

ADDRESSING ENERGY POVERTY IN AFRICA: THE ROLE OF INSTITUTIONAL QUALITY, TRADE OPENNESS, AND FINANCIAL DEVELOPMENT IN ENHANCING ACCESS TO CLEAN FUELS AND TECHNOLOGIES

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1. Introduction

Energy poverty occurs when individuals lack access to modern energy sources necessary for essential activities. It refers to situations “where there is a lack of adequate, affordable, reliable, quality, safe, and environmentally sound energy services to support development” (Habitat for Humanity, 2024). Access to modern energy is crucial for achieving the Sustainable Development Goals, prompting many countries and organizations to prioritize efforts to reduce energy poverty. Global initiatives in this area have led to notable progress. For instance, global investment in energy transition technologies reached US\$ 1.3 trillion in 2022, a 70% increase compared to pre-COVID pandemic levels in 2019 (World Bank, 2023). Despite these efforts, approximately 2.4 billion people, mostly in Asia and Africa, still lack access to clean cooking energy, relying instead on solid fuels that

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are inefficient, more polluting, and harmful to health. The environmental impact of this is comparable to greenhouse gas emissions from the aviation industry (Clean Cooking Alliance, 2023). Additionally, this reliance contributes to deforestation and poses significant health risks, costing more than US\$ 2.4 trillion annually (Murshed and Ozturk, 2023). To address energy poverty, substantial investment is needed—an estimated US\$ 8 billion per year by 2030. However, since 2014, only 68% of the required funding has been secured (Clean Cooking Alliance, 2023).

A significant portion of Africa's population lacks access to modern energy for domestic use (Murshed and Ozturk, 2023). While electricity access increased by 160 million people between 2010 and 2019, 40% of the continent's population still remains without electricity. Additionally, nearly 1 billion Africans depend on wood fuels, waste, and charcoal for cooking (IEA, 2022). The rural-urban divide is evident, with 86% of the urban population having access to clean fuels and technologies, compared to only 48.5% of the rural population (World Bank's WDI, 2023). As the fastest-urbanizing continent in the world, Africa faces severe developmental challenges if this situation is not addressed (World Bank's WDI, 2023). For example, around 4 million people die annually from cooking-related diseases caused by smoke inhalation, and women and children spend an estimated 20 hours a week gathering fuel, which hampers women's empowerment. Moreover, burning wood fuels contributes approximately one gigaton of carbon dioxide equivalent emissions annually, exacerbating climate change and global warming (Clean Cooking Alliance, 2023).

In 2022, African countries, through the African Union, adopted the African Common Position on Energy Access and Just Energy Transition to enhance modern energy accessibility. This "common position" aims to establish both short- and long-term development strategies that fast-track universal energy access and the transition to cleaner energy systems, without compromising the continent's developmental priorities. The initiative seeks to increase electricity accessibility in ways that promote socio-economic growth across Africa, while aligning with the continent's Agenda 2063, which envisions "a prosperous Africa based on inclusive growth and sustainable development" (African Union, 2022). Agenda 2063 also emphasizes addressing climate change and protecting the environment (African Union, 2015). In addition to these continental agreements, many African nations are signatories to global treaties such as the Paris Agreement and the United Nation's Sustainable Development Goals (SDGs). The Paris Agreement aims to limit global temperature rise to below 2°C above pre-industrial levels by 2050, while the SDGs focus on policies to among others combat climate change and ensure access to affordable, clean energy by 2030.

With nearly 1 billion Africans lacking access to clean energy (IEA, 2022), it is crucial to understand the factors influencing clean energy accessibility across the continent. Such analysis is essential to guide policymakers in formulating effective policies aligned with the African Common Position on Energy Access and Just

Energy Transition (African Union, 2022) to increase the proportion of Africans with access to clean energy. Numerous studies have identified various factors affecting clean energy accessibility. Micro-level studies have highlighted determinants such as price, income, age, family size, education, and the availability of clean energy (Awan and Bilgili, 2022; Bhagirath and Ali, 2017; Carter et al., 2020; Sharma et al., 2019; Pangaribowo and Iskandar, 2023; Przychodzen and Przychodzen, 2020). At the macro level, commonly identified factors include environmental cleanliness, trade openness, income, employment, and price (Asumadu-Sarkodie and Yadav, 2019; Bekun and Alola, 2022; Kwakwa et al., 2021; Murshed, 2020; Murshed et al., 2020). Unfortunately, the results remain inconclusive, and many macro-level studies are based on data from regions outside of Africa, making it challenging to design policies suited to African contexts. Therefore, research specifically focused on Africa is critical to successfully reducing energy poverty in the region.

Access to clean fuels and technologies remains a significant challenge in Africa and many developing countries, more so than in developed nations (Murshed, 2023a). In this context, financial development is often highlighted as a potential solution to address energy poverty across the continent. Since the late 1980s and early 1990s, financial sector liberalization has contributed to improving Africa's financial sector (World Bank's WDI, 2023). Moreover, Africa has become an attractive destination for foreign investors from America, Europe, and Asia, potentially increasing financial transactions (Kwakwa et al., 2023). The development of the financial system could support the production of clean energy by firms while enabling households to access clean fuels and energy technologies. However, when financial institutions operate with profit motives, reducing energy poverty may not be a priority (Dong et al., 2022). This raises the question of how financial development impacts energy poverty in Africa, an issue worth investigating. While there is considerable empirical research on the relationship between financial development and access to clean energy, the evidence has been mixed. Most studies have focused on developed nations and developing countries in Asia (Dong et al., 2022; Mohsin et al., 2022; Murshed, 2022), making it difficult to draw general conclusions or develop policies suited to Africa's unique political, social, and economic context. This prompts the critical question: what is the effect of financial development on access to clean energy and technologies in Africa?

Institutional quality plays a crucial role in improving living conditions (North, 1995), as effective institutions ensure the efficient allocation of resources, contributing to the welfare of citizens through measures such as reducing pollution from energy usage (Gyamfi et al., 2023). Strong institutions that can control corruption help lower the cost of business activities in the energy sector, thus facilitating energy transitions (Amoah et al., 2022). Furthermore, voice and accountability mechanisms encourage public sectors to operate efficiently, which includes the provision of clean energy for citizens (Kwakwa, 2023). However, many view the

state of institutions in Africa as weak (Aron, 2000; Ouedraogo et al., 2022; Siba, 2007). While there is significant evidence supporting the positive impact of institutional quality on energy poverty reduction, some recent studies present contradictory findings (Acheampong, 2023; Purcel, 2020). These conflicting results, the scarcity of research focused on Africa's weak institutions, and the failure of some past studies to examine the role of specific institutions, highlight the need for greater attention to Africa to guide effective policy formulation. With ongoing efforts by African leaders to strengthen and build vibrant institutions (Ouedraogo et al., 2022), it becomes essential to understand how institutional quality can impact the quality of life by improving access to clean energy. Thus, this study poses the question: what is the effect of institutional quality on access to clean energy and technologies in Africa?

Unlike developed countries, African nations have limited capacity to produce clean energy technologies and must rely on importing them. Trade openness, therefore, plays a critical role in facilitating the importation of these technologies, which can help improve energy accessibility across the continent (Gebreslassie et al., 2023). Africa's technological constraints and lack of innovation in the energy sector have hindered efforts to provide access to clean cooking fuels (Murshed, 2022). Despite engaging in international trade for many years, Africa's share in global trade remains disappointingly low, hovering around 3%, with significant fluctuations in the value of traded goods (WTO, 2022). From 2005 to 2019, Africa's export value ranged between US\$ 370 billion and US\$ 710 billion, while imports varied between US\$ 310 billion and US\$ 790 billion (WTO, 2022). Financial gains from exports could potentially enable governments to invest in cleaner energy solutions. However, empirical studies on the impact of trade openness on energy poverty show mixed results (Murshed, 2020; Xu et al., 2023). Some scholars suggest that strong institutions and financial development may enhance the positive effects of trade openness on reducing energy poverty (Hu et al., 2023; Sheraz et al., 2022; Yasin et al., 2021). Whether this holds true for Africa—a continent facing high energy poverty, weak institutions, and a developing financial sector—remains to be thoroughly explored.

Despite the increasing number of studies on access to clean energy, the outcomes in the literature have been mixed. Moreover, much of the evidence has been drawn from developed and Asian countries, which limits its applicability for shaping policy in Africa. This highlights the need for studies focused specifically on the African context. The social, political, and economic conditions in African countries differ significantly from those in developed and Asian nations, potentially influencing study outcomes and their practical applications. For instance, while developed and Asian countries generally enjoy political stability and lower levels of corruption, the opposite is often true in Africa (World Bank's WDI, 2023). Additionally, although financial development in Africa is progressing, it remains dominated by commercial banks and is characterized by lower financial inclusion

rates and higher levels of non-performing loans compared to developed and Asian countries (World Bank's WDI, 2023; Nsiah and Tweneboah, 2023). Also, heterogeneous analysis of the drivers of access to clean energy on the continent is rare despite Koenker and Bassett (1978) argument that explanatory variables can exert varying effects across different points in the distribution.

Based upon the aforementioned issues, this study seeks to examine: (a) the effect of trade openness, institutional quality and financial development on access to clean fuels and technologies in Africa; (b) how institutional quality moderates the effects of trade openness and financial development on access to clean fuels and technologies in Africa; (c) how financial development moderates the effect of trade openness on access to clean fuels and technologies in Africa; and (d) the heterogeneous effect of trade openness, financial development, and institutional quality on access to clean fuels and technologies in Africa.

The study offers several key contributions to the literature. First, it adds to the limited empirical research on this topic from Africa, a region with a high incidence of energy poverty. Second, it provides evidence on the effects of six different indicators of institutional quality on access to clean energy, as opposed to the single-indicator approach used in many prior studies. Third, the paper investigates the moderating role of institutional quality on the access to clean energy-financial nexus, as well as on the nexus between trade openness and access to clean energy. It also examines how financial development affects the nexus between trade openness and access to clean energy. This analysis is particularly relevant, as previous studies have suggested the potential for institutional quality to moderate various economic outcomes (Adams and Klobodu, 2016). For instance, institutional quality can either enhance or hinder the functioning of the financial sector, thereby influencing access to clean energy. Similarly, institutional quality may facilitate or restrict trade openness, impacting clean energy access. The financial sector, in turn, can either support or obstruct the effect of international trade on clean energy access through funding. While prior studies have explored the moderating role of institutional quality on the relationship between natural resources and growth (Asiedu, 2015; Epo and Faha, 2020; Raggl, 2017) and on carbon emissions (Kwakwa, 2023; Hu et al., 2023; Sheraz et al., 2022; Yasin et al., 2021), the role of institutions in moderating the effects of trade openness and financial development on clean energy access has yet to be empirically analyzed.

