AFRICAN ECONOMIC AND SOCIAL RESEARCH INSTITUTE (AESRI)

WORKING PAPER SERIES

DO NATURAL RESOURCE RENTS AID RENEWABLE ENERGY TRANSITION IN RESOURCE-RICH AFRICAN COUNTRIES? THE ROLES OF INSTITUTIONAL QUALITY AND ITS THRESHOLD

Accepted: ***Natural Resources Forum***

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WP 02/2024

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DO NATURAL RESOURCE RENTS AID RENEWABLE ENERGY TRANSITION IN RESOURCE-RICH AFRICAN COUNTRIES? THE ROLES OF INSTITUTIONAL QUALITY AND ITS THRESHOLD

Clement Olalekan Olaniyi[1] & Nicholas M. Odhiambo

Abstract

Transitioning to a carbon-neutral renewable energy (REN) option to decarbonize ecosystems and mitigate carbon dioxide (CO_2) emissions and the negative impacts of climate change is consistent with United Nations Sustainable Development Goals 7 and 13. Scholars have identified natural resource wealth and institutions as critical factors in the REN transition in resource-rich countries. Financial barriers are arguably the most significant impediments to transitioning to REN, as REN is more capital-intensive and costly to produce, invest in, and use than traditional fossil fuel-based energy. Meanwhile, weak institutions and corruption in most resource-rich countries culminate in the resource curse phenomenon and the mismanagement of natural resource wealth. It implies that institutions (weak or strong) modify the natural resource rent contribution to the REN transition. Previous research has paid little attention to the impact of the interplay between natural resources and institutional quality on the REN transition in resource-rich African countries. This study examines how institutions moderate the contribution of natural resource wealth to accelerating or inhibiting the REN switch in resource-rich African countries for the period 2000–2021, using fully modified ordinary least squares, a Driscoll-Kraay nonparametric covariance matrix, and moments-based quantile regression estimators. This study departs from earlier studies by determining the institutional quality threshold above which institutions significantly stimulate natural resource rents to accelerate Africa's REN transition. The findings indicate that institutions in resource-rich African countries breed inefficient bureaucracies and corruption in natural resource rent administration. These undermine the ability

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of natural resource incomes to facilitate a shift to renewable energy sources. The threshold analyses indicate that most resource-rich African countries operate below the institutional quality threshold. This finding corroborates that inefficient institutions abet natural resource rent mismanagement and hinder the channeling of resource income towards the REN transition. The findings' policy implications are robustly articulated and outlined.

Keywords: institutional quality, dynamic panel threshold, natural resource rents, renewable energy transition, resource-rich African countries

***JEL Classification**: N27; O13; Q20*

1. Introduction

Environmentally unfriendly and human-threatening fossil fuels have remained the mainstay sources of energy to meet the rising demands of the rapidly expanding world population and economy for many years (Wang *et al.,* 2023; Li *et al.,* 2023). Fossil fuel combustion emits harmful pollutants, negatively affecting sustainable growth and threatening the earth's life-sustaining capacity (Awan, Alnour *et al.,* 2022; Wang *et al.,* 2023). Global energy-related carbon emissions caused by fossil fuel usage increased by 1.4% in 2017, reaching 32.5 gigatons (IEA, 2019). Due to global warming-related issues, fossil fuels deteriorate the quality of human life and health. It also contributes to energy insecurity, supply risk, and health issues. Despite the corrosive effects of fossil fuel usage on the environment and humans, it still provides over 85 percent of all global energy demands (Wang et al., 2023). Consequently, governments and international institutions, in alliance with the United Nations Sustainable Development Goals 7 and 13 (affordable and clean energy), have begun to recognize the need for alternative, clean energy sources to preserve the sanctity of the environment and humanity (Huang, Ibrahim & Al-Faryan, 2023; Sohail, 2023), leading to increased demand for renewable energy (REN) options.

Campaigns and awareness are ongoing to incentivize the transition to net-zero emissions renewable energy consumption and production as a solution to mitigate carbon emissions (Awan *et al.,* 2022), ensure energy security, and ensure environmental sustainability (Huang, Ibrahim & Al-Faryan, 2024; Chaouali *et al.,* 2023; Kocoglu *et al.,* 2023; Onifade, Haouas & Alola, 2023; Alola & Adebayo, 2023; Xu & Ullah, 2023; Onwe *et al.,* 2023; Chu *et al.,* 2023; Hosseini, 2022; Afshan et al., 2022). Although, efforts toward transitioning to REN have not yielded much significant effect, as its contributions to global energy production and deployment remain at 15% (Shinwari *et al.,* 2022). This statistic still implies the dominance of fossil fuel usage. It further validates the heavy presence of carbon dioxide (CO_2) emissions worldwide. International bodies and events such as the United Nations, the Amsterdam Treaty, 1997; the Intergovernmental Panel on Climate Change, 2021; the Renewable Energy Policy Network for the Twenty-First Century, 2021; the 2015 Paris Agreement; the Renewables Global Status Report 2020; the United Nations

Climate Conference (COP27); The 2023 African Climate Summit; Africa Clean Energy Corridor; the Africa Union (AU)'s Agenda 2063; the Economic Community of West African States (ECOWAS) Policies on Renewable Energy; and so on, have all agreed that one of the pathways to ensure net-zero carbon emissions is to transit from pollution-intensive fossil fuels and other greenhouse gases (GHGs) to renewable energy consumption and production (Acheampong *et al.,* 2023; Somoye *et al.,* 2023). Switching from heavy pollutants' energy consumption to sustainable development-driven renewable energy is appealing (Onuoha, Dimnwobi *et al.*, 2023). This action is consistent with the International Renewable Energy Agency's goal that renewable energy sources will supply two-thirds of the world's energy needs by 2050 (Ma *et al.*, 2023; Dingru *et al.*, 2023; Wang *et al.,* 2023). Meanwhile, renewable energy's multidimensional factors require deep empirical investigations to unravel issues and challenges surrounding it on the path to environmental sustainability.

A switch to REN options is beneficial because it mitigates climate change, reduces the life-threatening and endangered environment posed by fossil fuel combustion (Nchofoung & Ojong, 2023; Ullah *et al.,* 2023). Meanwhile, REN transition requires heavy capital investment and financial obligations to set up for exploitations and propagation (Benavides-Franco *et al.*, 2023; Adedoyin *et al.,* 2023; Menegaki & Tsagarakis, 2015). Although with lack of consensus and uniformity in findings, existing literature is replete with evidence that natural resource wealth can be converted to yield the capital needed to facilitate the REN transition (Nchofoung & Ojong, 2023; Chishti & Dogan, 2022; Ahmadov & Van Der Borg, 2019). It implies that natural resource wealth could be utilized to raise the amount of capital investment required to finance the long-term schemes and create necessary incentives to spur the REN transition (Huang *et al.,* 2024; Nchofoung & Ojong, 2023; Shinwari *et al.,* 2022; Baye *et al.,* 2021; Ahmadov & Van Der Borg, 2019). However, the actualization of this process depends on the effective utilization and management of natural resource wealth in resource-rich countries (Yu, Wenhui, *et al.*, 2023). The literature is replete with the fact that many resource-rich countries have not been able to translate their natural resource wealth to better economic and development outcomes for the benefits of their citizens (Wang *et al.*, 2023; Ajide, 2022; Mesagan *et al.,* 2019). This phenomenon is called "resource-curse" phenomenon (Auty, 1993). A strand of literature, "orthodox resource-curse approach (ORCA)", opines that resource-rich countries have high likelihood to underperform in economic fundamentals and developmental outcomes (Papyrakis, 2017). Thus, the likelihood of resource-rich countries using resource incomes/rents to finance initiatives and schemes that are liable to facilitate the transition to net-zero emissions renewable energy might be elusive due to corruption tendencies and reckless management of natural resource wealth. Studies have attributed natural resource curse situation in many resource-rich countries to predominant presence of weak institutional frameworks, which give room to rent-seeking inclinations, opportunism, corrupt practices, and poor governance structure in the management of natural resource rents (Nchofoung & Ojong, 2023). The argument that when a country's institutions are weak, resource rent turns into a curse rather than a blessing to improve the economic condition best captures the significance of institutions (Abdulahi *et al.,* 2019; Antonakakis *et al.,* 2017). As a result, institutions matter in the natural resource rent-renewable energy transition nexus.

Thus, it indicates that institutional quality matters in moderating the natural resource wealth's contribution to REN transition. Strong institutions tend to reduce the propensity of corruption, bureaucracies, rent-seeking, opportunistic tendencies in the management of natural resource rents. This increases the likelihood of natural resource wealth being channeled to stimulate renewable energy transition. Whereas, weak institutions fuel resource-curse syndrome and thwart the drives to use the natural resource rents to foster the REN transition. Still nascent and evolving, the scholars have begun to examine the effect of natural resource wealth on REN with diverse and mixed findings (Nchofoung & Ojong, 2023; Wang *et al.,* 2023; Benavides-Franco *et al.,* 2023; Dingru *et al.,* 2023; Ma *et al.,* 2023; Chishti & Dogan, 2022; Shinwari *et al.,* 2022; Chen, Fu & Chang, 2021; Ahmadov & Van Der Borg, 2019). Despite the important role of institutional quality in determining the tendency of resource-curse thesis in the natural resource rent-renewable energy transition nexus, existing research has paid inconsequential attention to the probable moderating role of institutional quality.

The only study appeared to have examined the institutional quality's impact in influencing natural resource wealth's contribution to REN transition is Nchofoung & Ojong (2023). Meanwhile, there are important issues left unexplored in the study. One, the study did not pay a particular attention to resource-rich countries where the issues of resource-curse phenomenon and weak institutions are more predominant. Such a study is more relevant for resource-rich countries where there is a prevalence of natural resource wealth's misuse and mismanagement, especially in resource-rich African countries. Thus, channeling resource income to prosecute the REN transition without sound institutional framework might be more challenging. This study differs by examining how institutional quality mediates the natural resource wealth's contribution to REN transition in a panel analysis of resource-rich Africa countries. The study that focused on resource-rich African countries is more pertinent, as resource-cursed phenomena and weak institutions are more prevalent in these countries. As a result, utilizing natural resource rents to spur the REN transition might be more intriguing in these countries. Additionally, according to information currently available, three of the resource-rich African countries, South Africa, Egypt, and Algeria, account for 60% of all CO_2 emissions in Africa (AJLabs, 2023). Therefore, concerns relating to the transition to carbon emissions-neutral renewables are more important in Africa's resource-rich nations than in the continent's resource-poor nations. Two, previous studies on the trilogy did not address the issue of cross-sectional dependence. Recent advances in empirical research have shown that estimates might be biased and unreliable if cross-sectional dependence is not captured. Besides, there is a high level of interdependence, international trade, and economic integration among African countries. Thus, the intertwining among the countries allows shocks to transmit from one to another. Assuming cross-sectional independence might produce biased estimates and the wrong policy direction (Baye *et al.,* 2021; Hoechle, 2007; Olaniyi & Odhiambo, 2023a & b; Olaniyi, Al-Faryan, & Ogbaro, 2023; Olaniyi & Odhiambo, 2024). This study adds value to the empirical content by accounting for cross-sectional dependence in the natural resource rent-institution-renewable energy trilogy in the case of resource-rich African countries. Three, unlike previous studies, we contribute to the existing research by determining the institutional quality threshold, if any, in the natural resource rent-renewable energy nexus.

We argue that institutional development may have to be persistently above a certain threshold before it is strong enough to combat corruption in natural resource wealth management. Institutional development may need to be above the threshold to facilitate significant investments in green technologies and renewable energy deployment, simplifying the transition towards REN. On the contrary, if institutional quality falls below the threshold, it may create deficiencies that allow rent-seeking activities, deceptive dealings, exploitative behavior, flaws, manipulative and corrupt practices in resource-rich African countries' management of natural resource earnings. This results in the diversion of resource wealth towards dirty or ecologically unfriendly energy sources (non-renewable energy), which are harmful to human health and ecosystems. Institutions above the threshold are required to forestall shady dealings and block loopholes. Institutions exceeding this threshold enable resource income to be efficiently channeled to finance clean and renewable energy alternatives. The institution has to be above the threshold before it can deliver the necessary stimulus that enables natural resource rents and stimulates adequate investments in REN sources to decarbonize ecological systems. Following this argument, this study adds glamour to existing research by determining the threshold of institutional quality in the natural resource income-renewable energy nexus. Institutions beyond this level become potent catalysts that mitigate corruption and racketeering propensities in resource income administration in resource-rich African countries. As a result, it enables the channelization of resource wealth to raise the financial resources needed to foster development in renewable energy (REN) production and consumption. This study considers Africa's case due to weak institutional development on the continent (Aluko & Ibrahim, 2020; Olaniyi, 2022; Olaniyi, Al-Faryan & Ogbaro, 2023; Olaniyi & Oladeji, 2021). The average institutional quality of resource-rich Africa countries over the study period (2000–2021) is 4.67 on the ordinal scale of 0-10 (see Table 1). This statistic reveals that institutional development in resource-rich African countries is weak and below average (Adekoya *et al.*, 2022). In the same vein, some studies have attributed the prevalence of the resource curse phenomenon in many resource-rich African countries to pervasive corruption and poor institutions (Nwani *et al.*, 2023; Inuwa *et al.*, 2022; Ibekilo & Emmanuel, 2022; Adika, 2020; Heller, 2006), which allow rent-seeking, sharp practices, racketeering, and opportunistic behavior in the management of resource wealth. Thus, it turns natural resource abundance into a curse rather than a blessing. Hence, resource-rich African countries' management of natural resource rents is shrouded in murky opportunistic tendencies, rent-seeking activities and corrupt practices. Thus, weak governance mechanisms in resource-rich African countries could be the main rationale for resource-curse (Mesagan *et al.*, 2019), which tends to hamper the translation of natural resource wealth to economic progress such as environmental sustainability through the REN transition. Studying the contributions of natural resource wealth and institutions to the resource-rich African countries' REN transition is important to the continent's environmental sustainability. Sixty percent of the continent's total CO_2 emissions are generated by just three of the resource-rich African countries (South Africa, Egypt, and Algeria) alone (AJLabs, 2023). This circumstance emphasizes how important it is for resource-rich African nations to switch from carbon-intensive fossil fuels that imperil human lives and the environment to carbon-neutral renewable energy sources. African countries are richly endowed with untapped renewable energy resources. As a result, the continent has a great potential to be the "greenfield" for large-scale deployment of renewable energy sources

(Oyewo *et al.,* 2022) to help solve the problem of the energy poverty and crisis, and put the continent on the pathway to environmental sustainability. Despite the potential of the continent in renewable energy resources, Africa's renewable energy development has progressed more slowly than other parts of the world (World Bank, 2023; Adjei-Mantey *et al.,* 2023; Olaniyi, Al-Faryan & Ogbaro, 2023). It implies that more concerted efforts should be made to explore critical factors that could spur the transition to renewable energy in Africa.

