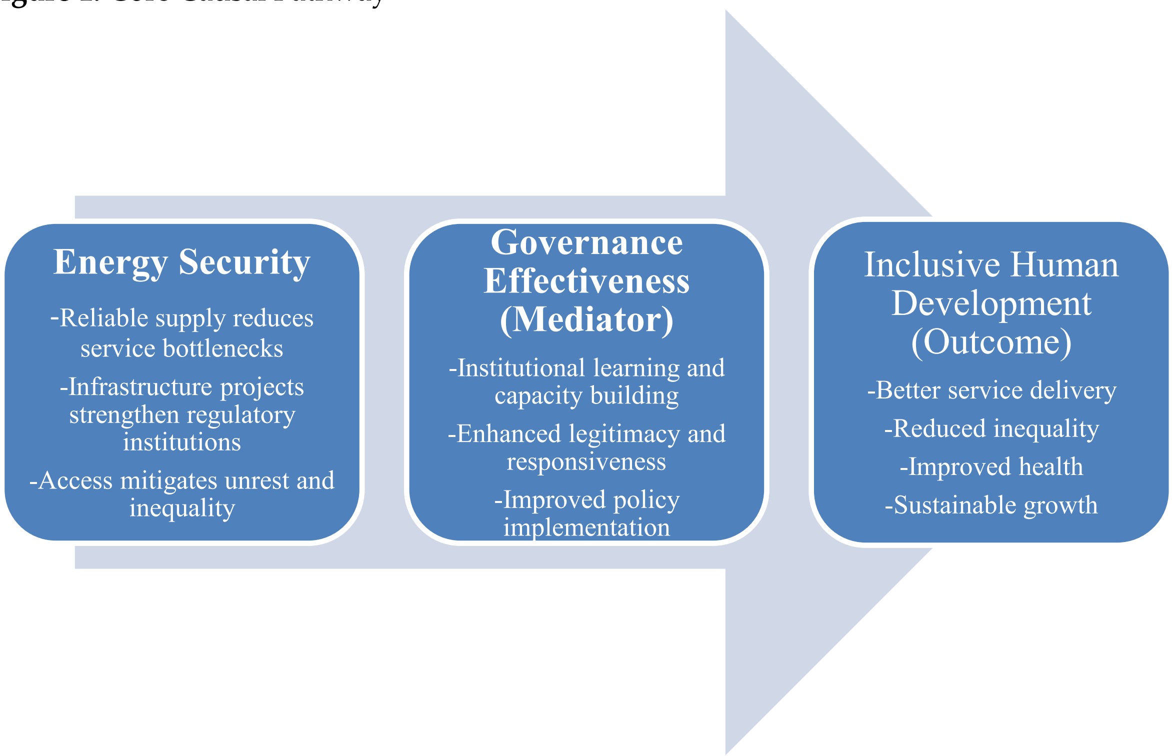
Energy security positively enhances inclusive human development in Africa.

Improvements in energy security can plausibly enhance governance effectiveness through several mechanisms. Reliable energy supply reduces administrative bottlenecks and strengthens state capacity to deliver essential services, thereby improving institutional performance (Sovacool & Brown, 2010). Large-scale energy infrastructure projects often necessitate regulatory reforms and institutional learning, which contribute to more effective governance structures (Goldthau & Sovacool, 2012). Moreover, energy access mitigates social unrest and inequality, enabling governments to consolidate legitimacy and responsiveness (Aklin & Urpelainen, 2018). While reverse causality is theoretically plausible—strong governance can also drive energy security through better regulation and policy enforcement (Cherp & Jewell, 2014)—this study however emphasizes the pathway from energy security to governance. Therefore we hypothesize that:

Government effectiveness as a mediator enhances the energy security – inclusive human development nexus.

Energy security has emerged as a critical determinant of state capacity and institutional performance. While governance quality is often theorized as a prerequisite for achieving energy security, this study emphasizes the reverse pathway: how improvements in energy security can enhance governance effectiveness. Reliable energy systems reduce administrative bottlenecks, strengthen regulatory institutions, and mitigate social unrest, thereby enabling governments to deliver services more effectively (Sovacool & Brown, 2010; Goldthau & Sovacool, 2012; Aklin & Urpelainen, 2018). In resource-dependent contexts, energy shocks frequently precede institutional reforms, making the energy → governance mechanism particularly salient (Cherp & Jewell, 2014). Accordingly, governance is positioned here as a mediator: an institutional outcome shaped by energy security, which in turn influences inclusive human development. This framing acknowledges the theoretical possibility of reverse causality but justifies the chosen direction by highlighting the mechanisms through which energy security improvements spill over into institutional effectiveness.

Figure 1. Core Causal Pathway



Source: Authors' development

The above study by Nchofoung et al. (2022) is the closest in the literature to the present study. The idea of energy security as a contributing element fills this gap in the literature, especially for the African region in the following ways; firstly, it differs greatly from other studies due to the use of an inequality adjusted human development index and not simply an the human development index. Secondly, it captures energy security as an index, and not single energy variables. Lastly, it adopts a policy exposing methodology (quantile regression) which produces better results. With this said, the methodology is better explained in the following section.

3. Methodology

3.1 Model specification

Making use of an energy security index built using the PCA, the following econometric model is established to capture the effect of energy security on inclusive human development (IHD) in Africa. The literature has presented several ways of measuring IHD, and therefore, this work draws its inspiration for an empirical model from the works of Dobdinga et al. (2023) and Asongu and Nnanna (2020).

$$IHD = f(Esec, Gov, Internet, STJA, Manu, ODA, FDI, Trade) \quad \textbf{(1)}$$

$$IHD_{it} = V + \beta_1 Esec_{it} + \beta_j W_{it} + \varepsilon_{it} \quad \textbf{(2)}$$

In the above equation, IHD stands for inclusive human development captured by the inequality adjusted human development index. Esec represents the energy security index, W is a vector of other explanatory variables that affect economy i, at time t. V represents the constant and ε, the residual.

3.2 Data, sources and variables

Secondary data were extracted from the WDI, WGI, OPEC, and the UNDP for both energy security and IHD index indicators, and control variables as well. The period 2010 to 2022 is studied, considering data availability of the main dependent variable under study for 34 African countries (see Table F of appendix for country list).

3.2.1 Dependent variable

The inequality adjusted human development index (IHDI), which is based on current African inclusive development research (Asongu et al., 2015; Dobdinga et al., 2023), is used to quantify inclusive human development. The IHDI modifies the HDI for inequality. Therefore, IHDI is a more accurate indicator of inclusive development since it takes poverty and inequality into account (Ravallion & Chen, 2003; Dollar & Kraay, 2003).

3.2.2 Independent variable

The main independent variable is the energy security index (Esec), constructed using the Principal Component Analysis (PCA) method. The first indicator used is access to electricity, followed by access to clean fuel and technologies for cooking (Wang et al., 2022; Lee et al., 2017; Pondie et al., 2023). Renewable energy (RES) in total final energy consumption is the next. The other indicators include energy intensity, CO2 emissions (Kt), and energy prices captured by crude oil prices (Alemzero et al., 2020; Le and Nguyen, 2019; Kruyt et al., 2009). See Table A of the appendices for energy security score index for various African countries. The above 6 variables are jointly considered to build an energy security index for Africa following the existing energy security discourse.

The International Energy Agency (2001) recognizes energy security as "the uninterrupted availability of energy sources at an affordable price", while the World Energy Council (2013) frames energy security within its "Energy Trilemma" of security of supply, energy equity, and environmental sustainability. Looking at the definition from authors such as Sovacool and Mukherjee (2011) who expand the view of the Energy Trilemma to include efficiency, governance, and sustainability. Elsewhere, Cherp and Jewell (2014) define energy security as 'the low vulnerability of vital energy systems', which highlights resilience from shocks. All of these perspectives signify the multidimensional nature of energy security as encompassing accessibility, affordability, environmental sustainability, and technological advancement (United Nations, 2015). The final choice of variables to include in the study rests on the availability of data on energy security indicators in Africa.

Therefore building on this multidimensional understanding of energy security (IEA, 2001; World Energy Council, 2013; Sovacool & Mukherjee, 2011; Cherp & Jewell, 2014; United Nations, 2015), our measurement strategy operationalizes the concept by putting in place a composite index that incorporates indicators of accessibility (access to electricity; access to clean cooking technology), affordability (prices), environmental sustainability (renewable energy sources, CO_2 emissions), vulnerability (prices), and technological efficiency (energy intensity). The table below therefore shows each component alongside its theoretical meaning, expected direction, and statistical contribution to the PCA.

Table 1. Components Along with Their Theoretical Significance, Expected Direction, and Statistical Contribution to PCA.

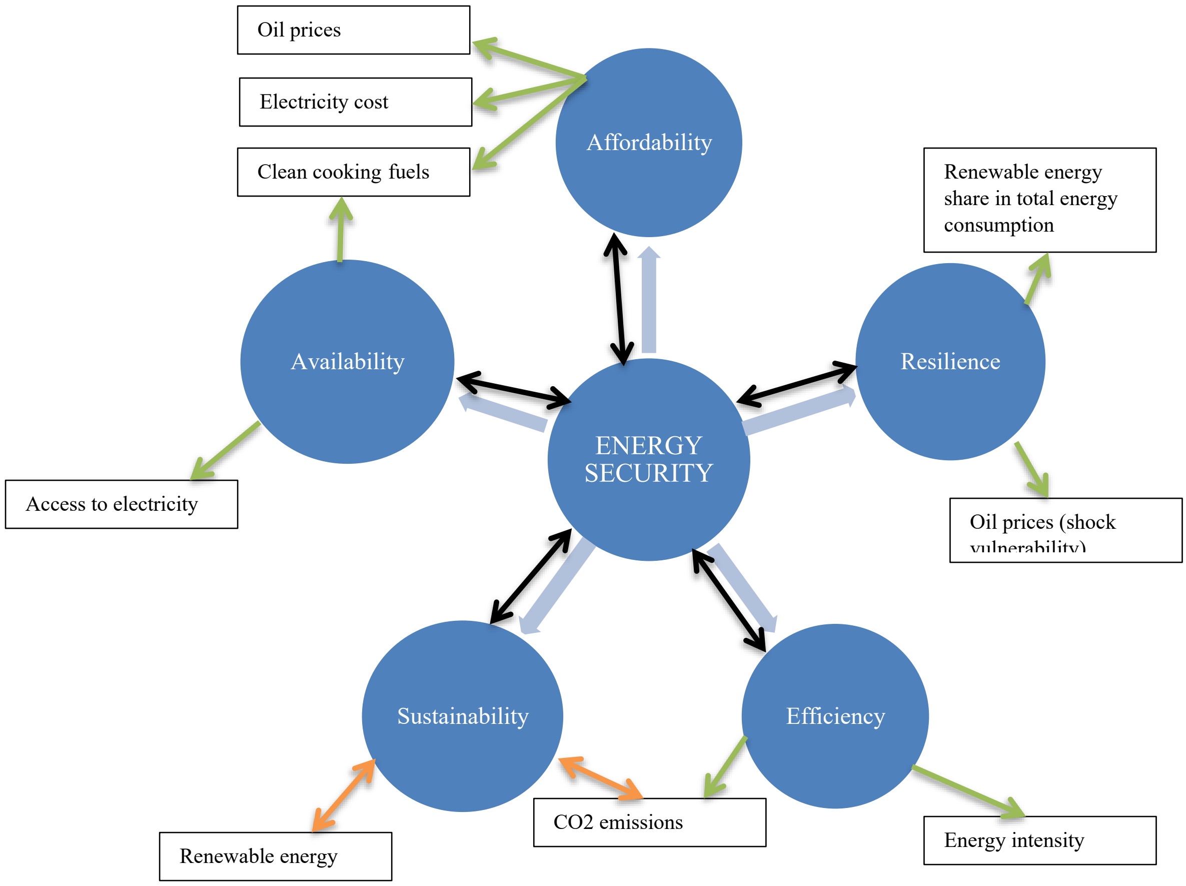
Indicator	Theoretical Meaning	Expected Direction	PCA loading
Access to electricity	Represents the foundational dimension of accessibility, an essential need for households and industries, and overall economic growth.	Higher access → improves energy security (+)	0.52
Access to clean cooking technology	It signals modern energy access and health outcomes: reliance on traditional biomass undermines energy equity and sustainability.	Higher access → improves energy security (+)	0.52
Renewable energy share in total energy consumption	This reflects environmental sustainability and diversification: higher renewable penetration reduces dependence on fossil fuels, mitigates emissions, and strengthens resilience against external shocks.	Higher share → improves energy security (less dependence on fossil fuels; +)	-0.52
Energy intensity	Indicates technological efficiency of energy use: high intensity signals wasteful consumption, undermining long-term security.	Higher intensity → worsens energy security (-)	-0.28
CO_2 emissions	Is a proxy for environmental sustainability: higher emissions suggest unsustainable energy systems that compromise future security and climate resilience.	Higher emissions → worsens energy security (unsustainable; risky; -)	0.33
Energy prices	Represents external vulnerability and affordability risks: volatility in oil markets directly affects economic stability and household affordability, which undermines secure access.	Higher prices → worsens energy security (exposure to volatility; unaffordable; -).	-0.05

