

Economic policy uncertainty and energy vulnerability in Africa: How crucial is governance quality?

Emmanuel Y. Gbolonyo, Bright Tetteh, Samuel Mensah and George Baffour Awuah

ERSA working paper 944

November 2026

The views expressed are those of the author(s) and do not necessarily represent those of the funder, ERSA or the author's affiliated institution(s). ERSA shall not be liable to any person for inaccurate information or opinions contained herein.

Economic policy uncertainty and energy vulnerability in Africa: How crucial is governance quality?

Emmanuel Y. Gbolonyo[1], Bright Tetteh[2], Samuel Mensah[3] and George Baffour Awuah[4]

Abstract

This study examines the relationship between economic policy uncertainty (EPU) and energy vulnerability. The study further investigates the role of governance indicators in the relationship between EPU and energy vulnerability. To address concerns of endogeneity, cross-sectional dependence, and non-linearity, the study applies the Lewbel Two-Stage Least Squares, Driscoll-Kraay Standard error, and a machine-learning based Kernel Regularized Least Squares technique on a sample of 26 African countries from 2000 to 2019. We find evidence that EPU deepens energy vulnerability. Assessing the role of governance quality (government effectiveness, rule of law, voice and accountability, control for corruption, regulatory quality and political stability), we estimate that although governance indicators do not completely offset the detrimental effect of EPU on energy vulnerability, they reduce the magnitude of the effect. We also demonstrate that increase in EPU is associated with an increase in energy vulnerability at medium (50^{th}) to high (75^{th}) levels of energy vulnerability. The findings emphasize that improving governance quality is essential for building energy resilience in Africa, particularly under conditions of heightened global economic uncertainty.

Keywords: Economic policy uncertainty; Energy resilience; Governance; Institutions; Africa

JEL Codes: Q43, E32, O55, P48

[1] Corresponding author. School of Economics, University of Cape Town, Rondebosch, Cape Town, 7701, South Africa, Email: gblemm001@myuct.ac.za /eygbolonyo@outlook.com

[2] Department of Economics, Management and Quantitative Methods, University of Milan; Department of Economics and Management, University of Pavia. bright.tetteh@unimi.it

[3] School of Economics, University of Cape Town, Rondebosch, Cape Town, 7701, South Africa, sammens34@gmail.com

[4] School of Economics, University of Cape Town, Rondebosch, Cape Town, 7701, South Africa; African Center for Economic Transformation, Email: gawuah@acetforafrica.org

1 Introduction

There has been mounting pressure on governments around the world to build robust energy systems amid recent economic and geopolitical turbulence. The concept of energy vulnerability captures the susceptibility of energy systems to disruptions and shocks. For instance, Gatto and Busato (2020) define energy vulnerability as "the degree to which an energy system (or entity) is more likely to get exposed to adverse events or change, and risks to fall into traps in economic, social, environmental and governance terms". Operationally, energy vulnerability entails multiple interlinked dimensions including energy access, efficiency, consumption patterns, import dependence and clean energy share — that collectively shape a country's exposure and resilience to energy-related shocks (Nguea & Cao, 2025*;* Gatto & Busato, 2020). Recent empirical literature suggests that energy vulnerability has deleterious effects on environmental sustainability (Liu et al., 2023; Liu & Nguea, 2025) human development outcomes (Djoudji & Nguea, 2025) and food security (Cao & Nguea, 2025). However, little is known about the key determinants of energy vulnerability and potential ways to curb it, especially in the world's most energy vulnerable regions. In view of this, we examine the effect of economic policy uncertainty on energy vulnerability and assesses whether governance indicators can mitigate the impact of economic policy uncertainty on energy vulnerability in Africa.

In Africa, energy vulnerability is acute as energy systems in most countries across the continent are characterized by outdated infrastructure, limited diversification, poor energy access and heavy reliance on imported fossil fuels. These weaknesses amplify the impact of external shocks, intensify poverty, constraints industrialization and undermine productivity. With a significant population still lacking access to modern energy, reducing energy vulnerability by addressing structural weaknesses is therefore both a resilience imperative and opportunity to unlock economic potential and create pathways for inclusive and sustainable development (Fotio et al., 2024).

Economic policy uncertainty (EPU) which arises from unpredictable fiscal, trade, and regulatory policies can worsen energy vulnerability by undermining long-term investment and transition to more resilient and sustainable energy systems. Studies show that economic uncertainty exacerbates energy vulnerability through multiple channels. First, economic uncertainty delays large scale infrastructure and renewable energy investments by introducing uncertainties in the energy sector, for instance, in terms of future regulations or incentives and returns (IEA, 2022; Khan & Su, 2022; Ogede et al., 2023). Second, it incentivizes short-termism in energy choices that reinforce fossil fuel dependence, import exposure and carbon lock-in

(Adjei-Mantey & Adams, 2023). Third, EPU heightens energy price volatility that worsens affordability and deepens energy poverty (World Bank, 2023). Finally, persistent economic uncertainty reduces fiscal space and erodes investment confidence, weakening both public private and financing for energy systems (Adjei-Mantey & Adams, 2023). Altogether, high and persistent economic uncertainty sustains or even worsens the fragility of energy supply.

Recent global crises have underscored the perils of uncertainty for energy systems. Major events such as Brexit, the US-China trade war, the COVID-19 pandemic, and the Russia–Ukraine conflict triggered abrupt shifts in global energy demand, altered consumption patterns drove sharp fluctuations in energy prices (IEA, 2022; World Bank, 2023). In an increasingly interconnected global economy, these shocks quickly transmit across borders, exposing fragile energy systems, most in developing regions including Africa, to swings in supply price and investment flows.

Beyond direct effect EPU on energy systems, it has indirect impact interacting through institutions and governance indicators to shape energy vulnerability (Ekeocha et al., 2023; Nguea & Cao, 2025; Gatto & Busato, 2020). To begin with, good governance marked by government effectiveness, transparent regulations, accountability and low corruption are enablers of energy system investment and diversification which are crucial pillars of energy resilience. Dube and Horvey (2023) for instance, documents that improving institutions or governance indicators correlate with increase in investor confidence to invest in energy-related projects. In contrast, weak governance or poor institutional frameworks are widely recognized as a major driver of adverse energy system outcomes in Africa, eroding policy credibility, undermining investor confidence and limiting adaptive capacity (Yin & Liu, 2025). Africa's energy systems are, thus, doubly jeopardized when economic policy uncertainty coincides with governance deficits, yielding unpredictable policies and weak institutional oversight which combine to heighten energy vulnerability.

Despite these insights, the nexus of economic policy uncertainty, governance, and energy vulnerability in Africa remains underexplored. Existing studies typically explore these dimensions in isolation focusing on the effects on economic policy uncertainty on energy security and policy (Dagar et al., 2024; Mengfeng et al., 2024) or institutions and energy vulnerability (Dube & Horvey, 2023), with few linking economic policy uncertainty and governance to energy vulnerability in developing countries (Hnainia & Mensi, 2025). Indeed, while the concepts of economic policy uncertainty and energy vulnerability are receiving significant attention in literature, the role of governance in the relationship between them has been largely overlooked. Likewise, while recent advances in measuring energy vulnerability

(e.g. Fotio et al., 2024) highlight socioeconomic drivers of vulnerability, the role of institutions and policy stability are unexamined. However, in the context of Africa's growing energy demands alongside increasing exposure to global shocks, a good understanding of how EPU and governance quality jointly influence energy resilience/vulnerability is timely and policy relevant.

This study addresses this gap by investigating the direct and joint effects of economic policy uncertainty and governance on energy vulnerability in Africa. In doing so, we extend the recent literature on determinants of energy vulnerability and provide evidence-based insights for policy makers aiming to reduce energy vulnerability in Africa under conditions of heightened uncertainty and weak institutional capacity. We address the following important questions:

1. How does economic policy uncertainty (EPU) affect energy vulnerability in Africa?
2. To what extent does governance quality condition the relationship between economic policy uncertainty and energy vulnerability in Africa?
3. How does the impact of EPU differ in relation to different levels of energy vulnerability (EV)?

This study aims to examine how economic uncertainty relates to energy vulnerability in 26 African countries over the period 2000 to 2019, guided by the research questions above. To this end, we use the newly constructed energy vulnerability (EV) index proposed by Liu et al. (2023), together with a composite economic uncertainty index that captures both economic and political developments. Recognising the importance of governance in promoting energy security and economic stability, we further assessed whether six governance indicators (rule of law, regulatory quality, voice and accountability, control of corruption, government effectiveness, and political stability), interacted with economic uncertainty, can influence this relationship. The indicators were obtained from the Worldwide Governance Indicators (WGI), which define governance as the traditions and institutions through which authority in a country is exercised (Kaufmann et al., 2010). For the purpose of our analysis, we refer to these variables broadly as governance indicators rather than institutional quality. Empirically, we address endogeneity, cross-sectional dependence, and distributional heterogeneity by applying the Lewbel two-stage least squares estimator, Driscoll-Kraay standard errors, and Kernel-based Regularized Least-Squares (KRLS), respectively. The results quantify the direction and magnitude of these effects and provide evidence-based guidance for policymakers.

A summary of our results suggests that economic policy uncertainty significantly increases energy vulnerability. However, improvement in governance and institutional indicators play a crucial role in minimizing the unfavorable impact of economic uncertainty on energy vulnerability. Finally, distributional heterogeneous effects estimated using the machine learning–based Kernel Regularized Least Squares approach indicate that economic policy uncertainty exacerbates energy vulnerability in countries with medium to high levels of energy vulnerability, while only government effectiveness and adherence to the rule of law emerge as crucial institutional factors that appear to mitigate energy vulnerability.

The rest of the study is organized as follows. Section 2 reviews the literature linking economic policy uncertainty, governance, and energy vulnerability. Section 3 presents the data and describes the econometric procedure for the analysis. Section 4 presents and discusses the empirical findings. Section 5 concludes, provides policy insights and direction for future research.

2 Literature review

2.1 Theoretical Literature

Theoretically, the relationship between EPU and energy vulnerability (EV) is best conveyed by the real options theory. According to real options theory, when future conditions are uncertain, firms gain value by delaying irreversible investments (Bernanke, 1983; Dixit & Pindyck, 1994). Broadly construed, the real options theory suggests economic actors will hold back on investments when there is uncertainty to avoid potential losses (Kellogg, 2014). Applied to energy systems where projects are capital intensive and payoffs are long dated, this implies that heightened EPU increases EV by stalling investments that are crucial to energy system development and resilience such as generation expansion, grid upgrades, diversification, and maintenance. Unclear signals about future renewable energy subsidies or regulations, for instance, could trigger a “wait-and-see” approach to investment in renewables.

It is worth noting that due to the complex nature of energy vulnerability as operationalized by Liu et al. (2023), uncertainty-induced investment delay propagates through the five sub-dimensions that constitute EV index. First, delayed generation and grid investment postpones new electricity connections and lengthens the time needed to obtain a permanent power connection, worsening the energy access sub-index (Dixit & Pindyck, 1994). Second, deferred upgrades to plant and distribution infrastructure preserve older, less efficient capital stock, keeping energy intensity high and depressing the efficiency sub-index. Third, because renewable and nuclear capacity additions are among the most capital-intensive, longest-payoff

investments in the energy portfolio, they are disproportionately exposed to a 'wait-and-see' logic, and hence, increased EPU is expected to reduce the clean-energy component. Fourth, stalled expansion of domestic generation, combined with continuing demand, is met in the near term through continued reliance on imported fuels and existing consumption patterns, raising both the import-dependence and total-consumption components of energy vulnerability. Fifth, postponed diversification investments keep the energy mix concentrated, lowering the Shannon–Wiener diversity component of the energy security sub-index. These mechanisms can collectively influence multiple dimensions of the composite energy vulnerability index, including energy access, renewable deployment, energy efficiency, and energy security.

Also, the nexus between governance and EV is grounded in institutional theory and frameworks of public governance. North (1990) defined institutions as "the rules of the game in a society, or more formally, the humanly devised constraints that shape human interaction". These entails both formal rules and informal norms that together shape "incentives in human exchange, whether political, social or economic". According to North (1990), the value of high-quality institutions lies in reducing uncertainty and transaction costs and thus enabling investment and long-term planning. In the energy sector, institutional quality directly affects energy system resilience. Effective institutions marked by independent energy regulators, well-enforced contracts, and transparent rule of law reduce investment risk and ensure consistent maintenance, capacity expansion, and innovation which are crucial to energy system resilience. Conversely, institutional weaknesses such as rampant corruption, unclear property rights, or political instability undermine energy system resilience by distorting incentives, allowing rent-seeking and compromising system planning and resource allocation.