The fourth contribution of this research lies in its departure from the static effects assumption made in many previous studies regarding the drivers of access to clean fuels and technologies. This assumption may not hold true universally, as the impact of these factors can vary across different points in the distribution (Koenker and Bassett, 1978). Since access to clean energy is unevenly distributed across the continent (World Bank's WDI, 2023), the effects of influencing factors may also differ by quantiles (Koenker and Bassett, 1978). Indeed, recent studies have indicated that economic variables, such as energy consumption and carbon

emissions, do not have uniform effects across distributions (Adjei-Mantey et al., 2023; Khan and Rana, 2021; Musah, 2023). Therefore, to ensure robustness and account for the heterogeneous distribution of variables, this research employs quantile regression analysis, adding a methodological contribution. Lastly, given that Africa is undergoing rapid urbanization, and that the urban population has greater access to clean energy compared to the rural population, the effect of urbanization on access to clean energy is also controlled for in the analysis.

2. Literature Review

Some Recent Efforts Aimed at Addressing Energy Poverty in Africa:

Energy security remains a critical challenge in Africa, with nearly a billion people lacking access to clean energy (IEA, 2022). According to the IEA, around 600 million people in Sub-Saharan Africa are without electricity, making up nearly 80% of the global population without access. As a result, many rely on traditional biomass sources like wood and charcoal for cooking and heating, leading to indoor air pollution and deforestation (Nforngwa, 2023). The lack of electricity also restricts access to essential services such as information, communication, and entertainment. The multifaceted effects of energy poverty are evident, with only about 28% of Sub-Saharan Africa's population having access to reliable electricity according to IEA estimates (Nforngwa, 2023). This deficit has hindered business productivity, competition, and innovation, while also negatively impacting vital sectors like agriculture, manufacturing, healthcare, and education. Energy poverty is estimated to cost Sub-Saharan Africa between 2% to 4% of its gross domestic product (Nforngwa, 2023). Recognizing the importance of addressing energy poverty to boost economic growth, human development, and climate resilience, African leaders have implemented various initiatives and policies. One such initiative is the African Common Position on Energy Access and Just Energy Transition, adopted in 2022, which aligns with Africa's Agenda 2063 and aims to significantly improve electricity accessibility (African Union, 2022).

In 2013, West African countries adopted the ECOWAS Renewable Energy Policy during the 43rd Ordinary Session of the ECOWAS Authority. This policy built on earlier initiatives, including the ECOWAS White Paper on a Regional Policy for Increasing Access to Energy Services in Peri-Urban and Rural Areas, the UN Sustainable Energy for All (SE4ALL) Initiative, and the ECOWAS Revised Master Plan for the Generation and Transmission of Electrical Energy for an integrated regional power market. The policy aimed at increasing the share of renewable energy excluding hydro (with hydro) in electricity production to 10% (35%) in 2020 and 19% (48%) in 2030 (ECOWAS, 2015).

In Africa, the countries in the northern part of the continent, with the exception of Sudan, have the highest rates of access to modern energy. Although the northern

African countries have universal access (excluding Sudan and Libya) when it comes to electricity, clean cooking fuels, and technologies, there are variations with quality of access, affordability, and stability of supply. However, the countries are heavily dependent on fossil fuels with hydropower constituting around 7% of total electricity generation (IRENA, 2023a). To address the issue, significant efforts have been made to achieve a 5% growth in renewable energy capacity in North Africa since 2011 (IRENA, 2023b). North African countries are also part of the Pan-Arab Strategy for the Development of Renewable Energy 2010-2030/Pan-Arab Sustainable Energy Strategy 2030, which aims to have renewable energy comprise 12.4% of the Arab region's electricity mix. In addition, they have collaborated with other members of the League of Arab States to establish the Regional Center for Renewable Energy and Energy Efficiency (IRENA, 2023b), aimed at promoting renewable energy development.

The East African Community (EAC) has developed the EAC Regional Strategy on Scaling-Up Access to Modern Energy Services with the goal of increasing access to modern energy through high-impact, low-cost scalable approaches. Key targets include: (a) ensuring 50% of traditional biomass users have access to modern cooking practices; (b) providing reliable electricity to all urban and peri-urban poor; (c) ensuring schools and health facilities like clinics and hospitals have access to modern energy services; and (d) giving all productive sectors access to mechanical power (East African Community, 2023). To improve energy security, reduce environmental damage from energy systems, and lower greenhouse gas emissions, the EAC has also established the East African Centre for Renewable Energy and Energy Efficiency (East African Community, 2023). In southern Africa, the Southern African Development Community (SADC) has implemented the Renewable Energy and Energy Efficiency Strategy and Action Plan (REEE-SAP), aiming to provide sufficient, reliable, least-cost, sustainable, and clean modern energy services to member countries by 2030. Achieving this vision depends on scaling up renewable energy and increasing energy efficiency (SADC, 2016).

Africa has several opportunities to address its energy security challenges. The continent can leverage existing policies and tap into its abundant renewable energy resources, such as solar power, which has the potential to generate up to 11,000 gigawatts (GW) of electricity (Nfomgwa, 2023). Additionally, Africa's natural gas and oil reserves can be harnessed with modern technology to mitigate environmental damage (Nfomgwa, 2023). The significant amount of solid waste produced in major African cities, which poses environmental risks, could also be converted into energy (Alhassan et al., 2024). Furthermore, with the declining cost of renewable energy technology, Africa has an opportunity to expand its renewable energy generation through public-private partnerships and official development assistance (ODA). However, realizing these opportunities will require strong leadership, financial resources, and international support (Alhassan et al., 2024).

Theoretical Framework: Two predominant theories explaining household energy choices are the energy ladder theory and the energy stacking theory. The energy ladder theory suggests that as households' social status, particularly income, improves, they transition from using traditional or solid fuels—such as firewood, crop waste, animal dung, and charcoal—to modern and cleaner fuels like kerosene, gas, LPG, natural gas, and electricity (Hosier and Dowd, 1987). This theory implies that households move from lower forms of energy to higher, more efficient forms, with income and fuel price being the primary factors influencing their energy choices (Crentsil et al., 2019). However, the observation that households often continue using older energy forms alongside newer ones, even as income grows, has been a central critique of the energy ladder theory. Critics argue that households tend to use a mix of energy sources as their income increases (Yadav and Monroe, 1993). This critique has led to the development of the energy stacking theory, which posits that households do not completely abandon traditional energy sources as their economic status changes. Instead, they adopt or “bundle” a combination of traditional and modern energy types. Factors such as the cost of modern energy, cultural practices, and accessibility are cited as reasons why households may choose to bundle a variety of energy sources rather than transitioning entirely to modern energy (Yadav and Monroe, 1993).

Studies like Mensah and Adu (2015), Karimu (2015), and Yadav and Monroe (1993) have employed either of these theories to analyze household energy choices. In many of these studies, income, urbanization, and other household characteristics are found to significantly influence access to clean and modern fuels (Wu and Lin, 2022). If household decisions to switch to cleaner energy are partly driven by energy accessibility, this concept can also be applied at the macro level. Therefore, at the macro level, factors such as income and other economic conditions may similarly influence access to clean energy.

Institutional Quality and Energy Poverty Nexus: Global efforts to achieve lower carbon economies and energy transitions have highlighted the importance of institutional quality, financial development, and trade openness. North (1995) defines institutions as the systems of rules and arrangements designed to shape societal actions for improved outcomes. The quality of these institutions has been recognized as essential in achieving better welfare results in an economy. By reducing asymmetric information, lowering transaction costs, and improving market efficiency, institutional quality can enhance energy accessibility (Nguyen and Su, 2022). The connection between institutions and access to clean fuels and technology can be linked to the technological innovation system theory, which suggests that the development and diffusion of technology are influenced by factors such as institutions (Wicki and Hansen, 2017).

Institutional quality is commonly measured by indicators such as control of corruption, political stability, rule of law, voice and accountability, governance effectiveness, and regulatory quality (World Bank's WDI, 2023). According to

Mahmood et al. (2022), institutional quality can influence both the composition of a country's energy mix and its level of energy consumption, as it aligns with energy needs and environmental goals. For instance, strong control of corruption can facilitate the efficient and successful implementation of clean energy accessibility programs. Furthermore, political stability and the absence of violence are crucial for attracting foreign investors to the clean energy sector in developing countries and for encouraging local investments in energy infrastructure.

Government effectiveness helps streamline bureaucratic processes, facilitating the realization of plans to improve access to clean energy. Additionally, voice and accountability act as mechanisms for holding governments accountable, ensuring that actions detrimental to the state or the environment, such as those that hinder a cleaner environment, are met with opposition. This can lead to reforms, including those aimed at increasing access to clean energy (Barkat et al., 2023). Similarly, the rules of law and regulatory quality ensure that resources are directed toward sectors that promote economic growth and environmental sustainability. Regulatory quality ensures that policies protecting environmental quality are effectively implemented, while the rule of law, with its enforcement of punitive measures against illegal or unproductive activities, enhances overall economic welfare (Onyeji, 2010). Therefore, the level of access to clean energy and technologies in Africa is likely influenced by institutional quality.

Trade and Energy Poverty Nexus: Trade openness provides a key avenue for increasing access to clean energy. By facilitating the import of clean energy technologies from more efficient producers to less efficient ones, trade openness helps bridge technological gaps (Murshed, 2020). Additionally, it can promote the transfer of clean technologies to countries with fewer resources, allowing firms and individuals to acquire the skills needed to produce clean energy technologies locally (Murshed, 2020). Moreover, trade openness supports infrastructure development (Xu et al., 2023) and industrial growth, both of which can enhance access to clean energy and technology. However, there is also a downside, as trade openness may lead to an influx of non-clean energy technologies, potentially resulting in underinvestment in renewable energy resources (Murshed, 2020).

Financial Development and Energy Poverty Nexus: Koomson and Danquah (2012) have highlighted that financial development plays a crucial role in reducing energy poverty. They argue that financial development, firstly, raises household income and reduces poverty, enabling people to afford clean energy technologies. Secondly, it enhances human development by providing access to credit, improving education and health outcomes. People with better health and education are rewarded more in the labor market, allowing them to invest in clean energy solutions. Thirdly, financial development directly improves energy accessibility by funding affordable and clean energy products. Thus, a well-developed financial sector enables firms to secure financial support for investing in clean energy technologies. Additionally, financial development provides the resources needed for

advertising and educating the public on the benefits of clean energy technologies, while also allowing individuals to secure funds to acquire these technologies. Furthermore, they suggest that financial development promotes overall economic growth, enabling economies to provide essential goods and services, including clean energy technologies.

Empirical Review: Energy issues have captured the attention of global leaders, scholars, and policymakers since the 1970s, though interest has intensified in recent years. This heightened focus is driven by concerns over the environmental impact of rising energy consumption, the persistence of energy poverty in many developing nations, and the macroeconomic effects of oil prices on energy-importing countries. A substantial body of research has explored the relationship between energy and economic growth (Purnomo et al., 2023; Xie et al., 2023). Other studies have examined the determinants of energy consumption (Dokas et al., 2022; Tzeiranaki et al., 2023) and others have assessed the impact of energy on environmental degradation (Khan et al., 2020; Chen et al., 2022).