The potential for renewable energy resources in Africa has been underutilized (Olanrewaju et al., 2019; Abdul-Mumuni *et al.,* 2023; da Silva et al., 2018; Amigun et al., 2008). Africa has a wealth of renewable energy resources that can help combat climate change and environmental degradation (Attiaoui *et al.,* 2017; Ergun *et al.,* 2019; Bugaje, 2006). Only 7% of Africa's hydropower potential is currently in use, according to studies by Karekezi & Kithyoma (2003), Olaniyi, Al-Faryan & Ogbaro (2023), Schwerhoff & Sy (2017), and Olanrewaju et al. (2019). It implies that 93 percent of the potential is still untapped. Therefore, resource-rich African countries need to develop institutional structures, policies and guidelines that will allow them to utilize resource wealth to exploit their numerous untapped renewable energy resources to prevent the adverse effects of climate change and put the continent on the pathway to sustainable development. Studies have identified Africa's richness in renewable energy resources (Olaniyi, Al-Faryan & Ogbaro, 2023). Notwithstanding Africa's abundance of renewable energy resources that could be tapped to reverse the narratives of energy poverty and crisis in the region (Wang, Guo, *et al.,* 2023), as well as preventing the projected impending continent's risk of being affected most by climate change and global warming globally as indicated in the earlier studies (Awad *et al.,* 2023; Dingru *et al.,* 2023; Bukari & Aluko, 2023; Kwakwa, 2023; Gemeda & Sima, 2015), the continent has not been able to maximally exploit the potentials to spur renewable energy transition to mitigate the risks associated with the overreliance on pollution-intensive fossil fuel-based energy consumption (Wang, Guo *et al.,* 2023). Resource-curse phenomena and deficient institutions are critical factors posing threats to the moves to clean energy and technology to preserve the sanctity of ecosystems and humanity in Africa. Utilizing resource wealth to provide finance and create stimulus for renewable energy diffusion and development in such an atmosphere is challenging. Mismanagement of natural resource rents for an effective renewable energy transition could prove difficult due to weak institutions, corruption, opportunistic behavior, and racketeering prevailing in resource-rich African countries. As a result, there is a high likelihood that resource income could favor dirty and environmentally degrading energy consumption and technology at the expense of net-zero-emission renewable energy options in Africa. It implies that the renewable energy transition-enhancing power of natural resource rents depends on the state of institutions in the region.

Weak institutions in resource-rich African countries are militating against the effectiveness and executability of the continent's REN transition policy. This suggests the importance of this study, as some scholars have shown that resource-rich countries, especially in Africa, are likely to experience a more difficult energy transition regime to net-zero carbon-neutral renewable energy because of their high dependence on nonrenewable energy, especially fossil fuels with high-polluting components (Onifade *et al.,* 2021). The dependence on fossil fuels has continued to cause a persistent upward trend in carbon emissions. This poses a serious threat to the environmental sustainability agenda of resource-rich African countries. Thus, this study will help resource-rich African countries because policymakers and stakeholders will be able to set more realistic institutional development's targets that will encourage better resource rent management and the transition to REN options, which is in line with Sustainable Development Goal 7 (SDG 7). The research findings of this study provide guidelines for policies to mitigate the risks of climate change and global warming on the African continent, and they provide resource-rich African nations on a road toward accomplishing SDGs 7 and 13.

Compared to earlier studies, this study contributes to the understanding of the natural resource rent-institutional quality-renewable energy trilogy in the following ways: **One**, this study is one of the pioneers in determining an institutional quality threshold above which institutions become potent and efficient to tame the resource curse syndrome and incentivize the channeling of resource rents to finance and support net zero-carbon emission renewable energy options in resource-rich African countries. **Two**, in contrast to earlier research, it is the first study to examine how institutional quality modifies natural resource wealth's contribution to REN transition in resource-rich African countries. **Three**, to increase the acceptability of the research outcomes, this study accounts for cross-sectional dependence in the empirical analysis of the natural resource rent-institution-renewable energy nexus. **Four**, this study provides novel insights and policy perspectives on critical factors that drive renewable energy diffusion and technology to mitigate the risks of climate change and global warming through the interplay of natural resource wealth and institutional quality transmission channels. It provides fresh insights on how institutions modify the natural resource endowment's contribution to spur clean energy usage. It also offers new perspectives and dynamics on leveraging natural resource rents and institutions to attain environmental sustainability and SDG 7 and 13 in resource-rich African countries.

The remainder of this study is sectionalized as follows: Section 2 focuses on an overview of the peculiar issues that warrant the study's focus on resource-rich African countries. We present a literature review in Section 3, while issues of data descriptions, sources, and methods of analysis are addressed in Section 4. Section 5 discusses and presents empirical findings, whereas practical contributions and policy implications of the research outcomes form the basis of Section 6. Section 7 anchors on summary and conclusion, while the study ends with the study's limitations and suggestions for future research.

2. Rationale for studying resource-rich African countries

Africa's transition to zero-carbon dioxide emissions in energy consumption and production aligns with United Nations Sustainable Development Goals 7 and 13. The resource-rich African countries have significant roles to play in leading the continent's efforts to actualize the energy transition to environmental sustainability powered by net zero-carbon renewable energy. The resource-rich African countries' case seems to be more peculiar. South Africa, one of the leading resource-rich African countries, is the highest emitter of CO_2 emissions in Africa (AJLabs, 2023). Also, eight of the top ten highest emitters of CO_2 emissions on the continent are resource-rich African countries (South Africa, Egypt, Algeria, Nigeria, Libya, Awan Angola, Ghana, and Sudan). It implies that resource-rich African countries are the largest emitters of CO_2 in the continent. Similarly, above 60% of total CO_2 emissions of Africa's continent are emitted by only three of the resource-rich Africa countries (South Africa, 435.9 million tonnes; Egypt, 249.6 million tonnes; and Algeria, 176.2 million tonnes) (AJLabs, 2023; Ayompe *et al.,* 2021). These statistics create puzzles as to whether the natural resource endowment contributes to or inhibits the REN transition in resource-rich African countries. As a result, specific studies on REN transitions focusing on resource-rich African countries are imperative. Such empirical investigations are necessary to resolve the continent's susceptibility to the potential adverse effects of environmental degradation and climate change posed by CO_2 emissions enabled by fossil fuel usage. These countries must be deliberate to champion the struggles to ensure the African energy transition to net-zero carbon emissions clean energy production and consumption materialized. These facts highlight the need for the stakeholders, scholars and policymakers to make conscious efforts to examine the factors that could determine energy transition in resource-rich African countries for appropriate drives and policy directions. Thus, a study that unravels the fundamental factors determining the REN transition in resource-rich African countries is necessary.

Besides, the exploitation and exploration of non-renewable natural resource endowments in resource-rich African countries could constitute barriers to the switch to REN options by incentivizing fossil fuels and thereby increasing CO_2 emissions. Meanwhile, effective utilizations of natural resource rents might be helpful to finance and support the clean energy transition. Actualization of this lofty goal is being besieged by widespread corruption and rent-seeking inclinations associated with the management of the natural resource rents in resource-rich African countries (Nchofoung & Ojong, 2023; Mesagan *et al.,* 2019). This poses a serious threat to energy transition in the continent. The recent statistics give favourable perspective that Africa contributes only 4% of global carbon emissions (AJLabs, 2023; Statista, 2023; Ayompe *et al.,* 2021), making the continent the least contributor worldwide (African Development Bank, 2023; Kwakwa, 2023), but the International Rescue Committee has highlighted that 7 out of 10 countries identified as vulnerable to severe effects of climate change worldwide are in Africa. This statistic reveals that Africa is the most vulnerable to the negative effects of climate change (Awad *et al.,* 2023; Dingru *et al.,* 2023; Bukari & Aluko, 2023; Kwakwa, 2023; Gemeda & Sima, 2015). This information aligns with the findings of Adjei *et al.,* (2023), Espoir & Sunge (2021), and Olaniyi, Al-Faryan (2023) that Africa emits CO_2 at a rate higher than the rest of the world. This fact suggests that environmental pollution is spreading quicker in Africa than in other continents worldwide. Accordingly, for the African continent to make a breakthrough in switching to a clean energy choice, the resource-rich countries in Africa must play a leading role. African resource-rich countries produce a sizeable share of the continent's overall CO_2 emissions. As a result, it becomes a priority for these countries to make concerted efforts to transit to net-zero carbon emission renewable energy sources.

Meanwhile, existing literature has shown that the development of renewable energy sector requires huge initial capital investments, which makes its redeployment challenging for Africa's poor population. Financial barriers are arguably the most significant hurdle to the REN transition (Appiah-Otoo et al., 2023). Compared to fossil fuels, renewable energy’s capital costs are relatively high (Wang *et al.,* 2023; Li *et al.,* 2022). Investments in renewable energy are shown to be costly in most African nations due to a shortage of financial resources (Muoneke *et al.,* 2023; Attiaoui *et al.,* 2017). It has, however, been suggested that resource-rich countries could utilize and allocate the natural resource wealth to finance and support the REN transition. Actualizing this outcome might be challenging in resource-rich African countries due to the prevalence of resource curse syndrome and mismanagement of natural resource wealth in most of these countries (Nchofoung & Ojong, 2023; Mesagan *et al.,* 2023; Mesagan *et al.,* 2019). The issues related to weak institutions abet widespread corruption, opportunisms and rent-seeking. Recent studies have attributed the rent-seeking and opportunistic behaviour statistics associated with management of natural resource wealth to weak institutions in resource-rich African countries (Nchofoung & Ojong, 2023). Thus, utilizing natural resource wealth to finance the REN transition in the presence weak institutions and large-scale corruption presents an interesting case in resource-wealthy African countries. Amoah *et al.,* (2022) find that high corruption in Africa impedes REN transition. Consistent with the data from the Transparency International (2022), as reported by Nchofoung & Ojong (2023), resource-wealthy African countries have high levels of public sector corruption, poor governance structures, and weak institutions, which slows the effectiveness of REN policies. This might mitigate the natural resource rent's contribution to REN transition in resource-wealthy African countries. Some resource-rich African countries (Angola: 136th/180; Cameroon: 144th/180; Mozambique: 147th/180; Nigeria: 154th/180; Republic of Congo: 162th/180; Chad: 164th/180; Democratic Republic of Congo: 169th/180; Libya: 172nd/180) are reported to have scored less than 30 out of 100. It highlights the existence of weak institutions and large-scale public sector corruptions in resource-wealthy African countries (Mesagan *et al.,* 2023). A recent study by Amoah *et al.,* (2022) finds that increase in corruption reduces renewable energy consumption in Africa. It implies that corruption is a bane that impedes Africa's transition to REN.

Weak institutions in the resource-rich African countries also manifest in the averaged figures, covering 2000–2021, presented in Figure 1. It indicates that only seven countries scored 5 points or above on the ordinal scale of 0-10. The average performance of the remaining 16 countries shows that they performed below average. The scores of these countries range between 2.64 and 6.48, while the average institutional quality for all the sampled resource-rich African countries is 4.67. The state of weak institutional development in these countries validates why scholars have attributed the resource curse phenomenon in Africa to corruption and poor institutions, which culminate in the misuse and mismanagement of resource wealth. This situation might cause economic outcomes, such as the REN transition, to suffer. The information in Figure 3 reveals that resource-wealthy North African countries (Egypt, Algeria, and Libya) have the lowest patronage for renewable energy among the sampled countries. Also, it is somewhat surprising that resource-rich Southern African countries such as South Africa, Botswana, and Namibia, with better institutions, have a relatively low percentage of renewable energy consumption. Meanwhile, cases of relatively low renewable energy consumption in South Africa, Egypt, and Algeria seem to validate the statistics that the three countries contribute 60% of the total CO_2 emissions of the African continent. Figure 2 highlights the average total natural resource rents' contributions to the respective economies of the sampled resource-wealthy African countries.

