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Does corruption undermine energy access? Investigating foreign direct investment and energy poverty dynamics in Sub-Saharan Africa

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ABSTRACT

This study investigates whether corruption dampens the impact of foreign direct investment on energy access in Sub-Saharan Africa. The study adopted panel data of 49 SSA nations from 2000 to 2023. Methodologically, the study employs Panel OLS, Generalized Linear Models, Fully Modified OLS, and the Dumitrescu-Hurlin causality approach to analyse three basic hypotheses: firstly, does corruption significantly moderates the impact of FDI on access to electricity and clean cooking fuels, secondly, does institutional effectiveness conditions FDI inflows into the energy sector, and thirdly, whether causal feedback exists among institutions, FDI, and energy access. Empirical findings from the study show that while FDI significantly increases electricity access, poor institutional environments limit its impact on access to clean fuels. The control of corruption significantly enhances the effect of FDI on energy outcomes, while government effectiveness attracts FDI. The interaction term between energy access and corruption provides evidence of bidirectional causality, supporting the co-evolution of institutions and infrastructure. The findings further suggest that while corruption may temporarily facilitate certain investment flows, sustained improvements in energy access require institutional effectiveness rather than reliance on informal or distortionary governance channels, thus recommending strengthening financial flows, institutional integrity, and governance reform to ensure sustainable energy access. The study provides policymakers and development partners with practical information on how to meet SDG 7 in the region.

1. Introduction

Energy poverty remains a persistent challenge across Africa despite the abundance of natural resources [1,2]. This paradox, often referred to as the “resource curse,” highlights the disparity between a region's resource endowment and its access to energy. In the energy sector, this paradox often manifests through rent-seeking behaviour, where politically connected actors divert energy investments toward private gain, thereby weakening service delivery and amplifying energy poverty. As illustrated in Fig. 1, Sub-Saharan Africa (SSA) alone accounts for 60% to 75% of the global population lacking access to electricity Panos et al., 2016; [4,5]. In Northern Africa, rural electrification rates in Sudan stand low at 43%. Many households across SSA and Northern Africa still rely on traditional biomass for cooking, perpetuating health, environmental, and socioeconomic challenges Aamaas et al., 2024; [6,7].

Despite the potential for renewable energy sources, millions in SSA still lack access to clean cooking fuel and reliable electricity [8]. Mperejekumana et al. [9] opined that in 2020, about 790 million people worldwide had no electricity access, most of whom were living in developing Asia and SSA. The situation is especially severe in countries like South Sudan and Chad, where electricity access rates were as low as 7% and 9%, respectively [10]. The SSA region's low energy consumption rate, averaging 181 kWh per capita compared to 13,000 kWh in the United States of America, further highlights the region's depth of energy poverty [11]. Without immediate action, this challenge will hinder progress toward achieving the Sustainable Development Goals (SDGs), particularly SDG 7, which aims for universal access to affordable, reliable, and modern energy services.

According to Guterres [12], the SSA's average electricity access rate stood at just 47% in 2019, the lowest globally, highlighting the acute

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nature of energy poverty in SSA. This low figure reflects not only the limited reach of national electricity grids but also the region's broader structural challenges, which include weak institutional capacity, poor policy implementation, and underinvestment in infrastructure. Kaygusuz [13] noted that electricity remains a luxury in many rural and marginalised communities, with various households relying on traditional biomass for lighting and cooking. The persistent gap in electricity access severely constrains industrial productivity, limits healthcare delivery, impedes educational advancement and reduces overall quality of life Sovacool, 2012 [14]. Without substantial and sustained investment, especially from foreign investors, SSA risks entrenching cycles of inequality and poverty driven by energy poverty.

Researchers such as Agoundedemba et al. [15] and Khaled et al. [16] emphasise that SSA must prioritise solutions tailored to their unique challenges and opportunities to accelerate energy access. Therefore, addressing systemic issues such as governance, institutional quality, corruption and foreign direct investment (FDI) is pivotal. Effective governance can drive coherent energy policies, enhance transparency, and attract international funding for sustainable energy projects. Similarly, strengthening institutional frameworks and fostering regulatory stability can encourage greater participation from private investors and development agencies. The role of FDI is particularly significant in scaling up renewable energy initiatives, building resilient energy infrastructure, and diversifying energy sources in SSA [17].

One of the core obstacles to resolving energy poverty in SSA is the persistent challenge of corruption Boamah et al., 2021; [18–21]. Corruption undermines governance and erodes investors' confidence, potentially distorting the allocation of energy resources and weakening efforts to expand energy access and combat energy poverty Gani, 2021; [22]. When transparency and accountability are lacking within a government structure, funds earmarked for energy-related projects may be misappropriated or siphoned for personal gain. International investors seeking stable economies for long-term investments are discouraged by these inefficiencies. Moreover, corruption contributes to delayed implementation, inflated project costs and substandard energy services, further deepening the energy access gap [23].

Corruption negatively affects the reliability and efficiency of the existing energy systems [24]. For instance, poor governance within the energy sector leads to financial mismanagement, non-cost-reflective pricing and irregular tariffs within state-owned utilities. These poor energy systems contribute to frequent power outages, supply shortages, and the inability of energy providers to expand services to underserved communities within the SSA Avordeh et al., 2024; [25,26]. A common practice within SSA is for corrupt officials to prioritise fossil fuel projects with short-term financial gains over sustainable and renewable energy projects that require long-term commitments. This misalignment hampers environmental goals and fails to provide sustainable and affordable solutions for the millions of energy-poor people.

Unlike previous studies that have investigated the determinants of energy poverty on FDI and corruption in isolation Aklin et al., 2018; [23, 27–32], our study is the first to simultaneously examine the moderating role of corruption on FDI for both electricity access and clean cooking fuels, while also testing for bidirectional causality among key variables within the SSA context. In doing so, three research objectives are formulated: first, to test the core moderating role of corruption in the FDI-energy access nexus. The second examines the institutional conditions under which FDI translates into improved energy access, and the third establishes the direction of influence between corruption control and energy access outcomes. To conclude, these objectives move the analysis beyond correlation toward identifying plausible causal pathways within the SSA context. The remainder of the study is structured as follows: Section 2 presents the literature review, Section 3 outlines the methodology, Section 4 discusses the analysis and findings, and Section 5 concludes with policy recommendations.

2. Literature review

2.1. Overview of energy poverty in SSA

As the challenge of energy poverty remains, it poses a significant barrier to socioeconomic progress in Africa, particularly in SSA. For instance, Sy and Copley [33] estimate that nearly 620 million people living in Africa lack access to reliable sources of electricity. This deficiency restricts economic opportunities and perpetuates health risks associated with low-cost alternative energy sources such as wood fuel Barasa et al., 2018 [34]. This challenge is exacerbated by weak energy institutions, ineffective legal and regulatory frameworks, and politically motivated energy policies that hinder efficient energy distribution and access Musonye et al., 2020 [35]. Such inefficiencies contribute to persistent energy poverty, underscoring the urgent need for reform and innovation in the energy sector.