Globally, fossil fuels continue to dominate the energy supply, raising significant concerns due to their high carbon dioxide emissions, which pose a threat to the global climate. As a result, countries are being urged to transition to cleaner energy sources for economic activities. Renewable energy, in particular, has been widely promoted by scholars and international organizations. Empirical studies have identified various factors influencing renewable energy consumption, including price, income, financial development, industrialization, technological innovation, trade, and political stability (Kwakwa, 2021; Li et al., 2020; Ergun et al., 2019; Yahya and Rafiq, 2019).

To reduce CO₂ emissions and improve quality of life, global leaders are committed to increasing access to clean energy by 2030. This goal has prompted researchers to examine factors influencing energy choices. Most studies have focused on household-level factors (Awan and Bilgili, 2022; Behera and Ali, 2017; Carter et al., 2020; Sharma et al., 2019; Pangaribowo and Iskandar, 2023; Przychodzen and Przychodzen, 2020). These studies reveal that household characteristics such as gender, age, employment, marital status, education, and household size impact energy choices for domestic cooking. However, recognizing that macroeconomic conditions and other indicators can also affect access to clean energy, macro-level analysis has gained traction. For instance, Acheampong (2023) found that in Sub-Saharan Africa, economic growth, education, and rural population increased access to clean fuels and technologies for cooking, while governance indicators hindered accessibility. Murshed (2022) found that income, female labor participation, and energy efficiency improved access to clean fuels in African countries, with financial development and foreign direct investment reducing access for low-income groups but increasing it for middle- and high-income groups. Dong et al. (2022) observed that financial development helped alleviate energy poverty by increasing clean energy consumption in China, with industrialization, technological innovation, and economic growth also improving the energy situation.

However, urbanization was linked to higher energy poverty. In Latin America, Mohsin et al. (2022) found that energy poverty decreased with financial development but increased with income inequality and income growth.

Murshed (2020) previously found that trade openness, income, and environmental pollution contribute to increased access to clean fuels and technologies in South Asia. In a study of six South Asian countries, Murshed et al. (2020) reported that ICT trade fosters the adoption of clean cooking fuels. In a broader analysis of 61 developing countries, Murshed (2023a) found that access to electricity is positively influenced by remittance inflows and institutional quality but negatively impacted by income inequality. Zhao et al. (2022), focusing on European countries, observed that trade openness, globalization, and income growth enhance access to clean energy in the short run. However, in the long run, trade openness reduces accessibility, while income and globalization continue to have positive effects. Bureaucracy was also identified as a barrier to clean energy access. Murshed (2023b) explored access to clean cooking fuels in 14 Latin American and Caribbean countries, revealing that income inequality and technological innovation hinder access, while institutional quality and remittance inflows improve the adoption of clean technologies.

In the energy and environment literature, two emerging areas of interest aimed at enhancing policy-making insights are moderation analysis and the heterogeneous effects of factors driving energy consumption and carbon emissions. For instance, Gyamfi et al. (2023) highlighted the moderation effect of trade openness on the relationship between energy intensity and renewable energy. Similarly, Kwakwa (2023) demonstrated that institutional quality moderates the impact of renewable energy on carbon emissions. Additionally, Adjei-Mantey et al. (2023) revealed that the drivers of carbon emissions are heterogeneous. However, such analyses remain limited when it comes to understanding access to clean energy. A similar conclusion was drawn by Altinoz and Dogan (2021).

The review indicates that while some studies have explored the macro-level drivers of access to clean technologies, there is limited evidence from Africa, and the results have often been inconsistent. Although certain variables, such as income, have been examined, the roles of trade openness, financial development, and institutional quality remain under-researched. Additionally, there is a lack of heterogeneous analysis regarding the effects of macroeconomic variables, and moderation analysis is rarely addressed in the literature. This study aims to fill these gaps and contribute to policy discussions by examining the impact of financial development, trade openness, and institutional quality on the adoption of clean cooking technologies in Africa.

3. Methodology

Theoretical and Empirical Modeling: The study models access to clean energy based on theories that incorporate energy choice, institutional quality,

financial development, and other factors. At the household level, the energy ladder theory and energy stacking theory suggest that economic status plays a pivotal role in energy selection. Specifically, economic status influences whether households transition from traditional to modern energy or opt to use clean energy alongside traditional sources. According to the energy stacking theory, access to energy is a prerequisite for choice—one must have access before deciding whether to use it. Micro-level studies (Crentsil et al., 2019; Mensah and Adu, 2015) have highlighted that income is key in determining access to clean energy, as higher income correlates with greater purchasing power and, thus, the ability to afford clean energy. Additionally, urban households are often more likely to access clean energy due to better-paying jobs and the concentration of clean energy producers and suppliers in urban areas rather than rural areas (Murshed, 2020).

Proponents of the energy stacking theory argue that, beyond income, households' decisions to transition from traditional to modern energy are influenced by a combination of technological and socio-cultural factors. Thus, in addition to income and urbanization, national characteristics such as financial development, trade openness, and institutional quality may also affect energy accessibility. Financial development can enable households to obtain financial support for cleaner energy (Koomson and Danquah, 2012), while trade openness facilitates the importation of clean energy technologies that are not produced domestically (Murshed, 2020). According to Wang et al. (2023) and Wickramasinghe (2011), Africa and some developing countries struggle with energy poverty due to insufficient technological capacity to meet energy demands, making the import of clean energy equipment necessary. In this context, trade openness becomes crucial. Additionally, institutional quality, as derived from the technological innovation system theory (Wicki and Hansen, 2017), can play a significant role in shaping the level of energy accessibility, thus improving citizens' well-being (Nguyen and Su, 2022; Barkat et al., 2023). Before the COVID-19 pandemic, Africa was recognized for its rapid economic growth, with an annual GDP increase of approximately 4.6% between 2000 and 2016, making it the second fastest-growing region globally (ODI, 2018). Some empirical studies have also shown that economic growth or income has a significant impact on renewable energy consumption (Murshed, 2020; Dong et al., 2022; Murshed, 2022).

From the above, at the macro level, access to clean energy can be modeled as equation (1):

$$ACE = (FD, Y, TO, UB, INST) \quad (1)$$

where ACE is access to clean energy, Y is economic growth, TO is trade openness, FD is financial development, UB is urbanization, and INST is institution.

It is assumed that equation (1) takes the form of a Cobb-Douglas function. The natural logarithm of equation (1) for a panel data then gives us equation (2):

$$\begin{aligned} \text{LACE}_{it} = & \alpha_0 + \alpha_1 \text{LY}_{it} + \alpha_2 \text{LFD}_{it} + \alpha_3 \text{LTO}_{it} + \alpha_4 \text{LINST}_{it} \\ & + \alpha_5 \text{LUB}_{it} + \varepsilon_{it} + v_{it} \end{aligned} \quad (2)$$

where α_0 is the intercept, α_1 through α_5 are the coefficients of the explanatory variables, and $\ln$ denotes the natural logarithm of the variables. Also, the i and t are the individual countries and time dimension of the study, respectively. Unobservable country-specific effect and disturbance terms are respectively represented by ε_{it} and v_{it} .

There are several indicators for institutional variables. In this analysis, control of corruption (COC), voice and accountability (VOA), regulatory quality (REQ), rule of law (ROL), political stability and absence of violence (POL), government effectiveness (GOE), and an institutional index (INDX) created from the six variables will be used to replace the variable INST in the final estimation. Due to the issue of high collinearity among these institutional variables, they are not included together in a single estimation model; instead, each variable is tested separately in different models. Furthermore, their natural logarithms are not applied in the estimation since the variables take on non-positive integers, which could skew the results (Adams and Klobodu, 2016). Incorporating these variables, and following the frameworks of Obobisa et al. (2022) and Acheampong (2023), the equations for the estimation are presented in equations (3) through (9):

$$\text{LACE}_{it} = \alpha_0 + \alpha_1 \text{LY}_{it} + \alpha_2 \text{LFD}_{it} + \alpha_3 \text{LTO}_{it} + \alpha_4 \text{COC}_{it} + \alpha_5 \text{LUB}_{it} + \varepsilon_{it} + v_{it} \quad (3)$$

$$\text{LACE}_{it} = \alpha_0 + \alpha_1 \text{LY}_{it} + \alpha_2 \text{LFD}_{it} + \alpha_3 \text{LTO}_{it} + \alpha_4 \text{VOA}_{it} + \alpha_5 \text{LUB}_{it} + \varepsilon_{it} + v_{it} \quad (4)$$

$$\text{LACE}_{it} = \alpha_0 + \alpha_1 \text{LY}_{it} + \alpha_2 \text{LFD}_{it} + \alpha_3 \text{LTO}_{it} + \alpha_4 \text{REQ}_{it} + \alpha_5 \text{LUB}_{it} + \varepsilon_{it} + v_{it} \quad (5)$$

$$\text{LACE}_{it} = \alpha_0 + \alpha_1 \text{LY}_{it} + \alpha_2 \text{LFD}_{it} + \alpha_3 \text{LTO}_{it} + \alpha_4 \text{ROL}_{it} + \alpha_5 \text{LUB}_{it} + \varepsilon_{it} + v_{it} \quad (6)$$

$$\text{LACE}_{it} = \alpha_0 + \alpha_1 \text{LY}_{it} + \alpha_2 \text{LFD}_{it} + \alpha_3 \text{LTO}_{it} + \alpha_4 \text{POL}_{it} + \alpha_5 \text{LUB}_{it} + \varepsilon_{it} + v_{it} \quad (7)$$

$$\text{LACE}_{it} = \alpha_0 + \alpha_1 \text{LY}_{it} + \alpha_2 \text{LFD}_{it} + \alpha_3 \text{LTO}_{it} + \alpha_4 \text{GOE}_{it} + \alpha_5 \text{LUB}_{it} + \varepsilon_{it} + v_{it} \quad (8)$$

$$\text{LACE}_{it} = \alpha_0 + \alpha_1 \text{LY}_{it} + \alpha_2 \text{LFD}_{it} + \alpha_3 \text{LTO}_{it} + \alpha_4 \text{INDX}_{it} + \alpha_5 \text{LUB}_{it} + \varepsilon_{it} + v_{it} \quad (9)$$

As highlighted by Adams and Klobodu (2016), institutional quality can moderate the impact of trade openness, urbanization, and financial development. Thus, without government institutions implementing favorable policies, the mere participation in international trade, urban growth, and financial sector development may not effectively lead to improved access to cleaner energy sources. To assess this moderating effect, interaction terms ($LFD \times INST$), ($LTO \times INST$), and ($LUB \times INST$) are introduced into the model for access to clean fuels and technologies as follows:

$$LACE_{it} = \alpha_0 + \alpha_1 LY_{it} + \alpha_2 LFD_{it} + \alpha_3 LTO_{it} + \alpha_4 INST_{it} + \alpha_5 LUB_{it} + \alpha_6 (LFD_{it} \times INST_{it}) + \varepsilon_{it} + v_{it} \quad (10)$$

$$LACE_{it} = \alpha_0 + \alpha_1 LY_{it} + \alpha_2 LFD_{it} + \alpha_3 LTO_{it} + \alpha_4 INST_{it} + \alpha_5 LUB_{it} + \alpha_6 (LTO_{it} \times INST_{it}) + \varepsilon_{it} + v_{it} \quad (11)$$

$$LACE_{it} = \alpha_0 + \alpha_1 LY_{it} + \alpha_2 LFD_{it} + \alpha_3 LTO_{it} + \alpha_4 INST_{it} + \alpha_5 LUB_{it} + \alpha_6 (LUB_{it} \times INST_{it}) + \varepsilon_{it} + v_{it} \quad (12)$$

Differentiating LACE with respect to LFD in equation (10), the possible moderation effect of institutional quality and the respective meaning are given below:

If $\alpha_2 > 0$ and $\alpha_6 > 0$, it implies financial development positively affects access to clean fuels and technologies and institutional quality further increases this positive effect.

