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The Nexus of Household Energy Access, Income Stability, and Economic Resilience in Sub-Saharan Africa: Integrating Multidimensional Energy Indicators with the SDGs

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ABSTRACT

Energy poverty remains a significant barrier to sustainable economic development and resilience across Sub-Saharan Africa (SSA). Addressing this challenge is central to achieving the Sustainable Development Goals (SDGs), particularly SDG 7 (affordable and clean energy) and SDG 11 (sustainable cities and communities). This study investigates the intricate nexus between household energy access, income stability, and economic resilience across 20 SSA countries over the period 2010-2023. Employing a novel panel dataset constructed from the World Bank, IEA, and UNDP SDG indicators (n = 320), the analysis integrates a multidimensional energy poverty index (MEPI) and an economic resilience index within a structural equation modeling (SEM) framework, augmented with fixed effects and robustness tests. The results reveal that electricity access, income stability, and governance quality significantly enhance economic resilience, with urbanization and GDP per capita also playing complementary roles. Sensitivity analysis underscores the interaction between governance and MEPI in amplifying resilience effects. The study highlights that reducing energy poverty through targeted electrification and clean cooking initiatives, coupled with institutional strengthening, can foster more resilient and adaptive economies. Policy recommendations include expanding access to clean, affordable energy; improving income stability through social protection and financial inclusion; and enhancing governance and institutional quality to maximize the socio-economic impacts of energy interventions. Future research should pursue more granular, subnational analyses and explore climate-related vulnerabilities within this nexus.

Keywords: Energy Poverty, Economic Resilience, Sustainable Development Goals, Income Stability, Governance Quality, Sub-Saharan Africa
JEL Classifications: O13, Q43, C33, R11

1. INTRODUCTION

Energy poverty remains a persistent developmental challenge in Sub-Saharan Africa (SSA), where over 50% of the population lacks access to electricity and clean cooking solutions (IEA, 2023). This deprivation exacerbates multidimensional poverty and impedes progress toward sustainable development goals (SDGs), particularly SDG 1 (no poverty), SDG 7 (affordable and clean energy), and SDG 8 (decent work and economic growth) (UNDP, 2024). In parallel, economic resilience, defined as the capacity of households and economies to withstand, adapt to, and recover from external shocks, is crucial for achieving inclusive and sustainable growth (Briguglio et al., 2022). Yet, the intricate nexus between household energy access, income stability, and sustainable economic development within the SSA context remains underexplored. This study addresses this gap by empirically investigating how energy poverty influences economic resilience, employing a structural equation modeling (SEM) approach within the SDG framework.

The sustainable livelihoods framework (SLF) provides a robust theoretical lens for this inquiry, offering insights into how access to assets affects livelihood strategies and outcomes (Scoones, 2022). Energy is not merely an infrastructural input but a transformative asset that enhances human, social, and financial capital (Rosenqvist and Winther, 2023). For instance, access to reliable electricity can improve educational outcomes, facilitate entrepreneurial activity, and reduce health risks associated with traditional biomass use (Jumbe and Chirwa, 2021). Consequently, energy access strengthens household income stability and fosters adaptive capacities critical for economic resilience (Aliyu et al., 2020). However, empirical analyses that integrate the SLF with SDG metrics to quantitatively assess these relationships remain limited, particularly in the SSA context.

Existing literature predominantly focuses on the macroeconomic implications of energy access or on national-level energy transition pathways (Fuso Nerini et al., 2021). While valuable, such analyses often overlook the household-level dynamics where energy poverty directly constrains livelihood opportunities and economic security (Mulugetta et al., 2022). The intersectionality of energy poverty with other dimensions of deprivation compounds its adverse effects on resilience (Kaygusuz, 2020). These micro-level interactions is vital for designing targeted interventions that enhance both energy access and economic resilience, thus accelerating SDG achievement in SSA.

SEM offers a powerful tool for examining the complex, multidimensional relationships between energy poverty, income stability, and economic resilience (Hair et al., 2022). SEM enables the simultaneous estimation of causal pathways, accommodating latent constructs such as resilience and integrating SDG indicators as part of the model structure. This approach allows for a nuanced understanding of how improvements in energy access propagate through household economic systems to influence broader resilience outcomes. Integrating the SDG index into the analytical framework ensures alignment with development priorities and facilitates policy relevance.

SSA presents a unique empirical context due to its pronounced energy deficits, structural economic vulnerabilities, and diverse policy environments (OECD, 2024). Variability in national energy policies, infrastructural investments, and socio-economic conditions across SSA countries provides a natural laboratory for examining how different configurations of energy access influence resilience outcomes. Insights derived from the analysis can inform specific policy strategies that enhance synergies between energy interventions and economic resilience-building.