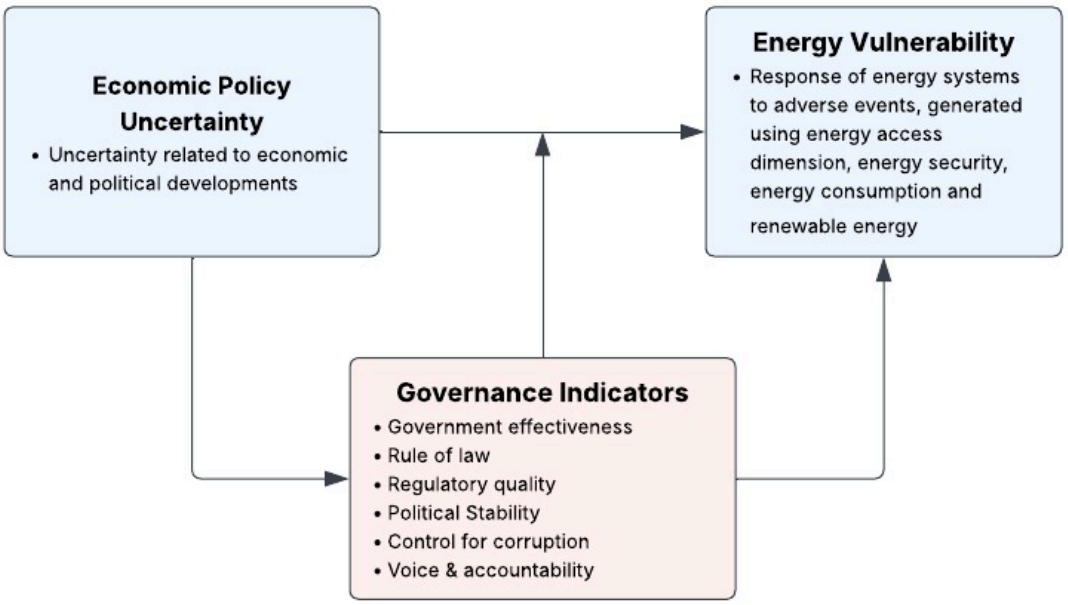
Public governance frameworks echo ideas of institutional theory by emphasizing accountability, transparency, inclusive participation, and rule-based decision-making. When applied to the energy sector, the public governance perspective emphasizes clear and consistent energy policies, strong regulatory agencies, transparent decision-making, and effective stakeholder participation as crucial to ensuring energy system resilience. Taken together, institutional theory (North, 1990) and public governance frameworks suggest strong, effective institutions and good governance systems reduce energy vulnerability by enabling accountability, stable investment, policy continuity and coordinated energy system development (Iormom et al., 2024; Musa et al., 2021; Sanusi et al., 2022), whereas institutional and governance failures increase energy vulnerability.

The last theoretical framework, risk governance and resilience theories, provides a unifying framework for understanding the interplay between economic policy uncertainty,

governance, and energy vulnerability. Risk governance theory suggests that how societies identify, assess, manage, and communicate risks determine their vulnerability to shocks (Renn, 2008; Renn et al., 2018), while resilience theory focuses on a system's ability to absorb disturbances, adapt, and continue functioning (Holling, 1973). In the energy sector, effective risk governance implies forward-looking planning, institutionalized contingency mechanisms stakeholder coordination, and credible regulatory oversight, among others, that ensures energy systems are prepared for uncertainty-related shocks (UNDP, 2024). Meanwhile, resilience theory would emphasize attributes such as redundancy, robustness, and adaptive capacity in terms of both infrastructure, energy sources, operations and policies. Crucially, governance by enabling learning, innovation, and stakeholder collaboration or otherwise shapes these resilience attributes. Together, these frameworks imply that governance act as a moderator in how uncertainty shocks impact energy vulnerability: strong, adaptive governance can act as buffer to shocks, while poor governance can amplify them.

The above theoretical perspectives collectively provide an integrated explanation of the EPU-energy vulnerability nexus. Real options theory explains why uncertainty delays irreversible investment in energy infrastructure. Institutional theory and public governance frameworks explain how governance quality influences the credibility, consistency, and implementation of energy policy under uncertainty. Risk governance and resilience theories provide the overarching lens by explaining how governance shapes the capacity of energy systems to anticipate, absorb, and adapt to shocks. The combined implication is that governance quality conditions the transmission of economic policy uncertainty into energy vulnerability. Figure 1 summarizes this conceptual framework and motivates the empirical specification that follows.

Figure 1: Conceptual framework linking economic policy uncertainty, governance quality, and energy vulnerability.



The control variables included in the empirical model also follow from this framework. GDP per capita captures resource availability for energy investment; urbanization reflects spatial demand and infrastructure pressures; internet access measures technological capability and information diffusion; and trade openness captures exposure to external energy and commodity markets.

2.2 Empirical Literature

2.2.1 Economic policy uncertainty (EPU) and energy vulnerability (EV)

Empirical evidence largely supports adverse effects of economic policy uncertainty on energy system outcomes, including reduced energy investment and consumption, especially for renewables. Cao et al. (2020), for instance, report a negative relationship between international oil price volatility and investment among renewable energy firms in China. A recent cross-country study corroborates the adverse effect of EPU on renewable energy investments (Nyiwul et al., 2025). Existing studies also report an adverse impact of EPU on renewable energy or broader energy use in the United States (Shafiullah et al., 2021) and among major blocs such as the G7 (Mengfeng et al., 2024; Dai et al., 2025), OPEC (Farouq & Sulong, 2024), and BRICS (Zhang et al., 2021; Zeng & Yue, 2021). Likewise, among a sample of 72 countries, Erzurumlu and Gozgor (2021) found that EPU is negatively associated with energy consumption.

However, the EPU-EV nexus is not uniformly negative. Several other studies reveal important nuances, including non-linear and energy-type-specific effects. Some studies find no significant effect or causality between EPU and EV, especially renewable energy investment (Appiah-Otoo, 2021), while others report asymmetric effects across positive versus negative EPU shocks and across energy types, such that positive EPU shocks reduce renewable energy consumption but increase non-renewable energy use and vice versa (Zeng & Yue, 2021). Meanwhile quantile-based evidence shows that uncertainty may coincide with energy diversification but only at upper quantiles of already highly diversified energy systems (Dagar et al., 2024). Evidence from Nigeria similarly shows temporally and distributionally heterogeneous effects of EPU on renewable energy adoption, where short-term uncertainty stimulates renewable energy consumption at lower adoption levels, but prolonged uncertainty discourages investment as deployment deepens (Iormom et al., 2025). These mixed, heterogenous and non-linear findings hint that conditioning country-specific factors including market conditions, fuel mix or institutional settings matter for how EPU translates into energy system outcomes.

2.2.2 Governance and energy vulnerability

Several studies have confirmed governance as a key determinant of energy system outcomes such as renewable energy capital flows, investment and consumption. For Africa, Dube and Horvey (2023) for a sample of some 20 African countries found that institutional quality significantly increases renewable energy capital flows, with an inverted-U pattern suggesting as institutional quality reduces, energy capital flows deteriorate. For a wider African panel, Dossou et al. (2023) report that improvements in institutional quality significantly increase renewable energy consumption and renewable electricity output in 33 African countries. Besides African sample, the existing evidence shows that institutional quality exerts significantly positive impact on renewable energy consumption in Nigeria (Iormom et al., 2025) and among other major blocs such as the OECD (Rafiq et al., 2025; Wang et al., 2022), Economic Cooperation Organization (ECO) (Mehrara et al., 2015), EU (Cadoret & Padovano, 2016) and mix sample of 38 developed and developing countries (Uzar, 2020).

Existing evidence further shows that good governance/institutional quality does not only exert positive impact on renewable energy consumption but may facilitate energy-mix substitution toward cleaner sources. For instance, among South Asian economies, Tabash et al. (2024) found that while institutional quality exerts positive impact on renewable energy consumption, the effect on consumption of fossil fuel energy is negative. Yet in other

developing country samples, Muhammad et al. (2021) found that institutional quality is positively associated with higher fossil-based consumption in the absence of effective energy-mix transition/clean energy substitution. In the African context, a similarly contrasting evidence of negative impact of governance quality on renewable energy consumption (e.g., Dossou et al., 2024) are often attributed to the fact that governance quality in Africa remains far below the threshold needed to redirect finance, policy, and planning away from fossil-based systems toward renewable energy.

Studies that model political incentives and institutional design show that ideology, regime characteristics, and interest-group pressures also influence energy system outcomes, particularly renewable energy consumption and investment outcomes. Specifically, left and center-oriented governments, democratically governed countries, and countries with parliamentary systems reported to be more supportive of renewable energy investment (Abban & Hasan, 2021; Cadoret & Padovano, 2016; Sequeira & Santos, 2018). Meanwhile, in terms of energy use, democratic institutions and fiscal decentralization have been found to promote renewable energy consumption and lower non-renewable energy use (Chen et al., 2021; Su et al., 2021). On the contrary, other works shows that political economy frictions such as political risk, lobbying and political party polarization depress renewable energy consumption (Wang et al., 2022; Cadoret & Padovano, 2016; Apergis & Pinar 2021).

2.2.3 Economic policy uncertainty (EPU), governance, and energy vulnerability nexus

Emerging empirical evidence suggests that governance or institutional quality, moderates the impact of uncertainty. William and Fengrong (2022) reports that institutional quality and political conditions moderate the adverse impact of EPU on innovation output and quality, which could be instrumental for developing energy products. Within the energy domain, a growing body of evidence shows that governance conditions the impact of EPU on energy-related outcomes including renewable energy innovation, energy poverty and energy consumption (Feng & Zheng, 2022; Che & Jiang, 2021; Hnainia & Mensi, 2025). The effects of EPU on these energy system outcomes are either significant only in high institutional quality countries (Feng & Zheng, 2022) or depend on specific governance dimensions such as government effectiveness and regulatory quality (Hnainia & Mensi, 2025). However, these studies typically examine the moderating role of governance in the relationship between uncertainty and single energy outcome (innovation, consumption, poverty), not systemic and multidimensional energy vulnerability.

Existing evidence from Africa suggests that uncertainty shocks are material, but governance may not always be strong enough to moderate them effectively. For a sample of 47 African countries Ekeocha et al. (2023), for instance, find that while uncertainty exert considerable influence on economic performance, governance do not significantly moderate the uncertainty-economic performance relationship. This could mean that African institutions may not yet be robust enough to counteract the adverse effects of uncertainty shocks on economic performance. Still, regional heterogeneity showed greater resilience for Central and North Africa compared to East and West Africa suggesting that institutional capacity and structural characteristics may lead to differences in uncertainty responses differently across contexts.

2.2.4 Literature gaps and contributions

The existing empirical literature reviewed in Section 2.2 leaves a clear gap that motivates the paper's contribution. First, the literature on EPU-EV nexus is limited in Africa, where the weak energy systems and the reliance on oversea investments in energy imports make the study necessary. Our study contributes to the knowledge by using robust energy vulnerability measure proposed by Liu et al (2023). Second, while a growing literature have established EPU–energy and governance–energy linkages, the moderating role of governance in the EPU–EV relationship remains largely untested, especially in Africa. For African countries, this gap is policy relevant as they face "double exposure" combining higher baseline uncertainty (due to political cycles, external shocks, etc.) with institutional constraints. The key point, however, is not simply that governance matters but that which dimension and what levels of improvements are crucial to achieving resilient energy systems because without sufficiently strong, credible, and transition-oriented institutions, institutional gains may drive energy use without delivering clean, sustainable and resilient energy systems.

Unlike Dube and Horvey (2023) who used single index (economic freedom index) for the analysis, this study used six dimensions of governance to explore their moderating effects on EV through EPU. Addressing this gap is, therefore, essential for understanding whether and at what levels of vulnerability governance reforms can meaningfully insulate energy systems from uncertainty-driven vulnerability. Lastly, employ a machine learning based analysis to explore the different levels of EPU affecting varying levels of EV, which most studies on African have not considered.

3 Data and Methods

3.1 Data sources

This study utilizes cross-national data for a sample of 26 African countries from 2000 to 2019 to estimate the effects of economic policy uncertainty (EPU) on energy vulnerability (EV) and the moderating role of governance. Table A1 displays the list of sampled countries (see Appendix). We use data on energy vulnerability index obtained from the work of Liu et al. (2023) as the dependent variable. The main independent variable of interest is EPU. This variable is proxied by world uncertainty index (Ahir et al., 2018). We obtained data on governance from World Governance Indicators (control of corruption, government effectiveness, political stability and absence of violence, rule of law, regulatory quality, and voice and accountability) provided by the World Bank's World Development Indicators (WDI) dataset (World Bank, 2024). The governance indicators are scored between -2.5 and 2.5, where positive integers correspond to better governance. Data on the control variables including GDP per capita, urbanization, access to internet, and trade are garnered from world development indicators. These control variables were chosen based on empirical literature on the subject matter (see Dube & Horvey, 2023; William & Fengrong, 2022). Summary of description of variables and their respective data sources are disclosed in Table 1.

3.1.1 Justification of variables

Outcome variable

Energy vulnerability (EV): Energy Vulnerability (EV) denotes the susceptibility of an energy system to disruptions and adverse shocks, risking ability to ensure reliable, affordable energy supply (Dong et al., 2024). In practice, energy system is vulnerable if it is easily disrupted by adverse shocks such as price spikes, supply interruptions, or demand surges, often worsening energy access and affordability (Dong et al., 2024). In line with the recent empirical works of Fotio et al. (2024) and Djoudji and Nguea (2025), our main outcome variable is energy vulnerability index constructed by Liu et al. (2023). Liu et al. (2023) computed the EV using improved entropy method covering five key areas of energy: energy access, energy efficiency, renewable energy, total energy consumption, and energy security (see Table A1 in the Appendix). This variable is considered because it employs wider range of variables to measure EV, making it advantageous over variables like energy consumption or only renewable energy.

Independent variable of interest

Economic policy uncertainty (EPU): Economic policy uncertainty captures unpredictability in the economic policy environment, including uncertainty about fiscal, monetary, and regulatory

decisions that alter expectations and create hesitation among economic actors. Baker et al. (2016) formalized economic uncertainty or EPU by developing index based on the frequency of newspaper coverage signaling unclear future policies. The main independent variable is EPU proxied by world uncertainty index (WUI) (see Ahir et al., 2018). The index captures uncertainty related to economic and political developments, encompassing both long-term and near-term concerns (e.g., uncertainty created by the United Kingdom's referendum vote in favor of Brexit). According to Ahir et al. (2018), the index is based on the accumulation of the number of times "uncertainty" is mentioned in the Economist Intelligence Unit (EIU) country reports, constructed at a quarterly frequency from 1996Q1 to 2018Q2. We then aggregate the quarterly frequencies to obtain annual frequencies consistent with the other control variables. The WUI is preferred to the conventional EPU (computed based on newspaper information) because the WUI is based on EIU reports tailored to national economic and political developments, which mitigates concerns about the ideological bias mostly associated with newspaper datasets (Beach and Hanlon, 2023).

In line with the first hypothesis, EPU can adversely affect investment decisions, fiscal planning, and regulatory stability, all of which are critical for energy system development (Adjei-Mantey & Adams, 2023). Heightened uncertainty discourages long-term energy investments, increases financing costs, and weakens supply reliability, thereby intensifying energy vulnerability. This effect can be particularly marked in African economies, where energy infrastructure and policy credibility remain fragile.