If $\alpha_2 < 0$ and $\alpha_6 > 0$, it implies financial development negatively affects access to clean fuels and technologies, but institutional quality dampens the negative effect of financial development.

If $\alpha_2 < 0$ and $\alpha_6 < 0$, it implies financial development negatively affects access to clean fuels and technologies and institutional quality further reduces the negative effect of financial development.

If $\alpha_2 > 0$ and $\alpha_6 < 0$, it implies financial development positively affects access to clean fuels and technologies, but institutional quality reduces the positive effect of financial development.

Similar interpretations apply to the derivatives with respect to LTO and LUB in equations (11) and (12), respectively. This study suggests that the impact of trade openness can be influenced by financial development. Given the current low level of technological advancement, importing clean energy equipment is essential. This is where financial development plays a critical role by offering the necessary funding for firms to import such equipment. As a result, an interactive term ($LTO \times LFD$) is introduced and incorporated into equation (3) to formulate equation (13).

$$LACE_{it} = \alpha_0 + \alpha_1 LY_{it} + \alpha_2 LFD_{it} + \alpha_3 LTO_{it} + \alpha_4 INST_{it} + \alpha_5 LUB_{it} + \alpha_6 (LTO_{it} \times LFD_{it}) + \varepsilon_{it} + v_{it} \quad (13)$$

Differentiating LACE with respect to LTO in equation (13) the possible moderation effect of financial development and the respective meaning are given below:

If $\alpha_3 > 0$ and $\alpha_6 > 0$, it implies trade openness positively affects access to clean fuels and technologies and financial development further increases this positive effect.

If $\alpha_3 < 0$ and $\alpha_6 > 0$, it implies trade openness negatively affects access to clean fuels and technologies, but financial development dampens the negative effect of trade openness.

If $\alpha_3 < 0$ and $\alpha_6 < 0$, it implies trade negatively affects access to clean fuels and technologies and financial development reduces this negative effect.

If $\alpha_3 > 0$ and $\alpha_6 < 0$, it implies trade positively affects access to clean fuel and technologies and financial development reduces this positive effect.

Data and Estimation Techniques: The study utilizes data from 32 African countries (refer to Appendix 1A) with sufficient information for the variables of interest. Due to data availability constraints, the analysis covers the period from 2002 to 2021. The data were sourced from the World Bank (World Bank's WDI, 2023). Urbanization is measured by the urban population as a percentage of the total population, and economic growth is measured using GDP per capita income. Financial development is measured by domestic credit provided by banks as a percentage of GDP, while trade openness is captured by trade as a percentage of GDP. Institutional quality is measured using seven different indicators, namely: corruption control (COC) measured as the control of corruption estimate; rule of law (ROL) measured as rule of law estimate; regulatory quality (REQ) measured as regulatory quality estimate; political stability (POL) is measured as political stability and absence of violence estimate; voice and accountability (VOA) is measured as voice and accountability estimate; and government effectiveness (GOE) is measured as government effectiveness estimate. Principal component analysis was applied to create an institutional quality index using the COC, REQ, ROL, VOA, GOE, and POL indicators. Table 1 presents the descriptive statistics and correlation of the variables, while Table 2 displays the results of the variance inflation factors (VIF) tests, confirming that the variables are not highly correlated as all VIF values are below 5.

Estimation Procedure and Methods: Before estimating the models, several preliminary investigations are conducted, including tests for cross-sectional dependence, unit root analysis, and cointegration testing. These steps are crucial because panel data often exhibit cross-sectional dependence, which can affect the results and influence the choice of the appropriate estimation technique. Additionally, the presence of unit roots in the variables can distort regression outcomes, while the cointegration test is used to verify the existence of a long-run relationship among the variables.

To test for cross-sectional dependence, the Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD tests are employed. In the absence of cross-sectional

Table 1
DESCRIPTIVE AND CORRELATION ANALYSIS

	Statistics											
	LACE	LFD	LY	LTO	LUB	VOA	ROL	REQ	POL	GOE	COC	INDX
Mean	2.168022	2.805972	7.235116	4.110019	3.690413	-0.549239	-0.653668	-0.587691	-0.517932	-0.690615	-0.635468	-0.028917
Median	2.163323	2.727354	7.130770	4.077316	3.742965	-0.674435	-0.716016	-0.624736	-0.442694	-0.715679	-0.712416	-0.368647
Maximum	4.604170	4.958795	9.301947	5.055365	4.300450	0.939651	1.023956	1.196947	1.116654	1.160920	1.244920	5.749430
Minimum	-2.302585	-0.710522	5.811188	3.031221	2.783158	-1.697053	-1.850253	-1.705047	-2.403348	-1.841436	-1.581135	-4.068401
Std. Dev.	1.818477	0.928857	0.851793	0.377713	0.367630	0.605677	0.597571	0.541994	0.760628	0.593255	0.569414	2.069295
	Correlations											
	LACE	LFD	LY	LTO	LUB	VOA	ROL	REQ	POL	GOE	COC	INDX
LACE	1.000000											
LFD	0.634546	1.000000										
LY	0.833591	0.616146	1.000000									
LTO	0.419770	0.253464	0.320297	1.000000								
LUB	0.552091	0.160987	0.398959	0.310091	1.000000							
VOA	0.125503	0.292237	0.211725	0.150457	-0.208459	1.000000						
ROL	0.362306	0.525369	0.412148	0.202104	-0.188890	0.702608	1.000000					
REQ	0.325021	0.531047	0.390101	0.235401	-0.274745	0.670045	0.906158	1.000000				
POL	0.159388	0.357440	0.210523	0.273899	-0.140868	0.629157	0.707063	0.633569	1.000000			
GOE	0.450575	0.562899	0.520739	0.263910	-0.102010	0.584849	0.906876	0.901316	0.593659	1.000000		
COC	0.250503	0.387934	0.295565	0.193839	-0.322454	0.625538	0.880724	0.829132	0.657625	0.831667	1.000000	
INDX	0.358659	0.540635	0.433947	0.255726	-0.239142	0.677646	0.968704	0.934969	0.764590	0.937331	0.921426	1.000000

Table 2
VARIANCE INFLATION FACTORS

Variable	Coefficient Variance	Uncentered VIF
LFD	0.000435	1.597395
LTO	0.000590	1.068171
LUB	2.43E-07	4.266057
LY	1.11E-06	1.677813
INDX	1.27E-06	3.719243

dependence, unit root tests such as Im, Pesaran, and Shin (2003) and Maddala and Wu (1999) are appropriate. On the other hand, if cross-sectional dependence is confirmed, a test like the cross-sectionally augmented IPS (CIPS) is applied for panel unit root testing. The cointegration analysis is performed using the Pedroni and Westerlund cointegration tests. After these preliminary tests, the models are estimated using the fully modified ordinary least squares (FMOLS) and the panel quantile regression model. The FMOLS method is applied because it addresses issues of endogeneity and serial correlation commonly found in panel data. Moreover, it remains robust even in the presence of cross-sectional dependence, as noted by Bai and Kao (2006). The FMOLS specification is presented in equation (14).

$$\hat{\beta}_{\text{fmol}} = \left[\sum_{i=1}^N \sum_{t=1}^T (x_{it} - \bar{x}_i)' \right]^{-1} \left[\sum_{i=1}^N \sum_{t=1}^T (x_{it} - \bar{x}_i) \hat{y}_{it}^+ + T \hat{\Delta}_{\varepsilon\mu}^+ \right] \tag{14}$$

where $\hat{\Delta}_{\varepsilon\mu}^+$ is the serial correlation correction term and $\hat{y}_{it}^+$ is the transformed variable of y_{it} to achieve the endogeneity correction. To ensure robustness, the results are compared with the outcome of the DOLS estimation.

Many of the studies that apply linear regression methods like FMOLS assume the effect of the explanatory variables is static. However, the effect of the explanatory variables may have different effects based on the heterogeneity of the dependent variable. Given the fact that the accessibility to clean energy is not uniform across Africa (World Bank’s WDI, 2023), it is expected that the effects of trade, income, urbanization, financial development, and institutional quality may differ from one quantile to another. The panel quantile regression analysis is used to establish the heterogeneous consequence of the explanatory variables on access to clean technology. The quantile regression for the panel data, which can provide useful valid results in the presence of cross-sectional dependence among panel data (Harding et al., 2020) is given in equation (15):

$$Y_{it} = \alpha_i + \beta(q)x_{it} + U_{it} \tag{15}$$

where i is the individual countries and t is the time dimension. Y is the dependent variable while x represents the explanatory variables. q denotes the quantile ($0 < q < 1$)

of the conditional distribution, and α denotes the presence of fixed effects. The impact of the explanatory variables is allowed to be determined by the quantile q . Following Koenker and Bassette (1978), the estimation of equation (4) for a number of quantiles simultaneously is obtained through minimization as given in equation (16):

$$\min_{\alpha\beta} \sum_{K=1}^T \sum_{j=1}^n \sum_{i=1}^m w_k P_{qk}(Y_{ij} - \alpha_i - \beta(qk))x_{ij} + \lambda \rho(a) \tag{16}$$

where $P_{qk} = u(q - I(u < 0))$ is the piecewise linear quantile loss function provided by Koenker and Bassette (1978). The weights w_k control the relative influence of the τ quantiles ($q_1, \dots, q_\tau$) on the estimation of the α_i parameters.

4. Results

Cross-Sectional Dependence and Unit Root: A test of cross-sectional dependence of variables was conducted (Tables 3 and 4). From Table 3, the residual terms of the countries in the models are related since all three tests reject the null hypothesis of no cross-sectional dependence. In Table 4, there are indications of cross-sectional dependence among the individual series. The appropriate unit root test in this case is the CIPS unit root. The results contained in Table 5 reveal that, at levels, the variables are not stationary but contain unit roots. The variables become stationary only at first difference fulfilling a condition for employing the FMOLS.

Cointegration Results: Cointegration analysis was employed for variables in the study. From the Pedroni test results (Table 6), four of them suggest that the variables in each model are cointegrated. For instance, Panel PP-Statistic, Panel ADF-Statistic, and Group PP-Statistic show that cointegration exists in all the models. Most of the test results also confirmed cointegration for the model containing the index for institutional quality. Table 7, which contains results from Westerlund cointegration, shows the existence of cointegration among the variables in each model. The implication is that trade openness, economic growth, urbanization, financial development, and institutional quality variables are the long-run driving forces of access to clean energy in Africa.