Source: Authors' development and computation using STATA

Note: Renewables tend to have a negative direction and CO_2 emissions a positive direction as opposed to the expected direction. This reveals the actual tradeoff that exists between expanding access to clean energies (energy transition) and ensuring sustainability through reduced emissions (Cherp and Jewell, 2014; Sovacool and Mukheree, 2011).

Building on established perspectives from the International Energy Agency (IEA), the World Energy Council (WEC), Sovacool and Mukherjee (2011), and Cherp and Jewell (2014), energy security can be comprehensively defined as the capacity of an energy system to ensure reliable, affordable, efficient, and resilient access to energy while maintaining environmental integrity. Within this framework, electricity access and clean cooking fuels reflect the dimensions of availability and affordability; crude oil prices capture vulnerability and resilience to external supply shocks; energy intensity and CO_2 emissions represent efficiency and environmental sustainability; and renewable energy share embodies system diversification and long-term resilience. The conceptual diagram (Figure 2) below visually links each indicator to these theoretical dimensions, thereby reinforcing the construct validity of the energy security index and distinguishing it from broader measures of sustainable energy performance. Energy transition and sustainability are broader paradigms which can be treated as lone studies, but based on the existing energy security frameworks, they are treated as dimensions feeding into security outcomes.

Figure 2. Conceptual diagram (Energy security dimensions)



Source: Authors' computation using STATA

The PCA then comes in to determine the index outcome by assigning a weight to each variable used for the index. From the results the first principal component (PC) is taken as the best representative value of the index (Le et al., 2019; Jolliffe and Cadima, 2016; Cherp and Jewell, 2014; Sovacool and Mukheree, 2011). In our case, the first PC explained 47% of the total variance, confirming its suitability as the composite energy security index. This level of variance is consistent with prior applications of PCA in energy security and efficiency studies, where the first component typically captures the dominant multidimensional tradeoffs. Although the first principal component explains 47% of the total variance, this proportion is consistent with thresholds commonly accepted in multidimensional social science constructs (Jolliffe, 2002; Kaiser, 1960). Prior studies have demonstrated that explained variance in the range of 30–50% is sufficient to capture the dominant underlying dimension (Cattell, 1966; Wold, 1978). Recent methodological work further confirms that moderate proportions can yield valid and interpretable indices (Perry et al., 2024). Kaiser (1960) introduced the "Kaiser criterion," emphasizing eigenvalues >1 as meaningful, even when variance explained is below 50%. Our eigenvalue greater than 1 (value of 2.81). See appendix Table B and C. Also, the signs of the weights are arbitrary and are often reversed for clarity and interpretation (Jolliffe and Cadima, 2016; Sovacool and Mukherjee, 2011). However we maintain the signs of the PCA in our study. For further confirmation of the PCA, to strengthen confidence in the robustness of the index, we conducted several sensitivity checks. First, we compared PCA-derived weights with equal weighting and had a correlation value of 0.53 (see Appendix Table G), reflecting that the 2 indices share some common variation. This suggests that while both indices capture underlying dimension, the PCA weighting provides additional differentiation by emphasing indicators with higher shared variance. We strengthen this result by calculating the index excluding one indicator at a time. The overall ranking of units remained consistent, with Pearson's r exceeding 0.7. The first principal component is st rongly correlated with the constructed index (r = -0.87). The negative sign reflects arbitrary orientation of PCA loadings and does not affect interpretation, as the component still captures the dominant shared variance among indicators (see Appendix Table H for full values). For Spearman rank correlations between the composite index and the principal components, the Spearman rank correlations ranked between -0.6 to 0.9. The strong positive correlations with components 2 to 4 indicate substantial consistency in rankings, while the negative correlations with components 1, 5, and 6 reflect inverse orientations of variance. These results highlight that weighting choices influence rankings, underscoring the importance of PCA-derived weights for construct validity. The sign of correlations is arbitrary in PCA and does not affect interpretation (see Appendix Table H for full values).

For visual clarity on the independent and dependent variables, Figure 3 (energy security) and Figure 4 (inequality adjusted human development index) below show a trend analysis in their evolution, and Figure 5 depicts a scatter plot showing possible correlation between the two variables.

Figure 3. Trends in energy security in Africa

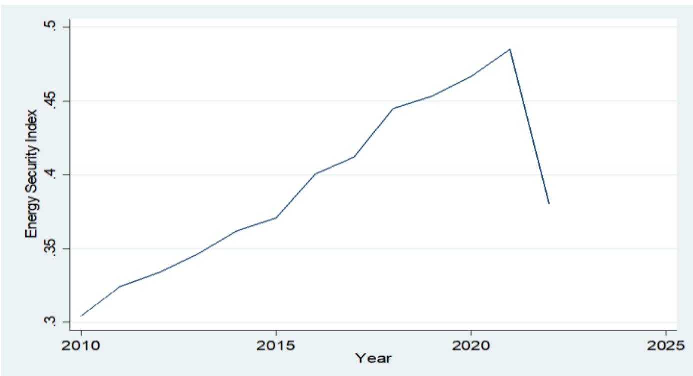


Figure 4. Trends in inequality adjusted human development in Africa

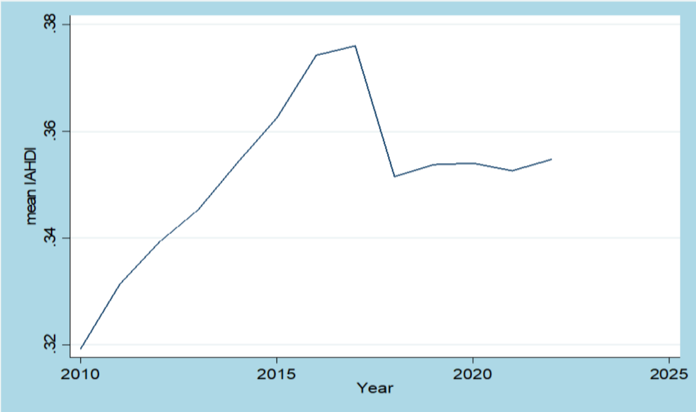
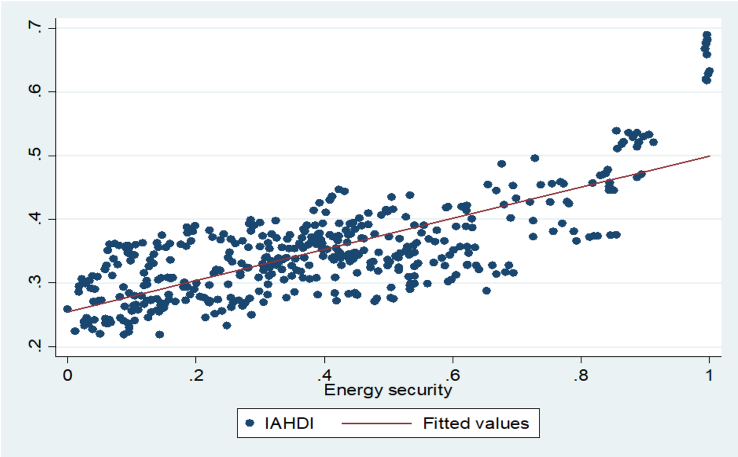


Figure 5. Scatter Plot (Energy security and inequality adjusted human development index)



Source: All figures generated by authors using STATA

Table 2. Control variables

Variable category	**Variable** name	**Purpose**	**Support studies**	**Expected sign**
Mediating & Control	Governance (GovE)	Measure for government effectiveness	Asongu and Nnanna (2020), Stylianou et al. (2023), and Dobdinga et al. (2023)	+
Other controls	Foreign aid	Measured by Net ODA received (% of GNI)	Asongu, (2014), Mlachila et al., (2017), and Asongu and Nwachukwu, (2016).	+/-
	Foreign Direct Investment (FDI)	Measured by FDI net inflows as a % of GDP	Dobdinga et al., (2023) and Asongu and Odhiambo, (2018)	+/-

Trade	Measured by trade % of GDP	Mustafa et al. (2017), Stylianou et al. (2023) and Asongu and Odhiambo (2018)	**+/-**
Digital economy	Measured by individuals using the internet (% of population)	Khan et al. (2019), Xholo et al. (2025), and Abbas & Zaman (2024)	+
Knowledge economy	Measured by scientific and technical journal articles	Mohamed et al. (2022) Kouton (2018)	**+/-**
Industrialization	Measured by manufacturing, value added (% of GDP)	Klafke et al. (2018) and Asghar et al. (2017)	**+/-**

Note: In this study, governance is conceptualized as a mediator in the energy security – inclusive human development nexus. The rationale is that governance operates as a mechanism through which energy security is translated into equitable social outcomes. Rather than merely altering the strength of the relationship (as a moderator would), governance channels energy security into improved education, health, and income opportunities. Our argument for this pathway finds backing in empirical evidence in the likes of Sen et al. (2026), Ofori (2026), and Chaiya (2026) who all argue and affirm that governance quality mediates the translation of energy security into sustainability outcomes, on inclusive development (considering marginalized populations), and on health outcomes. Taken together, these studies establish governance not as a background condition but as an active channel, justifying its adoption as a mediator in this analysis.