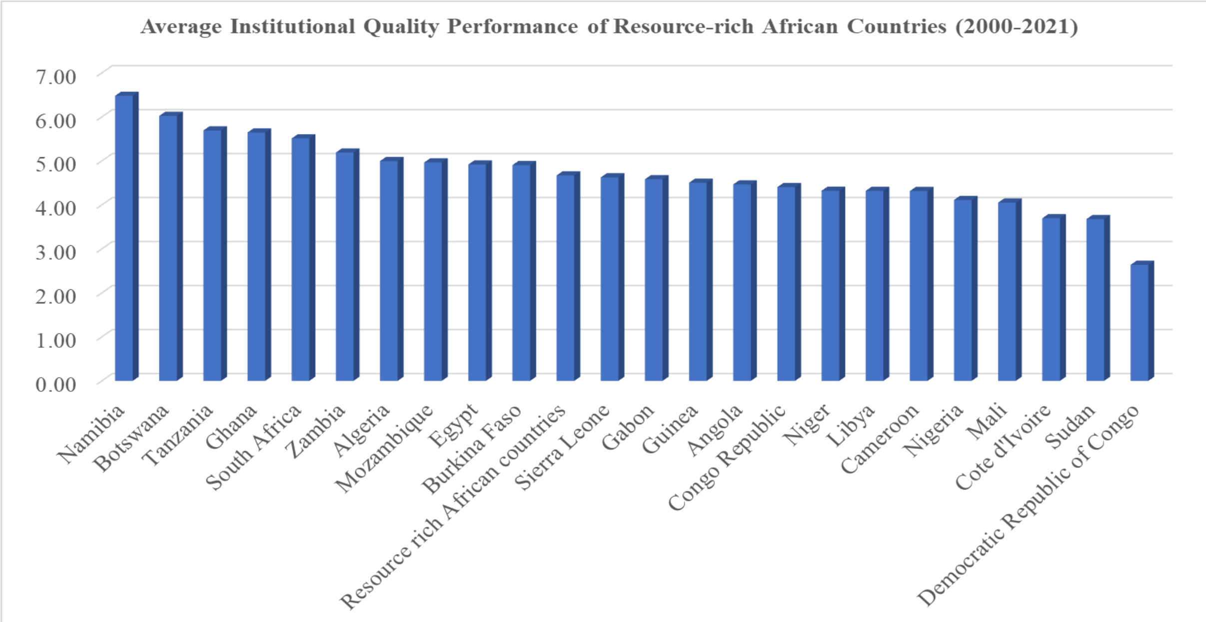

Figure 1: Average performance of institutional quality of resource-rich African countries

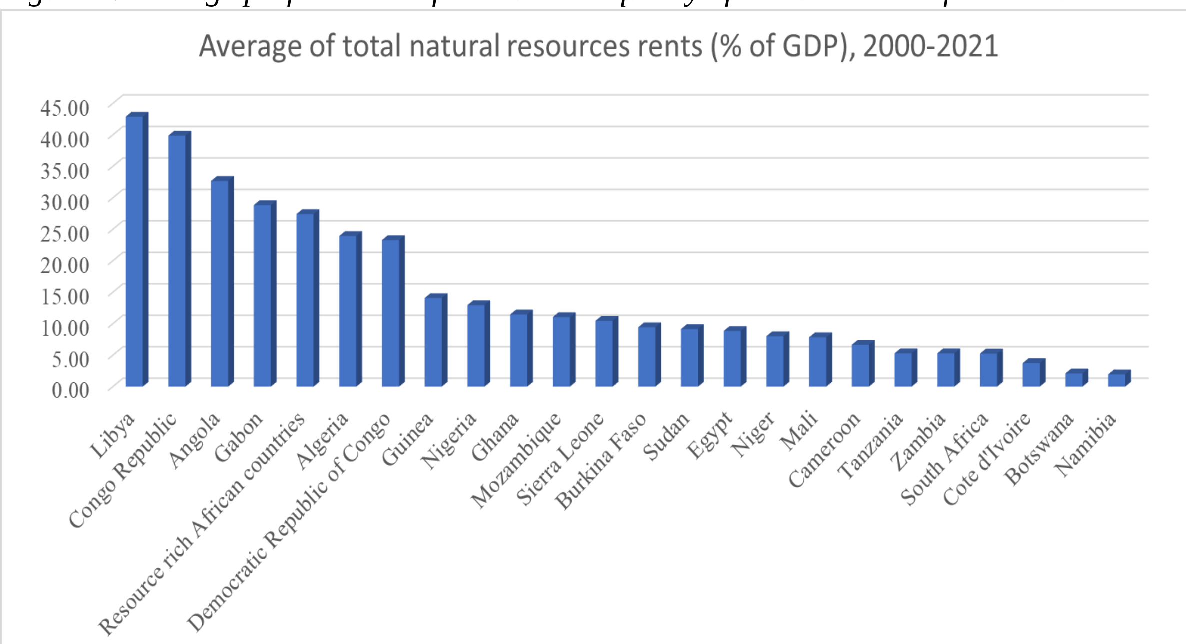

Figure 2: Average contributions of total natural resource rents to GDP of resource-rich African countries

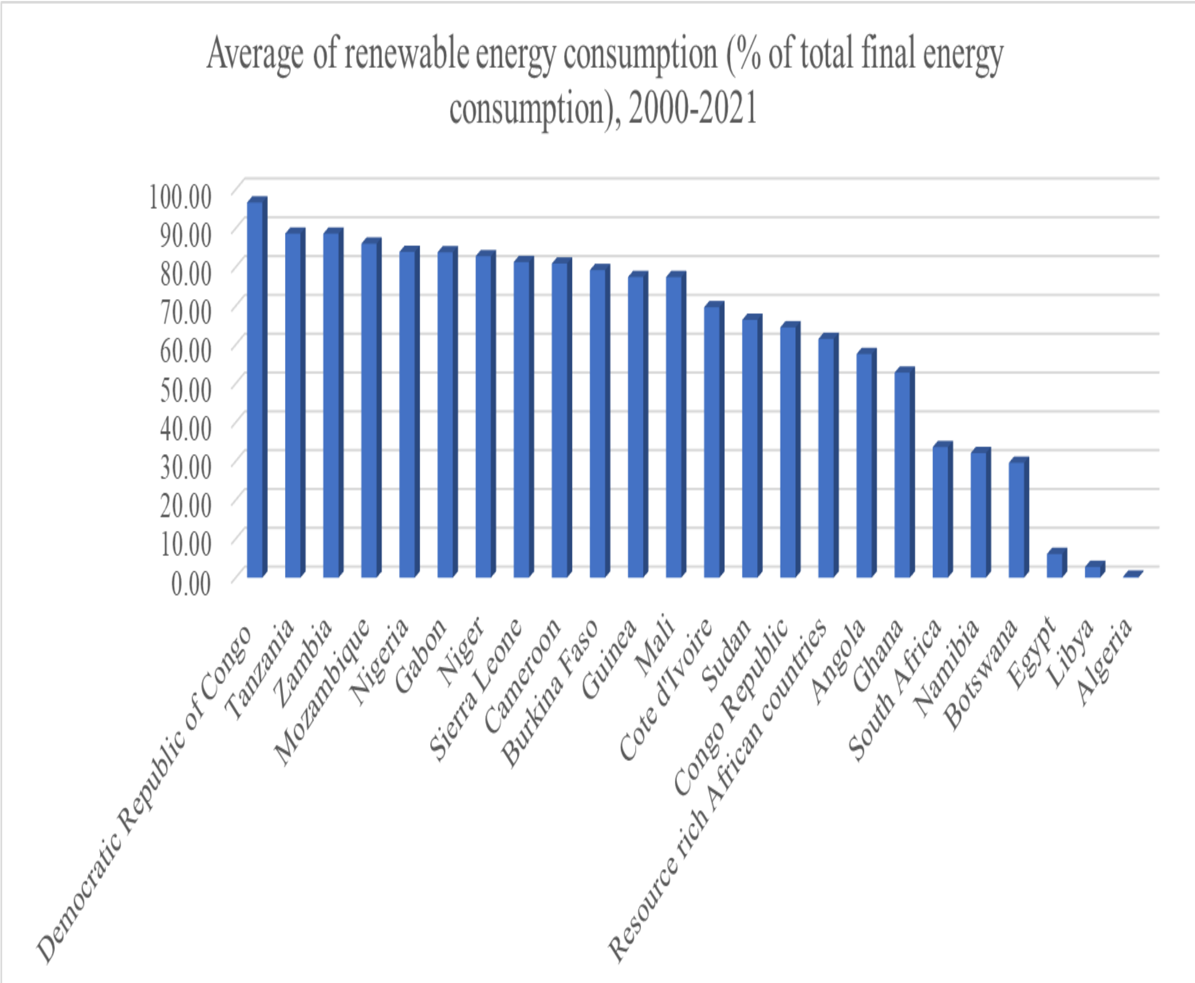

Figure 3: Average shares of renewable energy in the total energy consumption of resource-rich African countries

3. Literature review

3.1 Theoretical perspectives

The theoretical framework for the current research has its basis in energy transition theory, Hartwick's (1977) study, and the resource curse theory. According to the energy transition theory, in reaction to the corrosive effects of pollution-intensive fossil fuels and other dirty energy options on humanity, the environment, and climate change, countries (developed and developing), international institutions, and organizations champion the course of transitioning from traditional fossil fuels and high-carbon energy deployment and technology to more sustainable development-driven and net-zero carbon emission renewables and other clean energy sources to decarbonize the ecosystem and mitigate the consequences of climate change (Yu, Wenhui, *et al.*, 2023). This theory explains that the worldwide reactionary moves to shift from traditional pollution-intensive fossil fuel energy options to renewable energy alternatives is to preserve the sanctity of the ecosystem and the human race by mitigating CO_2 emissions and the negative consequences of climate change. Meanwhile, Financial constraint is a critical factor that constitutes a barrier to energy transition (Appiah-Otoo *et al.,* 2023). It could be because REN is more costly and capital-intensive than traditional pollution-intensive fossil fuel energy (Wang *et al.,* 2023; Li *et al.,* 2022). Hartwick's (1977) study argued that natural resource rents should be a positive driver of sustainable development-driven renewable energy to ensure intergenerational equity. The work suggests that natural resource rents represent capital investment made available, which could be put into productive use to finance investment in sustainable development-related issues, especially renewable energy initiatives in resource-rich countries. Thus, natural resource wealth is a potential capital investment to raise the needed financial resources to spur the REN transition in resource-wealthy countries. Meanwhile, there is ample evidence that most resource-rich countries grapple with weak institutions and widespread corruption. This situation facilitates rent-seeking and opportunism. The phenomenon culminates in the mishandling and misuse of natural resource wealth, which increases the potential to convert natural resource abundance into a curse rather than a blessing. As a result, it raises the likelihood that resource wealth may stall the REN transition spurred by sustainable development. The prevalence of resource curse syndrome in resource-rich countries suggests that natural resource rents' contributions to the REN transition depend on the quality of institutions in place. The success or failure of natural resource riches to promote the REN switch to decarbonize ecosystems and mitigate emissions is contingent on the strength or weakness of an economy's institutions.

3.2 Empirical evidence

Carbon- and pollution-intensive fossil fuel energy options and technologies still supply a significant portion of global energy needs despite their detrimental impacts on the ecosystem, human lives, and climate. Overreliance on environmentally degrading and human life-threatening fossil fuels increases the likelihood of aggravating global warming and climate change. It also threatens global energy security. Consistent with the United Nations Sustainable Development Goal number 7 (affordable and clean energy), international organizations, institutions, ecologists, economists, researchers, and sustainable development campaigners have continued to champion the transition to net-zero-carbon emission renewable energy consumption and production across the globe. Existing research has highlighted several factors that could spur the REN transition. Such factors include natural resource rents, financial development, institutional quality, human capital, government expenditure, energy prices, urbanization, foreign direct investment, foreign aid, trade openness, information and telecommunication technology, economic structure, and income. One major constraint that impedes the renewable energy switch is that it is more costly than the traditional fossil-fuel energy alternatives (Prempeh, 2023; Wang et al., 2023; Yu, Wenhui *et al.,* 2023; Bamati & Raoofi, 2020; Mukhtarov *et al.,* 2020). The renewable energy sources require huge initial capital investment (Benavides-Franco *et al.,* 2023; Adedoyin *et al.,* 2023; Shinwari *et al.,* 2022; Menegaki & Tsagarakis, 2015).

Emerging literature has emphasized the critical role of natural resource rents to the renewable energy switch. It is opined that natural resource wealth could be converted to capital to raise the needed financial resources to expedite the REN transition (Nchofoung & Ojong, 2023; Chishti & Dogan, 2022; Ahmadov & Van Der Borg, 2019). This hinges on the notion that natural resource wealth could be channeled to finance and create an incentivized system to accelerate the shift to

REN. Meanwhile, the prevalence of misuse and mismanagement of resource wealth has culminated in natural resource curse phenomena in resource-rich countries has been attributed to weak institutions and large-scale corruptions. This situation has spiked intense curiosity of scholars and stakeholders to investigate the role of natural resource wealth to spur REN transition in resource-rich countries. Although the empirical literature is still nascent, the findings of extant studies are mixed and inconclusive.

Ahmadov and Van Der Borg (2019) present the first empirical assessment of the contributions of natural resource wealth and petroleum rents to REN in a sample of 28 European Union member countries from 1997 to 2015. The study employs a mixed-methods approach. This estimator incorporates fixed-effects statistical analysis to demonstrate that total natural resource rents boost renewable energy generation. Meanwhile, specific natural resources, such as petroleum, restrict renewable energy deployment. These findings show that the role of natural resource wealth in incentivizing renewable energy switching varies depending on the type of natural resources considered. A comparable study by Baye *et al.*, (2021) indicates that natural resource rents provide impetus to stimulate an increase in renewable energy output in the region by using the Driscoll-Kraay estimator to account for cross-sectional dependency in examining panel data of 32 sub-Saharan African countries. As measures of natural resource rents, the results are consistent and robust for both forest rents and total natural resource rents. Also, a more recent work by Nchofoung & Ojong (2023) on 48 African countries for the period 2000-2020, using system generalized method of moments and quantile regression, reports that total natural resource rents enhance the continent's development of renewable energy. These findings are consistent with different measures of natural resource endowment, except for forest natural rents which impede the REN transition in Africa. On the contrary, Yu, Yan, *et al.*, (2023) find renewable energy-enhancing effect of forest rent, whereas other types of natural resources impede the diffusion of energy transition. The study concludes that natural resources' contributions to aid renewable energy development vary depending on the type of natural resources. Mixed findings are also reported in a related study of BRICS countries from 1988 to 2021 by Liu & Lu (2023). The study, using the quantile regression approach, reveals that oil and forest rents enhance the development of renewable electricity, while coal and mineral rents impede the diffusion of renewable electricity.