Interaction variables

Governance quality: In this study, governance quality is operationalized using the six WGI dimensions (Kaufmann, Kraay, & Mastruzzi, 2011), which measure key aspects of institutional quality in the remit of institutional economics (North, 1990). While institutional quality is the broader concept encompassing the formal and informal rules that structure economic and political interaction, (North, 2019; Acemoglu, et al., 2005) governance quality captures its observable, measurable expression through state capacity, accountability, regulatory effectiveness, and rule-based decision-making. In the energy sector, governance denotes the policy and regulatory frameworks, and institutional arrangements that shape energy resource development, infrastructure investment, and service delivery. Most existing empirical studies use these indicators as proxy for institutional quality (see e.g., Karimu et al., 2017; Gbolonyo & Tetteh, 2025). As explained in Section 2.2.3, governance quality, when interacted with EPU, can influence energy vulnerability by shaping policy credibility, regulatory effectiveness, and

institutional stability. More specifically, strong governance frameworks such as political stability, voice and accountability, government effectiveness, mitigate uncertainty by ensuring transparency, continuity, investor confidence, and enforcement. On the other hand, weak governance can amplify uncertainty-induced distortions in energy markets and infrastructure development. For instance, in settings like Africa, political instability and weak institutional accountability undermine transparency and policy effectiveness, thereby weakening electricity access initiatives and intensifying energy vulnerability (International Energy Agency [IEA] 2014; Acheampong et al., 2022).

Control variables

GDP per capita: In line with Dong et al. (2024), we include GDP per capita to capture a country's level of economic development which theoretically shows countries' capacity to finance energy infrastructure (Paul et al., 2025). Additionally, higher income levels are associated with improved energy access, system resilience, and diversification, thereby reducing energy vulnerability.

Urbanization: We control for urbanization since it influences energy demand and infrastructure efficiency. Albeit urban concentration could enhance economies of scale and expansion of energy infrastructure (Sadorsky, 2014; Fotio et al., 2024), rapid and unplanned urbanization (e.g., informal settlements) can exert pressure existing systems, increasing energy vulnerability especially in many African contexts (Garschagen & Romero-Lankao, 2015; Dong et al., 2024)

Access to internet: Access to internet represent a crucial aspect of information and communication technology (ICT). Regarding the implications of internet on energy vulnerability, we expect internet to reduce energy vulnerability by fostering knowledge, improving energy efficiency, and supporting cleaner energy and energy affordability (Zhao et al., 2022; Zhang et al., 2023; Dong et al., 2024).

Trade openness: We include trade openness to capture economic globalization. On the one hand, openness can enhance energy system resilience by facilitating access to energy technologies, capital, and diversified supply sources. On the other hand, excessive reliance on energy imports may expose economies to external shocks. For instance, Fotio et al. (2024) finds evidence that economic globalization exacerbates energy vulnerability in Africa.

Table 1: Variable description and data sources

Variable	Symbol	Description	Data source
Dependent variable			
Energy vulnerability index	EV	Response of energy systems to adverse events, generated using energy access dimension, energy security, energy consumption and renewable energy. The index is from 0 (no vulnerability) to 1 (highly vulnerable).	Liu et al. (2023)
Independent variable			
Economic policy uncertainty index	EPU	World uncertainty index. The index captures uncertainty related to economic and political developments, regarding both long-term and near-term concerns. It is based on the accumulation of the number of times "uncertainty" is mentioned in the Economist Intelligence Unit (EIU) country reports. A higher index shows a higher level of uncertainty and vice versa.	Ahir et al. (2018)
Interaction variables			
Voice and accountability	VA	Perceptions of the degree to which citizens can participate government selection, express their opinions without intimidation (score: -2.5 to 2.5).	World Bank (2024)
Political stability	PS	Perceptions of the probability political instability, politically motivated violence (score: -2.5 to 2.5).	World Bank (2024)
Government effectiveness	GE	Perceptions of the quality of public services, civil service independence, policy formulation and implementation, and government commitment (score: -2.5 to 2.5).	World Bank (2024)
Regulatory quality	RQ	Perceptions of the government's capacity to formulate policies that encourage the growth of the private sector (score: -2.5 to 2.5).	World Bank (2024)
Rule of law	ROL	Perceptions of the level of agents trust in social norms, property rights, contract enforcement,	World Bank (2024)

		the police, and the courts, likelihood of crime and violence (score: -2.5 to 2.5.)	
Control of corruption	CC	Perceptions of the extent to which public power is exercised for personal gain (score: -2.5 to 2.5.)	World Bank (2024)
Control variables			
GDP per capita	GDPpc	GDP per capita (constant 2015 US$)	World Bank (2024)
Urbanization	URB	People living in urban areas (% of total population)	World Bank (2024)
Access to Internet	ICT	Individuals using the Internet (% of population)	World Bank (2024)
Trade	TR	Exports plus imports of goods and services as a share of GDP (% of GDP)	World Bank (2024)

Source: Authors' compilation

3.2 Model specification

To examine the impact of EPU, governance and other explanatory variables on energy vulnerability, we draw motivation from Cao and Nguea (2025) to specify the baseline empirical model as follows:

$$EV_{it} = \beta_0 + \beta_1 EPU_{it} + \beta_2 GOV_{it} + \beta_3 lnGDPpc_{it} + \beta_4 lnURB_{it} + \beta_5 lnICT_{it} + \beta_6 lnTR_{it} + \varepsilon_{it} \quad (1)$$

where ln is logarithmic operator, EPU_{it}, $GDPpc_{it}$, URB_{it}, ICT_{it}, TR_{it} and GOV are economic policy uncertainty, GDP per capita, urbanization, internet access, trade (% of GDP) and governance indicators (role of law, voice and accountability, regulatory quality, political stability, and government effectiveness), respectively, for country i at time t. β_0 and ε_{it} are the constant and error terms, respectively. The main coefficient of interest is β_1, which measures the impact of EPU on EV.

Consistent with Brambor et al. (2006), the role of governance quality is examined empirically through interaction terms between economic policy uncertainty and each governance dimension. The sign and significance of the interaction coefficient (δ), together with the corresponding marginal effect, determine whether and how governance quality conditions the EPU–energy vulnerability relationship. We extend Eq.1 by including an interactive term of EPU and GOV in Eq. 2.

$$EV_{it} = \beta_0 + \beta_1 EPU_{it} + \beta_2 GOV_{it} + \delta(GOV \times EPU)_{it}\, \beta_3 lnGDPpc_{it} + \beta_4 lnURB_{it} + \beta_5 lnICT_{it} + \beta_6 lnTR_{it} + \varepsilon_{it} \quad (2)$$

where $GOV \times EPU$ is the interactive term EPU and each GOV variable. The rest of the variables are as already defined. The resultant net effect from the interaction between EPU and GOV on EV can be estimated as follows:

$$\frac{\partial(EV_{it})}{\partial(EPU_{it})} = \beta_1 + \delta_2(\widehat{GOV_{it}}) \quad (3)$$

where $(\widehat{GOV_{it}})$ is the mean threshold of the governance indicator(s). We calculated the marginal effects at using the averages of the GOV variables.

3.3 Estimation techniques

Lewbel Two Stage Least Square technique

The study uses the Lewbel (2012) two-stage least squares (Lewbel IV-2SLS) as our baseline technique. This estimator addresses endogeneity by constructing its internal instruments, which are heteroskedasticity-based (Lewbel, 2012). Specifically, the heteroskedasticity-based instruments are generated by multiplying the residuals of the auxiliary equation by the mean-centered form of each included exogenous variable, which serves to correct for endogeneity (Lewbel, 2012). One of the main advantages of the Lewbel IV-2SLS estimator is that it does not need to satisfy the standard exclusion restrictions. Thus, the estimator addresses identification challenges, particularly in cases where suitable external instruments are either unavailable or weak for identifying structural parameters in regression models with endogenous or mismeasured regressors (Lewbel, 2012). Additionally, this estimation technique provides reliable estimates without relying on external instruments (Lewbel, 2012). Barkat et al. (2023) opined that the Lewbel's (2012) estimator outperforms other estimators that use external instruments. The use of the Lewbel IV-2SLS is consistent with prior studies (Asaloko et al., 2025; Ntsama et al., 2025; Acheampong & Opoku, 2024; Njoya et al., 2024). It is worth noting that since the Lewbel IV-2SLS uses second moment conditions to explore heteroskedasticity patterns rather than excluded variables, the instruments generated instruments may have low correlation with endogenous variables. The low correlation may create weak instrument problems. We therefore test the identification of and the strengths of the instruments to ensure that the results are robust.

Notwithstanding, the Lewbel IV-2SLS does not explicitly accommodate potential cross-sections dependence problems arising from the fact that most Africa countries have similar growth patterns and a policy shock in one country may transmit to other countries. To circumvent this potential challenge, we used the Driscoll-Kraay (1998) [DKSE] Standard error (DKSE) to test the robustness of the Lewbel 2SLS estimates. The DKSE approach is specifically utilized since it can account for cross-sectional dependence commonly present in panel data. It also addresses time-invariant differences, thereby reducing potential bias (Fonchamnyo, 2022). More importantly, the approach is applicable in balanced as well as unbalanced panel data and can be employed in the presence of spatial and serial dependence (Heberle & Sattarhoff, 2017). Finally, the DKSE method automatically adjusts for dependence in the residual unlike methods that require specifying how cross-sectional units are related.

3.4 Distributional impact of economic uncertainty (EPU) on energy vulnerability (EV)

To address our third research question, we explore the extent of the impact of EPU on EV. In essence, we estimate the effect of EPU on different levels of EV using the panel Kernel-Regularized Least Squares (KRLS). The KRLS technique proposed by Hainmueller and Hazlett (2014) is a non-parametric regression method which relaxes assumptions about the functional form of relationships between variables. It is useful when dealing with complex, nonlinear relationships where standard linear regression models may not capture underlying patterns. More importantly, the KRLS is appropriate for handling model misspecification and produces more reliable and unbiased estimates in non-linear models (Hainmueller & Hazlett, 2014; Sarkodie and Owusu, 2020). The novelty of the KRLS is that it provides pointwise marginal effects using machine learning algorithm and thus allowing for better interpretation of how the predictor variable (EPU) affects the outcome variable (EV) at different levels. Hainmueller and Hazlett (2014) provide a more detailed mathematical expression of the KRLS technique. However, following Sarkodie (2021) and Gbolonyo et al. (2025), the KRLS approach can simply be expressed as:

$$\frac{\partial \hat{y}}{\partial x_i^{(d)}} = \frac{-2}{\sigma^2} \sum_j \sum_i c_{ie} \frac{-\| x_i - x_j \|^2}{\sigma^2} (x_i^{(d)} - x_j^{(d)}) \qquad (4)$$

where $\frac{\partial \hat{y}}{\partial x^{(d)}}$ indicates the pointwise derivative of dependent variable y with respect to x is the regressors, c_i represents the weight of the regressors, e denotes the exponential function, i is the unit of observations, j denotes a single observation, and σ^2 is the kernel bandwidth.

3.5 Summary Statistics

The summary statistics of the variables are reported in Table 2. The average energy vulnerability is 0.344 while economic uncertainty averaged 0.194 suggesting that most countries in the data are moderately vulnerable and have lower economic uncertainties. Governance indicators (voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption) all exhibit negative mean values ranging from -0.469 to -0.584, suggesting overall weak institutional quality with considerable cross-country heterogeneity. The average GDP per capita is $2,494 with large variation across countries as shown by the large standard deviation ($2,148). On average, 45.9% of the countries are urbanized, trade constitute 69.6% of GDP while only 13.6% of the sample have access to internet. Additionally, Figure 1A shows that while all the countries combined have low EV score on average, countries like Congo DRC, Tanzania and Ethiopia exhibit higher vulnerability (above 0.5) compared to Tunisia, Egypt and Morocco show lower EV (below 0.2). Likewise, Figures 1B to 1D (see appendix) depicts a large variation within and across countries for the institutional variables, suggesting heterogenous institutional development across the observed economies.

Table 2: Summary statistics

		Obs	Mean	SD	Min	Max
Energy vulnerability index	EV	520	0.344	0.142	0.095	0.59
Economic policy uncertainty index	EPU	520	0.194	0.196	0.000	1.343
Voice and accountability	VA	494	-0.469	0.691	-1.734	.983
Political stability	PS	494	-0.491	0.852	-2.474	1.201
Government effectiveness	GE	494	-0.562	0.599	-1.841	1.15
Regulatory quality	RQ	494	-0.524	0.625	-2.202	1.197
Rule of law	ROL	494	-0.559	0.630	-1.87	1.024
Control of corruption	CC	494	-0.584	0.578	-1.555	1.245
GDP per capita	GDPpc	520	2493.509	2147.807	252.807	10956.945
Urbanization	URB	520	45.875	16.310	14.74	89.741
Access to Internet	ICT	517	13.569	16.699	.006	84.12
Trade	TR	487	69.579	25.438	17.225	156.862

Note: Obs is Observation; SD is the Standard Deviation; Min is Minimum; Max is Maximum

Figures 1 and 2 preview the correlation between economic policy uncertainty, governance variables and energy vulnerability. Figure 1 shows a positive correlation between economic policy uncertainty and energy vulnerability across African countries, with notable heterogeneity in their distributions. The figure shows that Congo DRC, Tanzania, Mozambique, and Ethiopia have higher energy vulnerability levels (0.45-0.52) with varying economic uncertainty. In contrast, Tunisia, Egypt, Algeria, Morocco and Mauritius show lower energy vulnerability (0.10-0.15) and moderate economic uncertainty. Figure 2 is presented as descriptive evidence illustrating cross-country variation in uncertainty and vulnerability levels rather than evidence of a causal relationship. The considerable heterogeneity in the scatter plot, where countries with similar uncertainty levels show markedly different vulnerability outcomes, motivates both the empirical analysis and the exploration of conditioning factors such as governance quality.