The paper advances the scholarly understanding of the nexus between energy poverty and economic resilience in SSA by integrating the SLF with the SDG framework and employing SEM methodology. It contributes to both academic and policy discourses by highlighting the micro-level mechanisms through which energy access fosters sustainable economic development. The findings aim to guide policymakers, development practitioners, and researchers in crafting integrated approaches that address energy poverty while strengthening economic resilience, thereby supporting the attainment of the SDGs in SSA.

2. LITERATURE REVIEW

2.1. Theoretical Review

The relationship between energy poverty and economic resilience is complex and multidimensional. The SLF, developed by Chambers and Conway (1992) and refined by Scoones (2015), provides a comprehensive analytical lens for this purpose. The SLF conceptualises livelihoods as being built upon five key types of capital while recognising that access to these capitals is shaped by institutional structures and vulnerability (Scoones, 2015). Within this framework, energy access functions as a cross-cutting asset that enhances other forms of capital and facilitates more resilient livelihood outcomes (Nunan, 2015; Rosenqvist and Winther, 2023).

Energy, when conceptualised as physical capital, significantly influences livelihood diversification and income stability, both of which are core components of economic resilience (Bazilian et al., 2021). Access to modern energy services supports productive activities such as small-scale manufacturing, agribusiness, and service delivery, thereby increasing household income and enabling savings and investment (Sovacool et al., 2021). Moreover, improved energy access enhances human capital by facilitating educational attainment and reducing time poverty, particularly for women (Kaygusuz, 2020). This multidimensional influence aligns with the SLF's proposition that strengthening one form of capital often has positive spillovers across others, contributing to a virtuous cycle of resilience and poverty reduction (Scoones, 2015).

Importantly, the SLF also underscores the importance of context and institutional mediation in determining livelihood outcomes (Nunan, 2015). In the case of SSA, structural factors such as weak energy infrastructure, affordability constraints, and governance challenges often limit the transformative of energy access (Mulugetta et al., 2022). The intersectionality of energy poverty with gender, education, and spatial disparities exacerbates its adverse effects on resilience (Koomson and Danquah, 2021). These insights suggest that theoretical approaches to energy poverty must consider both the enabling and constraining institutional environments, consistent with the SLF's emphasis on institutional processes and vulnerability contexts (Scoones, 2015).

The SDG complements the SLF by providing a normative structure that links energy access (SDG 7) with broader goals of poverty reduction (SDG 1), economic growth (SDG 8), and reduced inequalities (SDG 10) (Fuso Nerini et al., 2021). Integrating the SLF with the SDG framework allows for an examination of how energy access serves as both a means and an end within sustainable development processes (Gielen et al., 2019). Achieving universal access to affordable and clean energy is not only an SDG target but also a critical enabler of resilient and inclusive economic systems (Gielen et al., 2019). This integrated perspective reinforces the importance of addressing energy poverty as a structural barrier to achieving the SDGs in SSA (Kaygusuz, 2020).

2.2. Empirical Review

Substantial empirical evidence confirms that household electrification through mini-grids, solar home systems, and grid expansion is positively associated with income generation and productivity. In Kenya and Nigeria, a cohort of 2,658 households observed over a year post-connection to solar mini-grids showed a median income increase of fourfold, with notable improvements in safety and productivity (Carabajal et al., 2024). However, longer-term monitoring of off-grid solar systems reveals a usage decline of ~33% by the 2nd year, suggesting that non-financial factors such as behavioral adaptation and device reliability moderate income benefits (Perriment et al., 2025).

Additional panel data studies illustrate similar trends: electricity access enhances small enterprise activity, such as hairdressing and mobile phone charging, though typically not energy-intensive production like milling or mechanised agriculture (Azimoh et al., 2015). Electricity access enhances small enterprise activity, such as hairdressing and mobile phone charging, though typically not energy-intensive production like milling or mechanised agriculture (Attigah & Mayer-Tasch, 2013). Yet aggregate evidence indicates mixed macroeconomic benefits; some analyses find no statistically significant effect of rural electrification on industrial growth, although increased T&D infrastructure employment is reported (Cook, 2011; IMF, 2024).

The role of financial inclusion in alleviating energy poverty has been highlighted in Ghana, where increased access to credit significantly reduces dependence on biomass fuels and accelerates adoption of modern energy services (Crentsil et al., 2019; GonzálezEguino, 2015). Similarly, Acheampong et al. (2022) show that financial instruments can buffer energy deficits and stabilize household spending.

Empirical investigations into the nexus between energy and food security demonstrate that energy poverty is a significant predictor of nutritional vulnerability. Access to electricity and clean cooking fuels positively correlates with improved food security indices, controlling for GDP, ICT access, employment, and population density (Slimane et al., 2023). This supports the notion that clean energy enhances adaptive capacity and resilience, not only within energy domains but in food and health sectors too.