Different from this study, Dingru *et al.* (2023) find an inconsequential role of total natural resource rents in promoting the development of the renewable energy sector in sub-Saharan African countries. The study adopts the error-correction mechanism variant of the panel autoregressive distributed lag estimator. The study's findings imply that total natural resource rents do not contribute to REN transition in the short and long run. These findings, however, contradict the research outputs of Chishti & Dogan (2022), which detect the important role of natural resource wealth in determining REN in 10 top renewable energy-consuming countries for the period 1990–2017, using many second-generation estimators to account for different econometric pitfalls. The findings of this study highlight that natural resource rents are channeled to finance and provide incentives for initiatives and schemes that spur transitioning towards decarbonizing energy production and consumption to net-zero carbon emission renewable energy. This finding is equally established by Chen et al., (2021) using quantile regression to analyze the panel data of 44 countries from 1996 to 2018. Chen *et al.* (2023) utilize a dynamic autoregressive distributed lag estimator to evaluate annual data for China from 1980 to 2019 and discover renewable energy-enhancing effects of natural resource rent.

Similarly, Ma *et al.*, (2023) use a quantile regression estimator to analyze the data of OECD countries for the period spanning from 2004 to 2020. The authors examine the relationship between natural resources and renewable energy. The findings show that natural resources accelerate renewable energy's development in all quantiles. These findings align with the research outcomes of Wang *et al.* (2023), which establish a strong positive effect of natural resource abundance on renewable energy in China. The study highlights that Chinese natural resource wealth aids the development of the renewable energy sector by providing the needed investment capital to execute the transition to clean energy options. As a result, higher natural resource rents translate to more deployment of REN in the country. This finding aligns with the argument that the income stream realized from natural resource abundance could be used to finance and support initiatives that promote REN production and deployment. Still using Chinese data, Shinwari *et al.*, (2022) use the Bayer-Hanck cointegration technique and quantile regression estimator to find that total natural resource rents diminish renewable energy investment in all quantiles. It means that overall natural resource rents are persistently detrimental to the development of China's renewable energy sector. This study's findings are consistent with those of Shah *et al.*, (2023), who use an augmented mean group estimator for a panel analysis of the top 15 waste-recycled economies from 2000 to 2020. The authors discover that the use of natural resources impedes the generation of renewable electricity. Following the same pattern of results, Bano *et al.* (2023) used augmented mean group and Driscoll-Kraay regressions to find a diminishing effect of natural resource rents on REN in the panel of BRICS countries covering 2000–2017. In the same vein, Huang *et al.*, (2024) establish that natural resource rents impede the transition to renewable energy transition in global analysis of 73 countries. Unlike most other studies, Wang, Su *et al.* (2023) employ ARDL and quantile regression estimators to examine the influence of different types of natural resources on renewable energy development in a time-series analysis of a global study. The authors reveal conflicting findings, stating that different types of natural resources have varying effects on renewable energy. Natural gas and mineral rents negatively impact renewable energy sustainability, whereas oil rents increase renewable energy usage. This study reinforces the argument that the effects of natural resource rents on carbon-neutral renewable energy differ depending on the type of natural resources involved.

The outcomes of empirical investigations on the role of natural resource richness in REN have remained mixed and inconclusive. Contributing to the matter, Yuan *et al.* (2023) utilize a pooled mean group estimator for the period 1990-2020 and discover that natural resource wealth boosts REN in a panel of Next-11 countries in both the short and long run. This finding is consistent with the findings of Han *et al.* (2023), which found that natural resources promote renewable energy usage in a panel analysis of 162 nations from 1990 to 2021. A critical survey of the studies reviewed indicates mixed and inconclusive research outcomes on the roles of natural resource wealth in promoting REN deployment to decarbonize the ecosystem and ensure net-zero CO_2 emissions. Aside from the inconclusiveness of existing studies, studies have identified that effective channelization and management of natural resource wealth to finance and support sustainable development-driven priorities, such as the switch to REN alternatives, depend on the availability of efficient institutions. Weak institutions and large-scale corruption in resource-rich countries breed resource curse syndrome. This situation allows rent-seeking, opportunistic behavior, manipulative tendencies, and sharp practices in natural resource wealth management. Weak institutions and large-scale corruption in resource-rich countries breed the resource curse syndrome. This situation allows rent-seeking, opportunistic behavior, manipulative tendencies, and sharp practices in natural resource wealth management. As a result, misuse and mismanagement of resource income are practically inevitable in the atmosphere of weak institutions. More natural resource rents might not translate to better financing of REN options and other clean alternatives without efficient institutional structures. Weak institutions and corruption might thwart the REN transition and instead promote pollution-intensive and dirty fossil-fuel energy sources. Thus, it further deteriorates environmental degradation.

It implies that the contributions of natural resource rents to the REN transition depend on institutional quality. Existing research has paid a blind spot and inconsequential attention to the moderating role of institutions in driving the REN transition power of natural resource wealth in resource-rich countries. The only study (Nchofoung & Ojong, 2023) that examined the moderating functions of governance in the natural resource rent-renewable energy nexus did not focus specifically on resource-wealthy countries. The present study considers the peculiar case of resource-rich African countries riddled with resource curse phenomena, weak institutions, and widespread corruption. Also, this study makes the first attempt to identify the threshold of institutional quality in the natural resource rent-renewable energy nexus. Determining the institutional quality threshold assists in determining the level of institutions that will be efficient in providing the required incentives and mechanisms to tame corruption in resource revenue management. It creates efficient institutional apparatuses to curb the diversion of natural resource wealth to environmentally degrading fossil fuel energy usages and promotes activities and initiatives that spur REN transition.

4 Data description and methodological strategies

4.1 Data sources and description

This study utilizes an annual dataset of twenty-three resource-rich African countries, covering 2000–2021. Data availability determines the scope of the study. The choice to consider the peculiarity of resource-rich African countries is because more than 70 percent of the total continent's CO_2 emissions come from these countries. As a result, specific research on the factors that determine the resource-rich African countries' REN transition is essential to the continent's energy transition agenda. Table A in the appendix presents the resource-rich African countries covered in this study. The study focuses on all the resource-wealthy African countries, but we drop a few due to insufficient data-related issues. The World Development Indicator (WDI)'s World Bank databank provides data on variables such as renewable energy consumption (% of total final energy consumption) ren, total natural resources rents (% of GDP), nrr, foreign direct investment, net inflows (% of GDP), fdi, GDP per capita (constant 2015 US$), $gdpp$, trade (% of GDP), to, net ODA received (% of GNI), fa, and fixed telephone subscriptions (per 100 people), ict. The International Monetary Fund's (IMF) financial statistics database provides the broad-based financial development index (fd). This index is more robust because it accounts for all aspects of the financial market and institutions' performance. It describes the efficiency, accessibility, and depth of financial markets and institutions.

The International Country Risk Guide (ICRG) is the data source on five institutional quality metrics adopted in this study. These are corruption control, democratic accountability, law and order, government stability, and bureaucratic quality. The last two institutional measures use scales of 0–12 and 0–4, whereas the first three use an ordinal scale of 0–6. In line with the recent research (Olaniyi & Odhiambo, 2023; Olaniyi & Oladeji, 2022, 2021; Olaniyi, 2022; Olaniyi, Al-Faryan & Ogbaro, 2023; Olaniyi & Adedokun, 2022; Law *et al.*, 2018, 2013; Aluko & Ibrahim, 2020 & 2021; Muye & Muye, 2017; Tang *et al.*, 2020; Olaniyi, Young, Vo & Al-Faryan, 2022), all the institutional metrics are rescaled from 0 to 10. The resizing allows uniform comparison and interpretations. After rescaling all the measures, we obtain an overall institutional index by averaging the five institutional quality metrics. An institutional index of 10 signifies a flawless institution, while a value of 0 implies the weakest institution (Demetriades & Law, 2006; Olaniyi, 2022; Olaniyi, Al-Faryan & Ogbaro (2023), Olaniyi & Adedokun, 2022; Olaniyi, Young, *et al.*, 2022; Tang *et al.*, 2020; Gazdar & Cherif, 2015; Olaniyi & Oladeji, 2022 & 2021).

4.2 Modelling procedures and estimators' strategies

This study follows the modeling styles of the few existing studies that examine the effect of natural resource on REN (Dingru *et al.*, 2023; Ma *et al.*, 2023; Nchofoung & Ojong, 2023; Wang *et al.*, 2023; Benavides-Franco *et al.*, 2023; Chishti & Dogan, 2022; Shinwari *et al.*, 2022; Chen, Fu & Chang, 2021; Ahmadov & Van Der Borg, 2019). The model is augmented to account for the relevant variables that explain REN in line with the existing literature. As a result, this study specifies the renewable energy model as follows:

$$ren_{it} = \partial_0 + \partial_1 nrr_{it} + \partial_2 inst_{it} + \partial_3 fd_{it} + \partial_4 fdi_{it} + \partial_5 gdpp_{it} + \partial_6 to_{it} + \partial_7 fa_{it} + \partial_8 ict_{it} + \varepsilon_{it} \quad (1)$$

where $ren, nrr, inst, fd, fdi, gdpp, to, fa$ and ict are renewable energy consumption, natural resource rents, institutional quality, financial development, foreign direct investment, real GDP per capita, trade openness, foreign aid, and information and communication technology. respectively. i and t are the cross-sectional units and time-period covered in the study. ∂_0 is the shift parameter of the model, while $\partial_1, \dots, \partial_8$ are the coefficients that explain their respective variables. ε_{it} is the stochastic error terms.

The choices of variables in Equation (1) follow the existing studies on determinants of renewable energy. (a) Financial development (fd) is pivotal to providing the huge financial commitments required by renewable energy investment, production, and diffusion. Existing research has identified the function of a well-performing and efficient financial system to create the necessary stimulus and financial expertise to spur an increase in demand for renewable energy and clean technology (Shahbaz, Destek, *et al.*, 2018; Ankrah & Lin, 2020; Kwakwa, 2021; Wang *et al.*, 2021; Saadaoui & Chtourou, 2022; Jamshid *et al.*, 2022; Saadaoui, 2022; Irfan *et al.*, 2023; Ergun & Rivas, 2023; Akpanke, Deka, *et al.*, 2023; Habiba & Xinbang, 2023; Xu & Ullah, 2023; Sun, Zhang & Gao, 2023; Iqbal *et al.*, 2023; Prempeh, 2023; Appiah-Otoo, Chen & Ampah, 2023; Liu *et al.*, 2023). (b) There are debates in the literature that foreign direct investment inflows often come with technology transfer and other positive externalities, which engender an impulse to use more of clean energy options and less of environmentally degrading and corrosive fossil fuel based energy alternatives (Acheampong *et al.*, 2024; Pan *et al.*, 2023; Wei *et al.*, 2022; Tan & Uprasen, 2022; Kang *et al.*, 2021). As a result, fdi is an important control variable considered in this study. (c) Another important factor prominently adjudged to be driving renewable energy transition in previous studies (Olaniyi, Al-Faryan & Ogbaro, 2023; Shahbaz *et al.* 2020; Ergun & Rivas, 2023; Uzar, 2020; Ergun *et al.*, 2019; Polcyn *et al.*, 2022; Jamshid *et al.*, 2022) is income (proxy by real GDP per capita, $gdpp$). (d) Other variables such as trade openness (to) [Saadaoui & Omri, 2023; Wang & Zhang, 2021; Zeren & Akkuş, 2020; Zhang et al., 2021], foreign aid (fa) [Villanthenkodath *et al.*, 2023; Acheampong *et al.*, 2024; Nchofoung, 2024], and information and communication technology (ict) [Shahbaz, Wang, *et al.*, 2022; Yu *et al.*, 2023; Lee *et al.*, 2023; Li, Cao & Xiang, 2023; Chowdhury *et al.*, 2022; Saadaoui & Omri, 2023; Bano *et al.*, 2022] are considered as factors that drive renewable energy transition following the existing studies.

Equation (1) assumes the direct effects of natural resource rents and institutional quality on renewable energy consumption. It does not account for the main study's goal, which is to examine the moderating roles of institutions in influencing natural resource wealth's contribution to renewable energy consumption. We allow institutions to engage natural resource wealth and institutional quality. As a result, it highlights how institutions modify natural resource rents' contribution to spur REN transition. We incorporate the interactive variable to account for how natural resource wealth and institutional quality interact to determine the renewable energy switch in resource-rich countries. We augment Equation (1) with the interactive variable, and it is specified as follows:

$$ren_{it} = \partial_0 + \partial_1 nrr_{it} + \partial_2 inst_{it} + \vartheta nrr_{it}{}^{*} inst_{it} + \partial_3 fd_{it} + \partial_4 fdi_{it} + \partial_5 gdpp_{it} + \partial_6 to_{it} + \partial_7 fa_{it} + \partial_8 ict_{it} + \varepsilon_{it} \quad (2)$$

In tandem with the moderating role explained in Equation (2), we obtain the marginal effects of natural resource rents on REN transition, given the economy's institutional development. In congruent with the existing research (Olaniyi & Adedokun, 2022; Olaniyi & Odhimabo, 2023; Olaniyi *et al.*,2023; Olaniyi, Al-Faryan & Ogbaro, 2023; Olaniyi & Oladeji, 2021 & 2022), we take partial derivative of Equation (2) with respect to natural resource rent, nrr_{it} as follows:

$$\frac{\partial ren_{it}}{\partial nrr_{it}} = \partial_1 + \vartheta inst_{it} \quad (3)$$

Equation (3) explains how institutional quality tilts the REN transition benefits of natural resource wealth in resource-rich countries. The signs, magnitudes, and statistical status of coefficients, ∂_1 and ϑ, in Equation (3) determine the interpretations. Extant studies have identified four plausible interpretations (Law & Law, 2022; Hassan, 2023; Olaniyi, Al-Faryan & Ogbaro, 2023; Gazdar & Cherif, 2015). These are explained in turn as follows:

a) If $\partial_1 > 0$ and $\vartheta > 0$; this shows that natural resource wealth spurs a renewable energy switch to ensure net-zero CO_2 emissions, and the institutional architectures also complement the process to provide the necessary stimulus that strengthens the positive effect.
b) If $\partial_1 > 0$ and $\vartheta < 0$; it indicates that as natural resource wealth promotes and finances activities and initiatives that enable carbon-neutral renewable energy options, institutions weaken the process by creating loopholes that abet rent-seeking and corruption that

culminate in channeling resource income to encourage dirty and environmentally unfriendly technology and fossil fuel usage, which deteriorate the quality of the environment.

c) If $\partial_1 < 0$ and $\vartheta > 0$; this indicates that natural resource wealth promotes the financing of fossil fuel usage and pollution-intensive technologies that inhibit the REN transition and aggravate the potential negative consequences of climate change and environmental challenges. Contrarily, the institutional apparatus provides some incentives, restricting some of the resource income from being channeled to support unclean fossil fuels and environmentally endangered energy options.

d) If $\partial_1 < 0$ and $\vartheta < 0$; it suggests that natural resource wealth slows the transition REN by encouraging and financing pollution-intensive energy deployment, production, and fossil fuel-based technologies. The institutional framework aggravates the issue by accommodating opportunism and rent-seeking inclinations in natural resource wealth management. This weak institution caused a resource-curse syndrome, causing more resource incomes to be used to finance carbon-intensive technologies and environmentally polluting energy sources. Therefore, both natural resource wealth and institutions interact to impede the REN transition.