Figure 2: Bivariate relationship between economic policy uncertainty and energy vulnerability

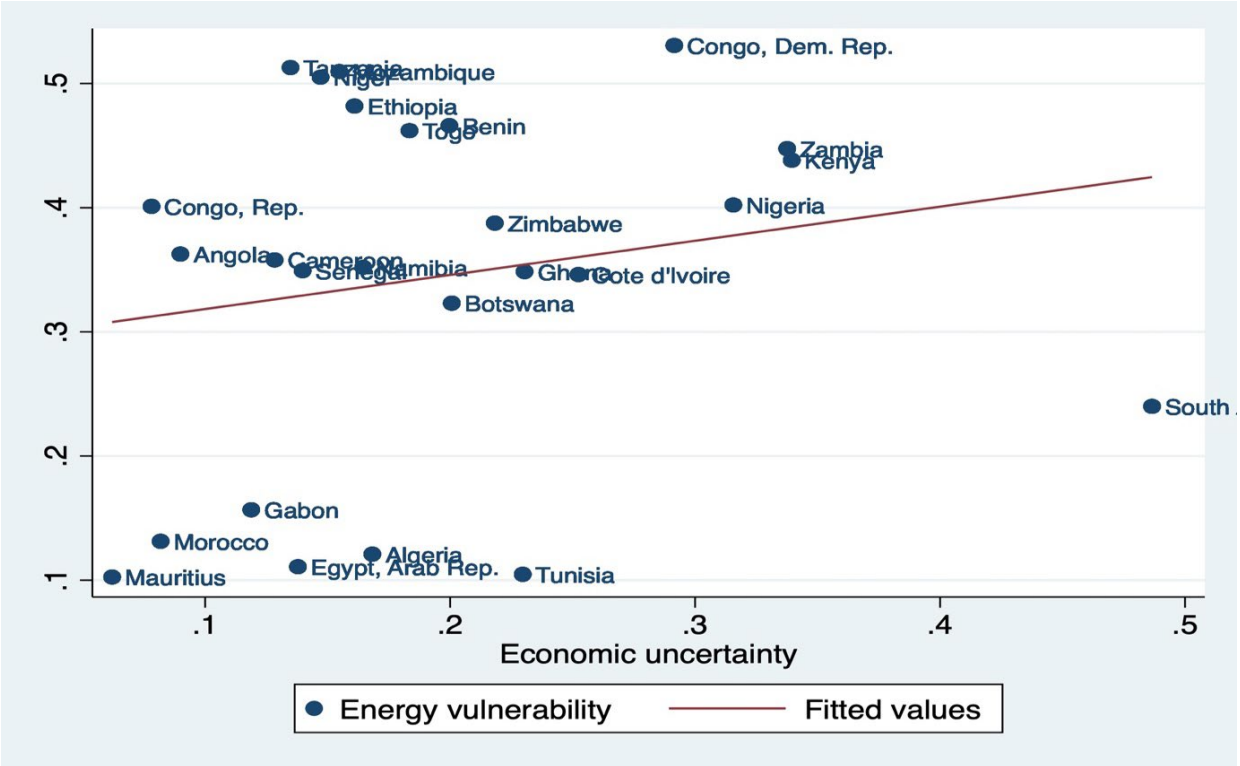
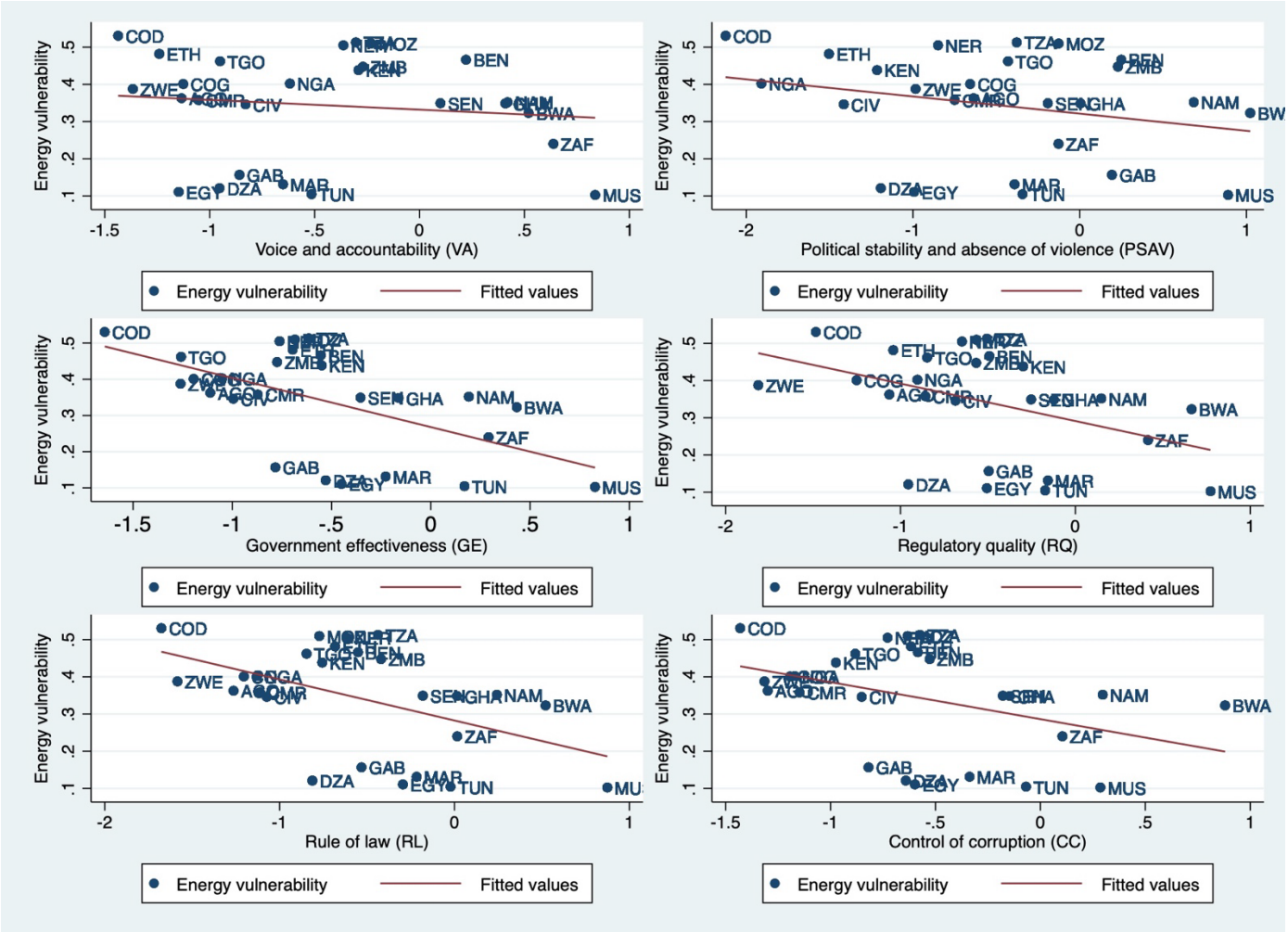


Figure 3 depicts the scatter plots showing the correlation between EV and each governance variable, which shows a consistent and strong negative correlation relation is recorded for each institutional variable and EV. Specifically, countries with weaker institutions (Congo DRC, Ethiopia, Zimbabwe) exhibit higher vulnerability, while those with stronger institutions

(Mauritius, South Africa, Tunisia) exhibit lower vulnerability. This is supported by the correlation matrix in Table A5, as all the institutional variables have negative and significant correlation with EV. As intuitions become more robust (negative to positive), energy policies improve, lowering EV.

Fig. 3: Bivariate relationship between governance indicators and energy vulnerability



4. Results and Discussions

4.1 Baseline results

Table 3 presents the main results for the Lewbel 2SLS from the models as specified in equations 1 and 2. Specifically, Model 1 is the results for equation 1 while Model 2 to 12 are the results for the interaction terms between economic policy uncertainty and the individual institutional variables (see Eq. 2) and their corresponding marginal effects.

The coefficient for the economic policy uncertainty for model 1 shows that economic

policy uncertainty (EPU) has positive and significant effects of energy vulnerability (EV) for the 26 countries considered in the study. Specifically, a one-unit increase in economic policy uncertainty significantly increases EV across all our model specifications. This finding is consistent with the prediction of real options theory (Bernanke, 1983; Dixit and Pindyck, 1994; Kellogg, 2014), which argues that heightened uncertainty stalls irreversible decisions. One plausible explanation is that policy unpredictability reduced investment confidence, delayed infrastructure development, and disrupted long-term energy planning, though these mechanisms are not directly tested in the present model, this result is consistent with the proposition that macroeconomic instability and policy unpredictability contribute to energy system fragility.

The adverse effects of EPU on EV resonate with the African context, where energy infrastructure is already fragile and heavily dependent on foreign investment and donor funding. Africa's energy vulnerability manifests in many ways, including unreliable supply (Berhe and Khemani, 2026), energy poverty, where 590 million people in sub-Saharan Africa still lack access to electricity (International Energy Agency, 2022) and overdependence on overseas energy services. We emphasise that although the present study does not explicitly estimate investment channels, one plausible mechanism through which EPU suppresses a robust energy system is by discouraging long-term domestic and foreign investment in energy infrastructure, slowing capacity expansion and diversification. In settings like Africa, where domestic capital markets are thin and energy infrastructure depends substantially on external financing, uncertainty is likely to carry a substantial penalty than in more financially autonomous economies. Our result is consistent with the findings of Liu et al. (2024) where the authors reported geopolitical risk increases vulnerability of energy markets and Khan and Su (2022) who reported that EPU reduces energy investment. However, the outcome, is in contrast with Wang et al. (2025) who reported that geopolitical risk positively influences energy transition. The authors suggest that geopolitical risks compel countries to be innovative and invest in alternative energy sources to reduce energy vulnerability. Our result is different from Wang et al. (2025) potentially because we focus exclusively on African countries where innovation and alternative energy sources is low. As documented in Shankar (2020), global policy uncertainties reduce the propensity of firms in African countries to innovate, making our results context-specific.

We estimate the coefficients for the interaction terms between EPU and individual governance variables with their corresponding marginal effects computed at the means. The discussion and explanation would however focus on the individual governance indicators and

the interaction effects. Table 3 reports that voice and accountability (VA), political stability (PS), regulatory quality (RQ) and control for corruption (CC) have positive and significant effects on EV. Specifically, an increase (from -2.5 to +2.5) in VA, PS, RQ and CC by one-unit result in 3.2%, 3.6%, 1.3% and 1.3%, respectively, suggesting that as these variables improve (-2.5 to +2.5) energy systems become more vulnerable. These underscore the general weak regulatory framework in most African countries, which make them unable to improve energy supply and distribution. For example, Obi et al. (2025) argued that energy services in Africa are mostly centralized and managed through rigid top-down approach led by a single governmental agency which is characterized with inefficiencies. Because of the inefficiencies, energy services cannot meet the needs of the people, making them vulnerable even in countries with relatively higher political stability and control for corruption. Furthermore, controlling corruption attracts more scrutiny and higher standards for energy security assessments, which fuel bureaucratic practices and delays in completing energy projects. This aligns with Isser et al. (2024) who documents that although there has been progress in enhancing accountabilities in public institutions in most African countries, yet most countries are constrained by weakness of checks and balance and uneven distribution of individual institutions. Our findings, however, contradict the conclusions from Dube and Horvey (2023), who found supportive effects of institution on energy investment. One reason could be that the authors used one institutional index which could mask the potential effects of individual institutional variables.

The negative coefficients for government effectiveness (GE) and rule of law (ROL) indicating these institutions reduce energy system vulnerability. This means that countries with more effective governments and robust legal frameworks experience lower energy vulnerability, since better governance enables infrastructure investment, policy implementation, and market regulation that enhance energy security as broadly alluded to by the institutional theory (North, 1990). However, our results contradict Wang et al. (2025) where the authors show that governance worsen energy transition, potentially making countries energy vulnerable.

The dynamics of the results for the individual governance indicators uncover the fact that some governance variables are more effective than others in terms of energy services and projects. Thus, using a single institution variable or index as presented by Dube and Horvey (2023) and Wang et al. (2025) could limit the understanding of how individual aspects of governance affects energy vulnerability. The positive interaction terms between the governance indicators and EPU demonstrate that governance quality does not overturn the adverse effects of EPU on EV. As indicated earlier, governance quality in Africa is notably poor, limiting the

capacity to absorb adverse external and internal shocks. For instance, when there are external shocks, most African countries struggle to provide short- and long-term stability. Ekeocha et al. (2023) reports similar outcome where Africa's institutional quality is unable to nullify the effects of economic policy uncertainties. This suggests institutional frameworks designed for stable environments prove insufficient during uncertainty shocks, as heightened unpredictability overwhelms governance capacity, magnifying energy system fragility regardless of institutional strength. Although some individual governance variables have negative coefficients their marginal effects are positive and significant. This difference can be attributed to the fact that the current level of governance variables (on the average) is not strong enough to completely mitigate EPU as documented by studies such as Ekeocha et al. (2023).

Regarding the control variables, GDP per capita, urbanization, and ICT have negative and significant effects on EVI. Specifically, we find that across all specifications, an increase in GDP per capita, urbanization and ICT significantly decrease EV. High GDP per capita and ICT penetration are indications of infrastructure and human capital development, which is important for investment and energy use efficiency. On the other hand, trade (% of GDP) has consistent positive and significant effects on EV, implying that international integration increases exposure to international energy volatility or supply disruptions. Dramani et al. (2025) document that African countries are vulnerable to oversee policy uncertainties like trade policy uncertainty, which adversely impact Africa's economic performance through trade. Table 2 reports that average trade among the 26 African countries is about 70% of GDP. Overdependence on international trade may heighten vulnerability through import dependence on petroleum products and exposure to global commodity price fluctuations.