3.3 Estimation strategy

3.3.1 Quantile Regression

After adopting the energy security index, we adopt the quantile regression technique. Consistent with Asongu and Nnanna (2020) and Wirajing et al. (2024), the adopted Quantile regression (QR) estimation approach is tailored to emphasize countries with low, intermediate and high initial levels of IHD.

According to Koenker & Bassett (1978) Koenker (2005), and Tchamyou & Asongu (2018), the QR approach differs from the methods employed by Asongu and le Roux (2019) and Asongu and Odhiambo (2018) in that it: (i) determines conditional quantiles (as opposed to conditional mean); (ii) is based on sufficient data (as opposed to an OLS technique, which can be used on a relatively small data set); (iii) follows an agnostic distribution, as opposed to the normality assumption; (iv) it is robust to the control of outliers (as opposed to sensitivity to outliers). The quantile regression strategy is credible because it establishes the levels at which the independent variables significantly influence the dependent variable (Chen & Huo, 2021). The basic OLS model is presented in Equation (3)

$$\mathrm{IHDI}_{i,t} = \alpha_0 + \alpha_1 X_{i,t} + \varepsilon_{i,t} \quad \textbf{(3)}$$

The P^{th} quantile estimator of IHD is obtained by solving for the following optimization problem which, is presented below;

$$\underset{\beta \epsilon R^k}{\mathrm{Min}} \left[\sum_{i\epsilon\{i:yi\geq \mathrm{xi}'\beta\}} P \left| yi - \mathrm{xi}'\beta \right| + \sum_{i\epsilon\{i:yi<\mathrm{xi}'\beta\}} (1-P) \left| yi - \mathrm{xi}'\beta \right| \right] \quad \textbf{(4)}$$

Where $P \in (1,0)$.

As opposed to OLS which is based on the minimization of the sum of squared residuals, with QR, it is the weighted sum of absolute deviations that is minimized. For example, the 25th or 75th quantiles (with P=0.25 or 0.75, respectively) are estimated by approximately weighing the residuals. The conditional quantile of IHD or y_i given x_i is:

$$Q_{yi}\ (P/\ x_i) = xi'\beta_P \quad \textbf{(5)}$$

Here, unique slope parameters are estimated for each P^{th} specific quantile. For Eq. (5), the dependent variable yi is inclusive human development whereas xi contains: a constant term, independent variable and other control variables. Separate regression equations for the OLS and QR are as follows. Equation (3) expanded to Equation (6) below incorporating the variables of the model.

$$\mathrm{IHDI}_{i,t} = \alpha_0 + \alpha_1 \mathrm{Esec}_{it} + \alpha_2 \mathrm{Gov}_{it} + \alpha_3 \mathrm{Internet}_{it} + \alpha_4 \mathrm{FDI}_{it} + \alpha_5 \mathrm{Stja}_{it} + \alpha_6 \mathrm{Trade}_{it} + \alpha_7 \mathrm{ODA}_{it} + \alpha_8 \mathrm{Manu}_{it} + \varepsilon_{i,t} \quad \textbf{(6)}$$

$$\mathrm{IHDI}_{i,t} = \alpha_0^{(q)} + \alpha_1^{(q)} \alpha_1 X_{i,t} + \varepsilon_{i,t}^{(q)} \quad \textbf{(7)}$$

The OLS and QR respectively in Eq. (6) and Eq. (7) above focus on the relevance of energy security in influencing IHD in Africa, where, IHDIi,t, is inclusive human development for country i in period t, $\alpha 0$ is a constant, X entails energy security index, and other control variables (governance, fdi, internet users, development assistance, manufacturing, knowledge economy, and trade openness), and $\varepsilon_{I,t}$ is the error term. (see Table D, Table E, Table F, and Table G of the appendices for the tests of heteroskedasticity, autocorrelation, endogeneity, and the variance inflation factor respectively). The quantile equation is specified in Equation (8) below;

$$\mathrm{IHDI}_{it} = \alpha_0 + \alpha_1 \mathrm{Esec}_{i(t-r)} + \sum_{k-1}^{n} \alpha 0 \mathrm{W}_{qi(t-r)} + \varepsilon_{it} \quad \textbf{(8)}$$

Where, W represents the control variables with their estimated coefficients at different quantile levels and ε represents the error term.

3.3.2 Mediation Analysis

After conducting the quantile regression, the study employs a mediation analysis to provide value by highlighting specific variables that improve the influence of energy security on IHD. A hypothesized causal chain known as mediation occurs when one variable influences another, which influences a third. The mediator is the intervening variable, M. It "mediates" the connection between an outcome and a predictor, X (Baron and Kenny, 1986). Following the literature on mediation analysis (Baron and Kenny, 1986; Hair et al., 2021), the following model and equations are developed for our study;

$$Y = \alpha x + \varepsilon_i \quad \textbf{(9)}$$

$$M = \beta x + \varepsilon_{ii} \quad \textbf{(10)}$$

$$Y = cx + \gamma m + \varepsilon_{iii} \quad \textbf{(11)}$$

Where Y is the dependent variable inequality adjusted human development (IHDI), X is energy security (Esec) the independent variable, and M is the mediating variable which include [governance (Gov)]. ε in all the equations depict the residuals. α, β, c, and γ represent the various coefficients of the variables in the different equations.

$$IHDI_{it} = \beta_0 + \beta_1 Esec_{it} + \beta_2 Gov_{it} + \varepsilon_{it} \quad \textbf{(12)}$$

β represents the coefficients of the various variables, ε the residual and β_0 the constant in the equation.

3.3.3 The two-step system GMM

The two-step system GMM outperforms the one-step estimator, according to Roodman (2009b). This model was initially presented by Arellano and Bond (1991), and it was subsequently improved by Arellano and Bover (1995), followed by Blundell and Bond (1998). The proliferation of instruments, which weakens Hansen's statistics as a result, is a prevalent issue with the system GMM (Tchamyou & Asongu, 2017). A potential option would be to set a ceiling for instrumentation that is either below (Roodman, 2009a) or just above the total number of panels. The instruments used for the GMM estimation are all exogenous by design. Although there is no set formula for selecting the most suitable instrument, the instruments kept after the exercise should be exogenous. According to the body of literature that already exists on the subject of instrument selection, we kept the second lag of the explanatory variables as an instrument in this regard (Kiviet, 2023). Nchofoung et al. (2023) used the conventional approach to further collapse these instruments. According to Roodman (2009a) recommendation, this is done to make sure there are fewer instruments maintained in the regression than there are cross-sections.

According to Roodman (2009a), using the GMM technique is sufficient for the cross-sectional dimension to exceed the time dimension, which is in line with Nchofoung and Asongu (2022) and Kouladoum (2023). The first prerequisite for implementing the GMM technique described in Roodman (2009b) is confirmed by the fact that the number of cross-sections (34 nations) is more than the number of time series (13 years). Additionally, the GMM is an instrumental strategy that attacks the issue of endogeneity from two directions, first by addressing reverse causality and second by accounting for time-invariant omitted variables through the control of unobserved heterogeneity (Blundell & Bond, 1998; Nchofoung & Asongu, 2022). Since cross-country variance is inherent to panel data studies, the GMM is an approach that is frequently used for data that has been organized in a panel form. 34 cross sections for 13 years make up the panel nature of our data. This model's validity depends on (i) the exogeneity criterion for instrument validity and overidentifying restrictions, for which the Hansen test's P-value should be negligible (i.e., larger than 10%), and (ii) the absence of order two autocorrelation. In order to use this model, there is need for the introduction of a lag on the dependent variable. The model specification can therefore be expressed as follows;

$$IHD_{it} = V + \beta_0 IHD_{it-1} + \beta_1 Esec_{it} + \beta_j W_{it} + \varepsilon_{it} \quad \textbf{(13)}$$

In the above equation, IHD stands for inclusive human development captured by the inequality adjusted human development index, which is the dependent variable. β_0 is the coefficient for the lagged dependent variable (IHD_{it-1}). Esec represents the energy security index, which is the main independent variable. W is a vector of other explanatory variables (determinants of IHD) that affect economy I, at time t. V represents the constant and ε, the residual.

$$IHD_{i,t} = \alpha_0 + \beta_0 IHD_{it-1} + \alpha_1 Esec_{it} + \alpha_2 Gov_{it} + \alpha_3 Internet_{it} + \alpha_4 FDI_{it} + \alpha_5 Stja_{it} + \alpha_6 Trade_{it} + \alpha_7 ODA_{it} + \alpha_8 Manu_{it} + \varepsilon_{i,t} \quad \textbf{(14)}$$

Where, $IHD_{i,t}$, is inclusive human development for country I in period t, α_0 is a constant, β_0 is the coefficient for the lagged dependent variable (IHD_{it-1}). X entails energy security index, energy indicators (access to electricity % total population, oil prices and others) and other control variables (governance, fdi, internet users, development assistance, manufacturing, knowledge economy, and trade openness), and $\varepsilon_{I,t}$ is the error term.

This method is used so as to capture the problem of endogeneity of the lagged dependent variable when there is correlation between the error term and an explanatory variable in the model. It is also considered because it controls for omitted variable bias, unobserved panel heterogeneity and measurement errors in the data. Hence, this estimator; that is the GMM is strong and efficient in handling the problems of heteroscedasticity and autocorrelation. The two-step GMM technique is the most suitable for our dataset and inspects overidentifying restrictions, measurement errors, auto-correlation, and endogeneity issues in the panel dataset (Roodman, 2009b). N (number of cross-sections) should be greater concerning the number of the period for using this technique. GMM techniques provide better outcomes with correct model specifications than single-equation techniques/models.

The two-step GMM is the best technique when we have no idea of the distribution of the dependent variable. Considering the fact that the one-step process only addresses the concern of homoscedasticity, we adopt the two-step procedure which helps to control for heteroscedasticity. The lag-value of IHD has been considered in GMM to make it a dynamic model and to overcome the issue of autocorrelation as prevalent in static regression models. Thus, GMM provides the most accurate and efficient estimates by controlling the lag-effect of its dependent variable, "IHD". The values of inclusive human development would rely on its previous values to predict the future values more accurately. The GMM technique has been recommended by many scholars for the panel dataset (Wirajing et al., 2023; Ofori et al., 2022; Abbas et al., 2021; Wang et al., 2022).

To conclude, our methodological choices are deliberately structured to complement one another rather than stand in isolation. We begin with pooled OLS as a baseline to establish average relationships, and then refine the analysis with fixed effects and random effects to account for country-specific heterogeneity. Recognizing the risk of endogeneity, we employ system GMM to strengthen causal inference. To move beyond mean effects, quantile regression uncovers distributional heterogeneity, showing how results differ across the spectrum of outcomes. Robustness checks and nonlinear analysis ensure that findings are stable and capture complex dynamics, while mediation analysis identifies the pathways through which energy security exerts influence. Taken together, these methods form a coherent empirical strategy: starting with broad estimates, progressively addressing bias and heterogeneity, and finally testing mechanisms to explain observed relationships. This can explicitly be seen in the results section below.