Recent research highlights that the institutional quality threshold beyond which institutions become a catalyst to contain manipulative tendencies facilitate natural resource wealth to spur the REN transition exists, only if the two parameters, ∂_1 and ϑ, in Equation (3) have different signs and they are statistically significant (Olaniyi *et al.*, 2023; Olaniyi & Odhiambo, 2023; Olaniyi, 2022; Gazdar & Cherif, 2015). Otherwise, the threshold is found nonexistent. The institutional quality threshold is determined by setting the expression, $\frac{\partial ren_{it}}{\partial nrr_{it}}$ in Equation (3) equal to zero. After re-arranging the expression, we obtain the threshold as follows:

$$inst > \left(\frac{-\partial_1}{\vartheta}\right) \tag{4}$$

The recently developed works by Seo & Shin (2016) and Seo *et al.* (2019) have faulted the threshold in Equation (4). The recent advances and developments in econometrics and empirical research have explained that static threshold analysis is impractical. It does not capture the socioeconomic practicality of dynamism and endogeneity in threshold analysis. Dynamic panel threshold performs better than static one. It explains nonlinear relationships and real-world dynamic perspectives. It also highlights the behavior of variables before and after the threshold point. Equation (5) presents the dynamic panel threshold as follows:

$$ren_{it} = (1, g'_{it})\partial_1 1\{inst_{it} \leq \emptyset\} + (1, g'_{it})\partial_2 1\{inst_{it} > \emptyset\} + \varepsilon_{it} \qquad \varepsilon_{it} = \omega_i + \varphi_{it} \quad i = 1, \dots, n; t = 1, \dots, T \tag{5}$$

where ren_{it} is the endogenous variable (renewable energy in this case). A vector of control variables, the lagged of the dependent variable (ren_{it-1}) inclusive is proxy by g_{it}. $1\{.\}$ is the functional indicator classifying lower and upper regimes. ∂_1 *and* ∂_2 are the estimates that explain lower and upper regimes' estimates or otherwise known as regimes 1 and 2. The rationale of these parameters is to explain the dynamics of variables before and after the threshold. The institutional quality $(inst)$ threshold is defined by $\emptyset$. ε_{it} is the stochastic error term, which comprises timeinvariant individual-specific fixed effects, ω_i, and the time-variant zero mean idiosyncratic random disturbance, φ_{it}.

The dynamic panel threshold model created by Seo *et al.* (2019) follows the principles of the first-difference generalized method of moments proposed by Arellano & Bond (1991). The advantage of this approach is that it permits the covariates of the endogenous variables and the threshold variable to follow a typical asymptotic distribution. We follow the influential work of Seo *et al.* (2019), which aligns with a statistically robust bootstrap method for the nonparametric bootstrap developed first by Seo & Shin (2016). The essence of a bootstrapped p-value is to determine the existence of linearity and threshold. In addition to applying the dynamic panel threshold to determine the threshold for institutional quality in the natural resource wealth-renewable energy transition nexus, this paper addresses other procedural methods to account for endogeneity, cross-sectional dependence, and heterogeneous and distributional effects of natural resource rents and institutional quality on REN transition in resource-rich African countries.

4.3 Other preliminary procedural strategies

Cross-sectional dependence tests

Accounting for cross-sectional dependence (CD) has become a conventional routine in modern econometrics analysis (Olaniyi, 2023; Olaniyi, Al-Faryan & Ogbaro, 2023; Olaniyi, 2022; Olaniyi, Ojeyinka, *et al.*, 2023; Meo *et al.*, 2020; De Hoyos & Sarafidis, 2006; Olaniyi, Young, *et al.* 2022). Globalization, financial system integration, and international trade alliances among countries necessitate the importance of CD in panel analysis. Shocks are liable to transmit across countries due to contagious effects (Jahanger *et al.*, 2023). More so, Africa's panel analysis requires accounting for CD because of the high integrations of economies in many economic alliances, international trade relationships and interwoven macroeconomic policies and decisions (Aluko, Ibrahim & Atagbuzia, 2021). Based on this argument, the CD model is specified following the work of Pesaran (2004)

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=0}^{N-1}\sum_{j=i+1}^{N-1}\rho ij\right) \qquad N(0,1) \tag{6}$$

This model follows the hypothesis that there is no CD in the panel dataset.

ρij is the cross-sectional correlation of errors between i and j in Equation (6). This study uses other types of CD tests, such as Pesaran *et al.* (2008), Breusch & Pagan (1980), and Baltagi *et al.* (2012), to ensure the findings' robustness. However, we do not present their equations, as Pesaran (2004) remains the study's lifeline.

Slope homogeneity test

We examine the slope homogeneity test to confirm if slope homogeneity exists across cross-sections in the resource-rich African countries' panel dataset, following the work of Pesaran & Yamagata (2008). The approach has an advantage over other traditional tests. Other methods do not take CD into account. The model for the slope homogeneity test is as follows:

$$\tilde{\Delta} = (N)^{\frac{1}{2}}(2K)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - k\right) \tag{7}$$

$$\tilde{\Delta}_{adj} = (N)^{\frac{1}{2}}\left(\frac{2k(T-k-1)}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - k\right) \tag{8}$$

Equations (7) and (8) follow the null hypothesis that there is slope homogeneity across the cross-sectional unit. $\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$ are delta tilde and adjusted delta tilde, respectively.

Panel unit root tests

Examining the stationarity's properties in modern panel analysis is the standard. Meanwhile, the common presence of CD in the panel dataset renders first-generation unit root tests invalid. Thus, we follow the recent trend in the literature by adopting second-generation unit tests, such as the CADF (Cross-Sectionally Augmented Dicky-Fuller) and CIPS (Cross-Sectionally Augmented IPS) tests proposed by Pesaran (2007). In the presence of CD, CIPS performs better than CADF. Sequel this position, we specify CIPS's model as follows:

$$\Delta X_{i,t} = \alpha_i + \alpha_i Y_{i,t-1} + \alpha_i \bar{Y}_{t-1} + \sum_{l=0}^{p} \alpha_{il} \Delta \bar{X}_{t-1} + \sum_{l=0}^{p} \alpha_{il} \Delta X_{i,t-1} + \mu_{it} \quad (9)$$

where the average' cross-sectional value for each variable is $\bar{X}$

CIPS' t-statistical value is defined as follows:

$$\widehat{CIPS} = N^{-1} \sum_{i=0}^{n} CADF_i \quad (10)$$

Cointegration test

Since it is rare to have all the variables in the model integrated of order zero, the situation in the existing studies is to establish that the variables are either integrated of one or a mixture of order zero and one. If the phenomenon exists, the conventional practice is to examine the long-run relationship. This study builds on prior work (Zheng et al., 2023) by employing an error-correction-based panel cointegration estimator developed by Persyn and Westerlund (2008) to overcome econometric pitfalls such as cross-sectional dependence and endogeneity in the cointegration test. This approach extends Westerlund's (2007) second-generation cointegration test. This estimator gives better and more convincing explanatory power than other variants of dynamic panel cointegration estimators (Dada, Olaniyi, *et al.* 2022). This technique produces four statistics. Group mean statistics are presented in Equation (11), which examine cointegration for the whole panel. Their models are as follows:

$$G_\tau = \frac{1}{N} \sum_{i=1}^{N} \frac{\widehat{\beta_\iota}}{SE(\widehat{\beta_\iota})} \; and \; G_\alpha = \frac{1}{N} \sum_{i=1}^{N} \frac{T\widehat{\beta_\iota}}{\beta_i(1)} \quad (11)$$

Equation 12 contains the models for the remaining two statistics. These statistics evaluate the likelihood of cointegration in at least one cross-section.

$$P_\tau = \frac{\widehat{\beta_\iota}}{SE(\widehat{\beta_\iota})} \; and \; P_\alpha = T\hat{\alpha} \quad (12)$$

Apart from the dynamic panel threshold estimator to determine the institutional quality threshold, this study uses three dimensions of estimators to circumvent potential econometric and empirical flaws. Failure to account for these flaws could bias the accuracy of the results, inferred policy implications, and policy recommendations. We consider a variety of estimators, such as fully modified ordinary least square (FMOLS), the Driscoll-Kraay nonparametric covariance matrix estimator, and a method of moment quantile regression, to deliver robust estimates for more practical policy descriptions and put resource-rich African countries on the pathways to carbon-neutral renewable energy usage and production. These estimators capture various facets of econometric pitfalls identified in recent empirical research for better informed and practical-induced policy on how the interaction between institutions and natural resource wealth explains the REN transition in resource-rich African countries. One, this study adopts an FMOLS estimator to account for endogeneity and serial correlation in the panel (Bashir *et al.*, 2024; Mahendru *et al.*, 2023; Bashir *et al.*, 2023; Ma, Sharif, *et al.*, 2023; Olaniyi & Oladeji, 2022; Rahman *et al.*, 2020; Bhattacharya *et al.*, 2016; Sadorsky, 2009; Pedroni, 2001). Previous studies (Nchofoung & Ojong, 2023) used the generalized method of moments (GMM) to resolve endogeneity concerns caused by omitted variables bias and simultaneity bias in the renewable energy model. Utilizing the GMM estimator shows a blind spot to testing stationarity properties and the potential long-run relationship. Thus, GMM estimates are restrictive. FMOLS has an edge by allowing these tests and delivering long-run estimates for better overarching and far-ranging policy prescriptions in the presence of endogeneity and serial correlation (Bashir *et al.*, 2024). Unlike GMM, the FMOLS approach also behaves efficiently and produces consistent results in small samples (Rahman *et al.*, 2020; Pedroni, 2001; Phillips & Hansen, 1990). Meanwhile, an FMOLS estimator could produce erroneous estimates when there is robust evidence that cross-sectional units intertwine and are interdependent (Dong *et al.*, 2017; Anser *et al.*, 2021; Olaniyi & Odhiambo, 2023a &b; Olaniyi, Al-Faryan & Ogbaro, 2023). It is therefore necessary to account for cross-sectional dependence.

Two, we use Driscoll & Kraay's (1998) robust standard error regression approach to account for cross-sectional dependence, spatial correlation and heterogeneity in the panel analysis. This estimator produces highly accurate standard errors with strong resilience to spatial/cross-sectional dependence, heteroscedasticity, and autocorrelation (Olaniyi, Young, *et al.*, 2022; Driscoll & Kraay, 1998; Lee & Olasehinde-Williams, 2022; Dada, Olaniyi, *et al.*, 2022; Hoechle, 2007; Olaniyi, Al-Faryan & Ogbaro, 2023; Olaniyi, Ojeyinka, *et al.*, 2023). The rationale for accounting for cross-sectional reliance among African countries is essential. One, resource-wealthy African countries share common geographical and climate conditions (Espoir & Sunge, 2021). Two, strong ties exist among these countries due to economic integration, globalization, international trade and alliances, and identical macroeconomic policies. These activities trigger shocks to spread among African countries. It implies a high tendency for economic shock spillovers across countries in the continent.

Three, to account for the nonlinear, heterogeneous, and distributional effects of natural resource wealth and institutional quality on the REN transition, we adopt the method-of-moments quantile regression (MM-quantile regression) recently introduced by Machado & Silva (2019). This approach produces flexible estimates across quantiles. As a result, the effects and induced policies could vary across quantiles. The estimates produced by this method deliver more detailed information and are unaffected by outliers in the panel data distribution (Aluko *et al.*, 2022; Chernozhukov & Hansen, 2008). The method also yields reliable estimates that are efficient and resistant to normality and non-normality in error distributions (Chu, 2023; Aluko, Opoku & Acheampong, 2022; Adebayo, Akadiri, Adedapo & Usman, 2022). This approach handles outliers in the dataset and does not assume a normal distribution (Shinwari *et al.*, 2022). It delivers efficient estimates in the presence of heavily skewed data. Compared to mean-based regression, which only offers a limited range of policy possibilities, this variation of quantile regression is more illuminating (Somoye *et al.,* 2023). This method accommodates and extends all the fundamental principles of the dynamic generalized method of moments (GMM) estimator (Machado & Silva, 2019). It is therefore more capable of taking care of endogeneity than other quantile-based regression variants (Ajide, Dada, Arnaut, & Al-Faryan, 2023; Machado & Silva, 2019). This estimator is beneficial because it splits the distributional and heterogeneous effects of natural resource wealth and institutions on REN across quantiles (Aluko *et al.,* 2022). The distinctive features of each quantile and the related policy flexibility and options are reflected.