Table 3
CROSS-SECTIONAL DEPENDENCE RESULTS

Test	Statistic	Prob.
Breusch-Pagan LM	2549.9196	0.0000
Pesaran scaled LM	68.3434	0.0000
Pesaran CD	6.5572	0.0000

Table 4
RESULTS FOR SERIES CROSS-SECTION DEPENDENCE TEST^a

Series	Test			
	Breusch-Pagan LM Statistic	Pesaran Scaled LM Statistic	Bias-Corrected Scaled LM Statistic	Pesaran CD Statistic
REQ	2355.18***	59.02***	58.18***	1.13
GOE	1604.09***	35.18***	34.34***	-1.58
POL	1990.73***	47.45***	46.61***	-1.95*
VOA	2096.68***	50.82***	49.97***	5.72***
ROL	2580.61***	66.18***	65.34***	0.85
COC	1763.88***	40.25***	39.41***	-0.81
LACE	7266.64***	214.96***	214.12***	34.78***
LFD	4402.09***	124.01***	123.17***	49.13***
LTO	1916.06***	47.58***	46.76***	12.85***
LUB	8817.74***	264.21***	263.37***	72.46***
LY	5547.82***	160.39***	159.55***	61.04***
INDX	2532.58***	64.66***	63.81***	-1.44

^a*** and * denote 1% and 10% levels of significance, respectively.

Results and Discussion of FMOLS Regression Analysis: The first results presented in Table 8 are the results of the FMOLS estimation technique. There is evidence of a positive effect of financial development, income, trade openness, and urbanization on access to clean fuel and technologies for cooking. Also, institutional quality indicators, except political stability, are observed to positively affect

Table 5
CIPS UNIT ROOT TEST RESULTS^a

Series	At Levels	First Difference
LUB	-1.06	-2.61*
LY	-2.09	-3.49***
ROL	-2.54	-4.28***
COC	-2.18	-4.37***
LACE	-2.04	-4.84***
LFD	-2.42	-4.53***
REG	-2.69	-4.41***
POL	-2.54	-4.84***
GOE	-2.69	-4.85***
VOA	-2.25	-4.17***
LTO	-2.54	-4.05***
INDX	-2.41	-4.24***

^a*** and * denote 1% and 10% levels of significance, respectively.

Table 6
PEDRONI COINTEGRATION TEST RESULTS^a

Test	Model with COC	Model with GOE	Model with REQ	Model with POL	Model with VOA	Model with ROL	Model with INDX
<i>Panel v-Statistic</i>	−0.378	−0.114	−0.961	2.072	−1.015	−2.257	0.508
<i>Panel rho-Statistic</i>	2.770	2.639	3.257	1.489	2.753	3.823	2.265
<i>Panel PP-Statistic</i>	−5.375***	−7.785***	−3.500***	−8.419***	−4.893***	−2.529***	−8.636***
<i>Panel ADF-Statistic</i>	−3.448***	−6.273***	−0.661	−4.942***	−1.520*	−0.515	−7.405***
<i>Group rho-Statistic</i>	5.766	5.480	5.954	6.039	5.709	5.800	5.389
<i>Group PP-Statistic</i>	−7.649***	−5.839***	−3.192***	−4.022***	−4.793***	−9.938***	−6.990***
<i>Group ADF-Statistic</i>	−1.645**	0.133	−0.564	−1.063	−0.590	−2.294***	−2.328***

^a***, **, and * denote 1%, 5%, and 10% levels of significance, respectively.

access to clean fuel and technologies. The DOLS method yielded similar results (see Appendix 1B).

Discussion on the Effect of Institutional Quality, Trade Openness, and Financial Development: The institutional quality variables, namely, corruption control, rule of law, regulatory quality, voice and accountability, government effectiveness, and institutional quality index exert a positive effect on access to clean fuels and technologies (Table 8). Thus, building strong and vibrant institutions will offer benefits to the African continent by reducing energy poverty. For instance, the ability to control corruption will help preserve the limited state resources to be

Table 7
WESTERLUND COINTEGRATION RESULTS

Model with	Westerlund Statistic	P-value
COC	1.65	0.049
GOE	1.57	0.057
REQ	2.58	0.004
POL	1.88	0.029
VOA	1.66	0.045
ROL	−0.85	0.08
INDX	−1.68	0.045

Table 8
FMOLS REGRESSION RESULTS^a

Variable	Coefficient (Std. Error)						
LFD	1.921*** (0.020)	1.406*** (0.020)	1.250*** (0.020)	2.475*** (0.020)	0.159** (0.071)	1.878*** (0.020)	1.934*** (0.020)
LY	1.324*** (0.012)	1.381*** (0.012)	0.865*** (0.012)	0.871*** (0.012)	1.476*** (0.223)	1.010*** (0.013)	0.893*** (0.012)
LTO	1.333*** (0.017)	1.375*** (0.017)	1.784*** (0.017)	1.357*** (0.017)	-0.013 (0.117)	1.417*** (0.017)	1.146*** (0.017)
LUB	1.412*** (0.0002)	1.527*** (0.0002)	1.491*** (0.0005)	1.314*** (0.0002)	1.125*** (0.413)	1.515*** (0.0002)	1.684*** (0.0003)
GOE	0.340*** (0.001)						
COC		0.561*** (0.0008)					
ROL			0.361*** (0.0009)				
POL				-0.126*** (0.001)			
VOC					0.157 (0.103)		
REQ						0.259*** (0.001)	
INDX							0.122*** (0.001)
Adj-R ²	0.80	0.87	0.88	0.72	0.97	0.81	0.81

^a*** and ** denote 1% and 5% levels of significance, respectively.

used in more nationally productive activities including subsidizing clean energy for the citizens. Curbing corruption also enhances energy sector performance thereby increasing accessibility to clean fuels and technologies (Lovei and McKechnie, 2012).

Government effectiveness reflects the ability of public services to operate without political interference, ensuring that these sectors function in the best interest of the nation. The positive effect of government effectiveness on access to clean fuels and technologies in Africa suggests that minimal political manipulation in public sector operations enhances the availability of clean energy. Similarly, voice and accountability have played a key role in driving developmental and structural changes across many economies, leading to improved living conditions (Fox, 2015). In Africa, the growth of NGOs, civil society organizations, and policy think

tanks in recent years has contributed to greater governmental accountability, leading to actions that improve energy accessibility. This aligns with Fox's (2015) observation that voice and accountability act as forms of social accountability, enhancing the performance of the energy sector for societal benefit. Supporting this, Mahbub and Jongwanich (2019) found a positive impact of accountability on foreign direct investments in Bangladesh's power sector, while Sovacool and Andrews (2015) emphasized the importance of transparency in improving the Extractive Industries Transparency Initiative (EITI) in Azerbaijan and Liberia.

The positive effect of regulatory quality on access to clean energy and technology can be attributed to regulations aimed at enhancing the welfare of African citizens and promoting a cleaner environment, which have increased access to clean fuels and technologies across the continent. Strong regulatory quality ensures that energy sector stakeholders adhere to established rules and procedures. Moreover, the rule of law plays a crucial role in shaping how energy markets function (Mehmood, 2022). Existing legal frameworks may have supported policies designed to improve access to clean energy and technologies.

Political stability and the absence of violence typically suggest a stable political climate, which should provide governments and policymakers the opportunity to implement policies that enhance access to clean energy and technologies, while also attracting investment in the energy sector. However, this study found a negative relationship between political stability and access to clean fuels and technologies, which contradicts the commonly held belief (Gyamfi, 2023). These findings align with some previous studies. Acheampong (2023) found that political stability and other governance indicators reduce access to clean fuels and technologies in Sub-Saharan Africa, attributing this to the weaknesses inherent in political stability across the continent, which has hampered progress in this area. Similarly, Purcel (2020) reported that political stability initially increases environmental pollution in 47 low- and middle-income countries. As Purcel (2020) argued, the level of peacefulness on the continent is insufficient to produce positive outcomes in terms of clean energy access. The current political stability has not yet attracted the necessary investment into clean fuels and technologies. Additionally, financial resources are often diverted toward maintaining political stability, such as combating terrorism, which depletes funds that could otherwise be invested in clean energy initiatives. These factors help explain the negative effects observed between political stability and access to clean energy. Nonetheless, the overall institutional quality index shows a positive impact, suggesting that institutional quality in Africa can drive the adoption of clean fuels and technologies, contributing to energy poverty reduction. These findings largely support previous research that links institutional quality to reductions in energy poverty (Barkat et al., 2023; Ullah and Majeed, 2023).

The positive effect of financial development indicates that improvements in Africa's financial sector lead to greater access to clean fuels and technologies

for cooking. This finding aligns with the argument that financial development alleviates the credit constraints households face when trying to acquire clean energy solutions (Kwakwa et al., 2023; Koomson and Danquah, 2021). Thus, as the financial sector develops, households can more easily obtain credit to purchase clean energy technologies. Additionally, companies involved in the clean energy sector can secure financial backing to expand their operations, thereby increasing the supply of clean fuels and technologies available to individuals. Financial development plays a crucial role in providing people with affordable credit options for acquiring clean energy solutions. Furthermore, financial institutions across the continent are increasingly recognizing their responsibility in contributing to the attainment of the Sustainable Development Goals (SDGs), particularly SDGs 7, 12, and 13, which focus on access to affordable clean energy, sustainable production and consumption, and climate action, respectively. As a result, some banks and financial institutions have introduced targeted initiatives aimed at minimizing environmental damage. For instance, in South Africa, the African Development Bank has partnered with four other banks to offer financial support for transitioning from fossil fuels to modern clean energy sources (Energy Capital Power, 2022).

In 2021, Kenya's Equity Group Holdings launched a clean cooking initiative aimed at helping educational institutions access modern cooking and lighting fuels. The company provides financial support to help acquire clean cooking and lighting technologies. Similarly, banks in Ghana, such as CalBank, Stanbic, Fidelity Bank, Absa Bank, and Ecobank, have financially supported the UNEP's ECOFRIDGES program, as well as the United for Efficiency and SUNREF initiatives by the European Union (Alhassan et al., 2024). In Egypt, Commercial International Bank (CIB) has financed a 500-megawatt (MW) wind farm along the Red Sea coast, contributing to the country's renewable energy transition by providing clean energy to thousands of Egyptians (CIBEG, 2022). Additionally, the African Green Bank Initiative, spearheaded by the African Development Bank, supports green financing across the continent, helping African nations implement their Nationally Determined Contributions (NDCs). This initiative also aims to increase annual access to clean energy funds from the current 3% to 10% by 2030 (AllAfrica, 2022). These examples illustrate how the financial sector is playing a crucial role in improving access to clean fuels and technology across Africa.

Trade openness has also been found to increase access to clean fuels and technologies (Table 8), likely because many clean energy products are manufactured outside Africa and imported into the continent. This openness to trade provides consumers with access to a variety of clean energy options, allowing them to make purchasing decisions based on their financial capabilities. The findings align with Murshed (2020) and Zhao et al. (2022), suggesting that liberalized trade can enhance access to clean cooking fuels and technologies across Africa. According to KPMG, Africa's importation of white goods, such as stoves and ovens, rose by over 10% in just four years (KPMG, 2014).