4. Result and Discussion

Table 3. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
IAHDI	449	.352	.081	.219	.69
IALE	226	2.678	6.878	.216	35.1
IAII	223	2.773	7.315	.242	37.3
IAEI	239	3.578	8.705	.123	41.4
Esec	434	0	1	-1.552	2.411
internet	415	19.087	16.794	.58	72.31
oda	455	6.18	5.457	.032	32.513
govern	455	0	1	-2.292	3.162
stja	385	674.047	2054.333	0	15884.53
manu	446	7.741	6.687	-17.292	32.752
trade	423	68.237	26.194	20.723	150.209
fdi	439	6.579	6.173	-10.038	37.323

Source: Authors' computation using STATA

Table 3 shows the summary statistics of the various variables used in the work. IAHDI stands for inequality adjusted human development index; IALE represents inequality adjusted life expectancy index; IAII is inequality adjusted income index; and IAEI is the inequality adjusted education index. Esec as seen in other sections is energy security, internet is the number of internet users, oda is official development assistance, govern is the governance, stja represents scientific and technical journal article publication, manu is manufacturing value added, trade is trade openness with outside world, and lastly fdi is foreign direct investment.

Table 4. Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) iahdi	1.000											
(2) iale	0.014	1.000										
(3) iaii	0.039	0.957	1.000									
(4) iaei	0.052	0.687	0.745	1.000								
(5) Esec	0.757	-0.004	-0.024	-0.094	1.000							
(6) internetusers	0.735	-0.107	-0.109	-0.113	0.775	1.000						
(7) oda	-0.439	-0.076	-0.064	-0.050	-0.611	-0.470	1.000					

(8) govern	0.612	-0.008	0.038	0.057	0.465	0.521	-0.144	1.000				
(9) stja	0.262	-0.054	-0.048	-0.046	0.375	0.514	-0.245	0.258	1.000			
(10) manufac	0.358	0.135	0.128	0.011	0.485	0.333	-0.238	0.301	0.051	1.000		
(11) trade	0.205	0.049	-0.009	-0.061	0.293	0.165	-0.276	-0.065	-0.129	0.201	1.000	
(12) fdi	-0.068	-0.080	-0.072	-0.044	-0.132	-0.159	0.154	-0.039	-0.142	-0.196	0.176	1.000

Source: Authors' computation using STATA

Table 4 above corresponds to the matrix of correlations adopted for the various variables identified and used in this study's model.

4.1 Baseline Regressions

Table 5. Baseline Regressions

	(Pooled OLS)	**(Fixed-effect model)**	**(Random-effect model)**	**(GMM-model)**
VARIABLES	**Dependent variable: IAHDI**			
L.iahdi				0.517***
				(0.0250)
Esec	0.0425***	0.0233***	0.0261***	0.00421**
	(0.00351)	(0.00409)	(0.00393)	(0.00162)
Internet users	0.000741*	0.000457***	0.000489***	0.000703***
	(0.000360)	(0.000134)	(0.000133)	(0.000111)
oda	-0.00179*	-0.00117***	-0.00124***	-0.00149***
	(0.000891)	(0.000421)	(0.000414)	(0.000342)
govern	0.0187***	0.00932**	0.0119***	0.0137***
	(0.00232)	(0.00392)	(0.00363)	(0.00241)
stja	0.002726	0.00536	0.00406	1.26e-06***
	(0.00796)	(0.00193)	(0.00796)	(2.28e-07)
manufac	0.00131***	0.00171***	0.00180***	0.00178***
	(0.000322)	(0.000282)	(0.000278)	(0.000148)
trade	5.04e-05	-0.000196*	-0.000119	-6.44e-05
	(5.41e-05)	(0.000102)	(9.74e-05)	(9.74e-05)
fdi	6.67e-05	0.000138	0.000149	-5.80e-05
	(0.000293)	(0.000229)	(0.000230)	(6.54e-05)
Constant	0.334***	0.346***	0.340***	0.162***
	(0.00740)	(0.00893)	(0.0123)	(0.0113)
Observations	344	344	344	344
R-squared	0.644	0.343		

Number of groups	33	33	33	33
Number of instruments				27
r2	0.644	0.343		
F_f		91.38		
r2_o		0.604	0.619	0.619
r2_b		0.618	0.635	0.635
ar1p				0.000167
ar2p				0.641
Prop> Hansen				0.564

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Authors' computation using STATA

From the results in Table 3, all 4 models, that is the OLS, fixed-effect, random effects and GMM models show that energy security has a positive significant effect on the inequality adjusted human development index in Africa. That is, a unit increase in energy security leads to an increase in inclusive human development by units ranging between 0.42 to 4.25. This means that the more energy secure nations and people get in Africa, there would be an improvement in the level of human development even after taking into consideration inequalities. These results corroborate those of Acheampong et al. (2021).

From the control variables, the digital economy, the knowledge economy, the level of industrialization and governance in Africa, all have a positive significant effect on inequality adjusted human development. The digital economy through the number of people having access to the internet tends to enhance IHD in Africa. These results are in accordance with those of Xholo et al. (2025) and (Abbas & Zaman (2024). Governance has been shown to have a very high influence on human development, even the extent to which inequality is accounted for. However, the main focus of the study was on government effectiveness which has a positive significant effect on the inequality adjusted human development index in Africa. The results correspond with those obtained by Akinbode et al. (2020) in Nigeria, and Asongu and Odhiambo (2019).

Next, when we consider the level of industrialization through manufacturing value added, the former has a positive significant influence on inequality adjusted human development index in Africa. Although the value is low, the positive significant influence is justifiable. This positively influences human development while concretely curbing out inequalities. These results are in line with those of Asghar et al. (2017). The knowledge economy in Africa is slowly but surely gaining momentum. Due to the exposure of knowledge, many have known the importance of preserving clean environments, and how dirty and unreliable energy sources affect health. All of this has played a role in bettering human development conditions in the region, while reducing levels of inequalities. These results corroborate those of Mohamed et al. (2022) but contradict Kouton (2018) who finds a rather negative influence on development.

On the other hand, from the GMM statistics, official development assistance turns out to have a negative significant effect on inequality adjusted human development index in Africa. The results contradict the results of Lee et al. (2019). The other variables, foreign direct investment and trade both have a positive, though insignificant effect on the inequality adjusted human development index in Africa. The results are positive just like those of Mbang (2022) in the long run for fdi, and Salatin and Olfat (2018) for trade respectively.

To address potential endogeneity, particularly simultaneity among governance, energy security, and inclusive human development, we employ the system GMM estimator. This approach mitigates bias by using lagged levels and differences of the explanatory variables as instruments. Specifically, we rely on second lags, which are theoretically valid under the assumption that past values influences current outcomes. The chosen lag structure is consistent with prior empirical studies (Kiviet, 2003) and confirmed through robustness checks, ensuring that results are not sensitive to alternative specifications. To avoid instrument proliferation, we collapse instruments, thereby maintaining parsimony and reliability. Diagnostic tests support the validity of our strategy: AR(1) results confirm expected first-order autocorrelation, AR(2) results indicate the absence of second-order correlation, and Hansen test statistics suggest that the instruments are not overidentified. In dynamic panel GMM, first-order autocorrelation in differenced residuals is expected. Normally, AR(1) should be significant ($p < 0.05$) and AR(2) should not be significant ($p > 0.05$), meaning there is the absence of second order autocorrelation. From the GMM results on Table 3, the Arellano–Bond test indicates significant first-order autocorrelation (AR(1), $p = 0.001$), which is expected in differenced residuals. Importantly, the AR(2) test is not significant ($p = 0.641$), confirming the absence of second-order autocorrelation and supporting the validity of the instruments. The Hansen test ($p = 0.564$) further suggests that the over-identifying restrictions are valid. Nonetheless, we acknowledge that residual endogeneity may remain, as observational panel data cannot fully establish causality. Our findings should therefore be interpreted as strong empirical associations rather than definitive causal claims.

Furthermore, compared to the static OLS, fixed effects, and random effects models, the dynamic system GMM specification reveals much stronger persistence in IAHDI, with the lagged dependent variable showing a coefficient of 0.517 versus 0.02–0.04 in static models. Energy security also exerts a larger positive effect under GMM, highlighting the importance of correcting for endogeneity, with its results supported by diagnostic tests as seen earlier. Overall, the dynamic GMM model provides more consistent and credible estimates than the static models. Equally, the adoption of the lagged dependent variable in the GMM and not in other regressions (OLS, Fe, and Re) is due to endogeneity and bias in dynamic panel models. It is therefore used to correct endogeneity in dynamic models which is not the case in static models. If adopted in static models like the OLS, it will cause endogeneity (between the dependent variable and the error term) which brings about biased estimates.

4.2 Conditional Distribution

Table 6. Accounting for the conditional distribution of the inequality adjusted human development index

VARIABLES	**(1)** **iahdi**	**(2)** **iahdi**	**(3)** **iahdi**	**(3)** **iahdi**	**(5)** **Iahdi**
Esec	0.0184***	0.0229***	0.0290***	0.0511***	0.0735***
	(0.00328)	(0.00730)	(0.0101)	(0.00816)	(0.0175)
Internet users	0.000682**	0.000448	0.000622*	0.000654*	0.000188
	(0.000276)	(0.000395)	(0.000322)	(0.000398)	(0.000847)
oda	-0.00178**	-0.00286**	-0.00316***	-0.00231**	-0.000542
	(0.000732)	(0.00124)	(0.000980)	(0.000956)	(0.00152)
govern	0.0151***	0.0177***	0.0198***	0.0156***	0.0139***
	(0.00389)	(0.00432)	(0.00439)	(0.00488)	(0.00446)

stja	6.05e-06***	3.82e-06	-1.31e-07	-4.44e-06***	-5.44e-06***
	(9.26e-07)	(2.42e-06)	(1.50e-06)	(1.30e-06)	(1.61e-06)
manufac	0.00131**	0.00140*	0.00158***	0.00267***	0.00369***
	(0.000593)	(0.000733)	(0.000554)	(0.000778)	(0.00102)
trade	0.000189**	9.43e-05	-0.000286**	-0.000423***	4.13e-05
	(8.30e-05)	(0.000114)	(0.000143)	(9.70e-05)	(0.000335)
Fdi	0.000194	0.000642	0.00164*	0.000764	0.000295
	(0.000671)	(0.000708)	(0.000966)	(0.000924)	(0.000672)
Constant	0.261***	0.297***	0.349***	0.389***	0.391***
	(0.0103)	(0.0195)	(0.0148)	(0.0130)	(0.0342)
Observations	283	283	283	283	251
Q	0.100	0.250	0.500	0.750	0.900
bwidth_req	0.0178	0.0166	0.0147	0.0176	0.0198
Bwidth	0.0178	0.0166	0.0147	0.0176	0.0198
Reps	100	100	100	100	100

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Authors' computation using STATA

Table 6 presents the conditional distribution for different quantiles, and how this differentiation acts in segregating and grouping various individuals into different strands, based on living standards. The results reveal a positive significant effect of energy security on all 5 quantiles. The first strand that qualifies the first quantile (Q 10) shows that the effect is lowest (0.018), and the fifth quantile (Q 90) shows the highest effect (0.073). These results actually reveal that those in the uppermost quantile who actually have the highest IAHDI value tend to benefit more from the positive effect of energy security, given their better access to energy that permits more spillover effects in their overall human development. Those at the lowest quantile (Q 10) are at the lowest given their bear minimal access to better and clean usable energy for their subsistence and daily use. The results in this section actually correspond to results in the literature (such as those of Acheampong et al., 2021) that argue that those at the bottom (categorized as the poor) tend to have little or no access to clean energies and energy technologies that actually guarantee and boost their collective wellbeing, as opposed to the rich (upper quantile) who have better access to these facilities, coupled with the fact that the latter are mostly in the urban areas as opposed to the lowest quantile in the rural areas.