Fig. 2, which shows 2022 data, highlights the global distribution of access to clean fuel for cooking. Sub-Saharan Africa and Asia continue to exhibit low access levels, with fewer than 20% of the population using clean fuel, underscoring the high prevalence of energy poverty in the region. In contrast, regions such as Europe, North America, and the Middle East have widespread access, with over 80% of the population benefiting from modern fuels. Roach and Al-Saidi [37] noted that

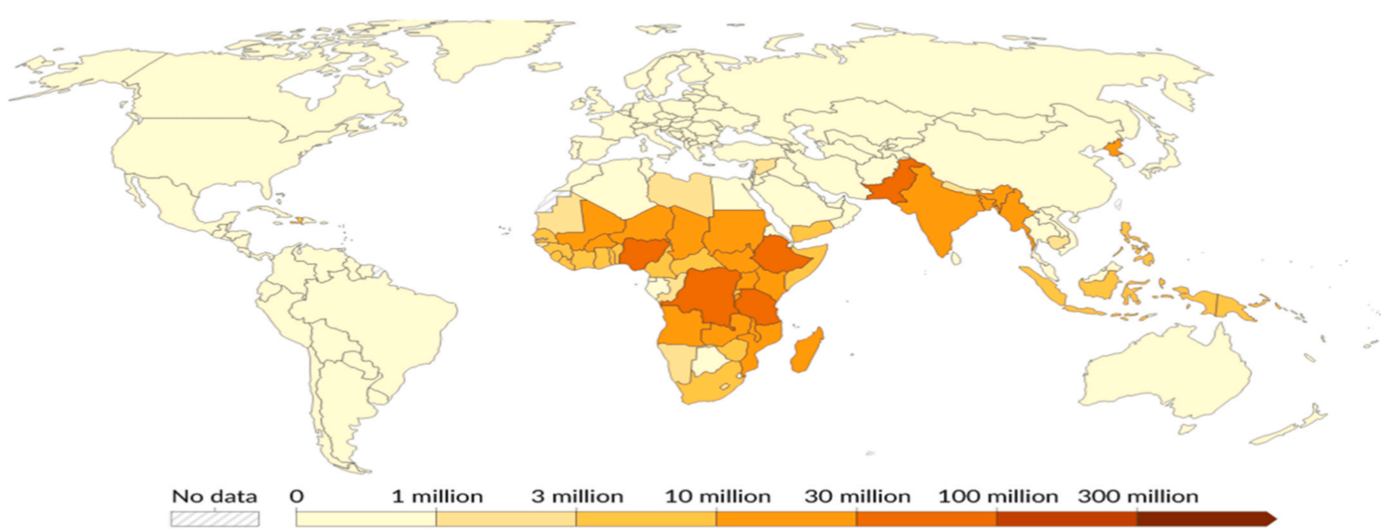

Fig. 1. Share of the Population without Access to Electricity in 2021. Data compiled by the World Bank; Ritchie [3].

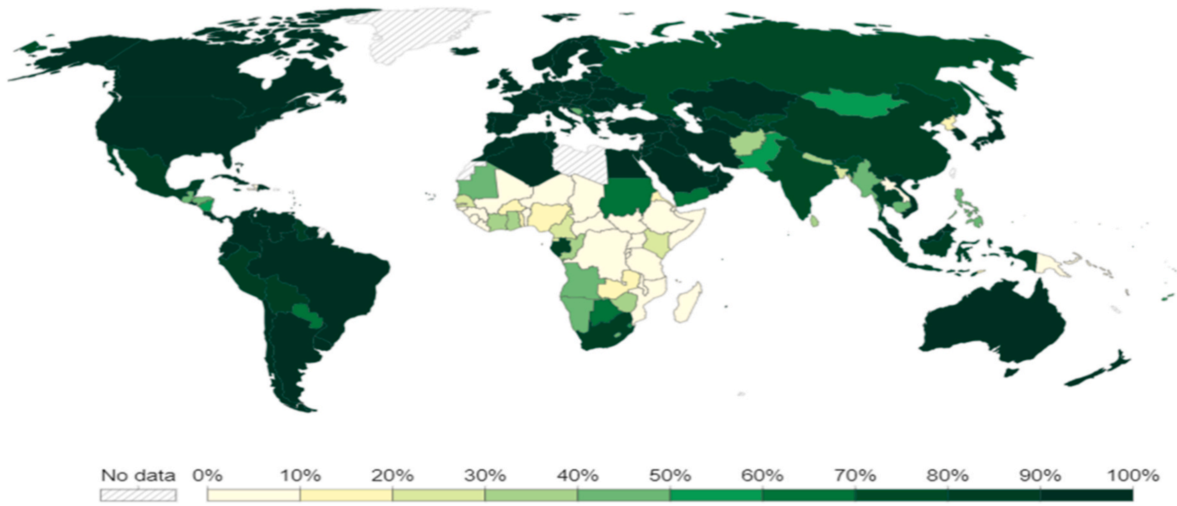

Fig. 2. Share of population with access to clean fuel for cooking, adapted from World Health Organisation [36].

conflict-affected regions in the Middle East, such as Yemen and Syria, also face severe issues with energy access due to instability and infrastructural damage. These disparities underscore the need for targeted policies and investments, particularly in low-access regions, to promote the adoption of clean energy and reduce reliance on traditional biomass, aligning with SDG 7.

2.2. The role of foreign direct investment

Foreign Direct Investment has emerged as a critical financing channel for energy infrastructure development in SSA, particularly in contexts where domestic savings, fiscal space, and public investment capacity are constrained [38,39]. Several studies identify FDI as a key driver of electricity generation capacity, grid expansion, and technology transfer in developing regions Mahbub et al., 2022; [40,41]. In SSA, FDI is particularly relevant for capital-intensive energy projects, such as power plants, transmission networks, and renewable energy installations.

Empirical evidence generally supports a positive association between FDI and electricity access, though the magnitude and consistency of this relationship vary across institutional contexts. Aluko et al. [42], used the Generalized Method of Moments (GMM) estimation for African countries to find that FDI significantly improves electricity access, with governance quality acting as a critical amplifying factor. Similarly, Zhou et al. [32] show that China's outward FDI under the Belt and Road Initiative has contributed to reducing energy poverty by improving infrastructure availability and regional spillovers. However, the literature also highlights heterogeneity in FDI outcomes across energy sub-sectors.

Meka'a et al. [30] find that while FDI supports renewable energy deployment, its effect on household-level energy poverty is weaker in countries with low absorptive capacity. This aligns with absorptive capacity theory, which suggests that external capital yields limited developmental benefits in environments lacking institutional coordination and regulatory enforcement [43]. Moreover, recent studies caution that FDI may exacerbate inequalities when governance is weak. Ganda and Panicker [38] demonstrate that FDI can shift toward carbon-intensive or enclave investments as electricity access improves, thereby limiting the inclusive benefits of energy. These findings suggest that FDI is not inherently pro-poor and that its effectiveness in reducing energy poverty depends critically on institutional quality, sectoral targeting, and regulatory.

2.3. Governance, institutional quality, and corruption as barriers

Governance quality, particularly in terms of corruption control and government effectiveness, has been consistently identified as a major determinant of energy sector performance in SSA Asongu & Odhiambo, 2022 [44]. Weak institutions distort investment decisions, reduce the efficiency of public investment, and undermine service delivery in the energy sector [19,23]. Corruption affects energy systems through multiple channels, including inflated procurement costs, project delays, rent-seeking in licensing, and the diversion of funds intended for infrastructure expansion.

Empirical evidence overwhelmingly indicates that corruption worsens energy poverty outcomes. Amoah et al. [45] find that higher corruption levels significantly reduce renewable energy consumption in Africa, while Gani [46] shows that corruption erodes the sustainability of energy assets in developing countries. Hamann et al. [29] further argue that corruption undermines justice in clean energy transitions by privileging elite interests over universal access. Nevertheless, the relationship between corruption and energy access is not entirely unidirectional. Beyond corruption, government effectiveness, which encompasses policy coherence, bureaucratic capacity, and service delivery quality, has emerged as a stronger predictor of sustainable energy outcomes. Gregory and Sovacool [8] argue that energy poverty in SSA reflects failures in financial, political, and technological governance, not corruption alone. This distinction is critical, as it suggests that anti-corruption efforts must be complemented by broader institutional reforms to improve investment absorption and energy planning.