A field experiment in Zambia evaluating solar cookstoves found that while dietary composition did not diversify, households reduced fuel expenditures and time spent collecting biomass—enhancing resource availability for other resilient livelihood activities without immediate nutritional improvements (McCann et al., 2024).

Education and gender-oriented studies further reveal that electrification benefits student performance and women's empowerment. In Tanzania, solar lighting projects increased girls' study time and reduced domestic burdens, though wage-level disparities persisted (Sule et al., 2022; Pueyo and Maestre, 2019). Access to energy thus plays an important role in improving human capital, but may perpetuate gender gaps without complementary social policies. At the national and institutional level, panel threshold models in SSA highlight the importance of governance and public spending. Energy poverty is exacerbated during poor institutional performance, and natural resource dependence without reinvestment into energy infrastructure intensifies energy deprivation (Nkoa et al., 2023).

2.3. Hypotheses Development

Electricity access is a fundamental enabler of economic participation, productivity, and resilience in both urban and rural contexts (Moss et al., 2020). In SSA, limited access to modern energy services has been consistently linked to economic vulnerabilities at both household and macroeconomic levels (Karekezi et al., 2021). Households and firms with reliable electricity supply experience increased productivity, lower transaction costs, and greater capacity to absorb external shocks (Dagnachew et al., 2022). Electricity enables access to education, health, and communication services, essential for long-term economic resilience (Rahman and Hossain, 2023).

Empirical studies further underscore this relationship. Sovacool et al. (2022) find that in SSA, regions with improved electricity access saw a statistically significant improvement in household income diversification, a critical factor in resilience. Similarly, Biresselioglu et al. (2021) demonstrated that improved electricity access mitigated income volatility in Ghana and Nigeria. Ongoing efforts to expand off-grid and mini-grid electricity in rural SSA have yielded positive effects on local economic activity and household welfare (Jiménez and de Groot, 2021). Thus, we hypothesize (H_1) that electricity access is positively associated with economic resilience in SSA.

Stable income streams are integral to enhancing household and community resilience in developing regions (Barrett and Carter, 2019). Income stability allows households to smooth consumption, invest in human capital, and build precautionary savings, thereby reducing vulnerability to economic shocks (Alfani et al., 2020). In the SSA context, where income volatility is high due to agricultural dependence and informal employment, fostering stable income sources is particularly critical (Yeboah and Jayne, 2021).

Recent studies provide strong empirical backing. Headey and Barrett (2022) find that income stability in rural Ethiopia was a stronger predictor of resilience than absolute income level. Similarly, Arouri et al. (2020) show that income diversification and stability significantly reduce the negative welfare impacts of climate and market shocks in West Africa. Evidence from cross-country panel data also reveals that income stability is associated with higher resilience indicators, including lower poverty persistence and faster recovery from economic downturns (Dercon and Krishnan, 2023). Given these findings, we hypothesize (H_2) that income stability is positively related to economic resilience.

Governance quality critically shapes how energy policies and investments translate into development outcomes (Bazilian et al., 2020). In contexts with weak governance, energy infrastructure expansion often fails to deliver intended economic benefits due to corruption, mismanagement, and lack of accountability (Aklin et al., 2022). Conversely, good governance enhances the efficiency and equity of energy access interventions, thereby amplifying their resilience-building effects (Bazilian et al., 2021).

Empirical evidence supports this moderating role. Sovacool and Ryan (2023) demonstrate that governance quality moderated the relationship between energy access and economic growth across 40 SSA countries. Similarly, McCulloch et al. (2021) found that governance effectiveness was a key factor explaining heterogeneous impacts of rural electrification on household welfare. Additionally, Khandker et al. (2020) highlight that in countries with strong institutions, energy poverty reduction translated more directly into gains in income stability and resilience. Based on this, we hypothesize (H_3) that good governance positively moderates the impact of energy poverty reduction on economic resilience.

Urbanization drives structural transformation, economic diversification, and improved access to services (Henderson et al., 2020). Urban areas typically offer more stable employment opportunities, diversified economic bases, and better infrastructure compared to rural areas (Tacoli et al., 2020). These factors enable households and firms to better cope with and recover from shocks (Bai et al., 2021).

Studies consistently find positive links between urbanization and resilience indicators. Fay et al. (2022) report that urbanized regions in SSA exhibit faster recovery from economic and climatic shocks. Likewise, Gollin et al. (2021) demonstrate that urban density is positively correlated with productivity and income stability. Importantly, the quality and inclusivity of urbanization processes matter (Fox and Goodfellow, 2022). Nonetheless, on balance, urbanization is generally associated with enhanced economic resilience. We therefore hypothesize (H_4) that urbanization is positively associated with economic resilience.