The quantile regression results reveal that higher-performing countries derive disproportionately greater benefits from energy security. This heterogeneity can be explained by differences in institutional quality, infrastructure readiness, and absorptive capacity. Countries with stronger institutions are better equipped to design and enforce regulatory frameworks that channel reliable energy supply into productive investment, thereby amplifying growth effects. Similarly, advanced infrastructure enables efficient integration of energy into industrial and service sectors, reducing transaction costs and fostering competitiveness. Finally, greater absorptive capacity—reflected in human capital, technological sophistication, and innovation systems—allows these economies to translate energy reliability into sustained productivity gains. Taken together, these mechanisms explain the heterogeneous effects observed in the quantile regression results. Countries at higher quantiles benefit disproportionately because they combine energy security with strong institutions, advanced infrastructure, and high absorptive capacity. For lower-performing countries, energy security alone is insufficient; without complementary improvements in governance, infrastructure, and human capital, the benefits will remain unevenly distributed. These findings underscore the importance of integrated policy approaches where institutional frameworks strengthen infrastructure investment, and build absorptive capacity to ensure that energy security contributes to inclusive and sustainable development across the entire distribution.

4.3 Robustness analysis

The robustness analysis examines the accuracy of the adopted methodology and consequent results obtained. Tables 5, 6, 7 & 8 below account for income differences, access to coastline, and non-linear effects respectively. Looking at the robustness checks, they all illustrate the same results as the main results which further lead us to affirm the enhancing effect of energy security on inclusive human development in Africa.

Table 7. Accounting for Income dynamics

	(1)	(2)	(3)
	General sample (Africa)	**Low income countries**	**Middle income countries**
VARIABLES	**Dependent variable: IAHDI**		
Esec	0.0414***	0.0393***	0.0491***
	(0.00813)	(0.00892)	(0.0113)
internetusers	0.000550	-0.00135	0.000117*
	(0.000417)	(0.000825)	(0.000531)
Oda	-0.00250***	-0.00247***	-0.00287*
	(0.000930)	(0.000663)	(0.00151)
govern	0.0193***	0.00620	0.0200***
	(0.00397)	(0.00461)	(0.00588)
Stja	-2.16e-06	-7.19e-06	-1.91e-06
	(1.39e-06)	(6.09e-06)	(1.53e-06)
manufac	0.00159***	0.00217***	0.000710
	(0.000570)	(0.000583)	(0.000745)
Trade	-1.59e-05	-0.000843***	0.000268
	(0.000145)	(0.000180)	(0.000205)
Fdi	0.000224	0.00215***	-0.000356
	(0.000792)	(0.000726)	(0.000974)
Constant	0.343***	0.392***	0.347***
	(0.0112)	(0.0199)	(0.0159)
Observations	251	106	145
R-squared	0.621	0.420	0.538
Prop> Hansen	0.253	0.173	0.270
Kleibergen-Paap (P-value)	0.0000***	0.0000***	0.0000***
Prob > F	0.0000***	0.0000***	0.00007***
r2	0.420	0.420	0.538
r2_a	0.372	0.372	0.511
r2u	0.988	0.989	0.981

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Authors' computation using STATA

Table 7 accounts for the case of the low and the lower middle income groups. The effect of energy security is positive and significant in both cases, but the effect is higher in the lower middle income countries. The results tie with those of Acheampong et al. (2021). The results can be backed by the fact that lower middle income countries have better income distribution, better distribution of technologies and amenities across their countries unlike the low income where development is most often centered in specific and often size restricted areas. Hence the lower middle income countries relatively have better access to energy security inducing technologies and resources as opposed to their counterparts – the low income countries.

Table 8. Accounting for differences in accessing the coastline

	(1)	**(2)**
	Coastal African countries	**Landlocked African countries**
VARIABLES	**Dependent variable:**	**IAHDI**
Esec	0.0238*	0.0375***
	(0.0122)	(0.0107)
internetusers	0.000588	0.000656
	(0.000913)	(0.000512)
oda	-0.00263**	-0.00334***
	(0.00129)	(0.000911)
govern	0.00505	0.0289***
	(0.00411)	(0.00468)
stja	-3.55e-06	-2.08e-06
	(6.74e-06)	(1.31e-06)
manufac	0.00333***	0.000608
	(0.000583)	(0.000843)
trade	-0.000561**	0.000486**
	(0.000223)	(0.000194)
fdi	0.00169**	3.70e-05
	(0.000848)	(0.00103)
Constant	0.345***	0.319***
	(0.0215)	(0.0160)
Observations	83	167
R-squared	0.617	0.677
Kleibergen-Paap (P-value)	0.0000***	0.0000***
Prob > Hansen	0.516	0.280
cdf	49.50	255.1
r2	0.617	0.677
r2_a	0.576	0.661
r2u	0.990	0.982

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Authors' computation using STATA

Table 8 accounts for differences in access to the coastline for the various African countries used in the sample. The results reveal that energy security has a positive significant effect on IHD in both landlocked and coastline countries. However, the effect is more significant in the landlocked countries as opposed to the coastal countries. The tendency is for coastline countries to have better availability and access to the use of cleaner energies such as wind, water, and thermal, but it appears that most coastal countries in Africa are yet to develop and highly make use of their coastal potential. As a result regional differences and country positioning (Acheampong et al., 2021) greatly affects how countries tap benefits from energy security for human development while considering inequality.

Table 9. Non-linear effects

VARIABLES	(1) iahdi	(2) iale	(3) iaii	(4) iaei
Esec (Linear effect)	0.00739***	-0.0453	-1.534***	0.0413
	(0.00215)	(0.492)	(0.257)	(0.954)
Ess_squared (non-linear)	**0.00888*** **	**0.504** **	**0.497*** **	**0.915* **
	(0.00220)	**(0.195)**	**(0.114)**	**(0.504)**
internetusers	0.000449***	-0.0654**	0.0331***	-0.00152
	(0.000107)	(0.0255)	(0.00707)	(0.0176)
oda	-0.00134***	0.0125	0.128***	0.0236
	(0.000444)	(0.0383)	(0.0309)	(0.118)
stja	7.56e-08	0.000137*	1.76e-05	-0.000249
	(4.60e-07)	(7.35e-05)	(6.19e-05)	(0.000187)
manufac	0.00172***	0.237***	0.0269	0.388**
	(0.000185)	(0.0326)	(0.0265)	(0.187)
trade	-6.61e-05	0.0398***	-0.000966	-0.0145
	(9.80e-05)	(0.00578)	(0.00209)	(0.0194)
fdi	-5.03e-05	0.0215	-0.0168***	0.0593
	(0.000112)	(0.0366)	(0.00405)	(0.0789)
govern	0.00401	-0.208	0.993***	0.595
	(0.00526)	(0.197)	(0.136)	(0.944)
L.iahdi	0.526***			
	(0.0281)			
L.iaei		1.086***		
		(0.0602)		
L.iaii			0.892***	
			(0.0121)	
L.iale				0.910***
				(0.0650)
Constant	0.149***	-4.980***	-1.408**	-3.695
	(0.0136)	(0.634)	(0.522)	(2.535)
Observations	309	106	168	170
Number of country	33	26	28	27
ar1p	0.000221	0.0922	0.0589	0.0773
ar2p	0.477	0.489	0.657	0.185
Instruments	27	25	27	21

Prop> Hansen	0.476	0.998	0.525	0.620

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Source: Authors' computation using STATA

Table 9 above accounts for the different components of the inequality adjusted human development index. When the present level of energy security is doubled, it would produce an enhancing effect on all components. We consider the following quadratic equation to compute a turning point (threshold) for this non-linear result:

$$IHD_{it} = V + \beta_1 ESec + \beta_2 ESec^2 + \varepsilon_{it} \quad (15)$$

Then the threshold is:

$$X* = -\frac{\beta 1}{2\beta 2} \quad (16)$$

Where $\beta_1 = 0.00739$ (linear term) and $\beta_2 = 0.00888$ (squared term).

After computing, the threshold is at -0.416 units of energy security which lies within our observed range of -1.552 to 2.411. Since $\beta_2 > 0$, the curve is said to be U-shaped. For ever value below -0.416, increases in energy security are associated with declining inclusive human development. On the other hand, for values above -0.416, increases in energy security produce progressively stronger improvements in inclusive human development. Hence this U-shaped relationship implies that IHD initially declines as energy security rises from very low levels, but beyond the threshold, further improvements in energy security generate increasingly stronger gains. This finding underscores the importance of surpassing the minimum threshold of energy security to unlock substantial development.

The non-linear effects model considers the different dimensions of the inequality adjusted human development index (iahdi) that is, the inequality adjusted education index (iaei), inequality adjusted income index (iaii) and the inequality adjusted life expectancy index (iale). For all three dimensions of the inequality adjusted human development index still under the non-linear model, energy security positively and significantly affects them in Africa. This is true in all three cases; (i) when people are exposed to considerable clean energy, have availability and access to timely energy resources like in hospitals and in homes as well, when energy used by individuals and communities have a lesser negative effect on the environment, it contributes in bettering living standards, thus an improvement in life expectancy (iale). (ii) equally access to timely energy, availability of energy on regular basis, cheaper energy rates for consumption all sum up in easing study time, access to the internet for study, and the use of practical technologies in schools both at secondary and tertiary levels, to ease learners' outcomes hence, reducing inequality in education, and better improvement in education (iaei). (iii) in the last place, energy security guarantees business creation, availability of reliable energy leads to better industrialization capacity which leads to job creation, better management of large scale farming schemes, the resultant effect is a rise in income earnings (iaii), which equally contributes in narrowing the inequality gap. Conclusively, the results based on the three dimensions shows the overall positive significant effect which energy security would have on inequality adjusted human development in Africa if the present level of energy security is doubled. However, this sub-indices (IALE represents inequality adjusted life expectancy index; IAII is inequality adjusted income index; and IAEI is the inequality adjusted education index) present a major challenge as data for this were available for a period of only eight years.