2.4. Empirical studies

Ganda and Panicker [38] employed a panel threshold regression model to examine the intricate relationships between energy access, FDI, and environmental outcomes in SSA. Their studies revealed that FDI initially reduces carbon emissions when electricity access is low. Still, this effect reverses as access improves, suggesting a shift toward more carbon-intensive investments. Additionally, energy consumption consistently correlates with rising emissions, while ICT shows an insignificant link. The findings highlight the critical role of institutional quality in shaping how FDI affects energy access and sustainability, pointing to corruption as a potential barrier to realising FDI's developmental benefits.

Aluko et al. [42] examine the persistent shortfall in electricity access across Africa despite numerous policy efforts. They attribute this to limited domestic financial resources and weak governance structures. Their study argues that FDI can be critical in closing this gap, mainly when supported by strong governance. Data from 36 African countries were used, and an instrumental variable approach was applied within the Generalized Method of Moments (GMM) framework. They found that both FDI and governance have a positive impact on electricity access. Their study also revealed that governance amplifies the effect of FDI, highlighting the need for robust institutional frameworks to unlock the full potential of foreign investment in the energy sector.

Zhou et al. [32] investigated China's outward FDI on energy poverty in 80 Belt and Road Initiative (BRI) countries from 2006 to 2018. Their study employed the spatial Durbin model and found that, although overall energy poverty has declined, regions such as SSA and South Asia still face significant deficits due to weak infrastructure and limited adoption of clean energy. China's outward FDI helps alleviate energy poverty by improving accessibility, infrastructure, and supply, with notable spillover effects in neighbouring countries. Their study highlights the role of strategic foreign investment in advancing energy access. Lu et al. [47] explored the links between energy poverty, FDI and public health using global panel data. The study finds that energy poverty worsens health outcomes, while FDI improves them in the long run. The Granger causality results reveal a two-way relationship between energy poverty and health, as well as a one-way link from FDI to health. The findings underscore the significance of institutional quality in shaping these outcomes, particularly in regions such as SSA.

Cummins and Gillanders [28] analysed the relationship between corruption and electricity access in Africa using Afrobarometer survey data. Interestingly, the study found that in areas where more people report paying bribes for household services, access to electricity tends to be higher. While this challenges conventional assumptions, the analysis suggests that corruption may sometimes "grease the wheels" by helping firms bypass bureaucratic barriers in countries with weak infrastructure and high regulatory burdens. The effect is especially pronounced in countries with limited access to electricity and significant private sector involvement, highlighting the complex and context-dependent role of corruption in energy access.

Amoah et al. [45] investigated the impact of corruption on renewable energy consumption, utilising panel data from 32 African countries between 1996 and 2019. Their study found that high levels of perceived corruption significantly reduce the share of renewable energy in total energy consumption. The study employed both GMM and instrumental variable estimation methods. The results consistently show that corruption hinders the uptake of renewable energy, even when accounting for differences in income levels and environmental performance. The study highlights the urgent need for stronger institutional frameworks to mitigate the negative impact of corruption on Africa's energy transition.

Gregory and Sovacool [8] critically examined why private sector investment in electricity infrastructure has remained limited in SSA, despite decades of encouragement from institutions such as the World Bank. While much of the literature blames poor governance, especially corruption, for deterring investment, Gregory and Sovacool [8] argue that this view is overly simplistic. Drawing on three governance perspectives: financial investment governance, political governance, and technological governance, the study highlights how a broader mix of institutional, political, and system-level barriers shapes investor decisions. The findings suggest that addressing corruption alone may be insufficient; a more holistic approach to governance reform is needed to attract sustainable private investment and improve regional electricity access.

3. Methodology

3.1. Theoretical framework

The theoretical context of the study is established through the integration of the institutional capacity theory [48], the absorptive capacity hypothesis [43], and the theory of public sector failure [49,50] to conceptualise how corruption distorts the translation of foreign investment into energy access outcomes. These theories do not operate in isolation but are interwoven with one another to establish a multi-dimensional theory of how institutional quality, i.e., the level of corruption, moderates the impact of FDI on alleviating energy poverty in SSA. Thus, in this framework, corruption operates as an efficiency-reducing mechanism that weakens investment transmission channels, particularly in institutionally fragile environments.

Therefore, institutional capacity theory posits that institutional structures influence economic performance by reducing transaction costs, fostering rule-of-law governance, and enforcing property rights [48]. Institutional strength enables proper planning, distribution, and delivery of energy infrastructure for energy access supply. On the other hand, weak institutions, particularly in corrupt settings, bias public investment choices and reduce the effectiveness with which FDI is translated into energy outcomes. In favour of this is the absorptive capacity hypothesis, which posits that a country's ability to absorb, adapt, and utilise external inputs depends on its domestic capabilities, including technical competence, institutional coordination, and regulatory frameworks [43]. In terms of energy investment, FDI will be successful only if the host country's private and public sectors can effectively manage, invest in, and utilise the capital towards clean fuel diffusion, renewable integration, and electricity grid extension.

Moreover, public sector failure theory offers another twist of theoretical depth. It suggests that if governments are corrupt, public funds are often misused for personal purposes, frequently through inflated contracts, bribes, and theft [49,50]. This misinvestment lowers the developmental impact of FDI. Consistent with this, even when capital flows in, observed indicators such as the proportion of people with power or access to clean cooking fuel do not change or improve marginally in corrupt nations.

To frame these theoretical ideas into an integrating analytical framework, the study uses an augmented Cobb-Douglas specification in level form, augmented to account for institutional biases. Let EA_{it} be the energy access level for country i at time t, FDI_{it} be foreign direct investment, and INS_{it} be institutional quality through control of corruption and government effectiveness. Then the base structural relation is specified by:

$$EA_{it} = A_i {}^* FDI_{it}^{\theta_1} {}^* INS_{it}^{\theta_2} {}^* \prod_{k=1}^{n} X_{kit}^{\theta_k} \tag{1}$$

Here, in this production function, $\boldsymbol{A_i}$ represents a fixed factor which is country-specific and captures varying levels of technology or history, and X_{kit} represents structural control variables such as GDP growth, renewable energy consumption, inflation, external debt, and population growth. FDI_{it} and INS_{it} interaction is of special concern since it captures the moderating effect of governance on investment efficiency.

To directly reflect the negative role of corruption, the model includes a distortion parameter μ_{it}, i.e., $\mu_{it} = 1 - COC_{it}$. As corruption is higher, COC_{it} decreases, causing $\mu_{it} \rightarrow 1$, and thus reducing FDI productivity. This inefficiency in institutions is directly included in energy access production as:

$$EA_{it} = A_i {}^* \left(\frac{FDI_{it}}{1 + \mu_{it}} \right)^{\theta_1} {}^* INS_{it}^{\theta_2} {}^* \prod_{k=1}^{n} X_{kit}^{\theta_k} \tag{2}$$

The distortion parameter captures the non-linear manner through which corruption alters the productivity of FDI, allowing governance failures to attenuate or amplify investment effects beyond what a linear form would imply. Moreover, this parameter is allowed to vary across countries but is assumed time-invariant within panels, with country-specific effects absorbed through fixed effects in the empirical specification. This formulation more accurately reflects the institutional frictions observed in weak regulatory environments.