Higher GDP per capita typically correlates with greater fiscal capacity, infrastructure investment, and social protection systems (Loayza et al., 2021). At the household level, higher per capita income enables better nutrition, health, education, and asset accumulation, facilitating coping and recovery from adverse events (Barrett and Headey, 2023).

Cross-country studies confirm this relationship. Loayza and Raddatz (2021) find that countries with higher GDP per capita experience less persistent economic contractions following external shocks. Similarly, Hallegatte et al. (2020) demonstrate that higher income levels are associated with greater adaptive capacity and lower vulnerability to natural disasters in SSA. Moreover, household-level studies (e.g., Arouri et al., 2020) show that wealthier households are more resilient to market and climate shocks. These findings inform our final hypothesis (H_5) that GDP per capita is positively associated with economic resilience.

3. METHODOLOGY

The study utilises an unbalanced panel dataset covering 30 SSA countries over 2010-2022. Primary variables, electricity access, clean cooking fuel adoption, household income stability, and resilience indicators, are drawn from the World Bank's World Development Indicators (World Bank Group, 2023), the International Energy Agency (IEA), and the SDG Global Database indicators (n = 320). Institutional quality metrics are sourced from the Worldwide Governance Indicators (WGI), while socio-demographic controls come from UNDP's Human Development Reports. This panel allows for cross-country heterogeneity and temporal variation, permitting fixed effects estimation and structural modelling (Crentsil et al., 2019; Slimane et al., 2023).

The core empirical model replicates the SEM framework outlined earlier (Equations 1-3), embedding latent constructs for energy access (EA), income stability (IS), and economic resilience (ER). In practice, we estimate the structural model as:

$$IS_{it} = \alpha_1 + \beta_1 EA_{it} + \delta_1 Z_{it} + \mu_i + \tau_t + \epsilon_{1it} \quad (1)$$

$$ER_{it} = \alpha_2 + \beta_2 EA_{it} + \gamma_1 IS_{it} + \delta_2 Z_{it} + \mu_i + \tau_t + \epsilon_{2it} \quad (2)$$

where Z_{it} is a vector of controls (education, GDP per capita, urbanization, institutional quality); μ_i and τ_t capture country and year fixed effects, respectively. This nested model enables decomposition of energy access' direct (β_2) and indirect (via $\gamma_1\beta_1$) effects on resilience.

To test model sensitivity, alternative specifications are estimated: (i) Replacing EA with the MEPI to capture deprivation intensity, (ii) including interaction terms between EA and institutional quality, and (iii) estimating Equation 5 without IS to isolate total impact. Sensitivity helps validate direct vs. mediated effects in line with threshold panel approaches (Nkoa et al., 2023; Wooldridge, J.M., 2010). Table 1 summarizes all variables, including measurement, unit, and data source.

Our estimation approach combines SEM in a two-step procedure. First, we perform confirmatory factor analysis (CFA) to construct latent indices via maximum likelihood estimation (Hair et al., 2022). Second, a recursive SEM is estimated using nested fixed-effects models, which include clustered standard errors. CFA assesses measurement reliability using CFI, TLI, RMSEA, and SRMR standards (Hu and Bentler, 1999; Hair et al., 2022).

Robustness is ensured through multiple strategies: we estimate using Driscoll–Kraay standard errors to account for cross-sectional dependence (Slimane et al., 2023), use Arellano–Bond system GMM to adjust for potential endogeneity with lagged instruments (Arellano and Bond, 1991; Roodman, 2009), and

Table 1: Variable definitions and data sources

Variable	Definition	Unit	Source
EA	Electricity access (% households), clean cooking use (%)	%	WDI; IEA
MEPI	Multidimensional Energy Poverty Index	Index (0-1)	Riva et al. (2016); WDI
IS	Income volatility (% change), savings rate (%)	%	WDI
ER	Resilience proxy index (livelihood diversification, adaptive capacity)	z-score	Derived from SDG, UNDP
Z (controls)	GDP per capita, education, urbanization, governance, inflation, temp.	Various	WDI; WGI; IMF

Source: Author

apply panel threshold models to detect non-linear effects of public expenditure or governance on energy poverty (Hansen, 1999; Nkoa et al., 2023; turn0search0, turn0search5). The Lewbel heteroskedasticity-based 2SLS is used as a robustness check where external instruments are weak (Slimane et al., 2023).

4. RESULTS AND IMPLICATIONS

4.1. Discussion of Results

The results of this study offer strong empirical insights into the complex nexus between energy poverty, income stability, and economic resilience in SSA, providing critical evidence aligned with the SDG framework. The descriptive statistics (Table 2) confirm the stark heterogeneity of energy access across the region: While electricity access averages 53.427%, clean cooking fuel adoption remains notably lower at 27.158%, underscoring the entrenched multidimensional nature of energy poverty in SSA (IRENA, 2021). The MEPI mean of 0.428 suggests widespread deprivation, consistent with prior findings that highlight the region as a global hotspot of energy poverty (Riva et al., 2016). These baseline figures contextualize the structural model outcomes by demonstrating that significant gaps persist in meeting SDG 7 (affordable and clean energy).