The bottom part of the Table shows an R-square of over 70% for all the models, suggesting that most of the variation in the outcome variable is influenced by the joint effects of the explanatory variables. Essentially, the diagnostics confirm that the model is robust and that the instrumental variable estimates are unlikely to suffer from weak-instrument bias, thereby supporting the reliability of the estimated coefficients. For instance, the Kleibergen–significant), indicating that the instruments are sufficiently correlated with the endogenous regressor(s). In addition, the Kleibergen–Paap F-statistic exceeds conventional critical thresholds (more than 10), suggesting that the instruments are not weak.

Table 3: Economic policy uncertainty, governance, and energy vulnerability in Africa [Lewbel 2SLS Estimates]

	Uncond-itional	EPU ×VA	Uncond-itional	EPU ×PS	Uncond-itional	EPU ×GE	Uncondi-tional	EPU ×RQ	Uncond-itional	EPU ×ROL	Uncond-itional	EPU ×CC
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
lnGDPpc	-0.106***	-0.107***	-0.106***	-0.109***	-0.083***	-0.0086***	-0.098***	-0.102***	-0.089***	-0.093***	-0.095***	-0.098***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
lnURB	-0.041***	-0.043***	-0.048***	-0.043***	-0.070***	-0.083***	-0.054***	-0.061***	-0.064***	-0.074***	-0.056***	-0.060***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.013)	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)
lnICT	-0.031***	-0.030***	-0.031***	-0.029***	-0.031***	-0.027***	-0.032***	-0.027***	-0.032***	-0.026***	-0.033***	-0.027***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
lnTR	0.046***	0.048***	0.033***	0.037***	0.046***	0.060***	0.048***	0.059***	0.047***	0.056***	0.048***	0.047***
	(0.010)	(0.010)	(0.011)	(0.010)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
EPU	0.094***	0.077***	0.154***	0.151***	0.135***	0.180***	0.137***	0.175***	0.133***	0.185***	0.137***	0.124***
	(0.020)	(0.014)	(0.022)	(0.021)	(0.022)	(0.024)	(0.022)	(0.022)	(0.023)	(0.025)	(0.022)	(0.022)
VA	0.032***	0.032***										
	(0.005)	(0.006)										
EPU ×VA		-0.005										
		(0.017)										
PS			0.036***	0.027***								
			(0.004)	(0.006)								
EPU ×PS				0.037**								
				(0.018)								
GE					-0.010	-0.042***						
					(0.008)	(0.010)						
EPU ×GE						0.113***						
						(0.026)						
RQ							0.013**	-0.015*				
							(0.006)	(0.008)				
EPU ×RQ								0.107***				
								(0.022)				
ROL									-0.002	-0.035***		
									(0.006)	(0.009)		
EPU ×ROL										0.123***		
										(0.026)		
CC											0.012*	-0.012
											(0.007)	(0.011)
EPU ×CC												0.054**
												(0.026)
Total effect		Na		0.133***		0.117***		0.119***		0.116***		0.092***
				(0.017)		(0.016)		(0.016)		(0.017)		(0.015)
Constant	1.149***	1.152***	1.213***	1.204***	1.063***	1.047***	1.114***	1.102***	1.082***	1.081***	1.106***	1.124***
	(0.045)	(0.041)	(0.046)	(0.044)	(0.044)	(0.041)	(0.046)	(0.042)	(0.044)	(0.041)	(0.044)	(0.041)
Observations	438	438	438	438	438	438	438	438	438	438	438	438
R-squared	0.786	0.786	0.788	0.791	0.763	0.767	0.764	0.767	0.763	0.767	0.763	0.767
Idstat	50.179	68.279	49.771	46.406	48.571	56.895	50.139	56.910	48.989	46.692	49.048	42.122
Idp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Widstat	34.222	287.765	37.872	88.861	36.620	192.769	34.674	96.822	36.321	114.60	34.918	162.228

Note: na means Not applicable; Standard errors in parentheses; $^{*}p<0.10$, $^{**}p<0.05$, $^{***}p<0.01$; Dependent variable: Energy vulnerability (EV); idstat is LM test statistic for under-identification (Anderson or Kleibergen-Paap); idp is p-value of under-identification LM statistic; widstat is F statistic for weak identification (Cragg-Donald or Kleibergen-Paap)

4.2 Robustness Checks

In this section, we estimate the baseline model using the Driscoll-Kraay Standard error (DKSE) and the Kernel-Based Regularized Least Squares (KRLS) to ensure the robustness of the baseline results. The results for the DKSE are presented in Table 4 and Table 5 reports on the KRLS.

4.2.1 Alternative estimation of technique (Driscoll-Kraay Standard error)

The DKSE results in Table 4 presents similar outcomes in relation to our benchmark regressions in Table 3[5]. For instance, in Table 4, the coefficients on economic policy uncertainty are positive and significant (Model 1), suggesting that policy uncertainty increases energy vulnerability. Likewise, GDP per capita, urbanization and internet access have significant negative relationship with EV while trade has positive association with EV. Again, the coefficient for the individual governance variables such as political stability, regulatory quality and control for corruption have positive relationship with EV, while government effectiveness and rule of law decrease energy vulnerability. Additionally, we find the coefficients of the interaction terms and their corresponding marginal effects to be positive similarly reported in Table 3. Thus, after accounting for potential biases in the standard errors, the results are consistent. We therefore argue that the main results in Table 3 are robust and suitable for policy purposes.

4.2.1 Energy importing countries versus energy-exporting countries

In response to concerns that countries' positions as net energy importers or exporters may shape their exposure to policy uncertainty, we further examine whether the relationship between economic policy uncertainty and energy vulnerability varies according to energy trade position. We distinguish between energy-importing and energy-exporting countries and interact the energy-importer indicator with economic policy uncertainty. The results, reported in Table A6 (see Appendix), provide evidence of significant heterogeneity across the two groups. The coefficient on economic policy uncertainty is positive but statistically insignificant for the

[5]Before we estimate DKSE method, we test for cross-sectional dependence (CD) because most African countries exhibit common vulnerability and macroeconomic dynamics. This implies that any potential shock could simultaneously and homogenously affect all countries, causing the estimates to be inefficient. If the data has CD, it could potentially affect the standard errors and render our coeffects spurious. The results reported in Table A3 (see appendix) reveal significant correlations across panel groups for most variables. Except PS, GE, RQ and ROL, the rest of the variables are cross-sectionally dependent. This suggests that for most of the variables, any shock or unobserved factors affecting one country could be transmitted to other countries which could affect the standard errors and make the results inefficient. Due to the results from the CD test, we use the Driscoll-Kraay that corrects the standard errors to ensure that the results are robust.

reference group of energy-exporting countries. In contrast, the interaction between EPU and the energy-importer dummy is positive and statistically significant. This indicates that the estimated relationship between economic policy uncertainty and energy vulnerability is significantly stronger among energy-importing countries than among energy-exporting countries. The positive interaction suggests that energy-importing economies experience a stronger increase in energy vulnerability as economic policy uncertainty rises.

This finding is consistent with the possibility that dependence on external energy markets increases the exposure of energy-importing economies to uncertainty. Policy uncertainty can affect investment decisions, exchange-rate conditions, financing costs, trade flows and expectations, which may be particularly consequential for economies that rely on imported energy to meet domestic demand. In such economies, uncertainty may compound exposure to international energy-price movements and supply-side disruptions, thereby increasing energy vulnerability. Energy-exporting countries may have greater access to domestic energy resources and may benefit from export revenues that provide foreign-exchange and fiscal resources to absorb some external energy-market pressures. Nevertheless, energy exporters are not insulated from uncertainty, particularly given their exposure to fluctuations in international commodity markets.

Table 4: Economic policy uncertainty, governance, and energy vulnerability in Africa [Driscoll Kraay Estimations]

	Unconditional	EPU ×VA	Unconditional	EPU ×PS	Unconditional	EPU ×GE	Unconditional	EPU ×RQ	Unconditional	EPU ×ROL	Unconditional	EPU ×CC
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
lnGDPpc	-0.117***	-0.117***	-0.116***	-0.116***	-0.094***	-0.096***	-0.110***	-0.111***	-0.099***	-0.099***	-0.107***	-0.108***
	(0.004)	(0.004)	(0.008)	(0.008)	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)
lnURB	-0.032***	-0.032***	-0.045***	-0.046***	-0.071***	-0.075***	-0.051***	-0.054***	-0.066***	-0.072***	-0.054***	-0.056***
	(0.010)	(0.011)	(0.013)	(0.014)	(0.011)	(0.011)	(0.011)	(0.011)	(0.013)	(0.013)	(0.011)	(0.012)
lnICT	-0.024***	-0.024***	-0.023***	-0.023***	-0.022***	-0.021***	-0.023***	-0.022***	-0.023***	-0.021***	-0.023***	-0.023***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
lnTR	0.046***	0.046***	0.036**	0.037**	0.057***	0.061***	0.054***	0.057***	0.057***	0.060***	0.054***	0.054***
	(0.012)	(0.013)	(0.014)	(0.014)	(0.010)	(0.010)	(0.011)	(0.011)	(0.010)	(0.010)	(0.011)	(0.011)
EPU	0.076***	0.077***	0.107***	0.118***	0.092***	0.125***	0.093***	0.121***	0.092***	0.129***	0.093***	0.112***
	(0.019)	(0.019)	(0.024)	(0.025)	(0.019)	(0.024)	(0.020)	(0.023)	(0.020)	(0.025)	(0.020)	(0.022)
VA	0.033***	0.032***										
	(0.005)	(0.007)										
EPU×VA		0.004										
		(0.020)										
PS			0.032***	0.028***								
			(0.005)	(0.008)								
EPU×PS				0.023								
				(0.017)								
GE					-0.014***	-0.027***						
					(0.004)	(0.006)						
EPU×GE						0.074***						
						(0.021)						
RQ							0.012**	-0.000				
							(0.005)	(0.007)				
EPU ×RQ								0.066***				
								(0.018)				
ROL									-0.007*	-0.022***		
									(0.004)	(0.005)		
EPU ×ROL										0.075***		
										(0.017)		
CC											0.011	0.004
											(0.008)	(0.011)
EPU ×CC												0.038**
												(0.015)
Net effect		Na		na		0.084***		0.086***		0.087***		0.090***
						(0.020)		(0.019)		(0.021)		(0.021)
Constant	1.178***	1.179***	1.256***	1.254***	1.083***	1.088***	1.151***	1.152***	1.104***	1.109***	1.147***	1.152***
	(0.059)	(0.057)	(0.073)	(0.072)	(0.046)	(0.044)	(0.057)	(0.055)	(0.046)	(0.043)	(0.056)	(0.054)
Observations	461	461	461	461	461	461	461	461	461	461	461	461
F	17297.600	16073.450	15712.663	14718.829	13918.245	11838.072	14782.385	15023.005	11422.317	15198.638	10196.814	10604.072

Standard errors in parentheses | $^{*}p<0.10$, $^{**}p<0.05$, $^{***}p<0.01$; Dependent variable: Energy vulnerability (EV)

4.3 Heterogeneous analysis – Kernel regularized least squares (KRLS) results

Table 5 discloses the results of the non-linear estimations. The estimated coefficients indicate that countries that are least energy vulnerable suffer the least from EPU. Specifically, for countries in the lower quartile (25th percentile) of the EV bracket, the impact of increasing EPU appears to be minimal, with a coefficient of (-0.021). This is potentially due to relatively robust energy infrastructure, diversified energy portfolios, or effective governance. As a result, these countries appear largely insulated from the destabilizing impacts of economic fluctuations. However, African countries with moderate EV (50th percentile), the coefficient rises to 0.021, indicating that these countries are consequently more susceptible to EPU. This increased vulnerability may emanate from a relatively heavy reliance on unstable energy sources or relatively weaker institutional capacities to manage energy-related shocks. The effect becomes more pronounced at the upper quartile (75th percentile), where the coefficient reaches 0.062. In such a scenario, EPU can exacerbate existing energy challenges, and hinder energy access and security.

Table 5: Point derivatives - KRLS results

Variable	Avg.	SE	T	P>|t|	P25	P50	P75
lnGDPpc	-0.06***	0.002	-27.478	0.000	-0.080	-0.062	-0.042
lnURB	-0.073***	0.005	-15.515	0.000	-0.132	-0.065	-0.023
lnICT	-0.008***	0.001	-9.798	0.000	-0.015	-0.009	-0.002
lnTrade	0.010**	0.004	2.538	0.011	-0.023	0.004	0.036
EPU	0.022**	0.008	2.895	0.004	-0.021	0.021	0.062
VA	0.044***	0.003	15.289	0.000	0.021	0.044	0.068
PS	0.024**	0.002	11.348	0.000	0.007	0.023	0.041
GE	-0.037**	0.004	-8.924	0.000	-0.057	-0.039	-0.017
RQ	-0.002	0.004	-0.570	0.569	-0.014	-0.003	0.010
ROL	-0.057***	0.004	-14.085	0.000	-0.084	-0.060	-0.031
CC	-0.002	0.004	-0.524	0.600	-0.026	-0.005	0.013
Lambda	0.2941	Sigma	11	R^2	0.9831	Obs	461
Tolerance	0.461	Eff. Df	86.52	Looloss	1.949		

Note: Avg. is Average marginal effect; SE indicates standard error; P25, P50 and P75 shows the 25th, 50th, and 75th percentile; Eff. df is the effective degrees of freedom; Dependent variable: Energy vulnerability (EV)

5.0 Conclusion and policy recommendation

This study augments the emerging discourse on strategies for mitigating energy vulnerability in the Global South, with particular focus on Africa, where a notable share of the population is

still without access to modern and reliable energy services. Using panel dataset from 26 African countries covering the period 2000–2019, the study employs multiple estimation techniques that are robust to endogeneity and cross-sectional dependence. The empirical findings reveal that economic policy uncertainty (EPU) significantly exacerbates energy vulnerability (EV). The results further reveal that most of the governance indicators (rule of law, government effectiveness, voice and accountability, control for corruption, regulatory quality and political stability) are positively associated with energy vulnerability except government effectiveness and rule of law, suggesting that prevailing governance structures and institutional weaknesses in Africa tend to worsen energy vulnerability outcomes. However, our findings corroborate the assertion that although governance does not fully offset the adverse impact of economic uncertainty on energy vulnerability, improvements in governance significantly diminish the magnitude of this detrimental effect.