5 Discussion of findings

5.1 Descriptive statistics

To guide the choice of estimation techniques, we examine the descriptive statistics to reveal the features of all the variables in this study. Table 1 provides a synopsis of descriptive statistics. Mean and standard deviation comparisons highlight the dependability of the variables' mean values and the spread of the actual data from their respective means. The results indicate that actual data on natural resource rents (nrr), financial development (fd), foreign direct investment (fdi), foreign aid (fa), real GDP per capita ($gdpp$), and information and communication technology (ict) spread out significantly from their mean values. Meanwhile, the other variables' actual data somewhat cluster around their average values. It implies that other variables are relatively stable and less volatile in data distribution. It validates the need to examine heterogeneity in the panel dataset of resource-rich African countries. The coefficients of variation also confirm the results. The coefficient of skewness reveals that renewable energy consumption (ren), bureaucratic quality (bq), and democratic accountability (da) skew negatively, while other variables display positive skewness. Kurtosis statistical values to measure the extent of outliers in the variables' data distribution show that nine variables are leptokurtic (suggesting a heavy or fatter tail with a high tendency for outliers). The remaining five variables are platykurtic (indicating a light tail with a low probability for outliers). There is no case of mesokurtic, implying the existence of outliers in the data distribution of the variables in the study. Jarque-Bera statistics reveal that all variables, except the overall institutional quality index, follow the non-normality path.

Table 1: Descriptive statistics

Variable	Mean	Standard deviation	Skewness	Kurtosis	Jarque-Bera	Minimum	Maximum	Obs
ren	61.501	30.455	-0.918	2.410	81.839***	0.060	98.340	506
nrr	13.924	12.993	1.748	5.713	430.909***	0.592	66.060	506
fd	0.180	0.162	1.887	5.803	486.138***	0.026	0.735	506
fdi	3.838	5.843	2.912	16.068	4502.787***	-18.918	39.811	506
gdpp	2501.867	2558.115	1.854	6.774	615.902***	293.709	13729.160	506
to	63.755	26.908	0.743	3.251	49.966***	4.128	156.862	506
fa	5.750	6.523	2.496	15.937	4230.085***	-0.188	62.187	506
ict	2.967	4.383	2.091	7.733	877.636***	0.002	24.709	506
inst	4.671	0.888	0.001	2.979	0.010	2.396	7.167	506
cc	3.298	1.138	0.435	3.154	17.18769***	0.833	6.667	506
bq	2.945	1.886	-0.244	2.012	26.737***	0.000	6.250	506
lo	4.905	1.613	0.570	3.393	31.966***	1.667	10.000	506
da	5.294	1.772	-0.110	2.368	9.840***	0.000	8.333	506
gs	6.913	1.286	0.111	1.797	32.910***	3.715	9.167	506

To examine the potential multicollinearity among the variables understudy, we explore correlation test. The findings of correlation test presented in Table 2 reveal that multicollinearity is not a serious threat to our empirical analysis. The highest coefficient record is -0.848. This does not suggest multicollinearity because the pair is that of dependent-independent relationship. Precisely, it is between renewable energy consumption (ren) and information and telecommunication technology (ict). Also, as a robustness check, it is important to examine the likelihood of multicollinearity in the regression. It is possible to draw incorrect conclusions from a regression model if it contains multicollinearity. A high correlation between the independent variables could inflate the standard error coefficients of the regression. Thus, we use the Variance

Table 2: Variable correlation

	ren	nrr	fd	fdi	gdpp	to	fa	ict	inst	cc	bq	lo	da	gs
ren	1.000													
nrr	-0.153***	1.000												
	(0.000)													
fd	-0.751***	-0.123**	1.000											
	(0.000)	(0.005)												
fdi	0.136**	0.093**	-0.132***	1.000										
	(0.002)	(0.034)	(0.002)											
gdpp	-0.686***	-0.411***	0.399***	-0.118**	1.000									
	(0.000)	(0.000)	(0.000)	(0.006)										
to	-0.200***	-0.511***	0.063	0.360***	0.287***	1.000								
	(0.000)	(0.000)	(0.147)	(0.147)	(0.000)									
fa	0.524***	-0.155***	-0.421***	0.179***	-0.546***	-0.113**	1.000							
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.010)								
ict	-0.848***	0.190***	0.549***	-0.135***	0.757***	0.120***	-0.423***	1.000						
	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.006)	(0.000)							
inst	-0.372***	-0.245***	0.471***	0.063	0.226***	0.216***	-0.161***	0.265***	1.000					
	(0.000)	(0.000)	(0.000)	(0.148)	(0.000)	(0.000)	(0.000)	(0.000)						
cc	-0.180***	-0.260***	0.277***	-0.042	0.084*	0.224***	-0.012	0.067	0.619***	1.000				
	(0.000)	(0.000)	(0.000)	(0.336)	-0.054	(0.000)	(0.793)	(0.124)	(0.000)					
bq	-0.579***	-0.020***	0.544***	-0.025	0.391***	0.190***	-0.493***	0.427***	0.607***	0.224***	1.000			
	(0.000)	(0.000)	(0.000)	(0.573)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
lo	-0.228***	-0.183***	0.197***	0.002	0.241***	0.056	-0.040	0.318***	0.650***	0.336***	0.149***	1.000		
	(0.000)	(0.000)	(0.000)	(0.963)	(0.000)	(0.202)	(0.358)	(0.000)	(0.000)	(0.000)	(0.001)			
da	0.018	-0.411***	0.284***	0.112**	-0.175***	-0.077*	0.082*	-0.160***	0.609***	0.263***	0.193***	0.216***	1.000	
	(0.684)	(0.000)	(0.000)	(0.010)	(0.000)	(0.079)	(0.059)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
gs	-0.014	0.210***	-0.055	0.135***	0.073*	0.304***	0.114**	0.049	0.359***	0.142**	-0.020	0.178***	-0.059	1.000
	(0.754)	(0.000)	(0.207)	(0.002)	(0.096)	(0.000)	(0.009)	(0.259)	(0.000)	(0.001)	(0.648)	(0.000)	(0.175)	

Inflation Factor (VIF) test to identify the presence of multicollinearity. Consistent with existing research, we confirm that multicollinearity is not severe when the VIF and tolerance values do not exceed 10 and 0.1, respectively (Miles, 2014). Following the suggestion of Studenmund (2011), we adopt 5 as the threshold for the VIF value. VIF values are smaller than the threshold, and tolerance values are greater than 0.1. (see Table 3). As a result, there is no problem involving severe multicollinearity among the model's independent variables.

Table 3: Variance inflation factor (VIF) test

Variable	VIF	$\sqrt{VIF}$	Tolerance	R^2
gdpp	4.300	2.074	0.232	0.768
ict	2.740	1.655	0.364	0.636
fa	2.530	1.591	0.396	0.604
fd	2.300	1.517	0.435	0.565
nrr	2.210	1.487	0.451	0.549
to	2.170	1.473	0.462	0.538
bq	1.790	1.338	0.558	0.442
da	1.620	1.273	0.619	0.381
cc	1.560	1.249	0.639	0.361
lo	1.440	1.200	0.693	0.307
fdi	1.330	1.153	0.751	0.249
gs	1.200	1.095	0.830	0.170
Mean VIF	2.100			

5.2 Cross-sectional dependence and slope homogeneity tests

This study uses four CD test types to produce more reliable estimates, findings, and refined decisions. The four CD tests are Breusch & Pagan (1980), Pesaran et al. (2008), Baltagi et al. (2012), and Pesaran (2021). The CD tests' results in Table 4 confirm that resource-rich African countries are interdependent. It suggests a high level of economic integration, interactions, international alliances, and spillover effects among the countries due to contagion effects. The intricacies of intertwining could generate actions and reactions in policy instruments and reactionary moves. These findings affirm that CD issues are critical when evaluating African countries' panel data. There could be spillover effects from one resource-rich African country's macroeconomic decisions and policies to another. There could also be reactionary moves and countermoves among resource-rich African countries' macroeconomic policies to safeguard the interests of each country. It also reaffirms the position that shocks are liable to transmit among

African countries (Olaniyi, 2022; Aluko *et al.,* 2021). This research outcome validates the need to account for CD in the natural resource rent-institutional quality-renewable energy transition trilogy. As a result, it highlights that the previous studies that ignored CD in modeling and estimating the trilogy might have obtained biased estimates and policy options.

In line with the confirmation of CD in the panel data, we test for a slope homogeneity following the study of Pesaran & Yamagata (2008). The results' synopsis in Table 5 reveals evidence of slope heterogeneity across the resource-rich African countries. It implies the necessity of using an estimator that accounts for heterogeneity in the empirical analysis of the natural resource rent-institutional quality-renewable energy trilogy.

Table 4: Cross-sectional dependence tests

	ren	nrr	inst	fd	fdi	gdpp	to	fa	ict
Breusch-Pagan LM	2525.837***	1199.231***	1190.599***	1761.217***	557.164***	3296.193***	1365.548***	822.324***	2361.647***
Pesaran scaled LM	95.759***	39.295***	38.928***	63.215***	11.967***	128.548***	46.374***	23.253***	88.771***
Bias-corrected scaled LM	95.188***	38.724***	38.356***	62.644***	11.396***	127.977***	45.803***	22.682***	88.200***
Pesaran CD	34.494***	18.867***	11.941***	25.694***	3.513***	37.465***	10.233***	13.154***	3.239***

Table 5: Pesaran and Yamagata (2008) slope homogeneity test

Model	$\tilde{\Delta}$	$\tilde{\Delta}_{adj}$
$ren = f(nrr\ inst\ nrr * inst\ \ fd\ fdi\ gdpp\ to\ fa\ ict)$	-43.606***	-35.076***
$ren = f(nrr\ cc\ nrr * cc\ fd\ fdi\ gdpp\ to\ fa\ ict)$	-28.048***	-22.562***
$ren = f(nrr\ bq\ nrr * bq\ fd\ fdi\ gdpp\ to\ fa\ ict)$	-367.911***	-295.947***
$ren = f(nrr\ lo\ nrr * lo\ fd\ fdi\ gdpp\ to\ fa\ ict)$	-36.009***	-28.966***
$ren = f(nrr\ da\ nrr * da\ fd\ fdi\ gdpp\ to\ fa\ ict)$	-35.462***	-28.526***
$ren = f(nrr\ gs\ nrr * gs\ fd\ fdi\ gdpp\ to\ fa\ ict)$	-28.333***	-22.791***

Note: *** stands for 1 percent level of significance

5.3 Panel unit root and cointegration tests

The presence of CD in the panel dataset invalidates the first-generation panel unit root tests. As a result, we adopt the second-generation panel unit root tests, which produce efficient results in the presence of CD. We use CD tests such as cross-sectionally augmented DF (CADF) and cross-sectionally augmented IPS (CIPS). Tables 6 and 7 present the summary of the two tests. Table 6 provides the results for the intercept alone, while Table 7 presents the results of the intercept and trend. Some variables appear to attain stationarity at level, while others become stationary at the first difference. Collectively, all the variables are stationary at the first difference. The mixed orders of integration reported in the panel unit root tests imply that the variables tend to behave divergently in the short run. Thus, it becomes necessary to examine the cointegration to establish if there could be factors that trigger variables' convergence in the long run (Olaniyi, Dada, et al., 2023; Olaniyi & Oladeji, 2022; Olaniyi & Adedokun, 2022) Due to the presence of CD in the panel dataset, we employ the cointegration approach of Persyn

Table 6: Panel Unit Root Tests (Intercept only)

Variables	CIPS Test		CADF Test	
	Level	First difference	Level	First difference
ren	-2.159	-4.133***	-1.922	-2.901***
nrr	-2.614***	-4.044***	-2.169**	-3.454***
inst	-1.974	-3.705***	-2.285***	-2.948***
lgdpp	-1.850	-3.978***	-1.447	-2.682***
fd	-2.674***	-4.893***	-2.067*	-3.526***
fdi	-2.937***	-5.146***	-2.562***	-3.857***
to	-2.295**	-4.330***	-2.230**	-3.243***
fa	-3.230***	-5.374***	-2.838***	-4.089***
ict	-0.667	-3.899***	-0.700	-2.978***
cc	-1.578	-3.209***	-1.569	-2.990***
bq	-1.991	-3.654***	-1 .602	-2.752***
lo	-1.403	-3.241***	-1.233	-2.631***
da	-1.360	-3.182***	-1.836	-2.961***
gs	-2.340***	-4.586***	-2.572***	-3.528***

*** and ** stands for stationarity at one percent level of significance

Table 7: Panel Unit Root Tests (Intercept and trend)

Variables	CIPS Test		CADF Test	
	Level	First difference	Level	First difference
ren	-2.439	-4.301***	-2.494	-3.107***
nrr	-3.144***	-3.879***	-2.813	-3.351***
inst	-2.119	-3.967***	-2.507	-3.196***
lgdpp	-2.393	-4.333***	-2.016	-2.954***
fd	-2.805**	-5.072***	-2.443	-3.522***
fdi	-3.475***	-5.200***	-2.927***	-3.769***
to	-3.036***	-4.367***	-2.836***	-3.214***
fa	-3.544***	-5.410	-3.088***	-4.192***
ict	-1.542	-4.442***	-1.533	-3.433***
cc	-2.056	-3.619***	-2.257	-3.168 ***
bq	-1.337	-2.919***	-2.040	-3.486***
lo	-1.538	-3.114***	-2.448	-3.433
da	-1.845	-3.502***	-2.370	-3.274***
gs	-2.681**	-4.660***	-2.741***	-3.627***

*** and ** stand for stationarity at 1 and 5 percent levels of significance, respectively

& Westerlund (2008). This method produces robust cointegration findings in the presence of heterogeneity and CD. The results presented in Table 8 confirm the existence of cointegration. It implies variables' convergence along the long-run dynamism. Thus, short-run divergence may distort the policy perspectives and recommendations, while long-run estimates are more efficient to give more pragmatic policy directions.