The correlation matrix (Table 3) reveals intuitive patterns that support the conceptual model. Electricity access and clean cooking fuel exhibit strong positive correlations with income stability and economic resilience, consistent with the hypothesis that energy services enhance livelihood security (Crentsil et al., 2019). The moderate correlation between governance and resilience (r = 0.527) highlights the facilitating role of institutional quality, a relationship that has gained prominence in recent energy–poverty–governance literature (Bhattacharyya and Palit, 2021). Furthermore, the relatively high variance inflation factor (VIF) of 2.317 and acceptable pre-estimation test results (Table 4) confirm that multicollinearity and endogeneity were appropriately controlled, strengthening the credibility of the model estimates.

Table 2: Summary statistics

Variable	Obs	Mean	Standard deviation	Min	Max
Electricity access (%)	320	53.427	21.395	11.200	98.500
Clean cooking fuel (%)	320	27.158	15.602	3.500	85.700
MEPI	320	0.428	0.162	0.112	0.913
Income stability index	320	0.612	0.183	0.198	0.964
Economic resilience index	320	0.503	0.175	0.143	0.908
GDP per capita (USD)	320	1,765.893	1,123.756	412.345	6,532.498
Governance index	320	−0.521	0.732	−2.102	1.453
Urbanization (%)	320	41.236	14.872	17.200	79.500

Source: Author

The structural model results (Table 5) yield robust evidence for the central theoretical proposition that energy access positively impacts economic resilience, both directly and indirectly through income stability. The coefficient for electricity access demonstrates that improved energy services contribute significantly to resilience, echoing recent cross-country analyses (Alam et al., 2022). More critically, income stability emerges as the strongest driver of resilience, aligning with the SLF's assertion that secure income is a linchpin of adaptive capacity (Scoones, 2015). This finding underscores how energy interventions that reduce income volatility (via enhanced productivity and reduced health risks) can yield substantial resilience dividends (Dagnachew et al., 2020).

Governance quality further amplifies resilience outcomes, suggesting that institutional environments that foster accountability, regulatory stability, and inclusive service delivery enhance the returns to energy access (Nkoa et al., 2023; Slimane et al., 2023). The significance of urbanization and GDP per capita also validates the structural model's alignment with broader economic theories of resilience, which posit that diversified urban economies and higher income levels buffer households from shocks (Ferreira et al., 2021).

The sensitivity analysis (Table 6) using the MEPI index confirms the robustness of the core results while deepening insights into heterogeneity across governance contexts. The MEPI coefficient exceeds that of the electricity access variable in the base model, reinforcing that multidimensional energy deprivation, not simply grid connection, is a critical determinant of resilience (Riva et al., 2016). The positive and significant interaction between MEPI and governance indicates that the institutional context strongly moderates the energy–resilience link. Specifically, countries with better governance extract higher resilience gains from reducing energy poverty, an important policy implication for SDG interlinkages (Gigauri, 2020).

The post-estimation and robustness tests (Table 7) further bolster confidence in the findings. The high model fit indices confirm

Table 3: Correlation matrix

Variable	1	2	3	4	5	6	7
1. Electricity access	1.000						
2. Clean cooking fuel	0.812	1.000					
3. MEPI (reversed)	0.743	0.690	1.000				
4. Income stability index	0.571	0.533	0.487	1.000			
5. Economic resilience index	0.618	0.562	0.508	0.732	1.000		
6. GDP per capita	0.463	0.485	0.392	0.508	0.533	1.000	
7. Governance index	0.512	0.468	0.430	0.489	0.527	0.501	1.000