Table 10. Different human development measure (HDI: Human Development Index)

	Fixed effects	Random effects	Pooled OLS	GMM
VARIABLES	**hdi**	**hdi**	**hdi**	**hdi**
L.hdi				0.876***
				(0.0165)
ESec	0.0192	0.148***	0.190***	0.0383***
	(0.0308)	(0.0286)	(0.0142)	(0.00528)
internetusers	0.00213***	0.00156***	0.00166*	-0.000423**
	(0.000646)	(0.000599)	(0.000970)	(0.000165)
oda	-0.000444	-0.000242	-0.00403***	-0.000367
	(0.000472)	(0.000523)	(0.00103)	(0.000397)
govern	0.0116	0.0218	0.0168**	0.0111***
	(0.0156)	(0.0154)	(0.00665)	(0.00186)
stja	-1.06e-05**	-1.29e-05**	-1.56e-05***	-3.93e-06***
	(5.10e-06)	(6.23e-06)	(3.48e-06)	(6.21e-07)
manufac	-0.00494**	-0.00496**	-0.00297***	-0.00161**
	(0.00208)	(0.00249)	(0.000747)	(0.000697)
trade	-0.000127	7.64e-05	-0.000856**	-7.49e-05
	(0.000158)	(0.000162)	(0.000357)	(6.70e-05)
fdi	0.000214	-0.000168	0.00283**	0.000184*
	(0.000218)	(0.000224)	(0.00111)	(9.89e-05)
Constant	0.220***	0.208***	0.259***	0.0588***
	(0.0240)	(0.0372)	(0.0318)	(0.0111)
Observations	442	442	442	414
R-squared	0.450		0.869	
Number of countrycode	33	33		33
r2_b	0.573	0.855		
r2_o	0.526	0.848		
N_g	33	33		33
r2_a	0.433		0.865	
ar1p				0.053
ar2p				0.159
hansenp				0.541
Instruments				25

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Authors' computation using STATA

From the results in Table 10, all models, with the exception of the fixed effects show that energy security has a positive significant effect on the human development index in Africa. These results further confirm our main results using the inequality adjusted human development index in Table 3. Furthermore, we note that the coefficients here (HDI) are larger than those under the (IAHDI) because the HDI does not account for inequality like the inequality adjusted human development index. This further spells out the significance and robustness of the analysis. Hence, the more energy secure nations and people get in Africa, there would be a substantial improvement in the level of human development as registered here.

4.4 Mediation analysis

Table 11. Baron and Kenny approach to testing mediation

Model: Governance as the mediating variable	**Coefficient**	**Std.Err**
(1) Governance: Energy security (X -> M)	0.406***	0.001
(2) IAHDI: Governance (M -> Y)	0.020***	0.001
(3) IAHDI: Energy security (X -> Y)	0.0027**	0.001
Indirect effects	0.008**	0.0001
Sobel test	0.008**	0.0001
Monte Carlo	0.008**	0.0001
Total effects	0.062***	
Direct effects	0.054***	
RIT (Indirect effect/Total effect) ratio	0.133	
RID (Indirect effect/Direct effect) ratio	0.154	

Std.Err = Standard error

Source: authors' computation using STATA

Table 11 above presents a mediation analysis of the effect of energy security on IAHDI through the governance channel. Where X is the independent variable of energy security, Y the dependent variable being the IAHDI, and M the mediating variable in this case, governance.

In a more detailed manner, the effect of X on M has a coefficient of 0.406, indicating that energy security strongly predicts governance. Next, M on Y shows that governance significantly influences inclusive human development with a value of 0.020, and X on Y, indicates 0.0027 direct effect of energy security on inclusive human development without governance in the picture. However the indirect effect of 0.008 shows the effect of energy security on inclusive human development through governance. All of this implies that policy makers through the provision of energy security (e.g., through building power plants, subsidizing renewables, etc) get direct benefits but if they leverage on strengthening government effectiveness (that is, the quality of public services, and its ability to act independently from political pressures both internal and external, the quality of policy formulation and implementation, and the credibility of the government's commitment to policies such as advancing energy transition), it will unlock an extra 0.133 boost in inclusive human development outcomes. The Sobel test confirms the indirect effect with a significant value of 0.008. The robustness and validity of the indirect effect is further affirmed by the Monte Carlo simulation test significant value.

From Table 11, we draw 2 main results of interest. The RIT and RID ratios as seen below;

i) RIT ratio of institutional quality (governance) = (Indirect effect / Total effect)

(0.008 / 0.062) = 0.133
Meaning that about 13 % of the effect of energy security on iahdi is mediated by governance
ii) RID ratio of institutional quality (governance) = (Indirect effect / Direct effect)
(0.008 / 0.054) = 0.154
That is, the mediated effect is about 0.2 times large as the direct effect of energy security on iahdi.

This therefore means that in Africa, for energy security to have a more enhancing effect on inequality adjusted human development, the government as indicated by the governance quality will have an important role to play, especially through government effectiveness. This is true as the level of human development and inequality in Africa is highly characterized by the type of government in place (Akinbode et al., 2020). Equally, how a government manages its national energy security (that is through infrastructures, renewables, energy type and quality, energy prices, overall energy availability, etc), goes a long way in either influencing its IHD. Therefore government effectiveness needs to be strengthened if energy security benefits will adequately boost human development.

Finally to conclude, mediation analysis helps in illustrating how governance channels part of the effect of energy security on inclusive human development, but it does not tackle endogeneity concerns. However, the problem of endogeneity is rightly targeted and treated using the system GMM estimator in this analysis, which is applied before the use of mediation. The GMM therefore corrects for simultaneity and unobserved heterogeneity first, before the mediation analysis is used, acting as a complementary analysis in illustrating the mechanism through which governance channels part of the energy security effect on inclusive human development.

5. Conclusion and Suggestion

The aim of this study was to examine the effect of energy security on inclusive human development in Africa. Using data from the year 2010 to 2022 for over 34 African countries, the results show after the application of the GMM, quantile regression, and the mediation analysis that energy security has an enhancing effect on inclusive human development in Africa. More specifically, a one unit increase in energy security will lead to an increase in inclusive human development in Africa of a value ranging between 0.421 - 4.25. From the quantile study, we clearly see that those in the upper inclusive human development quantile (Q90) have a better gain from energy security when compared to the lowest quantile (Q10) [0.0735 and 0.0184 respectively]. When income groups are considered, the lower middle income countries have a better output than lower income countries, with respect to an increase in inclusive human development (0.0491 and 0.0393 respectively). On the other hand, landlocked countries are differentiated from coastline countries, and the results reveal that in Africa, the landlocked countries have an upper hand in gaining from the effect of energy security as opposed to the coastline countries. On an interesting note, the effect of energy security on inclusive human development will become better when the present level of energy security is doubled, following the non-linear effect results. Finally on the results, governance acts as a good mediator in the energy security – inclusive human development nexus. When mediated, the result with governance provides a 0.2 times larger effect as opposed to the direct effect of energy security on inclusive human development. These results have a lot of implications for governments in Africa and the need to review their energy security strategies and energy systems if they aspire for better and more inclusive human development in the region as a whole and in various individual economies.

With these results, it is evident that with an increase, and a deepening of the present level of energy security in Africa, the region and its countries stand a better chance of enjoying not just any type of human development, but an inclusive one that accounts for inequality. Given the importance of the energy system to human wellbeing, there is no better time than this for African economies to pursue inclusive human development which centres on a better way for achieving this development in an inclusive way. Achieving this therefore is paving the way for enhancing sustainable development, and Agenda 2063 by fighting poverty and inequalities. To therefore achieve this, there is an urgent need for an energy security plan, which leverages on robust energy systems and infrastructures, green technologies and a replacement of dirty with clean energies. Moreover, there is need for governments all over Africa to leverage upon government effectiveness in bringing about equity from the benefits to the various strands of its population. This is to be done by focusing more attention on the lowest quantile (Q10) and providing them with the needed resources (like subsidizing renewables, providing more grid structures in secluded areas, villages) that would help shallow the gap between them and those in the other quantiles. The results highlight that energy security yields the greatest dividends where institutional quality, infrastructure readiness, and absorptive capacity are already strong. For policymakers in lower-performing countries, this implies that investments in governance reforms, infrastructure development, and human capital are critical complements to energy security initiatives. Without these foundations, the benefits of reliable energy supply will remain unevenly distributed, reinforcing existing disparities rather than closing them.

Equally, robust energy infrastructures such as more grid stations need to be put at their disposal, with focus on building solar voltaic power stations on vast hectares of land as a substitute for biomass, which has serious health and environmental consequences. Providing these clean energy resources would not only advance energy security, but enhance life expectancy and health through the replacement of dirty with clean energies; promote income creating activities via the new energy systems; and equally prolong study time, and making study time more comfortable with a consequence in advancing education. All of this would narrow down inequalities and make the benefits from energy security more palpable. With this, there would be a better and more inclusive human development which fosters a conducive social atmosphere.

To conclude, our empirical findings indicate that improvements in energy security are positively associated with inclusive human development outcomes. These results support targeted measures that strengthen renewable adoption at a scale consistent with existing fiscal and institutional capacities. While broader aspirations such as large-scale renewable infrastructure expansion projects, extensive solar investment, and government-led interventions remain important for Africa's long-term energy security and transition, they extend beyond the direct scope of our estimates. Such ambitions must be pursued but at the same time are limited under various contexts due to careful consideration of fiscal limitations, governance capacity, and political realities that shape implementation across diverse African economies.

6. Limitations and Future Research

The study anchors on a general frame, that is, Africa as a whole but the results may appear completely different on a country by country basis. This therefore limits the study and calls for future research to examine individual countries, and or sub-regional country groups. The study is equally limited in the area of the energy security index variables due to unavailability. Future research should consider expanding the index variables, to produce more robust results. Another limitation is in the area of data availability, especially for the sub-indices of the inequality adjusted human development index which had a lot of missing values. Scholars can build on this for a better future work. On a last note, we acknowledge that there might be a mutual relationship between governance and energy security, and that both may be jointly determined by broader institutional and development conditions. This not being handled in the work leaves an open wing to further scientific evidence. Although system GMM helps mitigate endogeneity, particularly simultaneity among governance, energy security, and inclusive human development, residual bias may persist. As with all observational panel data, causal inference remains limited, and our findings should be interpreted as robust associations rather than definitive causal claims.

Acknowledgement (if any)

N.A

Declaration of AI and AI-assisted technologies in the writing process (if author[s] utilize AI)

N.A

References

Abbas, H.S.M., Xu, X., Sun, C., Ullah, A., Gillani, S., & Raza, M.A.A. (2021). Impact of COVID-19 pandemic on sustainability determinants: A global trend. *Heliyon* 2021, 7, e05912.

Abbas, S. A., & Zaman, A. (2024). Does digitalisation help achieve (selected) socio-economic SDGs? Evidence from emerging economies. *Sustainable Development*, 32(6), 6088–6103. https://doi.org/10.1002/sd.2974

Acheampong, A. O., Erdiaw-Kwasie, M. O., & Abunyewah, M. (2021). Does energy accessibility improve human development? Evidence from energy-poor regions. *Energy Economics*, 96, Article 105165. https://doi.org/10.1016/j.eneco.2021.105165

Akinbode, O. S., Olabisi, J., Adegbite, R. R., Aderemi, A. T., & Alawode, M. A. (2020). Corruption, government effectiveness and human development in Sub-Saharan Africa. *Journal for the Advancement of Developing Economies*, 9(1), 38–56. https://doi.org/10.32873/unl.dc.jade912

Aklin, M., & Urpelainen, J. (2018). Renewables: The politics of a global energy transition. MIT Press.