Discussion on the Effect of Control Variables: An increase in income leads to greater access to clean fuels and technologies (Table 8), consistent with the energy ladder theory, which suggests that as people's economic status improves, they shift from using traditional "dirty" energy sources to cleaner options like electricity and LPG. Higher income not only drives a preference for a cleaner environment but also provides the purchasing power needed to afford cleaner energy services and products. On a national level, higher income allows governments to implement subsidy programs that help low-income groups gain access to clean fuels and technologies. For example, Ghana's Rural LPG (RLP) program, which began in 2013, aimed to provide 50% of Ghanaians with access to LPG by 2020, thereby reducing the reliance on fuel wood. As part of this initiative, the government offered free distribution of 14.5kg and 5kg LPG cylinders, subsidized LPG, provided fiscal incentives, installed free equipment for schools, hospitals, and prisons, and constructed the Ghana Cylinder Manufacturing Company (GCMC) factory in Accra (ACEP, 2015). These efforts were made possible due to Ghana's strong economic growth, as the country was among the fastest-growing economies at the time (World Bank's WDI, 2023). Similarly, the Ugandan government has undertaken an initiative to provide one million households with free gas cylinders, allowing beneficiaries to save approximately 170,000 Shillings to refill a 13kg gas cylinder, which typically costs 270,000 Shillings (Independent, 2022). Clearly, such programs require robust financial resources, underscoring the importance of higher income levels in their success.

Urbanization has a positive impact on access to clean energy (Table 8). Urban growth in Africa has risen from 35% in 2000 to approximately 42% in 2022 (Statistica, 2023). Additionally, the number of African cities has more than doubled, from 3,300 in 1990 to 7,600 in 2021, with a relatively young population (AfDB, 2022). Since many companies that supply clean fuels and technologies are located in urban areas, urban residents have greater access to these resources. Furthermore, the higher economic status prevalent in urban regions generates more demand for clean fuels and technologies compared to rural areas. This aligns with data from the World Bank (World Bank's WDI, 2023), which indicates that urban populations in Africa have consistently had higher access to clean cooking energy and technologies compared to rural populations. For example, in Sub-Saharan Africa (SSA), around 86.4% of the urban population had access to clean fuels and technologies in 2020, compared to only 48.5% of the rural population (World Bank's WDI, 2023). These findings are consistent with the studies of Murshed (2020) and Acheampong (2023).

Moderation Analysis: Table 9 presents how institutional quality moderates the impact of trade openness and financial development. For clarity, the discussion here focuses on the institutional quality index, while the detailed results for individual indicators of institutional quality are provided in Appendices 2A to 2C for FMOLS and Appendices 2D to 2F for DOLS. The findings indicate that income,

trade openness, and urbanization continue to have positive and significant effects on access to clean energy. In Model 1, the institutional quality index not only positively impacts access to clean energy but also strengthens the positive influence of financial development on clean energy access. This suggests that strong institutions are essential in attracting financial development to improve energy accessibility. It also implies that the quality of institutions plays a critical role in guiding the financial sector’s resource allocation toward reducing energy poverty. Policies and regulations implemented by a country can encourage financial players to contribute to energy poverty reduction efforts. The marginal effects of institutional quality, as shown in Table 9, are predominantly positive at the mean, minimum, and maximum values, suggesting that higher institutional quality boosts confidence in the financial sector’s support for clean energy initiatives.

Table 9
FMOLS RESULTS FOR MODERATION ANALYSIS^a

Variable	Model 1 Coefficient (Std. Error)	Model 2 Coefficient (Std. Error)	Model 3 Coefficient (Std. Error)	Model 4 Coefficient (Std. Error)
LFD	1.166** (0.021)	0.131*** (0.005)	0.706*** (0.021)	0.828*** (0.021)
LY	0.655*** (0.013)	1.126*** (0.019)	6.934*** (0.024)	0.810*** (0.007)
LTO	1.900*** (0.017)	0.008 (0.009)	2.104*** (0.0005)	0.572*** (0.012)
LUB	1.729*** (0.0006)	1.672*** (0.034)	1.113*** (0.001)	1.380*** (0.000)
INDX	0.042*** (0.001)	−0.001 (0.021)		0.123*** (0.001)
LFD × INDX	0.040*** (0.0003)			
LTO × INDX		0.038*** (0.005)		
LUB × INDX			0.755*** (0.001)	
LTO × LFD				0.034*** (0.001)
Adj R ²	0.88	0.97	0.81	0.94
Marginal Effects				
Mean	1.169	0.007	1.115	1.525
Maximum	1.399	0.226	5.467	2.257
Minimum	1.007	−0.146	−1.935	0.330

^a*** and ** shows significance at 1% and 5%, respectively.

Similarly, in Model 2, although trade openness by itself is not significant, its interaction with institutional quality leads to a notable improvement in access to clean energy. This indicates that strong institutions can ensure that trade policies with other countries are both environmentally friendly and welfare-enhancing, thereby enabling trade openness to have a positive impact on access to clean energy. In recent years, African nations have been renegotiating trade agreements with the goal of improving the well-being of their citizens, and the role of institutions in these negotiations is crucial. Here, the marginal effect of institutional quality on trade's influence on clean energy access is positive at both the mean and maximum levels (Table 9).

In Model 3, institutional quality is again found to positively moderate the effect of urbanization, with its marginal effect being positive at both the mean and maximum levels (Table 9). This suggests that institutional quality amplifies the positive impact of urbanization on access to clean fuels and technologies. As urbanization progresses, improvements in institutional quality help to implement policies that benefit citizens. Consequently, effective institutions that promote environmental quality and enhance quality of life facilitate access to clean fuels and technologies as countries urbanize. This aligns with findings from Adams and Klobodu (2016). These results support the idea that institutional quality can moderate the effects of trade openness, financial development, and urbanization on access to clean fuels and technologies, driving access through these channels.

In Model 4, where the moderation effect of financial development on the trade-access to clean energy nexus is reported, financial development is also shown to positively moderate the impact of trade. The marginal effect is higher at the mean and maximum levels, indicating that as countries engage in international trade, financial development plays a crucial role in improving access to clean fuels and technologies through trade openness. These findings are consistent with studies highlighting the significant moderation effect of institutional quality in enhancing societal welfare (Kwakwa, 2023).

Results and Discussion of Quantile Regression Analysis: The results from the quantile analysis are presented in Tables 10 through 12: Table 10 for models with ROL, REQ, and COC; Table 11 for models with POL, VOA, and GOE; and Table 12 for the model with INDX. Across all results, the strongest impact of financial development is observed at the 50th quantile. However, the effect at the lower quantile is greater than that at the highest quantile. This indicates that countries with lower access to clean fuels and technologies experience a more pronounced effect of financial development compared to those with higher levels of accessibility, except for those at the median. This could be attributed to the fact that countries with low accessibility may have prioritized financial sector development as a means to increase access to clean energy. In contrast, countries with the highest accessibility may feel somewhat satisfied with the financial sector's role in clean energy accessibility. The peak effect at the 50th quantile suggests that countries in this range may have better aligned their financial institutions to support

clean energy access compared to those outside this quantile. These findings are consistent with the assertions of Koenker and Basset (1978) and align with results in the energy and environmental economics literature, such as those by Adjei-Mantey et al. (2023) and Altinoz and Dogan (2021).

In Table 10, the impact of ROL (rule of law), REQ (regulatory quality), and COC (control of corruption) is strongest at the highest quantile, with the lowest effect observed at the 50th quantile. In Table 11, government effectiveness (GOV) has a more significant impact at lower levels of clean cooking energy access than at higher levels. Political stability (POL) shows a more pronounced reduction effect at higher quantiles, while voice and accountability (VOA) positively affects lower quantiles but has a negative effect at higher quantiles. In Table 12, the influence of the institutional quality index diminishes as we move toward higher quantiles. These results indicate that institutional quality has a heterogeneous effect on access to clean energy. For instance, countries with higher access to clean cooking energy experience greater benefits from ROL, REQ, and COC, suggesting that these institutions—rule of law, regulatory quality, and control of corruption—are functioning effectively to enhance clean cooking energy access. The lowest impact at the 50th quantile for ROL, REQ, COC, and INDX may indicate that institutions in countries within this range are not as effective compared to those outside the median. Regarding government effectiveness, the findings suggest that in countries with lower access to clean cooking energy, governments may be more focused on improving accessibility than in those with higher levels of access. Similar explanations apply to the effects of VOA and POL. Overall, institutional quality (as represented by the index) has a more significant impact in countries with lower access to clean cooking energy, likely because institutions in these countries are more aggressive in improving accessibility than those in nations with higher access. These results are further supported by the quantile slope equality test, which rejects the null hypothesis of equal coefficients across quantiles (see Appendix 3A) for all models. In conclusion, these findings align with previous suggestions that economic variables may exhibit heterogeneous effects (Koenker and Basset, 1978; Altinoz and Dogan, 2021).

The impact of income, on the other hand, is stronger at higher quantiles compared to lower ones (Tables 10-12). This suggests that countries with greater access to clean energy are likely those experiencing higher economic growth, as more citizens are financially capable of affording clean energy solutions. In contrast, the effect of urbanization decreases at higher quantiles. This indicates that in countries where access to clean energy is already widespread, the influence of urbanization is less pronounced. A possible explanation is that in these countries, the majority of the urban population already has access to clean energy, so urban growth primarily affects the smaller segment of the population still without access. In countries with lower access to clean energy, urbanization may be associated with a larger proportion of urban poor, which could lessen its impact on clean energy access. A similar pattern is observed for the effect of trade openness across the quantiles.