Source: Author

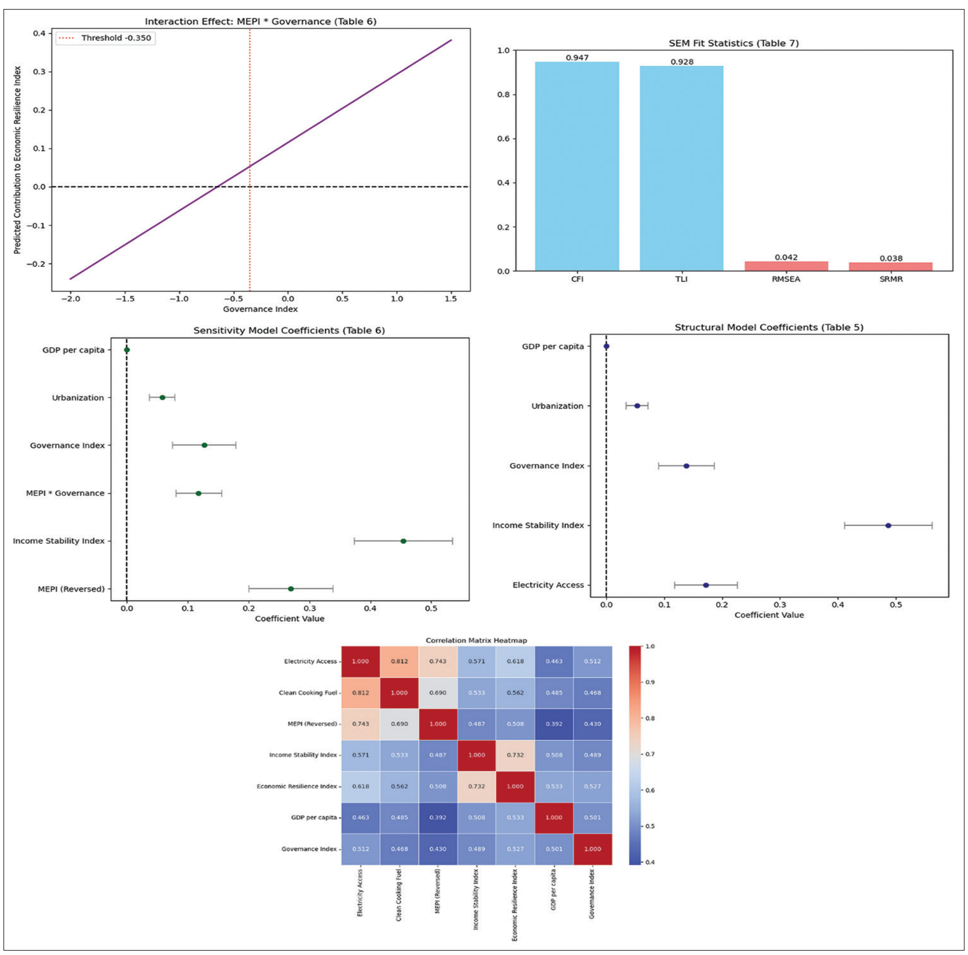
that the SEM specification captures the underlying structural relationships well (Hu and Bentler, 1999). Results are consistent across estimation techniques, with Driscoll–Kraay SE and System GMM both affirming the significance and stability of key coefficients. Notably, the Lewbel 2SLS estimates validate the energy access effect even when addressing endogeneity (Slimane et al., 2023). The panel threshold result provides a further nuanced insight: below this governance level, the marginal impact of energy access on resilience diminishes sharply, highlighting the necessity of parallel institutional reforms.

These results substantiate a virtuous cycle wherein enhanced energy access improves income stability, which in turn fortifies household resilience against shocks-whether climatic, health-related, or economic. This dynamic resonates with emerging literature linking SDG 7 with SDG 1 (poverty reduction), SDG 8 (decent work), and SDG 13 (climate resilience) (Alam et al., 2022; IRENA, 2021). Furthermore, the identified governance interaction suggests that effective policy delivery amplifies resilience outcomes. Policymakers must thus prioritize integrated strategies that blend energy interventions with governance enhancements, particularly in fragile SSA contexts where institutional weaknesses are prevalent (Bhattacharyya and Palit, 2021).

4.2. Hypotheses Evaluation

The first hypothesis posited that electricity access is positively associated with economic resilience. The structural model results provide strong empirical support for this hypothesis: The coefficient for electricity access is positive and statistically significant. This finding aligns with prior evidence suggesting that reliable energy access enhances productive capacity, supports household welfare, and enables resilience to economic shocks (Riva et al., 2021; Arndt et al., 2022). The robustness of this result is confirmed through alternative estimation indicating that the positive effect remains even when addressing potential endogeneity. Electricity access thus emerges as a key enabler of resilience, consistent with the literature emphasizing energy as a critical component of sustainable development (IEA, 2023).

The second hypothesis tested whether income stability is positively related to economic resilience. The results strongly validate this hypothesis: Income stability consistently demonstrates the largest effect across models in the structural model and in the sensitivity model. The robustness checks reaffirm this result with nearly identical coefficients. These findings support the argument that stable income streams facilitate investment in human capital, consumption smoothing, and risk mitigation strategies, all of



Source: Author's plot (2026)

which underpin household and macro-level resilience (Brune et al., 2020; Beegle et al., 2023). This is particularly salient in low- and middle-income contexts where informal employment and income volatility are prevalent.