Based on the study's findings, we suggest the following policy recommendations. First, African governments should prioritize policies that reduce macroeconomic and policy uncertainty, particularly through credible and consistent fiscal, monetary, and energy-sector policies. For instance, government can ensure consistency in energy-sector policies by avoiding abrupt tariff reversals, ad-hoc subsidy changes, and frequent regulatory amendments that reduce investor confidence. Second, there is a need for substantial improvements in areas related to regulatory effectiveness, control of corruption, and institutional accountability within the energy sector. This can be done through independent regulators, transparent procurement, and reduced political interference in tariff-setting. Third, policymakers should integrate governance reforms with energy-sector strategies, ensuring that institutional strengthening accompanies investments in energy access, renewable energy, and grid expansion.

Our study has some shortcomings which leave room for future research. First, we rely on country-level panel using and aggregate energy vulnerability index (EV), which may conceal important within-country heterogeneity or the main component of EV driving the effects. Precisely, the dependent variable is a composite measure of energy vulnerability encompassing energy access, energy efficiency, renewable energy deployment, total energy consumption, and energy security. Thus, our analysis identifies effects on aggregate energy vulnerability rather than its individual dimensions, which limits inference regarding the specific channels through which economic policy uncertainty affects energy vulnerability. Policy conclusions should therefore be interpreted at the system level rather than attributed to individual dimensions of vulnerability. Future research could decompose the index to identify which components are most responsive to uncertainty and governance quality.

Second, future research could examine potential threshold effects, particularly whether governance quality only begins to mitigate energy vulnerability beyond certain institutional or income thresholds. Third, future studies could adopt energy-sector regulatory quality, public investment efficiency, or utility-level performance indicators, to better isolate the institutional channels affecting energy vulnerability. Fourth, the marginal effects are computed at the means which may not give much information at different levels of institutions. Finally, differences in energy market structure, dominant energy sources, and regulatory frameworks may also influence the estimated relationships. Countries heavily dependent on imported fossil fuels may respond differently to uncertainty than countries with diversified domestic energy systems. Future research should incorporate measures of energy mix and market structure to examine these heterogeneous effects.

Appendix

Fig. A1: Energy vulnerability across selected African countries (2000 – 2019)

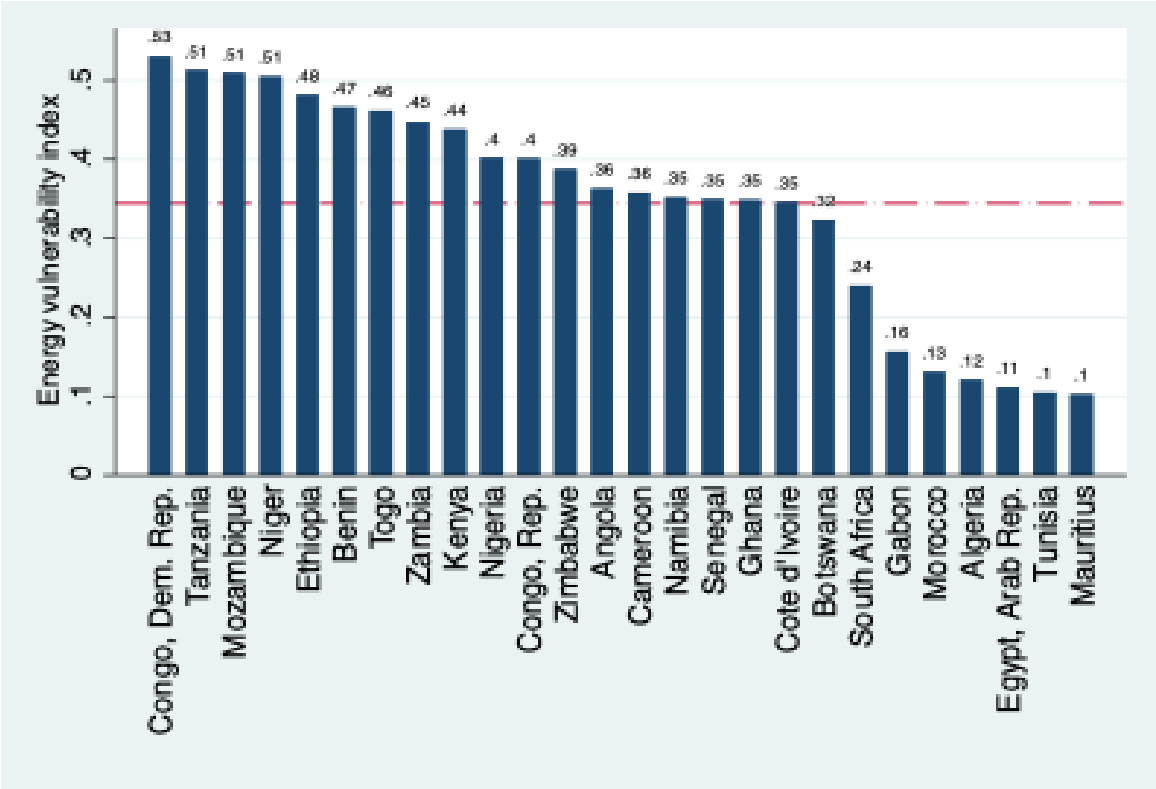


Fig. B1: Political institutions: (A) Voice and accountability and (B) Political stability and absence of violence

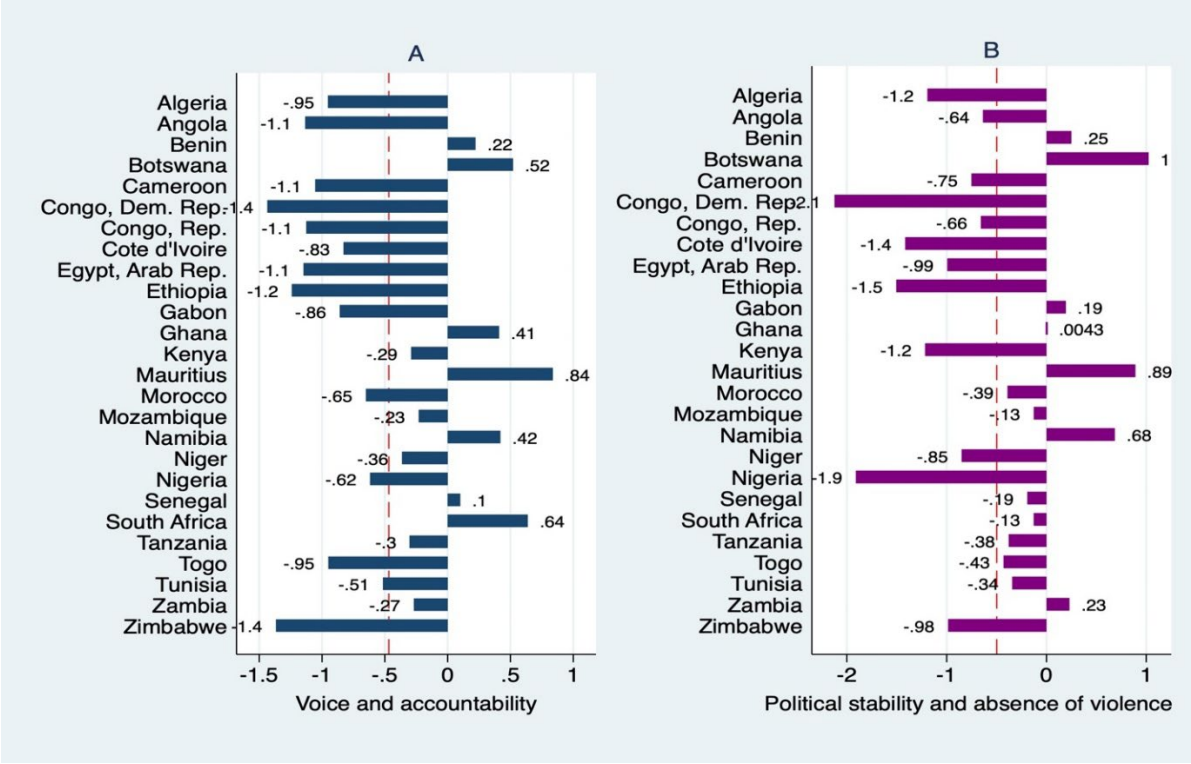


Fig. B2: Economic institutions: (C) Government effectiveness and (D) Regulatory quality

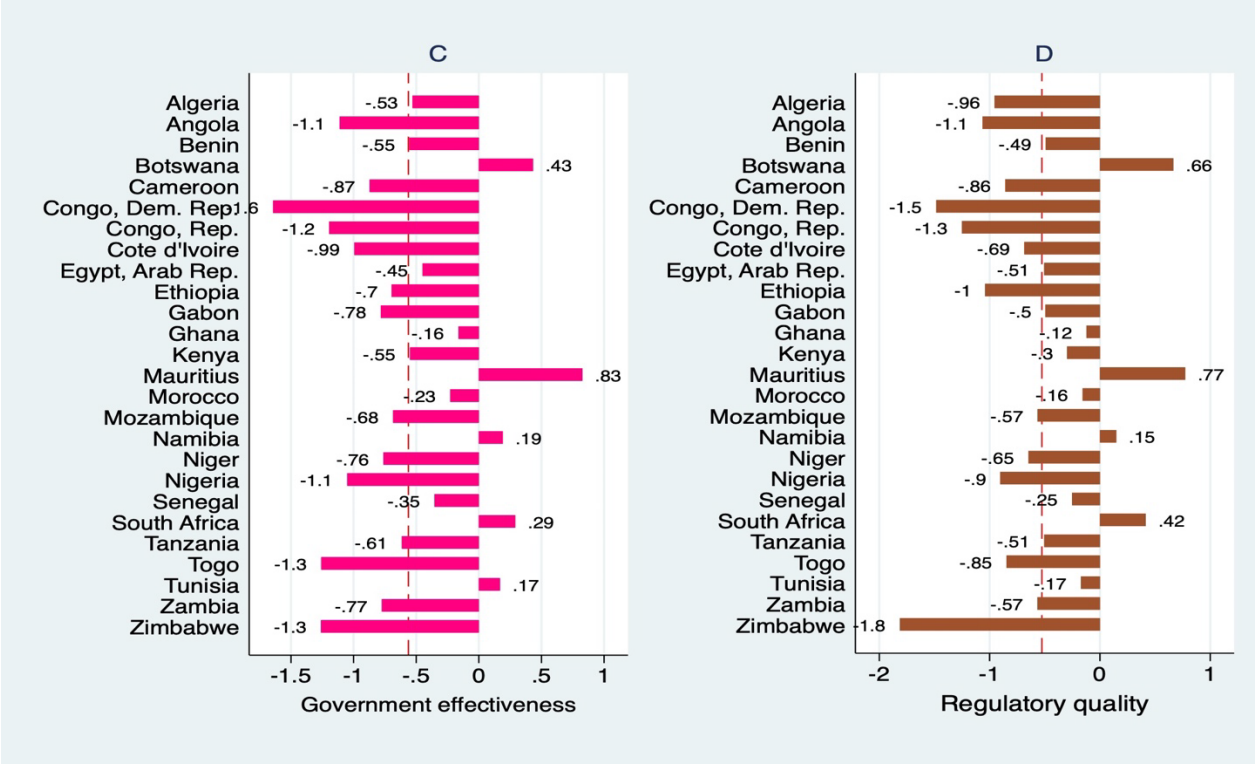


Fig. B3: Social institutions: (E) Rule of law and (D) Control of corruption

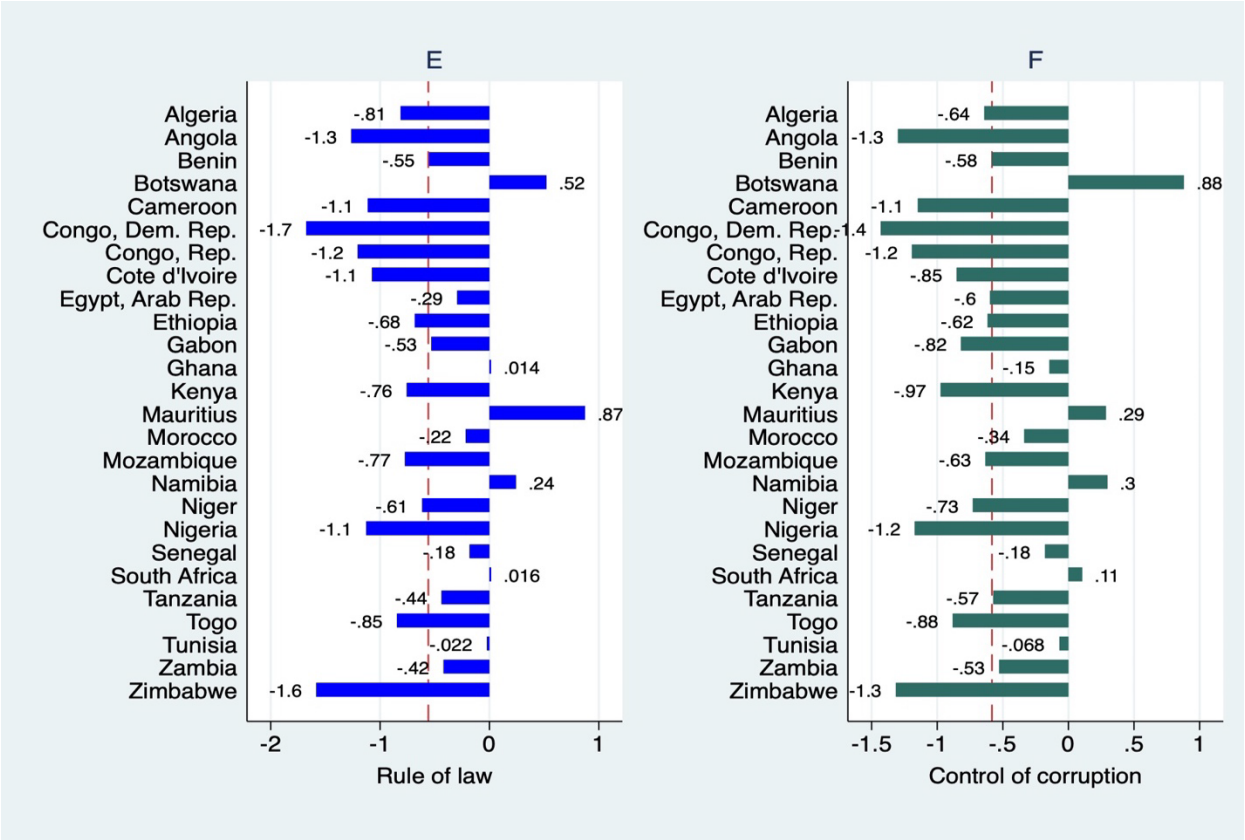


Table A1: Indicators for evaluating energy vulnerability index (EV)