Alemzero, A. D., Sun, H., Mohsin, M., Iqbal, N., Nadeem, M., & Vo, V. X. (2020). Assessing energy security in Africa based on multi-dimensional approach of principal composite analysis. *Environmental Science and Pollution Research*, 28, 2158–2171. https://doi.org/10.1007/s11356-020-10554-0

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, 58(2), 277–297.

Arellano, M., & Bover, O. (1995). "Another look at the instrumental variable estimation of error components models", *Journal of Econometrics*, 68(1):29-52.

Asongu, S. A. (2014). The questionable economics of development assistance in Africa: Hot-fresh evidence, 1996–2010. *The Review of Black Political Economy*, 41(4), 455–480. https://doi.org/10.1007/s12114-014-9190-8

Asongu, S. A., Efobi, U., & Beecroft, I. (2015). Inclusive human development in pre-crisis times of globalisation-driven debts. *African Development Review*, 27(4), 428–442. https://doi.org/10.1111/1467-8268.10271

Asongu, S. A., & Nwachukwu, J. C. (2016). The role of governance in mobile phones for inclusive human development in Sub-Saharan Africa. *Technovation*, 55-56, 1–13. https://doi.org/10.1016/j.technovation.2016.04.002

Asongu, S. A., & Odhiambo, N. M. (2018). Doing business and inclusive human development in Sub-Saharan Africa (AGDI Working Paper, No. WP/18/031). *African Governance and Development Institute*.

Asongu, S. A., & Odhiambo, N. M. (2019). How enhancing information and communication technology has affected inequality in Africa for sustainable development: An empirical investigation. *Sustainable Development*, 27(4), 647–656. https://doi.org/10.1002/sd.1929

Asongu, S. A., & le Roux, S. (2019). Understanding Sub-Saharan Africa's extreme poverty tragedy. *International Journal of Public Administration*, 42(6), 457–467. https://doi.org/10.1080/01900692.2018.1466900

Asongu, S. A., & Nnanna, J. (2020). Inclusive human development in sub-Saharan Africa (AGDI Working Paper, No. WP/20/014). *African Governance and Development Institute.*

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51(6), 1173–1182. https://doi.org/10.1037/0022-3514.51.6.1173

Bello, M. (2015). Renewable energy for sustainable socio-economic development in developing countries: A case study of Sub-Saharan Africa. *Advanced Materials Research*, 1116, 33–44. https://doi.org/10.4028/www.scientific.net/AMR.1116.33

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 87(1), 115–143.

Chaiya, C. (2026). Governance-driven macro-level health outcomes: Operationalizing the sustainability nexus through cross-national environmental informatics. *Sustainability*, 18(13), 6757.

Chambers, R. (1988). *Sustainable livelihoods, environment and development: Putting poor rural people first* (IDS Discussion Paper 240). Institute of Development Studies.

Cattell, R. B. (1966). The scree test for the number of factors. Multivariate Behavioral Research, 1(2), 245–276. https://doi.org/10.1207/s15327906mbr0102_10

Chen, L., & Huo, Y. (2021). A simple estimator for quantile panel data models using smoothed quantile regressions. *The Econometrics Journal*, 24(2), 247–263. https://doi.org/10.1093/ectj/utaa023

Cherp, A., & Jewell, J. (2014). The concept of energy security: Beyond the four As. *Energy Policy*, 75, 415-421. https://doi.org/10.1016/j.enpol.2014.09.00

Conway, R. G. (1983). *Agroecosystem analysis* (ICCET Series E, No. 1). Imperial College of Science and Technology.

Costa, L., Rybski, D., & Kropp, J. P. (2011). A human development framework for CO2 reductions. *PLoS ONE*, 6(12), e29262. https://doi.org/10.1371/journal.pone.0029262

Dobdinga, C. F., Boniface, N. E., Giyoh, G. N., & Asongu, S. A. (2023). The effects of institutional quality and biocapacity on inclusive human development in Sub-Saharan Africa (MANRECUR Working Paper, No. WP23/044). *Managing African Research Network*.

Dollar, D., & Kraay, A. (2003). Institutions, trade, and growth. *Journal of Monetary Economics*, 50(1), 133–162. https://doi.org/10.1016/S0304-3932(02)00206-4

Drèze, J., & Sen, A. (2002). India: Development and participation. Oxford University Press.

Eren, B. M., Taspinar, N., & Gokmenoglu, K. K. (2019). The impact of financial development and economic growth on renewable energy consumption: Empirical analysis of India. *Science of The Total Environment*, 663, 189–197. https://doi.org/10.1016/j.scitotenv.2019.01.323

Goldthau, A., & Sovacool, B. K. (2012). The uniqueness of the energy security, justice, and governance problem. Energy Policy, 41, 232–240. https://doi.org/10.1016/j.enpol.2011.10.042

Hair, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021). Mediation analysis. In Partial least squares structural equation modeling (PLS-SEM) using R: A workbook (pp. 139–153). *Springer International Publishing*.

International Energy Agency . (2001). *Toward a sustainable energy future.* Paris: IEA.

International Energy Agency. (2019). *CO2 emissions from fuel combustion 2019*. https://webstore.iea.org/co2-emissions-from-fuel-combustion-2019

Jolliffe, I. T. (2002). Principal component analysis (2nd ed.). Springer.

Jolliffe, I. T., & Cadima, J. (2016). Principal component analysis: A review and recent developments. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2065), 20150202. https://doi.org/10.1098/rsta.2015.0202

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. Educational and Psychological Measurement, 20(1), 141–151. https://doi.org/10.1177/001316446002000116

KfW Development Bank, GIZ, & IRENA. (2020). The renewable energy transition in Africa: Powering access, resilience and prosperity. *International Renewable Energy Agency*.

Khan, N. H., Ju, Y., & Hassan, S. T. (2018). Modeling the impact of economic growth and terrorism on the human development index: Collecting evidence from Pakistan. *Environmental Science and Pollution Research*, 25(34), 34661–34673. https://doi.org/10.1007/s11356-018-3388-z

Khan, N. H., Ju, Y., & Hassan, S. T. (2019). Investigating the determinants of human development index in Pakistan: An empirical analysis. *Environmental Science and Pollution Research*, 26(19), 19294–19304. https://doi.org/10.1007/s11356-019-05271-2

Khodabakhshi, A. (2011). Relationship between GDP and human development indices in India. *Society of Interdisciplinary Business Research*, 2, 251–253.

Kiviet, J. F. (2023). Instrument-free inference under confined regressor endogeneity and mild regularity. *Econometrics and Statistics*, 25, 1–22.

Klafke, R., Picinin, C. T., Lages, A. R., & Pilatti, L. A. (2018). The development growth of China from its industrialization intensity. *Cogent Business & Management*, 5(1), Article 1452140. https://doi.org/10.1080/23311975.2018.1452140

Koenker, R. (2005). *Quantile regression*. Cambridge University Press.

Koenker, R., & Bassett, G. (1978). Regression quantiles. *Econometrica*, 46(1), 33–50. https://doi.org/10.2307/1913643

Kouladoum, J. C. (2023). Digital infrastructural development and inclusive growth in Sub-Saharan Africa. *Journal of Social and Economic Development*, 1–25.

Kouton, J. (2018). Education expenditure and economic growth: Some empirical evidence from Côte d'Ivoire. *Journal of Economics and Sustainable Development*, 9(14), 22–34.

Kruyt, B., van Vuuren, D. P., de Vries, H. J., & Groenenberg, H. (2009). Indicators for energy security. *Energy Policy*, 37(6), 2166–2181. https://doi.org/10.1016/j.enpol.2009.02.006

Le, T. H., & Nguyen, C. P. (2019). Is energy security a driver for economic growth? Evidence from a global sample. *Energy Policy*, 129, 436–451. https://doi.org/10.1016/j.enpol.2019.02.046

Le, T.-H., Chang, Y., Taghizadeh-Hesary, F., & Yoshino, N. (2019). Energy insecurity in Asia: A multi-dimensional analysis. *Economic Modelling*, https://doi.org/10.1016/j.econmod.2019.09.036

Lee, K., Miguel, E., & Wolfram, C. D. (2017). *Electrification and economic development: A microeconomic perspective* (EEG State-of-Knowledge Paper Series). Energy Institute at Haas.

Mbang, O. M. (2022). Foreign direct investment and human development in Cameroon. *American Journal of Industrial and Business Management*, 12(1), 58–72. https://doi.org/10.4236/ajibm.2022.121005

Mlachila, M., Tapsoba, R., & Tapsoba, S. J. (2017). A quality of growth index for developing countries: A proposal. *Social Indicators Research*, 134(2), 675–710. https://doi.org/10.1007/s11205-016-1439-z

Mohamed, M. M., Liu, P., & Nie, G. (2022). Do knowledge economy indicators affect economic growth? Evidence from developing countries. *Sustainability*, 14(8), Article 4774. https://doi.org/10.3390/su14084774

Mustafa, G., Marian, R., & David, K. (2017). Growth, human development, and trade: The Asian experience. *Economic Modelling*, 61, 93–101. https://doi.org/10.1016/j.econmod.2016.12.007

Nchofoung, T. N., Asongu, S. A., Njamen Kengdo, A. A., & Achuo, E. D. (2022). Linear and non-linear effects of infrastructures on inclusive human development in Africa. *African Development Review*, 34(1), 81–96. https://doi.org/10.1111/1467-8268.10344

Nchofoung, T. N., & Asongu, S. A. (2022). Effects of infrastructures on environmental quality contingent on trade openness and governance dynamics in Africa. *Renewable Energy*, 189, 152–163.

Nchofoung, T. N., Nkemgha, G. Z., Fokam, D. N. D. T., & Njamen, K. A. A. (2023). Achieving the sustainable development goals through water and sanitation: Do information and communication technologies (ICTs) matter for Africa? *Journal of the Knowledge Economy*, 1–25.

Ofori, I. K. (2026). Distributional energy justice and the inclusive human development agenda in Africa. *World Development*, 198, 107223.

Ofori, I. K., Gbolonyo, E., & Ojong, N. (2022). Towards Inclusive Green Growth in Africa: Critical energy efficiency synergies and governance thresholds. *Journal of Cleaner Production*, ISSN 0959-6526, Elsevier Science, Amsterdam [u.a.], Vol. 365, pp. 1-48

Orbes, I., Dang, H. M., & Eapen, A. (2019). Foreign direct investment and human development. *Academy of Management Proceedings*, 2019(1). https://doi.org/10.5465/AMBPP.2019.10732abstract

Perry, R., Panigrahi, S., Bien, J., & Witten, D. (2024). Inference on the proportion of variance explained in principal component analysis. arXiv preprint arXiv:2402.16725.