3.2. Model specification

Based on the above theoretical constructs, two models were formulated to address objective 1, which aims to examine whether corruption substantially moderates the effect of FDI on enhancing access to electricity and clean fuel in SSA. These two models compare the two dimensions of energy poverty by having different but structurally isomorphic specifications for electricity access and clean fuel access, explicitly focusing on the conditioning role of corruption control. Thus, the first empirical specification for electricity access is expressed as:

$$elec_{it} = \alpha_0 + \alpha_1 fdi_{it} + \alpha_2 coc_{it} + \alpha_3 (fdi_{it} {*} coc_{it}) + \alpha_4 ren_{it} + \alpha_5 gdp_{it} + \alpha_6 exdebt_{it} + \alpha_7\, inf_{it} + \alpha_8 pop_{it} + \varepsilon_{it} \quad (3)$$

The corresponding model for clean fuels is expressed as:

$$fuel_{it} = \beta_0 + \beta_1 fdi_{it} + \beta_2 coc_{it} + \beta_3 (fdi_{it} {*} coc_{it}) + \beta_4 ren_{it} + \beta_5 gdp_{it} + \beta_6 exdebt_{it} + \beta_7\, inf_{it} + \beta_8 pop_{it} + \epsilon_{it} \quad (4)$$

$elec_{it}$ is the electricity, $fuel_{it}$ is the clean fuels and cooking technologies, fdi_{it} is the foreign direct investment, coc_{it} is the control of corruption, gdp_{it} is the economic growth, $exdebt_{it}$ is the external debt, inf_{it} is the inflation rate, and pop_{it} is the growth rate of the population. The FDI-corruption cross-term (($fdi_{it}*coc_{it}$) remains the empirical counterpart of the distortion channel in the theory. A negative and statistically significant coefficient on the estimate (either α_3 or β_3) would show that corruption undermines the contribution of FDI towards energy access, thereby confirming the hypothesised institutional constraint.

Additionally, the third model is constructed to achieve objective 2, focusing on the institutional conditions for the proper utilisation of FDI in the energy sector. The dependent variable in this case is fdi_{it}, while explanatory variables are the core institutional indicators and their interaction with the current level of energy access. The model is formulated as:

$$fdi_{it} = \gamma_0 + \gamma_1 coc_{it} + \gamma_2 geff_{it} + \gamma_3 (elec_{it} {*} coc_{it}) + \gamma_4 (elec_{it} {*} geff_{it}) + \gamma_5 (fuel_{it} {*} coc_{it}) + \gamma_6 (fuel_{it} {*} geff_{it}) + \gamma_7 ren_{it} + \mu_{it} \quad (5)$$

Here, $geff_{it}$ denotes government effectiveness. The interaction terms account for the possibility that investors respond to energy outcomes and the quality of institutions that support them. A positive and significant coefficient would confirm that good governance enhances the appeal of FDI in energy-intensive settings.

A dynamic panel model framework is employed to test objective 3, which confirms causal relations between FDI, corruption, and access to electricity. The overall model specification involves lags in order to permit temporal order and causality:

$$elec_{it} = \sum_{p=1}^{P} \delta_p fdi_{i,t-p} + \sum_{q=1}^{Q} \theta_q coc_{i,t-q} + \sum_{r=1}^{R} \lambda_r \left(fdi_{i,t-r} {*} coc_{i,t-r} \right) + \omega_{it} \quad (6)$$

Here, historical FDI and corruption control values are used to predict current electricity access, allowing the study to test for Granger-type causality in a panel setting. The empirical issue here is whether FDI and corruption control possess predictive power for future fluctuations in electricity access and vice versa, as with objective 3.

3.3. Estimation strategy

For Objective 1, testing whether corruption significantly reduces the effect of FDI on access to energy, the analysis begins with a Panel OLS estimation of a static panel model. This methodology requires the homogeneity of slope coefficients and robust standard errors clustered by country to be applied, correcting for heteroscedasticity and serial correlation across time. However, as the dependent variables are bounded electricity and fuel availability, both being ratios between 0 and 100, a Generalized Linear Model (GLM) of Nelder and Wedderburn [51] is also applied. The GLM specification allows for different distributional properties and link functions, making it appropriate for estimating percentage variables, particularly when the distribution is non-normal or skewed. A Gaussian family with an identity link function is specified for electricity access, where distribution is approximately symmetric. The Poisson distribution with a log-link function is appropriate for clean fuel access; however, it is right-skewed and over-dispersed in most SSA countries. The following is the general model of GLM used:

$$g(ea_{it}) = \eta_{it} = \beta_0 + \beta_1 fdi_{it} + \beta_2 coc_{it} + \beta_3 (fdi_{it} {*} coc_{it}) + \sum_{k=4}^{n} \beta_k X_{kit} \quad (7)$$

Where $g(.)$ is the link function (identity or log), and η_{it} is the linear predictor.

While a beta regression is also suitable for fractional outcomes, the Poisson GLM is preferred here due to the presence of boundary values at zero and one that are common in energy-access data. We note beta regression as a robustness check to be reported in future studies for supplementary analyses.

For objective 2, evaluating whether countries with improved institutions possess improved FDI implementation in the energy industry, three panel cointegration techniques are utilised to provide estimates of long-run relationships among non-stationary variables. These utilised techniques include fully modified least squares (FMOLS), dynamic least squares (DOLS), and canonical cointegration (CCR), each addressing endogeneity and serial correlation issues in different ways.

Thus, the FMOLS method removes serial correlation and endogeneity by checking semi-parametric adjustments. The estimator redefines the regress and the dependent variable to remove the long-run relationship between the cointegrating equation and the stochastic error term. The FMOLS estimator is:

$$\widehat{\beta}_{FMOLS} = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} X_{it}^{*} X_{it}^{*'} \right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} X_{it}^{*} Y_{it}^{*} \quad (8)$$

Where X_{it}^{*} and Y_{it}^{*} are transformed series that remove the influence of serial correlation. The DOLS estimator addresses endogeneity by including leads and lags of the first-differenced regressors in the cointegrating regression. The model is as follows:

$$Y_{it} = \alpha + \beta X_{it} + \sum_{j=-k}^{k} \gamma_j \Delta X_{i,t-j} + \varepsilon_{it} \quad (9)$$

This model delivers unbiased long-run coefficient estimates by absorbing potential omitted variable bias in dynamic settings. CCR, nonetheless, normalised the data using long-run covariance matrices and created a modified least squares estimator that removes endogeneity and simultaneity without employing lags. The most trustworthy and efficacious estimator among the three models (FMOLS, DOLS, and CCR) is identified by the study employing the Hausman [52] specification test. The Hausman test statistic is given by:

$$H = (\widehat{\beta}_1 - \widehat{\beta}_2)' [Var(\widehat{\beta}_1 - \widehat{\beta}_2)]^{-1} (\widehat{\beta}_1 - \widehat{\beta}_2) \quad (10)$$

A significant test value indicates that the difference in coefficients is systematic as opposed to being due to sampling variation, guiding the process of model selection.

For Objective 3, which investigates the direction of causality between FDI, control of corruption, and electricity access, the study uses the Dumitrescu and Hurlin [53] Granger non-causality test for panel data of heterogeneous type. The test calls for estimation of individual regressions by cross-section and aggregation of individual Wald statistics. The null of zero Granger causality in all the panel units, while the alternative allows for causality in at least one unit. Therefore, the generic form of the test model is:

$$EA_{it} = \alpha_i + \sum_{k=1}^{K} \delta_{ik} EA_{i,t-k} + \sum_{k=1}^{K} \theta_{ik} FDI_{i,t-k} + \varepsilon_{it} \quad (11)$$

The Wald statistics W_i of all the units are normalised and averaged to obtain the Z-bar statistic, which is contrasted with standard normal distribution critical values. The test is a reliable test of causality even in unbalanced panels and cross-sectional dependence.