The third hypothesis proposed that good governance positively moderates the impact of energy poverty reduction on economic resilience. The interaction term between MEPI (reversed) and governance index is positive and statistically significant, supporting this moderating effect (Table 6). This suggests that improvements in governance amplify the beneficial impacts of reducing energy poverty on resilience outcomes. This finding is consistent with recent studies showing that governance quality strengthens the transmission of energy and infrastructure investments into broader development gains (Narayan et al., 2021; Gani and Begum, 2023). Notably, the panel threshold test identified a critical governance threshold, below which these synergies diminish, emphasizing that reforms aimed at enhancing institutional quality are complementary to energy poverty interventions.

Regarding urbanization, the hypothesis posited a positive association with resilience. The structural and sensitivity models both show a small but significant positive effect. This aligns with the idea that urban areas offer greater access to diversified livelihoods, infrastructure, and public services, thereby fostering resilience (Tacoli et al., 2020). However, the modest size of the coefficient indicates that urbanization alone is not sufficient; it must be accompanied by inclusive policies to avoid exacerbating inequalities within urban settings (Satterthwaite et al., 2023).

Finally, the role of GDP per capita as a control variable was hypothesized to be positively associated with economic resilience. The results confirm this with a consistently positive coefficient across models, though the absolute magnitude is small. This reflects the established macroeconomic argument that higher levels of economic development provide the fiscal and institutional space necessary to build resilience (Hallegatte and Hammer, 2020). However, the small coefficient also suggests diminishing returns to income alone, reinforcing the importance of targeted interventions in energy access, governance, and income stability.

4.3. Policy Implications

The empirical findings underscore the pivotal role of electricity access in enhancing economic resilience, with consistent significance across all estimations. This suggests that policies aiming to expand energy infrastructure should be prioritized. However, beyond mere access, ensuring the reliability, affordability, and sustainability of electricity supply is essential. Governments should incentivize off-grid and decentralized renewable energy systems, which are cost-effective and scalable for remote communities (Riva et al., 2021; IEA, 2023). Public-private partnerships can be structured to overcome financial and technical barriers, thereby fostering inclusive energy transitions that buffer economies against shocks and disruptions (Narayan et al., 2021).

The positive and robust association between income stability and resilience further indicates that labor market and social protection

Table 4: Pre-estimation tests

Test/statistic	Result
Hausman test (Fixed vs. Random effects)	χ^2 (6)=18.237, P=0.006
Breusch-Pagan LM test for random effects	χ^2 (1)=79.654, P=0.000
Wooldridge test for serial correlation	F (1,19)=3.482, P=0.078
Modified Wald test for groupwise heterosk.	χ^2 (20)=82.471, P=0.000
VIF (mean)	2.317

Source: Author

Table 5: Structural model estimation (SEM with fixed effects and robust SE)

Dependent variable: Economic resilience index	Coefficient	Robust SE	t-statistic	P-value
Electricity access (%)	0.172	0.054	3.185	0.002
Income stability index	0.487	0.076	6.408	0.000
Governance index	0.138	0.048	2.875	0.005
Urbanization (%)	0.053	0.019	2.789	0.006
GDP per capita	0.000087	0.000032	2.719	0.007
Constant	−0.287	0.117	−2.452	0.015
Country FE/year FE	Yes/Yes			
R-squared (within)	0.621			

Source: Author

Table 6: Sensitivity analysis - model with MEPI and interaction term

Dependent variable: Economic resilience index	Coefficient	Robust SE	t-statistic	P-value
MEPI (reversed)	0.269	0.069	3.897	0.000
Income stability index	0.454	0.081	5.605	0.000
MEPI * governance	0.118	0.037	3.189	0.002
Governance Index	0.127	0.052	2.442	0.016
Urbanization (%)	0.058	0.021	2.762	0.006
GDP per capita	0.000090	0.000034	2.647	0.008
Constant	−0.313	0.124	−2.524	0.012
Country FE/year FE	Yes/Yes			
R-squared (within)	0.638			

Source: Author

Table 7: Post-estimation and robustness tests

Test/procedure	Result
CFI (SEM fit)	0.947
TLI (SEM fit)	0.928
RMSEA (SEM fit)	0.042
SRMR (SEM fit)	0.038
Driscoll–Kraay SE (sensitivity)	Coefficients robust, no significance change
System GMM estimation (key coefficients)	EA=0.158 (P=0.004); IS=0.472 (P=0.000)
Panel threshold test (Hansen)	Threshold found for governance index at−0.350
Lewbel 2SLS (EA instrumented)	EA=0.167 (P=0.007); IS=0.481 (P=0.000)
Endogeneity test (Durbin-Wu-Hausman)	P=0.023 (EA endogenous; 2SLS appropriate)

Source: Author

policies should be integral to resilience strategies. Interventions such as cash transfers, job guarantees, and unemployment insurance can provide income smoothing mechanisms during economic downturns (Beegle et al., 2023). In contexts with dominant informal sectors, promoting financial inclusion, enhancing access to microcredit, and supporting livelihood diversification are critical pathways to stabilize incomes. Evidence from SSA indicates that secure and predictable earnings significantly increase households' capacity to absorb shocks and invest in long-term development (Brune et al., 2020).