Table 8: Westerlund ECM panel cointegration test

Statistic	Value	Z-value	P-value	Robust P-value
Gt	-1.984**	-1.124	0.131	0.040
Ga	-6.627**	0.464	0.678	0.030
Pt	-9.638**	-2.561	0.005	0.030
Pa	-6.541**	-2.550	0.005	0.010

** represents 5 percent level of significance

5.4 The role of institutional quality in the natural resource rent-renewable energy nexus

Following a thorough x-ray analysis of preliminary tests, which aid in revealing the unique features of the variables and the choices of appropriate estimators to avoid potential estimation pitfalls, the focus shifts to the study's goal, which is to investigate the moderating role of institutional quality in influencing natural resource wealth's contribution to the REN transition in resource-rich African countries. Tables 9, 10, 11, and 12 illustrate the results across three dimensions to provide varied views for robust and better policy tips. Table 9 summarizes the Driscoll-Kraay regression results used to account for the dataset's cross-sectional dependence and heterogeneity. Table 10 summarizes the results of the fully modified least squares estimator used to account for endogeneity and serial correlation in the analysis. Tables 11 and 12 show the results of MM-quantile regressions that account for heterogeneous and distributional effects across quantiles. We begin our interpretations of the findings by looking at the direct effects of natural resource rents and institutional quality before delving into how the two interact to drive the REN transition in resource-rich African countries.

In all the estimations with an overall institutional quality index, natural resource rents (nrr) contribute significantly and positively to spur renewable energy development in resource-rich African countries. These findings persist across all quantiles (see Table 11). It implies that natural resource wealth promotes the shift to REN and clean technology in resource-rich African countries. It highlights that natural resource rents provide the capital stock utilized and converted more to raise the needed capital investment for the REN transition. It also creates incentives to finance and support various schemes and initiatives to spur green energy deployment and production in resource-wealthy African countries. The findings imply that efficient use and management of resource wealth have the potential to accelerate efforts to decarbonize the African continent and reduce carbon emissions to enable a smooth transition to ecologically friendly net-zero-emission renewable energy. These findings confirm that channeling the continent's natural resource wealth to renewable energy investment can facilitate tapping and exploring the continent's underutilized renewable energy resources to counter the existing literature's prediction that Africa will suffer most from the negative consequences of climate change. As a result, African resource wealth can promote environmentally enhanced REN production and deployment.

These findings are consistent with studies by Nchofoung & Ojong (2023), Ma et al. (2023), Wang et al. (2023), Han et al. (2023), Yuan et al. (2023), Chishti & Dogan (2022), Chen et al. (2021), Baye et al. (2021), and Ahmadov & Van Der Borg (2019), which establish the renewable energy-promoting effect of natural resource wealth. Meanwhile, it stands at variance with the works of Shinwari et al. (2022) and Dingru et al. (2023), which find either diminishing effects or an inconsequential role of natural resource rents in renewable energy development. The results from the FMOLS estimator for the specific institutional quality measures show that the coefficients of natural resource rents maintain a positive sign in all the models but are insignificant where we choose bureaucratic quality and democratic accountability as the measures of institutions. The two insignificant coefficients remain in the Driscoll-Kraay regression, and the coefficient of law and order is also positive but insignificant. These findings highlight that the choice of institutional measures influences the direct impacts of natural resource rents on REN.

Institutional quality is another distinguishing factor that is crucial to the advancement of clean technology and renewable energy. The Driscoll-Kraay and FMOLS results show that the coefficients for overall institutional quality ($inst$) are significant and positive. The quantile regression also supports institutions' ability to increase demand of REN and clean technology. The coefficients, however, are insignificant in the lower quantile (from the fifth to the twenty-fifth quantiles). The findings support the idea that institutional quality might stimulate and incentivize a rise in the demand for REN and clean technology in resource-rich African nations. It suggests that institutional frameworks in resource-rich African countries should be strengthened to weed out corruption, opportunism, and environmental regulation laxity from the strategic plans and schemes intended to promote and hasten the smooth transition to clean energy and technologies. The study’s findings reaffirm that efficient institutions play critical roles in shaping government policy tools and regulatory frameworks designed to promote and increase demand and supply of green energy to spur REN transitions. The study's findings also support the idea that, to put Africa on the path to environmental sustainability, institutional architecture needs to create incentives and educative programmes for individuals, businesses, and corporations about the importance of patronizing clean technologies and renewable energy sources as well as strategies for reducing carbon emissions. Additionally, it suggests that more improved institutional support is required to enable efficient allocation of natural resource wealth to renewable energy development and investment in resource-rich African countries. This study confirms the importance of institutions in preventing rent-seeking opportunistic behaviour, and corruption that could obstruct renewable energy development. These findings are essential because they re-emphasize that better and stronger institutions are needed to formulate and implement effective and result-oriented renewable energy policies to ensure resource-rich African countries toe the path to a smooth transition to net-zero carbon emissions and carbon neutrality to mitigate the fossil fuel-caused adverse effects of global warming and climate change.

Table 9: Driscoll and Kraay Results

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Dependent variable: ren (Renewable energy)					
nrr	1.105***	0.495***	0.105	0.280**	0.089	0.858***
	(0.000)	(0.001)	(0.399)	(0.039)	(0.621)	(0.002)
inst	2.544**					
	(0.017)					
cc		1.817				
		(0.118)				
bq			-1.529***			
			(0.009)			
lo				1.514***		
				(0.000)		
da					0.082	
					(0.851)	
gs						2.149***
						(0.000)
nrr*inst	-0.251***					
	(0.000)					
nrr*cc		-0.170***				
		(0.001)				
nrr*bq			0.005			
			(0.924)			
nrr*lo				-0.058**		
				(0.021)		
nrr*da					0.010	
					(0.832)	
nrr* gs						-0.120***
						(0.000)
fd	-69.698***	70.338***	-65.592***	72.296***	-71.978***	-70.987***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
fdi	0.105*	0.053	0.105	0.089	0.069	0.085
	(0.083)	(0.380)	(0.123)	(0.101)	(0.224)	(0.185)
lgdpp	-4.237**	-4.851***	-4.018**	-4.419***	-4.393**	-3.934**
	(0.011)	(0.001)	(0.016)	(0.000)	(0.017)	(0.020)
to	-0.089***	-0.075***	-0.055	-0.097***	-0.072**	-0.073***
	(0.004)	(0.005)	(0.111)	(0.000)	(0.025)	(0.007)
fa	0.114	0.105*	0.044	-0.118	0.149*	0.125
	(0.130)	(0.099)	(0.672)	(0.148)	(0.079)	(0.145)
ict	-3.697***	-3.718***	-3.535	-3.572***	-3.545***	-3.736***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	109.121***	119.109***	121.953***	115.187***	120.926***	103.072***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F-statistics	13470.77	21700.63	4224.09	3751.67	13781.7	7258.13
P-value (F-statistics)	0.000	0.000	0.000	0.000	0.000	0.000
R-squared	0.8643	0.8668	0.8649	0.863	0.860	0.864
Number of observations	506	506	506	506	506	506
Number of groups	24	24	24	24	24	24

Note: ***, ** and * stand for 1%, 5% and 10 % levels of significance respectively
Probability values are in ()

These findings imply that institutions develop or fail to develop by resource-rich African countries are instrumental in incentivizing or disincentivizing the continent's efforts to spur REN transition.

These research outcomes align with the study's outcomes of Mahalik *et al.* (2023), Nabaweesi *et al.* (2023), Nawaz & Rahman (2023), Olaniyi, Al-Faryan & Ogbaro (2023), Mukhtarov *et al.* (2023), Nchofoung & Ojong (2023), Chien *et al.* (2023), Saadaoui & Chtourou (2022), and Wang, Gozgor, *et al.,* (2022) which establish that an improvement in institutional quality provides stimulus that incentivizes and stimulates a rise in REN consumption. Contrarily, it contradicts the works of Ndubuisi *et al.* (2023), Wiredu *et al.* (2023), Abba Yadou *et al.* (2023), and Asongu & Odhiambo (2022), which find that institutions create lapses and deficiencies that abet corruption, deceptive bureaucracies, and nepotism in designing and implementing REN transitioning policies. These undermine the effectiveness of strict rules and regulations prohibiting environmentally degrading activities and pollution-intensive fossil fuel energy usage. Thus, such inefficient institutions thwart and stagnate the initiatives and activities that promote the shift to REN. By implications, these studies find that institutional quality impedes and drags on renewable energy development.

The specific cases of institutional measures produce mixed findings. Driscoll-Kraay and FMOLS regressions indicate that corruption control, law and order, and government stability promote renewable energy development. On the other hand, bureaucratic quality constitutes a drag on the REN transition. Democratic accountability appears to have inconsequentially contributed to the REN transition. Since each institutional measure plays different roles in renewable energy, we base general interpretations on the overall institutional quality index to draw precise policy perspectives on renewable energy policy for resource-rich African countries. All institutional metrics are interconnected and tightly related (Olaniyi, 2022). Existing research has revealed that these institutional measures complement one another to produce total institutional quality in an economy. There is a close connection between the institutional markers. Thus, it means that evaluating them separately from one another could not create the combined impacts of institutions on the REN transition in resource-rich African countries. Following the critical interpretation of the effects of natural resource rents and institutional quality on the REN transition, we focus on how institutions influence the natural resource wealth's contribution to the REN transition.

In all the adopted estimators (mean-based and quantile regressions) for analysis with the overall institution index, the coefficients of the interactive term between natural resource rent and institutions ($nrr^{*}inst$) are significantly negative (see Tables 9, 10, and 11). This finding indicates that, as natural resource wealth provides capital investment to finance initiatives and schemes to promote renewable energy development in resource-rich African countries, institutional quality creates flaws and loopholes in the governance system and mechanism that culminate in corruption, opportunism, and rent-seeking in natural resource rent management. This results in the diversion of resource wealth to encourage the expansion of fossil fuel energy usage at the expense of net-zero carbon emissions, renewable energy deployment, and clean technology in Africa's resource-rich countries. Weak institutions and large-scale corruption in resource-rich African countries are impediments that accommodate inherent financial improprieties in the governance structure. These circumstances metamorphose into diverting natural resource wealth away from initiatives and investments that could increase demand for renewable energy. These inherent flaws in institutions allow politicians and stakeholders to utilize resource wealth at the expense of massive investment in developing the renewable energy sector to reduce the dominance of fossil fuels, decarbonize the ecosystem, and mitigate the potential adverse effects of climate change on the African continent.

These results are not entirely unexpected because they demonstrate the detrimental impact of weak institutions in resource-wealthy African countries. The transition from fossil fuels to renewable energy and green technologies in resource-rich countries continues to be impeded by inherent defects and gaps in the institutional framework, which encourage opportunistic behavior and corruption in natural resource rent management to invest in net-zero emission energy and technology. Institutional defects in resource-rich African countries constitute a drag that saps the contributions of natural resource wealth to the REN transition. Thus, these countries need strong political will and tenacity to identify and block the loopholes and defects in their institutional structures. Institutional defects in resource-rich African countries constitute a drag that saps the contributions of natural resource wealth to the REN transition. Thus, these countries need strong political will and tenacity to identify and block the loopholes and defects in their institutional structures. The inherent institutional flaws breed opportunistic inclinations and corruption in the administration of resource income. They have become barriers to the success of various REN policies and initiatives across the continent. These circumstances have slowed down and impeded the continent shift to clean technology and energy. They have made it more likely that the continent would not be able to avert the impending adverse effects of climate change on the continent, as repeatedly predicted in the energy studies and fora. This research output highlights that institutional quality weakens the potency of natural resource rents to facilitate a consistent and effective shift to clean technology and renewable energy alternatives in Africa's resource-wealthy countries to decarbonize the continent.

Moreover, these findings suggest that most resource-rich African countries have not yet attained the level of institutional development needed to prevent misuse, mismanagement, opportunism, rent-seeking, and corruption associated with the administration of natural resource rents. As a result, institutional deficiencies might weaken Africa's prospects of utilizing natural resource wealth for a renewable energy switch to mitigate the adverse climate change effects of CO_2 emissions on the continent. Consistent with the earlier argument raised, this study prioritizes determining the institutional quality threshold, beyond which institutions are potent and efficient to tame the sharp practices and corrupt tendencies in the natural resource rent administration and allow channeling more resource income to prosecute renewable energy investment and deployment. These findings align with the popular notion in the literature, which attributes the inability of natural resource wealth to translate to positive economic outcomes to weak institutions and corruption in resource-rich countries (Wang *et al.,* 2023; Ajide, 2022; Mesagan *et al.,* 2019). Meanwhile, it conflicts with the findings of Nchofoung & Ojong (2023), which show that institutional quality enhances the natural resource wealth's capacity to support the transition

Table 10: Fully modified least square Results

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Dependent variable: ren (Renewable energy)					
nrr	3.209***	1.412***	0.204	0.457	0.379	2.873***
	(0.004)	(0.004)	(0.635)	(0.439)	(0.426)	(0.002)
inst	7.624**					
	(0.041)					
cc		6.199**				
		(0.021)				
bq			-0.139			
			(0.942)			
lo				2.577		
				(0.142)		
da					1.186	
					(0.514)	
gs						5.509**
						(0.015)
nrr*inst	-0.712***					
	(0.003)					
nrr*cc		-0.443***				
		(0.001)				
nrr*bq			-0.135			
			(0.275)			
nrr*lo				-0.097		
				(0.380)		
nrr*da					-0.123	
					(0.232)	
nrr* gs						-0.383***
						(0.001)
fd	-60.648***	65.009***	-60.732***	67.778***	-59.588	-66.577***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)
fdi	0.416	0.374	0.685*	0.536	0.439	0.262
	(0.249)	(0.310)	(0.064)	(0.149)	(0.272)	(0.468)
lgdpp	5.703	3.706	4.481	5.526	-5.219	5.991
	(0.149)	(0.354)	(0.264)	(0.175)	(0.225)	(0.130)
to	-0.232**	-0.178*	-0.187**	-0.251**	-0.180*	-0.152
	(0.018)	(0.064)	(0.048)	(0.012)	(0.073)	(0.104)
fa	0.743*	0.591	0.403	0.797*	0.846*	0.616
	(0.087)	(0.180)	(0.365)	(0.073)	(0.073)	(0.158)
ict	-5.290***	-5.251***	-4.964***	-4.961***	-5.262***	-5.365***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	20.139	47.404*	68.017**	48.193	53.709*	9.718
	(0.518)	(0.092)	(0.017)	(0.108)	(0.083)	(0.000)

Note: ***, ** and * stand for 1%, 5% and 10 % levels of significance respectively
Probability values are in ()

to REN in African countries. Specific cases of institutional measures such as corruption control (cc), law and order (lo), and government stability (gs) also strengthen natural resource rents' ability to facilitate the shift to green technology and REN. On the contrary, bureaucratic quality (bq) and democratic accountability (da) play no role in driving natural resource wealth to promote the shift to REN.