Dimension	Indicator	Definition
1. Energy access	Electricity acquisition	Access to electricity as a percentage of the population
	Period to obtain power	Number of days to obtain permanent power connection
2. Energy efficiency	Energy intensity	Energy consumption per unit of economic output
	GDP per unit of energy use	PPP GDP per kg of oil equivalent energy use
	Overall system conversio efficiency	Final energy consumption / Total primary energy supply × 100
3. Clean energy	Renewable energy	Share of renewable energy in total final energy consumption
	Alternative and nuclear energy	Share of alternative and nuclear energy in total energy use
	Renewable electricity output	Share of electricity generated from renewables
4. Total energy consumption	Electric power consumption	Electricity output excluding transmission losses
	Energy use	Primary energy use before conversion
5. Energy security	Energy mix diversity	Diversity of energy sources (Shannon–Wiener Index)
	Energy imports	Energy imports as a share of total energy use
	Fuel exports	Fuel exports as a share of merchandise exports

Sourced from Liu et al. (2023).

Table A2: List of sampled African countries

Country name	Code	Country name	Code	Country name	Code
Algeria	DZA	Gabon	GAB	South Africa	ZAF
Angola	AGO	Ghana	GHA	Tanzania	TZA
Benin	BEN	Kenya	KEN	Togo	TGO
Botswana	BWA	Mauritius	MUS	Tunisia	TUN
Cameroon	CMR	Morocco	MAR	Zambia	ZMB
Congo, Dem. Rep.	COD	Mozambique	MOZ	Zimbabwe	ZWE
Congo, Rep.	COG	Namibia	NAM		
Cote d'Ivoire	CIV	Niger	NER		
Egypt, Arab Rep.	EGY	Nigeria	NGA		
Ethiopia	ETH	Senegal	SEN		

Table A3: Cross-sectional dependence results

Variable	CD-test	p-value	corr	abs(corr)
EV	46.28***	0.000	0.589	0.821
EPU	18.98***	0.000	0.242	0.311
VA	2.68**	0.007	0.034	0.362
PS	-0.31	0.757	-0.004	0.350
GE	-0.33	0.743	-0.004	0.344
RQ	0.77	0.443	0.010	0.355
ROL	0.73	0.465	0.012	0.384
CC	-2.25*	0.025	-0.028	0.316
GDPpc	45.53***	0.000	0.602	0.690
URB	41.90***	0.000	0.564	0.935
ICT	69.05***	0.000	0.918	0.918
TR	17.36***	0.000	0.240	0.436

Notes: Under the null hypothesis of cross-section independence, CD ~ N(0,1) P-values close to zero indicate data are correlated across panel groups

Table A4: Unit root tests

Variables	Augmented Dickey–Fuller tests (ADF)		Phillips–Perron (PP)	
	Inverse logit	Modified inv. chi-squared	Inverse logit	Modified inv. chi-squared
EV	-6.624***	9.2394***	-0.563	5.606***
EPU	-12.175***	17.197***	-5.532***	6.821***
VA	-8.497***	11.528***	-2.528***	5.474***
PS	-11.564***	16.304***	-5.771***	8.499***
GE	-10.775***	14.896***	-4.222***	5.708***
RQ	-9.394***	12.435***	-2.495***	3.226***
ROL	-8.203***	10.428***	-1.004	1.242
CC	-10.795***	14.799***	-4.364***	5.637***
GDPpc	-1.883**	5.241***	4.237	-0.408
URB	5.221	16.089***	-14.838***	17.169***
ICT	16.104	-4.202	11.893	-5.012
TR	-7.536***	9.228***	-0.284	-0.060

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

Table A5: Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) EV	1.000											
(2) EPU	0.037	1.000										
(3) VA	-0.121	0.130	1.000									
(4) PS	-0.229	-0.164	0.670	1.000								
(5) GE	-0.534	-0.044	0.753	0.648	1.000							
(6) RQ	-0.403	-0.012	0.812	0.675	0.891	1.000						
(7) ROL	-0.465	-0.046	0.792	0.730	0.917	0.898	1.000					
(8) CC	-0.383	-0.008	0.775	0.681	0.895	0.856	0.911	1.000				
(9) GDPpc	-0.747	0.010	0.399	0.478	0.642	0.601	0.584	0.534	1.000			
(10) URB	-0.671	0.043	0.023	0.252	0.183	0.170	0.148	0.165	0.629	1.000		
(11) ICT	-0.621	0.290	0.214	0.130	0.356	0.279	0.344	0.298	0.517	0.448	1.000	
(12)TR	-0.249	-0.120	0.170	0.384	0.237	0.211	0.218	0.241	0.429	0.395	0.042	1.000

Table A6: EPU GOV, and Energy vulnerability: [DKSE Estimates]

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
lnGDPpc	-0.115***	-0.114***	-0.082***	-0.101***	-0.086***	-0.099***
	(0.004)	(0.008)	(0.004)	(0.006)	(0.004)	(0.005)
lnURB	-0.022*	-0.038***	-0.036***	-0.024	-0.030**	-0.024
	(0.013)	(0.011)	(0.012)	(0.014)	(0.013)	(0.014)
lnICT	-0.024***	-0.023***	-0.026***	-0.026***	-0.025***	-0.026***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
lnTrade	0.040***	0.032**	0.041***	0.041***	0.040***	0.041***
	(0.013)	(0.013)	(0.010)	(0.011)	(0.010)	(0.011)
EPU	0.036	0.075**	0.082***	0.072**	0.079***	0.075**
	(0.031)	(0.029)	(0.025)	(0.029)	(0.026)	(0.026)
Energy importer (dummy)	-0.006	-0.004	0.046***	0.029***	0.049***	0.033***
	(0.011)	(0.014)	(0.008)	(0.009)	(0.010)	(0.007)
EPU x Energy importers	0.092**	0.070**	0.027	0.053	0.031	0.049*
	(0.036)	(0.025)	(0.030)	(0.031)	(0.032)	(0.028)
VA	0.032***					
	(0.007)					
PS		0.030***				
		(0.007)				
GE			-0.029***			
			(0.004)			
RQ				0.001		
				(0.005)		
ROL					-0.026***	
					(0.005)	
CC						-0.004
						(0.010)
Constant	1.158***	1.233***	0.899***	1.016***	0.908***	0.996***
	(0.036)	(0.092)	(0.031)	(0.047)	(0.026)	(0.048)
Observations	461	461	461	461	461	461
F	10069.333	10113.411	8165.767	7750.201	8046.340	7760.784

Standard errors in parentheses | * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

References

1. Abban, A. R., & Hasan, M. Z. (2021). Revisiting the determinants of renewable energy investment-New evidence from political and government ideology. *Energy policy*, *151*, 112184. https://doi.org/10.1016/j.enpol.2021.112184

2. Acemoglu, D., Johnson, S., & Robinson, J. A. (2005). Institutions as a fundamental cause of long-run growth. *Handbook of economic growth*, *1*, 385-472.

3. Acheampong, A. O., & Opoku, E. E. O. (2024). Analyzing the health implications of rising income inequality: What does the data say?. *Economics of Transition and Institutional Change*, *32*(4), 1003-1035. https://doi.org/10.1111/ecot.12410

4. Acheampong, A. O., Shahbaz, M., Dzator, J., & Jiao, Z. (2022). Effects of income inequality and governance on energy poverty alleviation: Implications for sustainable development policy. *Utilities Policy*, *78*, 101403. https://doi.org/10.1016/j.jup.2022.101403

5. Adam, M. A. (2019). United States Power Africa Initiative, The Eu and China–Investment or International Politics? https://www.jstor.org/stable/resrep31251

6. Adjei-Mantey, K., & Adams, S. (2023). Renewable energy, foreign direct investment and carbon dioxide emissions: do sectoral value additions and policy uncertainty matter? *Energy Nexus*, *10*, 100193. https://doi.org/10.1016/j.nexus.2023.100193

7. Adom, P. K., Appiah, M. O., & Agradi, M. P. (2020). Does financial development lower energy intensity? *Frontiers in Energy*, *14*, 620-634. https://doi.org/10.1007/s11708-019-0619-x

8. Apergis, N., & Pinar, M. (2021). The role of party polarization in renewable energy consumption: Fresh evidence across the EU countries. *Energy Policy*, *157*, 112518. https://doi.org/10.1016/j.enpol.2021.112518

9. Appiah-Otoo, I. (2021). Impact of economic policy uncertainty on renewable energy growth. *Energy Research Letters*, *2*(1). https://doi.org/10.46557/001c.19444

10. Asaloko, P. P., Asongu, S., & Zogo, T. E. (2025). Does peak technology combat energy poverty in developing countries? *International Journal of Energy Sector Management*. https://doi.org/10.1108/IJESM-12-2024-0028

11. Beach, B., & Hanlon, W. W. (2023). Historical newspaper data: A researcher's guide. *Explorations in Economic History*, *90*, 101541. https://doi.org/10.1016/j.eeh.2023.101541

12. Berha, A., & Khemani, S. (2026). Unreliable Electricity in Developing Countries: The Role of Weak Institutions (No. 11290). The World Bank.

13. Bernanke, B. S. (1983). Irreversibility, uncertainty, and cyclical investment. *The quarterly journal of economics*, *98*(1), 85-106.

14. Cadoret, I., & Padovano, F. (2016). The political drivers of renewable energies policies. *Energy Economics*, *56*, 261-269. https://doi.org/10.1016/j.eneco.2016.03.003

15. Cao, H., Guo, L., & Zhang, L. (2020). Does oil price uncertainty affect renewable energy firms' investment? Evidence from listed firms in China. *Finance Research Letters*, *33*, 101205. https://doi.org/10.1016/j.frl.2019.06.003

16. Cao, L., & Nguea, S. M. (2025). Vulnerable Energy, Vulnerable Food: assessing the effects of Energy Vulnerability on Food Security in Africa. *Energy*, 135105. https://doi.org/10.1016/j.energy.2025.135105

17. Che, X., & Jiang, M. (2021). Economic policy uncertainty, financial expenditure and energy poverty: Evidence based on a panel threshold model. *Sustainability*, *13*(21), 11594. https://doi.org/10.3390/su132111594

18. Chen, C., Pinar, M., & Stengos, T. (2021). Determinants of renewable energy consumption: Importance of democratic institutions. *Renewable Energy*, *179*, 75-83.

19. Dagar, V., Dagher, L., Rao, A., Doytch, N., & Kagzi, M. (2024). Economic policy uncertainty: Global energy security with diversification. *Economic Analysis and Policy*, *82*, 248-263. https://doi.org/10.1016/j.eap.2024.03.008

20. Dai, J., Farooq, U., & Alam, M. M. (2025). Navigating energy policy uncertainty: Effects on fossil fuel and renewable energy consumption in G7 economies. *International Journal of Green Energy*, *22*(2), 239-252.

21. Dixit, A. K., & Pindyck, R. S. (1994). *Investment under uncertainty*. Princeton University press.

22. Djoudji, S. T., & Nguea, S. M. (2025). The role of energy vulnerability in shaping human development outcomes: A multidimensional analysis. *Energy Reports*, *13*, 538-547. https://doi.org/10.1016/j.egyr.2024.12.044

23. Dong, K., Liu, Y., Wang, J., & Dong, X. (2024). Is the digital economy an effective tool for decreasing energy vulnerability? A global case. *Ecological Economics*, *216*, 108028. https://doi.org/10.1016/j.ecolecon.2023.108028

24. Dossou, T. A. M., Kambaye, E. N., Asongu, S. A., Alinsato, A. S., Berhe, M. W., & Dossou, K. P. (2023). Foreign direct investment and renewable energy development in sub-Saharan Africa: does governance quality matter? *Renewable Energy*, *219*, 119403. https://doi.org/10.1016/j.renene.2023.119403

25. Dossou, T. A. M., Pascal, D. K., Kambaye, E. N., Asongu, S., & Alinsato, A. S. (2024). The Financial development-renewable energy consumption nexus in Africa: Does governance quality matter? (No. WP/24/020). AGDI Working Paper. https://hdl.handle.net/10419/303216

26. Dube, A., & Horvey, S. S. (2023). Institutional quality and renewable energy capital flows in Africa. *Future Business Journal*, *9*(1), 55. https://doi.org/10.1186/s43093-023-00234-z

27. Dramani, J. B., Duodu, E., Tetteh, B., Ntsiful, E., & Frimpong, P. B. (2025). Trade Policy Uncertainty, Trade, and Economic Growth in Africa: What Can the African Continental Free Trade Area (AfCFTA) Offer? *The International Trade Journal*, *39*(6), 596-621. https://doi.org/10.1080/08853908.2025.2538861

28. Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of economics and statistics*, *80*(4), 549-560. https://www.jstor.org/stable/2646837

29. Ekeocha, D. O., Ogbuabor, J. E., Ogbonna, O. E., & Orji, A. (2023). Economic policy uncertainty, governance institutions and economic performance in Africa: are there regional differences? *Economic Change and Restructuring*, *56*(3), 1367-1431. https://doi.org/10.1007/s10644-022-09472-7

30. Erzurumlu, Y. O., & Gozgor, G. (2021). Effects of economic policy uncertainty on energy demand: Evidence from 72 countries. *Journal of Chinese Economic and Business Studies*, *20*(1), 23-38. https://doi.org/10.1080/14765284.2021.2009999

31. Farouq, I. S., & Sulong, Z. U. N. A. I. D. A. H. (2024). Economic policy uncertainty and renewable energy consumption: Evidence from oil-rich countries. *Journal of Sustainability Science and Management*, *19*(2), 150-172. http://doi.org/10.46754/jssm.2024.02.008

32. Feng, G. F., & Zheng, M. (2022). Economic policy uncertainty and renewable energy innovation: International evidence. *Innovation and Green Development*, *1*(2), 100010. https://doi.org/10.1016/j.igd.2022.100010

33. Fonchamnyo, D. C., Angyie, E. A. P., Afumbom, N. S., Dinga, G. D., & Asongu, S. (2022). Structural change, environmental pollution and health expenditure: Evidence from a global panel (No. WP/22/071). *AGDI Working Paper*.