3.4. Data and scope

The study is based on a balanced and full panel dataset for 49 SSA countries[1] from 2000 to 2023. Countries were selected based on the coverage and durability of macroeconomic indicators, institutional quality, and energy access data. The sample captures SSA's diversity in economic models, governance frameworks, and energy development paths and therefore permits regional inference. Dependent variables are electricity access ($elec_{it}$) and clean cooking fuels and technologies access ($fuel_{it}$), both represented as percentages of the population. Together, these two indicators serve as proxies for energy poverty and are sourced from the World Development Indicators (WDI) database.

The primary independent variables are foreign direct investment (fdi_{it}), measured in percentage of GDP; control of corruption (coc_{it}); and government effectiveness ($geff_{it}$), both from the World Governance Indicators (WGI) dataset. Besides these, control variables include GDP growth (gdp_{it}), external debt as a percentage of GNI ($exdebt_{it}$), inflation (inf_{it}), population growth (pop_{it}), and renewable energy consumption (ren_{it}) as percentage of final energy consumption. These controls capture macroeconomic and structural determinants that both underlie energy access and FDI inflows.

The study's period scope is chosen to coincide with significant international and regional energy policy, investment trends, and governance reform shifts. It encompasses several international energy development agendas, including the Millennium Development Goals (MDGs), Sustainable Energy for All (SEforALL), and the Sustainable Development Goals (SDGs), specifically SDG 7 for clean and affordable energy and SDG 16 on governance and anti-corruption.

3.5. Data replication

It is worth noting that all empirical analyses were conducted using Stata 15.1 econometric software, and the data employed for the analysis were primarily obtained from the World Bank's World Development Indicators (WDI) and World Governance Indicators (WGI) databases. Meanwhile, the dependent variable, which is electricity access, is measured using the World Bank indicator code EG.ELC.ACCS.ZS, while access to clean fuels and technologies for cooking is measured using code EG.CFT.ACCS.ZS. For key independent variables, net foreign direct investment is proxied by the World Bank indicator code BX.KLT.DINV.WD.GD.ZS, while the institutional quality indicators were proxied by control of corruption (CC.EST) and government effectiveness (GE.EST), which were both sourced from the WGI. Besides, all control variables were sourced from the WDI with each of the indicator codes: gdp growth (NY.GDP.PCAP.KD.ZG), external debt (DT.DOD.DECT.GN.ZS), inflation (FP.CPI.TOTL.ZG), population growth (SP.POP.GROW), and renewable energy consumption (EG.FEC.RNEW.ZS). A balanced panel was constructed without interpolation for missing observations. Moreover, for the Dumitrescu–Hurlin panel causality tests, the lag order was set to two based on the Akaike Information Criterion. To conclude, the replication code and the constructed dataset are available from the authors upon reasonable request.

4. Empirical result and discussion

4.1. Preliminary result

The descriptive statistics in Table 1 provide an overview into the distributional properties of the SSA variables in the study. The mean level of access to electricity is at 39.90 percent, with extremely large disparities ranging from no access at all (0.00%) to total access (100.00%), indicating severe energy inequality across the nations. Access to clean fuels is further limited, at an average of 19.26 percent, consolidating the perpetuation of energy poverty in cooking technologies. FDI average inflow records are at 4.29 percent of GDP but with large fluctuations; it is at one time highest at 103.34 percent and lowest negatively at −17.29 percent, referring to the cases of capital flight or net disinvestment. The control of corruption and government effectiveness have negative mean values of −0.615 and −0.768, respectively, indicating poor overall institutional quality in the region. Renewable energy consumption is high, at a mean of 60.51 percent, implying that most countries rely on conventional renewables, which may include biomass, but this is not always a clean source. GDP growth shows wide variation, while inflation sees a record high of 557.20 percent, showing instances of hyperinflation. Both external debt and population growth are also heterogeneous, reflecting macroeconomic divergence during the sample.

The correlation matrix in Table 2 shows a high and positive correlation between electricity access and clean fuel access (0.689),

Table 1
Descriptive statistics.

Variable	Description	Obs.	Mean	Std. Dev.	Min	Max
$elec_{it}$	Electricity access (% of population)	1176	39.897	26.380	0.000	100.000
$fuel_{it}$	Clean fuels and technologies (% of population)	1176	19.258	26.736	0.000	100.000
fdi_{it}	Net foreign direct investment inflows (% GDP)	1176	4.289	7.715	−17.292	103.337
coc_{it}	Control of corruption estimate	1176	−0.615	0.651	−1.970	1.699
$goeff_{it}$	Government effectiveness estimate	1176	−0.768	0.648	−2.440	1.150
ren_{it}	Renewable energy consumption (% final energy consumption)	1176	60.512	30.607	0.000	98.300
gdp_{it}	Real gross domestic product growth rate	1176	3.947	5.474	−46.082	63.380
$exdebt_{it}$	External debt (% of GNI)	1176	54.194	62.667	0.000	610.452
inf_{it}	Inflation rate, CPI	1176	9.766	33.475	−16.860	557.202
pop_{it}	Population growth (% of to)	1176	2.441	1.063	−5.416	6.410

Source: Authors' Computations (2025).

[1] Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo (Brazzaville), Congo (Democratic Republic), Côte d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, São Tomé and Príncipe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

Table 2
Correlation statistics.

Variable	$elec_{it}$	$fuel_{it}$	fdi_{it}	coc_{it}	$goeff_{it}$	ren_{it}	gdp_{it}	$exdebt_{it}$	inf_{it}	pop_{it}
$elec_{it}$	1.000									
$fuel_{it}$	0.689	1.000								
fdi_{it}	0.032	0.026	1.000							
coc_{it}	0.362	0.463	0.076	1.000						
$goeff_{it}$	0.391	0.540	0.040	0.859	1.000					
ren_{it}	−0.588	−0.495	−0.038	−0.410	−0.431	1.000				
gdp_{it}	−0.056	−0.091	0.133	0.048	0.068	0.101	1.000			
$exdebt_{it}$	−0.123	−0.106	0.144	−0.015	−0.037	0.136	−0.084	1.000		
inf_{it}	−0.056	0.009	−0.002	−0.102	−0.102	0.023	−0.116	0.031	1.000	
pop_{it}	−0.381	−0.412	0.071	−0.379	−0.278	0.272	0.218	0.016	−0.057	1.000

Source: Authors' Computations (2025).

indicating that energy poverty in electricity and fuel is closely linked. Both energy access measures have positive relationships with control of corruption and government effectiveness, consistent with the sanction of institutional quality to energy infrastructure and service improvement. Interestingly, renewable energy consumption is inversely related to access to electricity (−0.588) and to access to clean fuels (−0.495), suggesting that extensive dependency on traditional biomass does not characterise contemporary energy access. FDI weakly positively correlates with the majority of variables, whereas inflation and population growth negatively correlate with energy access and governance, suggesting their destabilising nature.

Table 3 reports the Pesaran Cross-sectional Dependence (CD) test findings, which confirm statistically significant cross-sectional dependence across all variables at the 1 percent level, suggesting that common regional shocks, policy contagion, or market interdependencies are driving energy and institutional performance across countries.