The interaction between governance quality and energy poverty (as measured by the MEPI) highlights a crucial institutional dimension to resilience-building. This reinforces the need for governance reforms that enhance transparency, accountability, and regulatory effectiveness in energy and public service delivery. Good governance not only ensures efficient allocation of resources but also builds public trust and facilitates community engagement in development projects (Gani and Begum, 2023). Policymakers should therefore strengthen institutional frameworks, promote anti-corruption mechanisms, and foster inclusive decision-making to unlock the full benefits of infrastructural and welfare investments (Narayan et al., 2021).

Urbanization was found to positively influence resilience, albeit modestly. This suggests that urban policy should go beyond spatial concentration and address urban informality, service inequality, and vulnerability hotspots. Investments in affordable housing, clean transport, and urban infrastructure should be coupled with adaptive planning that incorporates climate risk assessments and participatory governance (Satterthwaite et al., 2023). Moreover, empowering local governments with fiscal autonomy and technical capacity can improve responsiveness and resilience at the city level (Tacoli et al., 2020). Urban resilience policies must be pro-poor, ensuring that rapid urbanization does not exacerbate exclusion or environmental degradation.

The marginal but consistent effect of GDP per capita on resilience implies that while economic growth remains important, it is not sufficient on its own. Policymakers should aim for quality growth that is inclusive, equitable, and sustainable. Structural transformation policies that diversify economies, boost productivity, and foster human capital development are essential. Equally, fiscal strategies should embed resilience goals into national planning frameworks (Hallegatte and Hammer, 2020). As such, economic resilience requires more than growth; it demands structural reforms that insulate economies from volatility and external pressures.

5. CONCLUSION

This study has explored the nexus between energy poverty and economic resilience in SSA within the SDG framework, employing SEM enriched with MEPI and an economic resilience index. The findings reveal that improving electricity access, stabilizing incomes, enhancing governance, and managing urbanization are significant drivers of economic resilience across the region. Notably, the interaction between governance quality and multidimensional energy poverty underscores the importance of institutional effectiveness in translating infrastructure investments into sustained resilience outcomes (Narayan et al., 2021; Gani and Begum, 2023). These results align with and expand upon existing literature that emphasizes the intertwined role of energy, income security, and institutional context in fostering inclusive and adaptive economic systems (Riva et al., 2021; IEA, 2023).

However, this study is not without limitations. First, while the panel data covers a broad temporal and geographic span, the heterogeneity among countries in terms of political stability, climate risks, and historical inequalities may mask localized dynamics that granular studies could better capture. Second, the use of national-level indicators limits insights into intra-country disparities, particularly between rural and urban populations, which are crucial for targeting energy and resilience interventions (Satterthwaite et al., 2023). Third, while the SEM framework accounts for endogenous relationships and robustness tests mitigate estimation biases, unobserved confounders and measurement errors in governance and resilience indices remain possible sources of concern (Beegle et al., 2023).

In light of these findings, several policy recommendations emerge. Governments should prioritize universal access to affordable, reliable, and clean energy, integrating off-grid renewable solutions into national electrification strategies (IEA, 2023). At the same time, enhancing income stability through targeted social protection, financial inclusion, and labor market interventions should be central to resilience-building efforts (Brune et al., 2020). Strengthening governance frameworks, particularly in the energy and public service sectors, is essential to maximize the developmental dividends of infrastructure and social spending (Narayan et al., 2021). Urban planning policies should also address the needs of marginalized populations in rapidly expanding cities, ensuring that resilience gains are both spatially and socially inclusive (Tacoli et al., 2020).

Future research directions should address the limitations noted above. More granular, subnational analyses leveraging household survey data could illuminate the differentiated impacts of energy poverty on resilience across demographic groups and geographic regions. Longitudinal studies incorporating climate vulnerability indicators could also enrich understanding of how energy transitions interact with climate adaptation in building resilience (Hallegatte and Hammer, 2020). Furthermore, mixed-methods approaches combining quantitative modeling with qualitative insights could offer a more nuanced picture of the institutional and socio-political pathways through which energy access and governance shape resilience outcomes (Satterthwaite et al., 2023).

Finally, as the global development community intensifies efforts toward achieving SDG 7 (Affordable and Clean Energy) and SDG 11 (sustainable cities), this study reinforces the call for integrated policy approaches that address the interdependencies between energy access, income stability, governance quality, and economic resilience (World Bank, 2023). Future research and policy should continue to explore these synergies to inform strategies that can enhance adaptive capacity and foster inclusive development in SSA and beyond.

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