Pîrlogea, C. (2012). The human development relies on energy: Panel data evidence. *Procedia Economics and Finance*, 3, 496–501. https://doi.org/10.1016/S2212-5671(12)00186-4

Pondie, M. T., Engwali, F. D., Nkoa, O. E. B., & Domguia, N. E. (2023). Does energy poverty increase starvation? Evidence from Sub-Saharan Africa. *Environmental Science and Pollution Research*, 30(17), 50304–50317. https://doi.org/10.1007/s11356-023-25997-4

Ravallion, M., & Chen, S. (2003). Measuring pro-poor growth. *Economics Letters*, 78(1), 93–99. https://doi.org/10.1016/S0165-1765(02)00205-4

Rivera, M. A. (2017). The synergies between human development, economic growth, and tourism within a developing country: An empirical model for Ecuador. *Journal of Destination Marketing & Management*, 6(3), 221–232. https://doi.org/10.1016/j.jdmm.2016.04.002

Roodman, D. (2009a). "A Note on the Theme of Too Many Instruments", *Oxford Bulletin of Economics and Statistics*, 71(1):135-158.

Roodman, D. (2009b). "How to do xtabond2: An introduction to difference and system GMM in Stata", *Stata Journal*, 9(1):86-136.

Salatin, P., & Olfat, A. A. (2018). The impact of trade liberalization on human development index in selected countries. *Theoretical and Applied Economics*, 25(2), 209–224.

Sasmaz, M. U., Sakar, E., Yayla, E. Y., & Akkucuk, U. (2020). The relationship between renewable energy and human development in OECD countries: A panel data analysis. *Sustainability*, 12(18), Article 7450. https://doi.org/10.3390/su12187450

Satrovic, E. (2018, October 19–27). *The human development relies on renewable energy: Evidence from Turkey* [Paper presentation]. 3rd International Energy & Engineering Conference, Gaziantep, Turkey.

Sen, A. (1980). *Equality of what?* In S. McMurrin (Ed.), The Tanner lectures on human values. University of Utah Press.

Sen, A. (1987). *The standard of living*. Cambridge University Press.

Sen, K. K., Karmaker, S. C., & Saha, B. B. (2026). Good governance and energy security in OECD countries: The mediating role of environmental policy stringency. *Energy Policy,* 211, 115100.

Sinha, A., & Sengupta, T. (2019). Impact of natural resource rents on human development: What is the role of globalization in Asia Pacific countries? *Resources Policy*, 63, Article 101410. https://doi.org/10.1016/j.resourpol.2019.101410

Smith, S. (2016). Determinants of human development index: A cross-country empirical analysis. National Institute of Bank Management, 3, 0–19.

Sovacool, B. K., & Brown, M. A. (2010). Competing dimensions of energy security: An international perspective. Annual Review of Environment and Resources, 35(1), 77–108. https://doi.org/10.1146/annurev-environ-072209-102502

Sovacool, B.K., & Mukherjee, I. (2011). Conceptualizing and measuring energy security: A synthesized approach. *Energy,* 36(8), 5310-5319. https://doi.org/10.1016/j.energy.2011.06.043

Stylianou, T., Rakia, N., & Muhammad, W. (2023). Inclusive human development and governance nexus: Causality analysis of selected Asian countries. *Economies*, 11(3), Article 97. https://doi.org/10.3390/economies11030097

Sule, I. K., Yusuf, A. M., & Salihua, M. K. (2022). Impact of energy poverty on education inequality and infant mortality in some selected African countries. *Energy Nexus*, 5, Article 100034. https://doi.org/10.1016/j.nexus.2021.100034

Tchamyou, S. V. & Asongu, S. A., (2017). "Information Sharing and Financial Sector Development in Africa", *Journal of African Business*, 18(1), pp. 24-49.

Tchamyou, V. S., & Asongu, S. A. (2018). Conditional market timing in the mutual fund industry. *Research in International Business and Finance*, 42, 1355–1366. https://doi.org/10.1016/j.ribaf.2017.07.073

Tran, N. V., Tran, Q. V., Do, L. T. T., Dinh, L. H., & Do, H. T. T. (2019). Trade off between environment, energy consumption and human development: Do levels of economic development matter? *Energy*, 173, 483–493. https://doi.org/10.1016/j.energy.2019.02.042

United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development.* New York: United Nations.

Wang, N., Ullah, A., Lin, X., Zhang, T., & Mao, J. (2022). Dynamic influence of urbanization on inclusive green growth in Belt and Road countries: The moderating role of governance. *Sustainability*, 14(18), Article 11623. https://doi.org/10.3390/su141811623

Wang, Z., Bui, Q., & Zhang, B. (2020). The relationship between biomass energy consumption and human development: Empirical evidence from BRICS countries. *Energy*, 194, Article 116906. https://doi.org/10.1016/j.energy.2020.116906

Wang, Z., Danish, Zhang, B., & Wang, B. (2018). Renewable energy consumption, economic growth and human development index in Pakistan: Evidence form simultaneous equation model. *Journal of Cleaner Production*, 184, 1081–1090. https://doi.org/10.1016/j.jclepro.2018.02.260

Wirajing, M. A. K., Tii, N. N., & Tsafack, R. N. (2023). Revisiting the Inequality-Well-being Nexus: The Case of Developing Countries. *Global Social Welfare* https://doi.org/10.1007/s40609-023-00278-7

Wirajing, M. A. K., Tsafack, R. N., & Mboutchouang, K. A. (2024). Examining the environmental tax and the fishing grounds footprint nexus: Case of the African fishing industry. *Natural Resources Forum*, 1–25. https://doi.org/10.1111/1477-8947.12411

Wold, H. (1978). Cross-validatory choice and assessment of statistical predictions. Technometrics, 20(4), 397–405. https://doi.org/10.1080/00401706.1978.10489693

World Energy Council. (2013). *World Energy Trilemma: Time to get real – the case for sustainable energy investment.* London: WEC.

World Economic Forum. (2025). *Fostering effective energy transition 2025: Insight report*. pdf https://www.weforum.org/reports/fostering-effective-energy-transition-2025/

World Health Organization. (2018). *Household air pollution and health*. https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

Xholo, N., Ncanywa, T., Garidzirai, R., & Asaleye, A. J. (2025). Promoting economic development through digitalisation: Impacts on human development, economic complexity, and gross national income. *Administrative Sciences*, 15(2), 50.

Appendices

Figure A. Energy Security Index score for countries in Africa

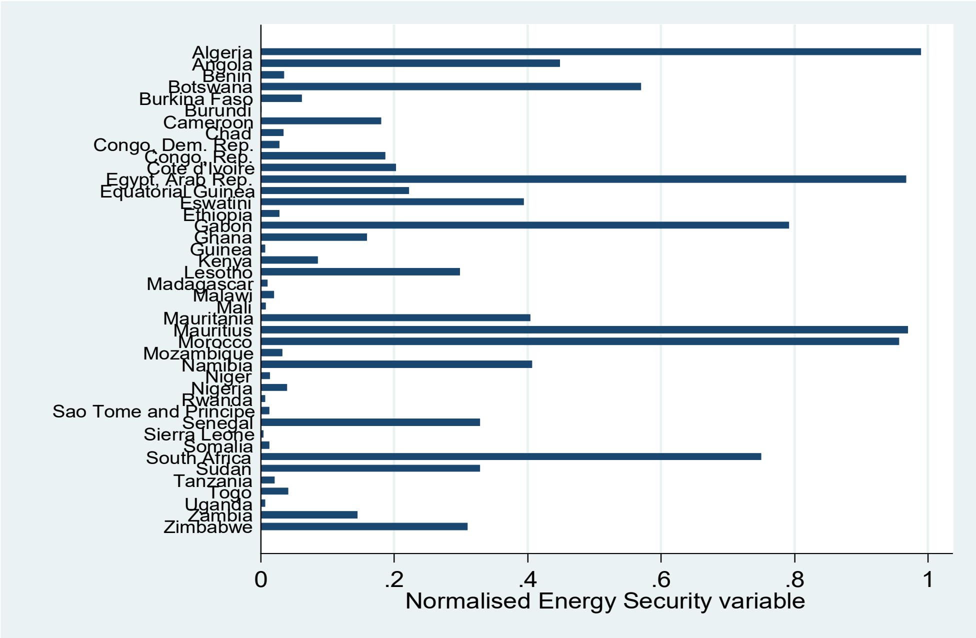


Table A: Unrotated principal components: Eigen values

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.816	1.737	0.469	0.469
Comp2	1.079	0.093	0.179	0.649
Comp3	0.986	0.373	0.164	0.813
Comp4	0.613	0.319	0.102	0.916
Comp5	0.293	0.079	0.049	0.964
Comp6	0.214	.	0.037	1.000

Table B. Rotated Components

Component	Variance	Difference	Proportion	Cumulative
Comp1	1	0.000	0.167	0.167
Comp2	1	0.000	0.167	0.333
Comp3	1	0.000	0.167	0.500
Comp4	1	0.000	0.167	0.667
Comp5	0.999	0.000	0.167	0.833
Comp6	0.999	.	0.167	1.000

Test for heteroskedasticity

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance

Variables: fitted values of iahdi

chi2(1) = 55.57

Prob > chi2 = 0.0000

Autocorrelation test
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
F (1, 32) = 54.926
Prob > F = 0.0000

Tests of endogeneity
Ho: variables are exogenous
Robust score chi2(1) = 3.10665 (p = 0.0780)
Robust regression F(1,153) = 3.08749 (p = 0.0809)

Table C. Variance inflation factor

	VIF	1/VIF
iaii	15	.067
iale	12.872	.078
ESec	3.931	.254
internetusers	3.307	.302
iaei	2.385	.419
oda	1.771	.565
govern	1.631	.613
stja	1.488	.672
manufac	1.474	.678
trade	1.383	.723
fdi	1.163	.86
Mean VIF	4.218	.

Final Country list

Angola, Benin, Burkina Faso, Burundi, Cameroon, Chad, Congo Dem, Congo Rep, Ivory Coast, Eswatini, Ethiopia, Gabon, Ghana, Guinea, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Namibia, Niger, Nigeria, Rwanda, Sao Tome, Senegal, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia, Zimbabwe

Figure B. Equal weighting Versus PCA weighting

	eqw_in~x	ESec
eqw_index	1.0000	
ESec	0.5272	1.0000

Table D. Correlations between Composite index and PCA components (one indicator drop components)

Component	Pearson r with ESec	Spearman ρ with ESec	Interpretation
Pca1	-0.8698	-0.8000	Strong inverse relationship; higher ESec ranks correspond to lower

			pca1 scores.
Pca2	0.8641	0.7822	Strong positive correlation; rankings align closely
Pca3	0.8910	0.8429	Very strong positive correlation; consistent ordering
Pca4	0.8938	0.8075	Strong positive correlation; rankings remain consistent
Pca5	-0.7364	-0.6602	Moderate inverse correlation; later component captures residual variance.
Pca6	-0.8328	-0.7471	Strong inverse correlation; reflects secondary variance dimension.

Note: Signs are arbitrary in pca ((Jolliffe and Cadima, 2016; Sovacool and Mukherjee, 2011).
Source: Authors' computation using STATA