Additionally, the panel unit root test in Table 4, applying the Levin-Lin-Chu approach, indicates that all the variables are stationary at level (I(0)) such as FDI, control of corruption, government effectiveness, GDP growth, external debt, inflation, and population growth. Nevertheless, access to electricity, access to clean fuels, and renewable energy consumption are non-stationary at level but turn stationary after first differencing and thus are integrated of order one (I(1)).

Finally, Table 5 presents the Kao residual cointegration test results for the three models as outlined in the methodology section. Test statistics are generally insignificant in Model 1, corresponding to electricity access, indicating no long-run equilibrium among the variables considered. Nevertheless, Models 2 (clean fuels) and 3 (FDI and its institutional conditioning) exhibit pronounced evidence of cointegration across all test specifications.

Hence, preliminary investigations confirm the presence of cross-sectional dependence a mixture of I(0) and I(1) unit root variables, and long run equilibrium condition, thereby justifying the selected estimators in the subsequent section.

Table 3
Cross-section dependence statistics.

Variable	CD-test	P-value	Average Joint T	Mean ρ	Mean Abs(ρ)
$elec_{it}$	152.478***	0.000	24.000	0.910	0.910
$fuel_{it}$	95.132***	0.000	24.000	0.570	0.650
fdi_{it}	7.553***	0.000	24.000	0.040	0.240
coc_{it}	37.860***	0.000	24.000	0.230	0.430
$goeff_{it}$	55.057***	0.000	24.000	0.330	0.510
ren_{it}	123.947***	0.000	24.000	0.740	0.740
gdp_{it}	20.177***	0.000	24.000	0.120	0.220
$exdebt_{it}$	41.845***	0.000	24.000	0.250	0.450
inf_{it}	24.401***	0.000	24.000	0.150	0.240
pop_{it}	10.118***	0.000	24.000	0.060	0.410

Source: Authors' Computations. ***, **, and * respectively represents 1%, 5%, and 10% significance level

4.2. Estimation result

Table 6 presents the estimated results of the impact of FDI and anti-corruption on electricity access in SSA. The interaction term (FDI × Control of Corruption) captures how changes in corruption control modify the marginal impact of FDI on energy access. Across all three models, FDI has a persistently positive and statistically significant coefficient on access to electricity, reinforcing its core position in infrastructure development. Above all, the interaction between FDI and corruption control has a positive and significant relationship in both Panel OLS and Poisson estimates, which implies that corruption reduces the potency of foreign capital in delivering electricity outcomes; as the level of controlling corruption increases, the margin effect of foreign investment on electricity access increases. Whereas the standalone effect of corruption control only emerges in the GLM models, its interaction with foreign investment highlights the importance of governance in energy transitions. Access to electricity is negatively affected by utilising renewable energy in all the models, possibly due to reliance on non-modern sources like biomass. Population growth continues to outpace infrastructure development in all models, with a uniform and strong negative effect. External debt reduces electricity access in the Panel OLS and Poisson models, highlighting budget constraints, while inflation is only negatively and significantly related in the GLMs. GDP growth is weak and only significantly positively related to electricity access in the Poisson model.

In practical terms, the estimated interaction implies that a one-standard-deviation improvement in corruption control amplifies the marginal effect of FDI on electricity access by a substantively meaningful magnitude, whereas the same institutional improvement dampens the FDI effect on access to clean cooking fuels.

Table 7 shows the estimation results of the effect of FDI and corruption control on clean fuel access in SSA. FDI is not statistically significant in the Panel OLS model, but it is negative and significant in the two GLM models, which suggests that FDI inflows have been inefficiently translated into increased clean fuel availability and may displace domestic attempts where governance is poor. Control of corruption is highly positive and significant across all models, further confirming that institutional integrity immediately enhances access to clean energy, presumably through improvements in public investment efficiency, regulation, and technology transfer. Above all, the relationship between FDI and corruption control is negative and statistically significant in the GLM results, in contrast to the findings regarding electricity access, implying that without robust corruption control, FDI may perpetuate inequality or misallocation in clean fuel activities.

Renewable energy consumption remains negatively associated, possibly reflecting residual biomass consumption, and external debt continues to hinder access to clean fuels, indicating fiscal restraint. This negative association is consistent with 'traditional biomass poverty,' where reliance on fuelwood and charcoal inflates renewable energy shares while signalling limited access to modern energy services. Population growth is significant and has a consistently negative coefficient,

Table 4
LLC unit root test.

Variable	Level		First Difference		Remark
	Statistic	P-value	Statistic	P-value	
$elec_{it}$	1.522	0.936	−21.130***	0.000	I (1)
$fuel_{it}$	12.870	1.000	−5.806***	0.000	I (1)
fdi_{it}	−4.194***	0.000	————	————	I (0)
coc_{it}	−22.633***	0.000	————	————	I (0)
$goeff_{it}$	−27.726***	0.000	————	————	I (0)
ren_{it}	22.129	1.000	−9.595***	0.000	I (1)
gdp_{it}	−9.173***	0.000	————	————	I (0)
$exdebt_{it}$	−3.126***	0.001	————	————	I (0)
inf_{it}	−37.654***	0.000	————	————	I (0)
pop_{it}	−6.950***	0.000	————	————	I (0)

Source: Authors' Computations. ***, **, and * respectively represents 1%, 5%, and 10% significance level

Table 5
Kao cointegration test.

Test	Model 1		Model 2		Model 3	
	Statistic	P-value	Statistic	P-value	Statistic	P-value
Modified Dickey-Fuller t	0.053	0.479	−17.288***	0.000	−14.307***	0.000
Dickey-Fuller t	−0.797	0.213	−2.734**	0.003	−13.072***	0.000
Augmented Dickey-Fuller t	−0.138	0.445	−0.191	0.424	−9.062***	0.000
Unadjusted modified Dickey t	−0.972	0.166	−17.697***	0.000	−20.620***	0.000
Unadjusted Dickey-Fuller t	−1.510*	0.066	−2.831**	0.002	−14.504***	0.000

Source: Authors' Computations. ***, **, and * respectively represents 1%, 5%, and 10% significance level

Table 6
Estimation result for objective 1 (electricity access).

Dependent Variable: $elec_{it}$			
Variable	Panel-OLS	GLM-Gaussian	GLM-Poisson
fdi_{it}	0.305** (0.004)	0.003* (0.096)	0.003*** (0.001)
coc_{it}	1.186 (0.417)	0.064** (0.008)	0.030** (0.001)
$fdi_{it}*coc_{it}$	0.340** (0.004)	0.002 (0.391)	0.003** (0.002)
ren_{it}	−0.422*** (0.001)	−0.009*** (0.001)	−0.010*** (0.001)
gdp_{it}	0.106 (0.374)	0.002 (0.421)	0.002** (0.042)
$exdebt_{it}$	−0.019** (0.014)	0.001 (0.653)	−0.001*** (0.001)
inf_{it}	−0.039 (0.190)	−0.004** (0.001)	−0.002** (0.001)
pop_{it}	−5.624*** (0.001)	−0.121*** (0.001)	−0.122*** (0.001)
$constant_{it}$	80.354*** (0.001)	4.532*** (0.001)	4.546*** (0.001)
N	1176	1176	1176

[a] Reported coefficients are accompanied by heteroskedasticity-robust standard errors clustered at the country level, with their respective significant probabilities at 99%, 95%, and 90% confidence intervals reported in brackets to represent 1% (***), 5% (**), and 10% (*) significant levels, respectively.
Source: Authors' Computations (2025).[a]

Table 7
Estimation result for objective 1 (clean fuel).