Table 10
QUANTILE REGRESSION RESULTS FOR MODELS WITH ROL, REQ, AND COC^a

	ROL			REQ			COC		
Variable	25 th qtle	50 th qtle	75 th qtle	25 th qtle	50 th qtle	75 th qtle	25 th qtle	50 th qtle	75 th qtle
LFD	0.394*** (0.077)	0.511*** (0.080)	0.080 (0.097)	0.395*** (0.077)	0.494*** (0.084)	0.201* (0.112)	0.393*** (0.082)	0.473*** (0.084)	0.229*** (0.084)
LY	1.027*** (0.113)	1.357*** (0.070)	1.111*** (0.084)	1.061*** (0.115)	1.345*** (0.071)	1.154*** (0.088)	1.080*** (0.114)	1.280*** (0.080)	1.144*** (0.074)
LTO	0.678*** (0.158)	0.318** (0.134)	-0.010 (0.139)	0.682*** (0.149)	0.284** (0.131)	-0.031 (0.166)	0.583*** (0.166)	0.335*** (0.131)	-0.145 (0.145)
LUB	1.717*** (0.202)	1.234*** (0.119)	1.386*** (0.155)	1.698*** (0.204)	1.271*** (0.127)	1.367*** (0.192)	1.709*** (0.220)	1.373*** (0.136)	1.345*** (0.141)
ROL	0.265*** (0.076)	0.050 (0.117)	0.477*** (0.205)						
REQ				0.277** (0.111)	0.112*** (0.127)	0.371* (0.206)			
COC							0.344*** (0.096)	0.245** (0.122)	0.344** (0.134)
C	-15.97*** (0.433)	-14.86*** (0.713)	-10.16*** (0.254)	-16.17*** (0.433)	-14.70*** (0.720)	-10.80*** (1.128)	-15.88*** (0.519)	-14.69*** (0.712)	-10.23*** (0.893)
Adj R ²	0.57	0.57	0.54	0.56	0.57	0.54	0.57	0.57	0.54

***, **, and * shows significance at 1%, 5%, and 10%, respectively.

Table 11
QUANTILE REGRESSION RESULTS FOR MODELS WITH POL, VOA, AND GOE^a

	POL			VOA			GOE		
Variable	25 th qtle	50 th qtle	75 th qtle	25 th qtle	50 th qtle	75 th qtle	25 th qtle	50 th qtle	75 th qtle
LFD	0.482*** (0.053)	0.516*** (0.083)	0.371*** (0.064)	0.473*** (0.052)	0.560*** (0.080)	0.468*** (0.555)	0.433*** (0.062)	0.507*** (0.087)	0.244* (0.135)
LYPC	1.035*** (0.078)	1.362*** (0.076)	1.327*** (0.049)	1.043*** (0.079)	1.202*** (0.112)	1.332*** (0.041)	0.959*** (0.104)	1.343*** (0.074)	1.172*** (0.123)
LTO	0.851*** (0.115)	0.335** (0.143)	0.131 (0.171)	0.853*** (0.109)	0.385** (0.153)	0.165 (0.155)	0.743*** (0.133)	0.306** (0.131)	0.044 (0.167)
LUB	1.411*** (0.162)	1.173*** (0.160)	0.718*** (0.139)	1.421*** (0.156)	1.353*** (0.231)	0.686*** (0.136)	1.727*** (0.222)	1.232*** (0.115)	1.232*** (0.130)
VOA	0.011 (0.058)	-0.100 (0.127)	-0.334*** (0.077)						
POL				-0.045 (0.078)	-0.352*** (0.068)	-0.357*** (0.062)			
GOE							0.256*** (0.083)	0.083 (0.104)	0.239 (0.226)
C	-16.04*** (0.4669)	-14.83*** (0.801)	-11.20*** (1.160)	-16.13*** (0.442)	-14.79*** (0.642)	-11.56*** (0.976)	-15.90*** (0.463)	-14.68*** (0.104)	-10.91*** (1.591)
Adj R ²	0.57	0.55	0.55	0.57	0.58	0.55	0.56	0.57	0.54

^a***, **, and * shows significance at 1%, 5%, and 10%, respectively.

Table 12
QUANTILE REGRESSION RESULTS FOR INSTITUTIONAL QUALITY INDEX^a

Variable	25 th qtle Coefficient (Std. Error)	50 th qtle Coefficient (Std. Error)	75 th qtle Coefficient (Std. Error)
LFD	0.385*** (0.078)	0.511*** (0.084)	0.290* (0.156)
LYPC	1.035*** (0.115)	1.357*** (0.075)	1.266*** (0.123)
LTO	0.663**** (0.163)	0.307** (0.131)	−0.039 (0.186)
LUB	1.759*** (0.221)	1.230*** (0.126)	1.190*** (0.183)
INDX	0.080*** (0.026)	0.012 (0.035)	0.027 (0.070)
C	−16.279*** (0.442)	−14.844*** (0.718)	−11.415 (1.544)
Adj R ²	0.57	0.57	0.54

^a***, **, and * shows significance at 1%, 5%, and 10%, respectively.

5. Conclusion and Recommendations

Access to clean fuels and technologies is essential for poverty reduction, and global leaders have committed to achieving this goal by 2030. While progress has been made in some countries and regions, Africa lags behind. To support policy-makers in closing this gap, it is crucial to identify the macroeconomic factors influencing access to clean fuels and technologies in Africa. The scarcity of empirical studies on these factors prompted this research. This paper modeled access to clean fuels and technologies as a function of income, trade openness, financial development, urbanization, and institutional quality. Using data from 32 African countries spanning the period from 2002 to 2021, panel FMOLS and quantile regression techniques were employed for the analysis. The findings revealed the following:

- a) Income, trade openness, financial development, urbanization, and institutional quality all positively influences access to clean fuels and technologies.
- b) Institutional quality, to a large extent, has a direct and substantial positive impact on access to clean fuels and technologies.
- c) The magnitude of these effects varies across the distribution of the countries.
- d) Institutional quality amplifies the positive effects of trade openness, urbanization, and financial development on access to clean fuels and technologies.

- e) Financial development strengthens the effect of trade openness on access to clean fuels and technologies.

There are four key policy recommendations derived from the findings. First, energy sector reforms aimed at reducing energy poverty in Africa must consider the significant roles of institutional quality and financial development. Institutional quality can be enhanced by government efforts to channel resources into the clean energy sector and provide financial support to help citizens access clean cooking energy and technologies. Additionally, stronger institutions that combat resource wastage, such as reducing corruption, will enable African countries to maximize the value of programs designed to improve access to clean energy. Empowering pressure groups and civil society organizations to contribute insights and scrutinize government actions will also aid in reducing energy poverty. Effective regulatory bodies are necessary to ensure that both state and private actors work in the best interests of the public. Vibrant financial institutions can also play a crucial role by providing support to firms to increase the supply of clean energy and technologies, as well as offering affordable financial credits to individuals for acquiring clean energy solutions. Thus, reforms focused on alleviating energy poverty must address the institutional and financial barriers that may hinder their success. Furthermore, given the evolving nature of governance and institutions in promoting access to clean energy, appropriate reforms should be implemented to adapt to new conditions on the continent and within the global context.

Second, strengthening institutional quality across the continent is essential to build upon the progress made in reducing energy poverty. While certain institutional factors, such as political stability and the absence of violence, may appear to indirectly reduce access to clean energy, this does not suggest that promoting political stability is detrimental. Instead, it highlights the need to leverage a peaceful environment to attract necessary investments in clean energy sources. Additionally, cost-effective measures should be implemented to promote rule of law, voice and accountability, governance effectiveness, and corruption control. The intensification of efforts to combat corruption is crucial to freeing up resources for investment in clean fuels and technologies. Law enforcement and other state agencies must be adequately funded and empowered to carry out their responsibilities effectively, benefiting the overall economy. Policymakers should align institutional development with economic transformation agendas to maximize the impact of these efforts. The significant moderation effect of institutions on the trade-clean energy accessibility nexus, financial development-clean energy accessibility nexus, and urbanization-clean energy accessibility nexus is an indication that that African countries could achieve substantial gains in the energy sector if the right institutions are in place to guide resource allocation and influence sector development.

Third, the positive impact of financial development highlights the importance of further enhancing the financial sector across Africa. While recent improvements

have been made, the financial sector still lags behind those in developed nations and certain Asian developing countries. Issues such as high lending rates and strict loan collateral requirements remain challenges that need addressing. Greater attention should be given to overcoming barriers to green finance in Africa. Policies aimed at creating a robust financial sector that supports international trade and facilitates access to clean energy should be prioritized. Governments should consider introducing reforms or collaborating with financial institutions to make capital more accessible for firms involved in the importation of clean fuels and technologies. Additionally, African leaders should leverage the African Continental Free Trade Agreement (AfCFTA) to attract foreign companies into the clean energy manufacturing sector and encourage the establishment of assembly plants on the continent. Moreover, trade policies that focus on expanding infrastructure for international trade should be strengthened to support these initiatives.

Lastly, the heterogeneous effects of the explanatory variables in this study underscore the need to tailor policy measures according to each country's unique economic and social development conditions, particularly the severity of energy poverty. For example, countries experiencing high levels of energy poverty may need to engage more actively with their financial sectors to provide stronger support to firms and businesses involved in the production and distribution of clean energy technologies, compared to countries with lower levels of energy poverty.

This study focused on energy poverty by examining access to clean fuels and technologies in 32 African countries, alongside variables such as trade openness, financial development, institutional quality, economic growth, and urbanization, due to data limitations. To gain deeper insights into energy poverty, future research could expand the number of countries analyzed as more data becomes available. Additionally, sub-regional analyses could be conducted to capture regional variations. Future studies might also explore other dimensions of energy poverty, considering additional variables that may influence energy access. In an increasingly globalized world, where external shocks like financial crises and the COVID-19 pandemic can significantly impact African countries, it is essential to assess the effect of such events on energy poverty. In this study, financial development was measured using domestic credit, but future research could explore other indicators of financial sector development. Given that different financial indicators can yield varying effects on economic outcomes, it would be valuable to conduct further analysis when data permits. Moreover, future studies could employ other advanced estimation techniques such as time-varying panel quantile estimations and panel spatial predictions to identify the drivers of energy poverty more accurately. Exploring the impact of energy poverty on overall welfare is another important avenue for future research.

APPENDIX

APPENDIX 1A: LIST OF COUNTRIES SELECTED FOR THE STUDY

Algeria	Congo, Rep.	Liberia	Rwanda
Angola	Côte d'Ivoire	Madagascar	Senegal
Benin	Egypt	Mauritania	Sierra Leone
Botswana	Gambia	Mauritius	South Africa
Burkina Faso	Ghana	Morocco	Tanzania
Cameroon	Guinea	Mozambique	Togo
Comoros	Guinea-Bissau	Namibia	Tunisia
Congo, DR	Kenya	Nigeria	Uganda

APPENDIX 1B: DOLS REGRESSION RESULTS^a

Variable	Coefficient (std. error)						
	COC	REQ	ROL	VOA	GOE	POL	INDX
LFD	0.179** (0.066)	0.169*** (0.037)	0.125*** (0.033)	0.148*** (0.044)	0.167*** (0.001)	0.173*** (0.066)	0.151** (0.064)
LY	1.205*** (0.225)	0.895*** (0.061)	0.931*** (0.863)	0.900*** (0.103)	0.765*** (0.003)	1.139*** (0.233)	0.934*** (0.230)
LTO	−0.048 (0.114)	−0.026 (0.044)	−0.013 (0.053)	0.002 (0.049)	0.062*** (0.001)	−0.090 (0.112)	−0.014 (0.114)
LUB	1.459*** (0.411)	1.553*** (0.141)	1.372*** (0.175)	1.491*** (0.188)	1.579*** (0.006)	1.544*** (0.419)	1.922*** (0.424)
GOE	0.242** (0.124)						
COC		0.259*** (0.059)					
ROL			0.273*** (0.067)				
POL				0.013 (0.024)			
VOC					0.123*** (0.002)		
REQ						0.282** (0.130)	
INDX							0.113*** (0.041)
Adj-R ²	0.97	0.97	0.97	0.96	0.96	0.97	0.81

^a*** and ** denote 1% and 5% level of significance, respectively.