34. Gbolonyo, E. Y., Obeng, C. K., Nunoo, J., & Armah, M. K. (2025). Women's empowerment and renewable energy consumption in Ghana: bridging gender disparities and advancing inclusive development. *Energy Efficiency*, *18*(7), 86. https://doi.org/10.1007/s12053-025-10372-8

35. Gbolonyo, E. Y., & Tetteh, B. (2025). Energy access and gender gaps in Sub-Saharan Africa: The role of institutional quality. *World Development Perspectives*, *40*, 100722. https://doi.org/10.1016/j.wdp.2025.100722

36. Garschagen, M., & Romero-Lankao, P. (2015). Exploring the relationships between urbanization trends and climate change vulnerability. *Climatic Change*, *133*(1), 37-52. https://doi.org/10.1007/s10584-013-0812-6

37. Gatto, A., & Busato, F. (2020). Energy vulnerability around the world: The global energy vulnerability index (GEVI). *Journal of Cleaner Production*, *253*, 118691. https://doi.org/10.1016/j.jclepro.2019.118691

38. Hainmueller, J., & Hazlett, C. (2014). Kernel regularized least squares: Reducing misspecification bias with a flexible and interpretable machine learning approach. *Political Analysis*, *22*(2), 143-168. https://www.jstor.org/stable/24573219

39. Heberle, J., & Sattarhoff, C. (2017). A fast algorithm for the computation of HAC covariance matrix estimators. *Econometrics,* *5*(1), 9. https://doi.org/10.3390/econometrics5010009

40. Hnainia, H., & Mensi, S. (2025). The role of institutional factors in shaping the relationship between economic policy uncertainty and energy consumption in Gulf countries: An empirical analysis. *Journal of Financial Economic Policy*, *17*(2), 246-269. https://doi.org/10.1108/JFEP-02-2024-0049

41. Holling, C. S. (1973, November). *Resilience and stability of ecological systems*.

42. IEA (2022), Africa Energy Outlook 2022, IEA, Paris https://www.iea.org/reports/africa-energy-outlook-2022, Licence: CC BY 4.0

43. International Energy Agency. (2014). A focus on energy prospects in Sub-Saharan Africa. International Energy Agency IEA. Retrieved from https://www.icafrica.org/en/knowledgehub/article/africa-energy-outlook-a-focus-on-energy-prospects-in-sub-saharan-africa-263/

44. Kellogg, Ryan. 2014. The Effect of Uncertainty on Investment: Evidence from Texas Oil Drilling. *American Economic Review* 104 (6): 1698–1734**.** https://www.jstor.org/stable/42920863

45. International Energy Agency (IEA). 2022. Africa Energy Outlook 2022. Available at: https://www.oecd.org/content/dam/oecd/en/publications/reports/2022/08/africa-energy-outlook-2022_58c5e4bf/2abd9ce2-en.pdf

46. Iormom, B. I., Jato, T. P., Ishola, A., & Diyoke, K. (2025). Economic policy uncertainty, institutional quality, and renewable energy transitioning in Nigeria. *Energy RESEARCH LETTERS*, *6*(Early View). https://doi.org/10.46557/001c.127515

47. Iormom, I. B., Usman, O., Bature, N. B., & Ogba, J. L. (2024). Modelling asymmetries among consumer price index, currency price, gross domestic output and aggregate import demand in an emerging economy: The case of Nigeria. *SN Business Economics*, *4*, 35. https://doi.org/10.1007/s43546-023-00615-0

48. Isser, D. H., Raballand, G., Watts, M. J., & Zovighian, D. (2024). Governance in Sub-Saharan Africa in the 21st Century. World Bank. https://documents1.worldbank.org/curated/en/099808303042442715/pdf/IDU143e8beba17307142d319f8b1504c365946ed.pdf

49. Kaufmann, D., Kraay, A., & Mastruzzi, M. (2011). The worldwide governance indicators: Methodology and analytical issues1. *Hague journal on the rule of law*, *3*(2), 220-246. https://doi.org/10.1017/S1876404511200046

50. Khan, K., & Su, C. W. (2022). Does policy uncertainty threaten renewable energy? Evidence from G7 countries. *Environmental Science and Pollution Research*, *29*(23), 34813-34829. https://doi.org/10.1007/s11356-021-16713-1

51. Liu, Y., Dong, K., & Jiang, Q. (2023). Assessing energy vulnerability and its impact on carbon emissions: A global case. *Energy Economics*, *119*, 106557. https://doi.org/10.1016/j.eneco.2023.106557

52. Liu, Y., & Nguea, S. M. (2025). Linking Energy Vulnerability to Environmental Sustainability in Africa: An Ecological Footprint Approach. *Renewable Energy*, 125005. https://doi.org/10.1016/j.renene.2025.125005

53. Liu, Z., Wang, Y., Yuan, X., Ding, Z., & Ji, Q. (2025). Geopolitical risk and vulnerability of energy markets. *Energy Economics*, *141*, 108055. https://doi.org/10.1016/j.eneco.2024.108055

54. Mehrara, M., Rezaei, S., & Razi, D. H. (2015). Determinants of renewable energy consumption among ECO countries; based on Bayesian model averaging and weighted-average least square. *International Letters of Social and Humanistic Sciences*, *54*, 96-109. https://doi.org/10.18052/www.scipress.com/ILSHS.54.96

55. Muhammad, A., Liu, L., & Najid, A. (2021). Impact of institutional quality on environment and energy consumption: evidence from developing world. *Environment, Development and Sustainability*, *23*(2), 1646-1667. https://doi.org/10.1007/s10668-020-00644-x

56. Musa, M. S., Jelilov, G., Iorember, P. T., & Usman, O. (2021). Effects of tourism, financial development, and renewable energy on environmental performance in EU-28: does institutional quality matter? *Environmental Science and Pollution Research*, *28*(38), 53328–53339. https://doi.org/10.1007/s11356-021-14450-z

57. Njoya, L., Ngouhouo, I., Ngounou, B. A., Njoupouognigni, M., & Nguena, C. L. (2024). Informality and inclusive growth: what lessons in the literature from the African experience? *Environmental Modeling & Assessment*, *29*(1), 157-178. https://doi.org/10.1007/s10666-023-09934-w

58. North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge University Press.

59. Ntsama, S. N. E., Asongu, S. A., & Ndelna, S. (2025). The Impact of Financial Innovation on Well-Being: The Role of State Capacity in Selected African Countries. *International Social Science Journal*. https://doi.org/10.1111/issj.70020

60. Nyiwul, L., Hu, Z., Koirala, N. P., & Wasson, H. (2025). Economic uncertainty and renewable energy investment. *International Economics and Economic Policy*, *22*(3), 48. https://doi.org/10.1007/s10368-025-00675-7

61. Obi, J. N., Ojo, E., & Ujah, C. O. (2025). Decentralised Renewable Energy in Sub-Saharan Africa: A Critical Review of Pathways to Equitable and Sustainable Energy Transitions. *Unconventional Resources*, 100267. https://doi.org/10.1016/j.uncres.2025.100267

62. Paul, A., Behera, M. K., Sahoo, D., & Mohapatra, S. (2025). Do energy risks drive the renewable transition in the Asia-Pacific? Insights from the method of moments quantile regression. *Journal of the Asia Pacific Economy*, 1-36. https://doi.org/10.1080/13547860.2025.2587665

63. Rafiq, S., Paramati, S. R., Alam, M. S., Hafeez, K., & Shafiullah, M. (2025). Does institutional quality matter for renewable energy promotion in OECD economies? *International Journal of Finance & Economics*, *30*(1), 477-492. https://doi.org/10.1002/ijfe.2926

64. Renn, O. (2008). Risk governance: Coping with uncertainty in a complex world. https://doi.org/10.4324/9781849772440

65. Renn, O., Klinke, A. & Schweizer, PJ. Risk Governance: Application to Urban Challenges. *Int J Disaster Risk Sci* **9**, 434–444 (2018). https://doi.org/10.1007/s13753-018-0196-3

66. Sadorsky, P. (2014). The effect of urbanization and industrialization on energy use in emerging economies: Implications for sustainable development. *American Journal of Economics and Sociology*, *73*(2), 392-409. https://doi.org/10.1111/ajes.12072

67. Sanusi, Y. A., Ohadugha, C. B., Martins, V. I., & Olaide, S. A. (2022). Analysis of energy governance in Southern Africa. *Polityka Energetyczna-Energy Policy Journal*, 73-94. Doi: 10.33223/epj/155790

68. Sarkodie, S. A. (2021). Environmental performance, biocapacity, carbon & ecological footprint of nations: Drivers, trends and mitigation options. *Science of the Total Environment*, *751*, 141912. https://doi.org/10.1016/j.scitotenv.2020.141912

69. Sarkodie, S. A., & Owusu, P. A. (2020). How to apply the novel dynamic ARDL simulations (dynardl) and Kernel-based regularized least squares (krls). *MethodsX*, *7*, 101160. https://doi.org/10.1016/j.mex.2020.101160

70. Sequeira, T. N., & Santos, M. S. (2018). Renewable energy and politics: A systematic review and new evidence. *Journal of Cleaner Production*, *192*, 553-568. https://doi.org/10.1016/j.jclepro.2018.04.190

71. Shankar, N. (2020). Role of global economic policy uncertainty on firms participation in innovation and new product introductions: an empirical study in African SMEs. *Transnational Corporations Review*, *12*(4), 360-378. https://doi.org/10.1080/19186444.2020.1832425

72. Su, C. W., Umar, M., & Khan, Z. (2021). Does fiscal decentralization and eco-innovation promote renewable energy consumption? Analyzing the role of political risk. *Science of the Total Environment*, *751*, 142220. https://doi.org/10.1016/j.scitotenv.2020.142220

73. Tabash, M. I., Farooq, U., & Ahmed, A. (2024). How does institutional quality determine energy consumption? Empirical evidence from the South Asia region. *Management of Environmental Quality: An International Journal*, *35*(3), 712-727. https://doi.org/10.1108/MEQ-05-2023-0149

74. United Nations Development Programme. (2024). *UNDP annual report 2024: Accelerating progress on the Sustainable Development Goals*. United Nations Development Programme. https://www.undp.org/media/document/1467991. https://www.undp.org/sites/g/files/zskgke326/files/2025-11/undp_rp_2024_annual_report.pdf

75. Wang, H., Zhang, T., Zhang, Z., & Feng, Y. (2025). What is the global causality between geopolitical risks, government governance, and energy transition? Empirical evidence from cross-country data. *Carbon Balance and Management*, *20*(1), 31. https://doi.org/10.1186/s13021-025-00322-3

76. Wen, K., Alessa, N., & Tawiah, V. (2024). The impact of Chinese investment on energy independence in Africa. *Energy Policy*, *192*, 114198. https://doi.org/10.1016/j.enpol.2024.114198

77. William, M., & Fengrong, W. (2022). Economic policy uncertainty and industry innovation: Cross country evidence. *The Quarterly Review of Economics and Finance*, *84*, 208-228. https://doi.org/10.1016/j.qref.2022.01.012

78. World Bank. (2024). *World development indicators (WDI). Retrieved from https://databank.worldbank.org/source/world-development-indicators*

79. Mengfeng, X., Farooq, U., Tabash, M. I., & Aljughaiman, A. A. (2024). How does economic policy uncertainty influence energy policy? The role of financial sector development. *Energy Strategy Reviews*, *55*, 101523. https://doi.org/10.1016/j.esr.2024.101523

80. Yin, R., & Liu, J. (2025). How does corruption hinder energy transition? A perspective from Sub-Saharan Africa. *Energy Policy*, *206*, 114778. https://doi.org/10.1016/j.enpol.2025.114778

81. Zeng, Q., & Yue, X. (2022). Re-evaluating the asymmetric economic policy uncertainty, conventional energy, and renewable energy consumption nexus for BRICS. *Environmental Science and Pollution Research*, *29*(14), 20347-20356.

82. Zhang, S. H., Yang, J., & Feng, C. (2023). Can internet development alleviate energy poverty? Evidence from China. *Energy Policy*, *173*, 113407. https://doi.org/10.1016/j.enpol.2022.113407

83. Zhang, Y., Qamruzzaman, M., Karim, S., & Jahan, I. (2021). Nexus between economic policy uncertainty and renewable energy consumption in BRIC nations: The mediating role of foreign direct investment and financial development. *Energies*, *14*(15), 4687. https://doi.org/10.3390/en14154687

84. Zhao, S., Hafeez, M., & Faisal, C. M. N. (2022). Does ICT diffusion lead to energy efficiency and environmental sustainability in emerging Asian economies? *Environmental Science and Pollution Research*, *29*(8), 12198-12207. https://doi.org/10.1007/s11356-021-16560-0