Dependent Variable: $fuel_{it}$			
Variable	Panel-OLS	GLM-Gaussian	GLM-Poisson
fdi_{it}	0.214 (0.161)	−0.014** (0.009)	−0.002** (0.027)
coc_{it}	9.326*** (0.001)	0.577*** (0.001)	0.440*** (0.001)
$fdi_{it}*coc_{it}$	0.217 (0.258)	−0.031*** (0.001)	−0.007*** (0.001)
ren_{it}	−0.279*** (0.001)	−0.013*** (0.001)	−0.013*** (0.001)
gdp_{it}	−0.150 (0.223)	−0.003 (0.410)	−0.012*** (0.001)
$exdebt_{it}$	−0.025** (0.002)	−0.002** (0.001)	−0.002*** (0.001)
inf_{it}	0.021 (0.408)	−0.005* (0.068)	0.001*** (0.001)
pop_{it}	−5.519*** (0.001)	−0.244*** (0.001)	−0.199*** (0.001)
$constant_{it}$	56.639*** (0.001)	4.490*** (0.001)	4.358*** (0.001)
N	1176	1176	1176

[a] Reported coefficients are accompanied by heteroskedasticity-robust standard errors clustered at the country level, with their respective significant probabilities at 99%, 95%, and 90% confidence intervals reported in brackets to represent 1% (***), 5% (**), and 10% (*) significant levels, respectively.
Source: Authors' Computations (2025).[a]

symbolising demographic stress on energy facilities. Inflation yields conflicting estimates, with positive results in the Poisson model but negative ones in the Gaussian model. GDP growth is negative and significant only in the Poisson model, implying that near-term growth does not necessarily support clean energy equity. In conclusion, these findings highlight that while institutional quality enhances access to clean fuels independently, FDI must have robust governance protection to achieve effective outcomes for clean cooking technology.

Table 8 presents the FMOLS estimation results for the second objective (since the Hausman test confirms FMOLS as the superior estimator vis-à-vis DOLS and CCR), testing whether institutional quality influences FDI deployment in the energy industry in SSA. Control of corruption has a significant and negative effect on FDI, and it shows that perceived corruption is negatively correlated with FDI inflows. On the other hand, government effectiveness has a significant and positive impact on FDI, suggesting that effective institutions, rather than the mere absence of corruption, attract foreign investment. Of the interaction terms, the interaction between corruption control and clean fuel access is positive and highly significant for FDI, indicating that with rising clean fuel access in the absence of corruption, investor confidence and capital inflows rise. The interaction between the effectiveness of the government and access to clean fuels is, however, negative and significant, and this may mean that private investors in well-governed countries may be held to stricter rules or crowded out by public energy projects, which will repress FDI. Statistical effects on access to electricity are insignificant, implying that FDI reacts more to clean fuel outcomes than to access to electricity. Renewable energy consumption has an insignificant effect, showing no indirect impact on FDI in this model.

Table 9 presents the Dumitrescu and Hurlin [53] panel causality results considering dynamic and one-directional relationships among FDI, electricity access, and institutions. The outcomes demonstrate a one-directional causal relationship between the accessibility of electricity and FDI, where improved energy networks precede and can attract FDI, but not vice versa. There is a two-way causal interaction between control of corruption and access to electricity, indicating a reinforcing balance where institutional integrity supports

Table 8
Estimation result for objective 2 (FDI).

Dependent Variable: fdi_{it}			
Variable	FMOLS	DOLS	CCR
coc_{it}	−72.474*** (0.001)	0.000 .	−77.074** (0.003)
$geff_{it}$	73.720*** (0.001)	0.000 .	79.020** (0.006)
$elec_{it}*coc_{it}$	0.181 (0.175)	−4.899 .	0.176 (0.458)
$elec_{it}*geff_{it}$	−0.147 (0.273)	4.876 .	−0.141 (0.556)
$fuel_{it}*coc_{it}$	2.105*** (0.001)	5.869 .	2.263*** (0.001)
$fuel_{it}*geff_{it}$	−2.226*** (0.001)	−6.120 .	−2.405** (0.001)
ren_{it}	−0.001 (0.550)	−0.114 .	0.001 (0.984)
$constant_{it}$	0.107 (0.655)	0.000 .	0.081 (0.954)
R^2	0.407	1.000	0.564
RMSE	0.854	.	0.855
Hausman	*FMOLS vs. DOLS* 34615.73*** (0.001)		*CCR vs. FMOLS* 0.090 (1.001)

[a] Reported coefficients are accompanied by heteroskedasticity-robust standard errors clustered at the country level, with their respective significant probabilities at 99%, 95%, and 90% confidence intervals reported in brackets to represent 1% (***), 5% (**), and 10% (*) significant levels, respectively.
Source: Authors' Computations (2025).[a]

Table 9
Estimation result for objective 3 (causal influence: Dumitrescu & Hurlin [53]).

Causal Inference	W-bar	Z-bar	Remark
fdi_{it} granger cause $elec_{it}$	0.747	−1.253 (0.210)	Unidirectional causality from electricity access to FDI
$elec_{it}$ granger cause fdi_{it}	2.092	5.406*** (0.001)	
coc_{it} granger cause $elec_{it}$	1.465	2.302** (0.021)	Bidirectional causal influence between control of corruption and electricity access
$elec_{it}$ granger cause coc_{it}	3.611	12.923*** (0.001)	
$geff_{it}$ granger cause $elec_{it}$	0.926	−0.367 (0.714)	Unidirectional causality from electricity access to government effectiveness
$elec_{it}$ granger cause $geff_{it}$	3.730	13.513*** (0.001)	
$fdi_{it}*coc_{it}$ granger cause $elec_{it}$	0.751	−1.233 (0.218)	Unidirectional causality from electricity access to the interaction between FDI and corruption
$elec_{it}$ granger cause $fdi_{it}*coc_{it}$	2.046	5.175*** (0.001)	

[a] Reported coefficients are accompanied by heteroskedasticity-robust standard errors clustered at the country level, with their respective significant probabilities at 99%, 95%, and 90% confidence intervals reported in brackets to represent 1% (***), 5% (**), and 10% (*) significant levels, respectively.
Source: Authors' Computations (2025).[a]

electrification, and improved energy access promotes institutional building through enhanced service delivery and transparency. Similarly, access to electricity Granger-causes government effectiveness but not the other way around, suggesting that public electricity provision can improve bureaucratic performance and citizen trust in government. The connection between FDI and control of corruption does not Granger-cause electricity access, but electricity access significantly causes this interaction term, indicating that the amount of governance-influenced investment reacts more to improvements in energy than it produces. These causal outcomes are visually represented as shown in Fig. 3 to ensure simplicity and clarity.

The two-way causality between electricity access and control of corruption suggests a virtuous cycle: investments that improve electrification can create transparency and reduce rent extraction opportunities, and stronger anti-corruption institutions in turn enhance the effectiveness of subsequent energy investments. Policy designs that target simultaneous infrastructure delivery and governance reforms (for example, independent project monitoring combined with grid extension) can exploit this co-evolutionary dynamic.

4.3. Discussion of results

Findings from the research present a compelling narrative on the interaction between FDI, corruption, and energy poverty in SSA. The positive and significant effect of FDI on electricity access remains a central funding instrument for infrastructure development in SSA. However, the moderating influence of corruption control introduces significant insight into this relationship. Under better institutional integrity environments, foreign capital indicates higher marginal returns to enhance electricity penetration, as evidenced by the positive interaction effect. This corroborates Aluko et al. [42] and Zhou et al. [32] that good governance makes foreign capital more efficient. Conversely, the negative interaction between corruption and FDI in accessing clean fuel suggests yet another aspect. In contrast, institutionally supported investment in electricity is feasible; however, clean cooking energy is structurally under-supplied and vulnerable to elite capture and poor public-private delivery institutions. This reaffirms earlier evidence from Amoah et al. [45] and Gani [46] regarding the role of corruption in distorting energy resource provision and worsening energy poverty across dimensions of basic household energy.