APPENDIX 2A: MODERATION ROLE OF INDIVIDUAL INSTITUTIONS
ON THE EFFECT OF FINANCIAL DEVELOPMENT (FMOLS RESULTS)^a

Variable	Coefficient (std. error)					
	COC	REQ	ROL	VOA	GOE	POL
LFD	0.009 (0.097)	1.541*** (0.0210)	0.213*** (0.014)	0.259*** (0.061)	−0.191** (0.020)	0.643*** (0.010)
LY	1.292*** (0.167)	1.256*** (0.012)	1.146*** (0.024)	1.478*** (0.154)	1.323*** (0.012)	0.484*** (0.007)
LTO	−0.003 (0.079)	0.657*** (0.017)	−0.016 (0.012)	−0.077 (0.079)	0.453*** (0.017)	−1.344*** (0.011)
LUB	1.024*** (0.283)	1.500*** (0.0005)	0.854*** (0.042)	0.629** (0.279)	0.795*** (0.0003)	0.575*** (0.028)
GOV	0.769*** (0.226)					
LFD × GOV	−0.151** (0.070)					
COC		0.221*** (0.0010)				
LFD × COC		0.057*** (0.0009)				
ROL			0.448*** (0.032)			
LFD × ROL			0.036*** (0.010)			
POL				−0.141 (0.113)		
LFD × POL				0.069* (0.039)		
VOC					0.104*** (0.0009)	
LFD × VOC					0.154*** (0.0009)	
REQ						0.575*** (0.028)
LFD × REQ						0.032*** (0.008)
Adj-R ²	0.97	0.89	0.97	0.97	0.95	0.81

^a***, **, and * denote 1%, 5%, and 10% level of significance, respectively.

APPENDIX 2B: MODERATION ROLE OF INDIVIDUAL INSTITUTIONS
ON THE EFFECT OF TRADE OPENNESS (FMOLS RESULTS)^a

Variable	Coefficient (std. error)					
	COC	REQ	ROL	VOA	GOE	POL
LFD	0.192*** (0.006)	0.206*** (0.046)	0.160*** (0.020)	0.231*** (0.008)	0.893*** (0.020)	0.178*** (0.001)
LY	1.259*** (0.023)	1.053*** (0.159)	1.122*** (0.012)	1.520*** (0.025)	0.964*** (0.012)	1.179*** (0.005)
LTO	0.087*** (0.020)	0.186 (0.132)	0.769*** (0.017)	0.002 (0.015)	0.143*** (0.017)	−0.385*** (0.004)
LUB	0.951*** (0.040)	1.123*** (0.272)	0.975*** (0.0005)	0.430*** (0.045)	0.828*** (0.0003)	1.073*** (0.021)
GOV	−0.296*** (0.090)					
LTO × GOV	0.143*** (0.021)					
COC		−0.637 (0.594)				
LTO × COC		0.028* (0.145)				
ROL			0.447*** (0.001)			
LTO × ROL			0.028*** (0.0007)			
POL				−0.026 (0.034)		
LTO × POL				0.001*** (0.0004)		
VOC					0.153*** (0.0009)	
LTO × VOC					−0.406*** (0.001)	
REQ						2.084*** (0.021)
LTO × REQ						−0.433*** (0.005)
Adj-R ²	0.97	0.97	0.96	0.97	0.95	0.97

^a***, **, and * denote 1%, 5%, and 10% level of significance, respectively.

APPENDIX 2C: MODERATION ROLE OF INDIVIDUAL INSTITUTIONS
ON THE EFFECT OF URBANIZATION (FMOLS RESULTS)^a

Variable	Coefficient (std. error)					
	COC	REQ	ROL	VOA	GOE	POL
LFD	0.615*** (0.003)	0.132** (0.022)	0.220*** (0.012)	0.281*** (0.020)	−0.030 (0.022)	0.027*** (0.003)
LY	0.155*** (0.016)	0.964*** (0.076)	2.003*** (0.047)	1.373*** (0.012)	2.094*** (0.129)	0.687*** (0.010)
LTO	−0.033*** (0.004)	−0.048 (0.035)	0.806*** (0.016)	0.664*** (0.016)	−0.244*** (0.048)	−0.474*** (0.003)
LUB	0.056 (0.045)	1.602*** (0.128)	−1.403*** (0.112)	0.772*** (0.0002)	1.101*** (0.191)	1.212*** (0.012)
GOE	−0.601*** (0.008)					
LUB × GOE	0.156*** (0.014)					
COC		3.298*** (0.077)				
LUB × COC		−0.835*** (0.077)				
ROL			−8.833*** (0.228)			
LUB × ROL			2.593*** (0.061)			
POL				0.901 (0.001)		
LUB × POL				−0.340*** (0.0008)		
VOC					−1.669*** (0.404)	
LFD × VOC					0.356** (0.100)	
REQ						11.108*** (0.044)
LUB × REQ						−2.975*** (0.012)
Adj-R ²	0.99	0.95	0.98	0.96	0.96	0.96

^a***, **, and * denote 1%, 5%, and 10% level of significance, respectively.

APPENDIX 2D: DOLS RESULTS FOR MODERATION ROLE OF INDIVIDUAL INSTITUTIONS ON THE EFFECT OF FINANCIAL DEVELOPMENT^a

Variable	Coefficient (std. error)					
	COC	REQ	ROL	VOA	GOE	POL
LFD	0.083* (0.043)	0.191*** (0.042)	1.142*** (0.097)	0.187*** (0.036)	0.030*** (0.010)	0.059*** (0.021)
LY	0.928*** (0.065)	0.952*** (0.053)	0.039 (0.066)	0.958*** (0.071)	0.512*** (0.033)	0.586*** (0.045)
LTO	-0.025 (0.033)	0.001 (0.031)	-1.370*** (0.124)	0.006 (0.033)	0.112*** (0.006)	0.046*** (0.016)
LUB	1.490*** (0.129)	1.495*** (0.138)	1.224*** (0.187)	1.408*** (0.144)	1.656*** (0.052)	1.052*** (0.103)
GOV	0.341*** (0.106)					
LFD × GOV	-0.055* (0.029)					
COC		0.218** (0.104)				
LFD × COC		0.032 (0.031)				
ROL			0.488* (0.274)			
LFD × ROL			0.086 (0.080)			
POL				-0.056 (0.048)		
LFD × POL				0.030* (0.015)		
VOC					0.072*** (0.026)	
LFD × VOC					0.008*** (0.003)	
REQ						0.220*** (0.178)
LFD × REQ						0.017 (0.0159)
Adj-R ²	0.97	0.97	0.40	0.97	0.96	0.94

^a***, **, and * denote 1%, 5%, and 10% level of significance, respectively.

APPENDIX 2E: DOLS RESULTS FOR MODERATION ROLE OF INDIVIDUAL INSTITUTIONS ON THE EFFECT OF TRADE OPENNESS^a

Variable	Coefficient (std. error)					
	COC	REQ	ROL	VOA	GOE	POL
LFD	0.158*** (0.0001)	0.067*** (0.0002)	0.083*** (0.001)	0.085*** (0.024)	0.102*** (0.024)	0.081*** (0.025)
LY	0.174*** (0.0007)	0.459*** (0.0008)	0.293*** (0.002)	0.333*** (0.111)	0.621*** (0.089)	0.552*** (0.113)
LTO	0.188*** (0.0006)	0.079*** (0.001)	0.014*** (0.002)	0.125** (0.055)	−0.060 (0.056)	−0.133** (0.061)
LUB	1.686*** (0.001)	1.060*** (0.003)	1.751*** (0.006)	0.710*** (0.254)	1.425*** (0.266)	1.976*** (0.268)
GOV	−0.436*** (0.002)					
LTO × GOV	0.092*** (0.0006)					
COC		−0.241*** (0.004)				
LTO × COC		0.050*** (0.001)				
ROL			0.111*** (0.001)			
LTO × ROL			0.008*** (0.002)			
POL				0.174 (0.118)		
LTO × POL				−0.001 (0.003)		
VOC					0.723*** (0.266)	
LTO × VOC					−0.161** (0.064)	
REQ						0.853** (0.341)
LTO × REQ						−0.186** (0.083)
Adj-R ²	0.98	0.97	0.98	0.99	0.99	0.99

^a***, **, and * denote 1%, 5%, and 10% level of significance, respectively.

APPENDIX 2F: DOLS RESULTS FOR MODERATION ROLE OF INDIVIDUAL INSTITUTIONS ON THE EFFECT OF URBANIZATION^a

Variable	Coefficient (std. error)					
	COC	REQ	ROL	VOA	GOE	POL
LFD	0.106*** (0.019)	0.455*** (0.057)	0.251*** (0.042)	0.065*** (0.021)	0.138*** (0.031)	0.079*** (0.019)
LY	0.422*** (0.057)	0.551*** (0.092)	0.296*** (0.063)	0.712*** (0.076)	1.001*** (0.068)	0.545*** (0.065)
LTO	-0.023 (0.026)	-0.626** (0.089)	-0.366*** (0.079)	-0.055 (0.029)	-0.052 (0.038)	-0.055 (0.027)
LUB	1.639*** (0.175)	-0.146 (0.161)	0.419*** (0.098)	1.678*** (0.197)	1.137*** (0.149)	2.056*** (0.175)
GOE	0.043 (0.321)					
LUB × GOE	0.008 (0.083)					
COC		5.043*** (0.589)				
LUB × COC		-1.288*** (0.150)				
ROL			6.917*** (0.584)			
LUB × ROL			-1.640*** (0.151)			
POL				0.566*** (0.205)		
LUB × POL				-0.147*** (0.054)		
VOC					1.302*** (0.397)	
LUB × VOC					-0.319*** (0.100)	
REQ						1.172*** (0.403)
LUB × REQ						-0.283*** (0.104)
Adj-R ²	0.99	0.94	0.96	0.98	0.97	0.99

^a***, **, and * denote 1%, 5%, and 10% level of significance, respectively.

APPENDIX 3A: QUANTILE SLOPE EQUALITY TEST

3A1: SUMMARY AND DETAIL RESULTS FOR SPECIFICATION:
LACE LFD LY LTO LUB INDX C

Test Summary		Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Wald Test		51.07071	10	0.0000
Quantiles	Variable	Restr. Value	Std. Error	Prob.
0.25, 0.5	LFD	−0.097381	0.089202	0.2750
	LY	−0.337281	0.097817	0.0006
	LTO	0.409464	0.137655	0.0029
	LUB	0.385458	0.170593	0.0239
	INDX	0.051430	0.030941	0.0965
0.5, 0.75	LFD	0.263852	0.114831	0.0216
	LY	0.188368	0.119051	0.1136
	LTO	0.423074	0.151886	0.0053
	LUB	0.056398	0.188554	0.7649
	INDX	−0.043870	0.059310	0.4595

3A2: SUMMARY RESULTS FOR OTHER SPECIFICATIONS

Specification with	Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
REQ	Wald Test	45.82980	10	0.0000
COC	Wald Test	63.16476	10	0.0000
POL	Wald Test	54.78374	10	0.0000
VOC	Wald Test	72.16661	10	0.0000
GOE	Wald Test	50.28640	10	0.0000
ROL	Wald Test	84.12001	10	0.0000

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