Additionally, the second objective provides new insights into the conditions under which FDI is invested in the energy sector. The negative influence of control of corruption on FDI might appear contradictory but is consistent with the “greasing the wheels” argument in corrupt environments, where rent-seeking contracts bring forward-looking certainty in adverse institutional settings, as Cummins and Gillanders [28] argued. However, the positive impact of government effectiveness on FDI suggests that institutional efficiency, rather than just the absence of corruption, ultimately makes investors confident. The contrast demonstrates that corruption and inefficiency are not ideal complements in driving investment choice. Access to electricity and control of corruption have a two-way causal relationship that also establishes the theoretical hypothesis that institutions and infrastructure co-evolve. Better energy services support public trust and state capacity to govern, leading to a virtuous cycle of state legitimacy and service delivery, as researched by Gregory and Sovacool [8]. This study also corroborates that energy poverty is not merely a technical problem of resource availability but a structural outcome conditioned by the political economy, institutional quality, and finance flows for development. Hence, SSA energy poverty can be minimised through the necessary capital injection, but institutional reform is required to ensure productive investment absorption and the equitable distribution of energy benefits.

Notwithstanding, the divergent institutional sensitivity between electricity access and clean cooking fuels likely reflects differences in market structure and project scale, especially in the SSA region, which is prone to energy instability. In this wise, the grid-based electricity investments tend to involve large, centralised infrastructure with clearer contractual frameworks, while clean cooking initiatives rely more heavily on decentralised supply chains, household adoption, and subsidy mechanisms, which are more vulnerable to elite capture and administrative leakage. This distinction between the two energy parameters aligns with public sector failure theory and helps explain why governance quality plays a more decisive role in clean fuel outcomes.

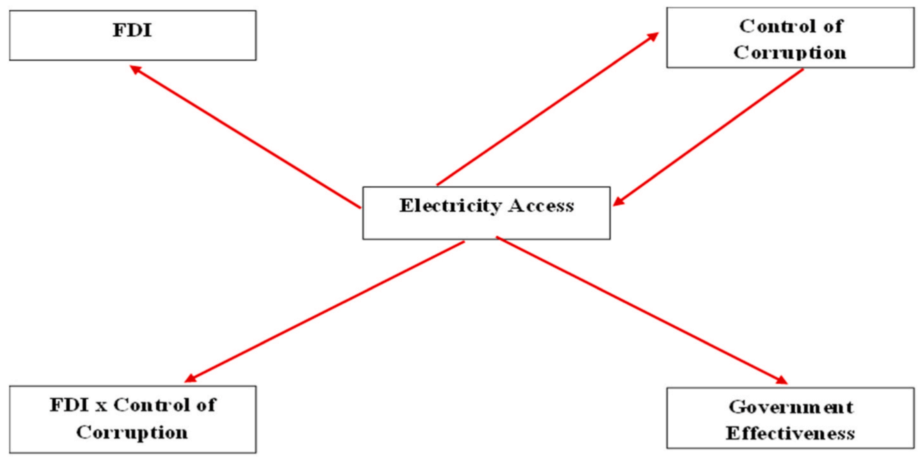

Fig. 3. Causal Flow Diagram Based on Dumitrescu-Hurlin Panel Causality Tests Source: Authors' Computation (2025).
Note: single arrow (→) denote unidirectional causality; double arrows (⇄) denotes bidirectional causality.

5. Conclusion and policy implication

5.1. Main conclusion

The study examined the moderating effect of corruption on the relationship between FDI and energy poverty in SSA. Applying a robust econometric framework and panel data for 49 SSA countries between 2000 and 2023, the results show that FDI plays an important role in improving electricity access but is comparatively weak at advancing clean fuel access unless institutional quality, especially corruption control, is accorded the highest priority. Results also revealed that access to clean fuel is more responsive to governance forces than electricity, suggesting sectoral asymmetry in the manner in which institutional capacity translates into energy outcomes.

In addition, the results revealed that government effectiveness is a stronger pull factor in foreign investment than merely exercising control over corruption, which means that institutional stability and policy coherence are the most important factors to boost energy-sector FDI. Bidirectional causality between control of corruption and electricity access reflects the co-evolving interdependence between infrastructure and governance. These findings underscore the utmost urgency for a twin-track development strategy, with capital mobilisation and institution building as its highest priorities. The implications are significant; corruption is not only a structural failure of the government but also a development impediment that stifles investment efficiency and prolongs energy poverty. These findings underscore the role of SDG 16, peace, justice, and strong institutions, as a necessary institutional foundation for achieving universal energy access under SDG 7.

5.2. Policy recommendations

Based on the empirical evidence, the below actionable policies are of utmost importance. Policymakers should mandate transparent public bidding platforms for energy projects, including mandatory online publication of tender awards and independent third-party audits for major contracts. Moreover, the government should link international climate finance disbursements to governance performance by conditioning tranches on measurable improvements in procurement transparency and anti-corruption indices. Finally, policymakers should promote decentralised renewable energy systems through community-managed models and transparent subsidy mechanisms to reduce central-level rent-seeking and improve household uptake.

5.3. Key contributions/strengths

The key strengths of this study lie in its simultaneous examination of two distinct dimensions of energy poverty via electricity access and clean technology, its explicit modelling of corruption and government effectiveness as moderating institutional forces, and its integration of dynamic causality analysis to explore feedback mechanisms among energy poverty, FDI, and institutional quality. Consequently, the combination of interaction models with panel causality tests in an SSA context advances both methodological rigour and policy relevance, which are necessary to address energy insecurity within the SSA region.

5.4. Limitations of the study

Several limitations can be derived from this study, which warrant further consideration. Firstly, the renewable energy consumption variable largely reflects traditional biomass use in SSA, which may mechanically generate a negative association with modern energy access outcomes. Secondly, institutional quality metrics are proxied using perception-based indices, which may not fully capture informal governance dynamics due to the nature of SSA geopolitical and economic differences. Thirdly, while panel causality tests strengthen inference about causal interaction and feedback loops, they do not establish structural causation. Finally, the findings may not generalise beyond SSA due to region-specific institutional and energy market characteristics that differ from those of other advanced economies worldwide.

5.5. Suggestions for future research

Subsequent studies should analyse the disaggregated channels through which corruption creates distortions in investment in the energy sector, focusing on project-level inefficiencies in public-private partnerships. Micro-level data can inform us about how corruption affects household-level access to clean cooking solutions versus grid expansion. Additionally, there can be further research into how digital governance innovations (such as blockchain, e-governance, and remote monitoring) can reduce corruption along energy investment pipelines. Additionally, studies can assess robustness through the incorporation of alternative institutional quality measures, which differ from the WGI measures used in this study. Examining the role of regional institutions and multilateral donors in mitigating energy sector governance failures will also yield actionable policy lessons toward increasing investment while addressing institutional barriers.

Credit author statement

Godswill Osuma: Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation. Akindele John Ogunsola: Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation. Talent Thebe Zwane: Writing – review & editing, Writing – original draft, Validation, Methodology, Supervision, Funding acquisition. Ntokozo Nzimande: Writing – review & editing, Writing – original draft, Validation, Methodology, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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