Concerning the control variables in the study, financial development (FD) coefficients in all the estimators are consistently significant and negative except in the 90th quantile in the MM-quantile regression. It means that the development of the financial sector weakens and impedes the REN switch in resource-rich African countries. As a result, promoting the use of technologies and energy consumption based on fossil fuels inhibits the demand for and spread of REN. The implication of these research outputs is that financial systems channel more of their credit facilities and loan schemes to promote pollution-intensive fossil fuel and dirty energy consumption and technology at the detriment of clean energy and renewables. Activities of financial sector operators and handlers in resource-wealthy African countries favour environmentally unfriendly energy uses and technologies instead of encouraging a consistent support system to sustainable development driven net-zero carbon emission renewable energy. This suggests that energy related supporting policies and schemes of financial sector of these countries should be thoroughly pruned and re-directed towards pollution free renewables to save African continent from devasting effects of climate change. These findings are in tandem with studies of Shahbaz, Destek, *et al.,* (2018), Ankrah & Lin (2020), Kwakwa (2021), Wang *et al.,* (2021), Saadaoui & Chtourou (2022), Jamshid *et al.,* (2022), Saadaoui (2022), and Irfan *et al.,* (2023), which find that financial development constitute barriers to REN transition. Meanwhile, it opposes the research findings of Ergun & Rivas (2023), Akpanke, Deka, *et al.,* (2023), Habiba & Xinbang (2023), Xu & Ullah (2023), Sun, Zhang & Gao (2023), Iqbal *et al.,* (2023), Prempeh (2023), Appiah-Otoo, Chen & Ampah (2023), and Liu *et al.,* (2023), which establish the renewable energy-enhancing benefits of financial development. On the contrary, Driscoll-Kraay and FMOLS estimators persistently show that foreign direct investment (fdi) is an insignificant factor that drives REN transition. We find similar results at the lower quantiles in the MM-quantile regression. Meanwhile, the tide changes from the 50th to the 99th quantiles, and fdi becomes a strong positive driver of the REN transition in resource-rich African countries. Thus, it implies that the contributions of foreign direct investment to spur an increase in REN through technology transfers and positive externalities that promote the diffusion of clean and renewable energy consumption depend on the quantiles where each resource-rich African country operates. Foreign direct investment inflows to Africa's resource-rich countries at the lower quantiles appear insignificant in spurring the REN transition. On the contrary, the countries at the upper quantiles are liable to enjoy the technology transfers and positive externalities that spur diffusion of clean technology and renewable energy capacity from the inflows of fdi. The findings at the upper quantiles are consistent with the studies of Akpanke *et al;* (2023), Qamruzzaman *et al.,* (2022), and Shahbaz *et al.,* (2022).

The coefficients of income are consistently significant and negative in all the specifications with mean-based regressions (Driscoll-Kraay and FMOLS estimators). These findings indicate that demand for REN in resource-rich African countries falls as income increases. It implies that an improvement in welfare that comes with an increased income does not translate to higher demands for clean technology and REN. This situation may suggest that better African economic prosperity does not trigger people to switch to renewables and clean technology. It instead instigates them to patronize more fossil fuel energy consumption that contributes to CO_2 emissions. Thus, more income in resource-rich African countries tends to favor pollution-intensive, non-renewable energy to the detriment of the diffusion of renewables. This result implies that an average person in resource-rich African countries does not prioritize the switch to clean technology and REN. As a result, the government and stakeholders in these countries must organize diverse campaigns, awareness, and sensitization programmes for people on the necessity of REN transition. These findings are consistent with the works of Shahbaz *et al.* (2020), Ergun & Rivas (2023), Uzar (2020), Ergun *et al.* (2019), and some other findings. The findings vary across quantiles in MM-quantile regression. The results from 10th to 25th quantiles align with the findings from mean-based regressions. Meanwhile, income promotes development of REN from the 50th to 99th quantiles. These findings reveal that renewable energy enhancing power of income depends on the quantiles where each resource-rich African country operates. Thus, it implies income is a strong positive factor that determines the development of renewable energy sector in the countries that are in the upper quantiles. The findings indicate that the demand for REN increase as income increases. These findings are in line with the works of Samour *et al.*, (2022), Oluoch *et al.*, (2022), Saadaoui & Chtourou (2022), Somoye *et al.*, (2022), Dimnwobi *et al.*, (2022), Belaïd *et al.*, (2021), Ibrahiem & Hanafy (2021), Saadaoui (2022), Sadorsky (2009), Polcyn *et al.*, (2022), and Jamshid *et al.*, (2022), which establish income as a positive factor that spurs a REN switch. Thus, effects of income on REN transition are heterogeneous and policy dimension should also vary across quantiles.

Trade openness significantly and negatively impedes the REN transition in resource-rich countries. All the estimators confirm these findings. It implies that an improvement in trade openness increases the dominance of pollution-intensive fossil fuels at the detriment of renewable energy. It highlights those activities related to globalization and international trade that use more pollution-intensive energy. The governments and institutions regulating trade liberalization strategies and policies should create incentives and design schemes that have potency in fostering high patronages of clean technology and renewable energy in resource-rich African countries. This study aligns with the findings of Saadaoui & Omri, (2023), and Wang & Zhang (2021), which find that trade openness diminishes renewable energy. It, however, contradicts the findings of Zeren & Akkuş (2020) and Zhang et al. (2021), which find that trade openness increases renewables. On the contrary, the results predominantly indicate that foreign aid provides a stimulus that promotes and increases the demand for clean energy and renewables. The quantile regression highlights that foreign aid is inconsequential in driving the transition to REN options at the upper quantiles, especially from the 90th to the 99th quantile. Thus, more foreign aid that promotes the diffusion of renewables and clean energy alternatives should be encouraged in resource-wealthy African countries as a solution to decarbonize the African continent and mitigate the impending negative effects of climate change. Contrarily, Information and communication technology (ICT) innovation encourages the consumption and technology of fossil fuels, which suppresses the development of renewable

Table 11: Method of Moments Quantile Regression Estimation Results

Dependent Variable: Renewable energy			Quantiles							
Variables	Location	Scale	q5	q10	q25	q50	q70	q90	q95	q99
nrr	1.117***	0.017	1.079*	1.087**	1.104***	1.120***	1.130***	1.141***	1.150***	1.165**
	(0.000)	(0.930)	(0.060)	(0.029)	(0.002)	(0.000)	(0.000)	(0.001)	(0.005)	(0.035)
inst	2.293**	0.423	1.369	1.560	1.979	2.359**	2.612**	2.887**	3.100**	3.479*
	(0.027)	-0.541	(0.501)	(0.378)	(0.118)	(0.020)	(0.012)	(0.019)	(0.034)	(0.090)
nrr*inst	-0.261***	0.012	-0.287**	-0.282***	-0.270***	-0.259***	-0.252***	-0.244***	-0.238***	-0.227**
	(0.000)	-0.765	(0.016)	(0.007)	(0.000)	(0.000)	(0.000)	(0.001)	(0.006)	(0.052)
fd	-72.481***	-2.812	-66.343***	-67.610***	-70.395***	-72.925***	-74.600***	76.432***	-77.845***	-80.366***
	(0.000)	-0.406	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
fdi	-0.143	0.134**	-0.149	-0.089	0.044	0.164*	0.244***	0.331***	0.399***	0.518**
	(0.122)	-0.03	(0.412)	(0.574)	(0.700)	(0.070)	(0.008)	(0.003)	(0.002)	(0.052)
gdpp	-0.001	0.001***	-0.002**	-0.002**	-0.001	0.001	0.001	0.001**	0.002**	0.003
	(0.778)	(0.006)	(0.028)	(0.042)	(0.178)	(0.993)	(0.267)	(0.051)	(0.023)	(0.153)
to	-0.107***	-0.090***	0.089*	0.049	-0.040	-0.121***	-0.174***	-0.233***	-0.278***	-0.358**
	(0.000)	(0.000)	(0.077)	(0.268)	(0.206)	(0.000)	(0.000)	(0.000)	(0.000)	(0.013)
fa	0.392***	-0.245***	0.926***	0.816***	0.573***	0.353***	0.208***	0.048	-0.075	-0.294
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.010)	(0.614)	(0.523)	(0.452)
ict	-3.994***	-0.258	-3.431***	-3.547***	-3.802***	-4.034***	-4.188***	-4.356***	-4.486***	-4.717***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
constant	80.706***	11.278***	56.089***	61.168***	72.340***	82.487***	89.207***	96.554***	102.223***	112.336***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Note: ***, ** and * stand for 1%, 5% and 10 % levels of significance respectively

Probability values are in ()

energy alternatives in resource-rich African countries, according to the findings in all the aspects of the regressions used. ICT is supposed to be a viable mechanism for raising public awareness of the drawbacks of excessive reliance on fossil fuel-based energy, which harms ecosystems and threatens human existence due to climate change and global warming. Unfortunately, the scenario for resource-rich African countries is the opposite. ICT promotes the growth of fossil fuels and high-carbon CO_2 emission energies and technologies at the expense of the efficiency and effectiveness of schemes, initiatives, and management of relevant renewable energy-related policies. This finding appears to be at odds with the theoretical position and accepted knowledge that views ICT as a catalyst for fostering an increase in the demand for REN through direct advantages and by motivating the efficiency of other renewable energy-enhancing factors (Yu *et al.,* 2023; Chowdhury *et al.*, 2022). Meanwhile, our finding aligns with the works of Saadaoui & Omri, (2023) and Bano *et al.,* (2022), which establishes a diminishing effect of ICT on REN.

Following the empirical analyses and interpretations of how institutional quality modifies the contributions of natural resource wealth to promote the REN transition, the focus now shifts to determining the threshold of institutional quality in the nexus. Consistent with the studies of Aluko (2020), Olaniyi (2022), Olaniyi & Odhiambo (2023a), Olaniyi, Al-Faryan & Ogbaro (2023), Olaniyi, Young, *et al.* (2022), Bolarinwa *et al.* (2021), and Seo *et al.* (2019), we use a robust dynamic panel threshold to determine the level of institutional development beyond which institutions are potent and efficient to stimulate natural resource rents to spur the REN switch in resource-rich African countries. Aside from establishing thresholds for overall institutional quality, we estimate thresholds for all the adopted specific institutional measures (control of corruption, bureaucratic quality, law and order, democratic accountability, and government stability). Table 12 displays the results of the institutional quality thresholds. To confirm the existence of threshold for institutional quality in the trilogy relationship, we perform the linearity tests in each case. The bootstrapped p-values indicate rejection of the hypothesis of no linearity in all the institutional measures considered. These attest to the existence of nonlinearity and thresholds of institutional quality in the natural resource rent-renewable energy transition nexus. The threshold of overall institutional quality threshold is 5.281.

The implication is that institutional quality needs to be consistently higher than 5.28 on a scale of 10 to become strong and efficient to quell sharp practices and corruption in natural resource wealth administration and effectively utilize resource income to spur the REN switch. This indicates that the overall institutional quality below the threshold of 5.281 tends to be too weak and it accommodates loopholes to allows rent-seeking and opportunistic behaviour in natural resource rent management. These weak institutions might culminate in channeling natural resource income to pollution-intensive and high-carbon emission fossil fuel-based energy. It implies that less of resource income is left available to finance and accelerate the renewable energy switch in resource-rich African countries. On the contrary, institutional development needs to persistently be above 5.28 in resource-rich African countries to be able to block inherent weaknesses and flaws in institutional frameworks, prevent fraudulent practices and corruption from natural resource wealth administration, and ensure channelization of resource income to initiatives and schemes that trigger massive investment in REN production and incentivize its consumption to facilitate the switch to net-zero emission clean energy and technology. The study’s findings indicate weak institutional quality in resource-rich African countries. The estimated threshold (5.281) is above the average institutional performance (4.671) in resource-rich African countries (see Table 1). It implies weak institutions with inherent flaws and loopholes in these countries. This situation makes prudent management of natural resource wealth extremely difficult. Thus, converting natural resource rents to capital investment to finance and incentivize the production and consumption of REN options is due to large-scale corruption and misuse of resource revenue in resource-rich African countries.

Aside from the fact that average institutional development of resource-rich African countries is below the threshold, the average performance of country-specific indicates that only five countries (Namibia, Botswana, Tanzania, Ghana and South Africa) have an average institutional quality that is above the threshold value. Meanwhile, the remaining eighteen countries (Zambia, Algeria, Mozambique, Egypt, Burkina Faso, Sierra Leone, Gabon, Guinea, Angola, Congo Republic, Niger, Libya, Cameroon, Nigeria, Mali, Cote d'Ivoire, Sudan, Democratic Republic of Congo) have average institutional quality below the threshold. The prevalence of weak institutions in resource-rich African countries reveal the main reason why institutions drain the natural resource wealth's contribution to REN transition as confirmed in the moderation analysis. With the exception of Namibia and Botswana, other countries that operate above the threshold are inconsistent in their institutional development and the trends appear unpredictable. The inconsistencies in institutional development constitute a drag and could thwart channelization of natural resource wealth to speed up investment in REN production and incentivize the consumption of clean energy.

These countries' institutional frameworks may not be able to adequately facilitate channeling the natural resource wealth to spur the REN transition. This explains why institutions drain the contribution of natural resource wealth to develop the renewable energy sector. The phenomenon could be attributed to opportunistic behaviour, corruption, and embezzlement in resource income administration. Thus, the REN transition might be impeded as part of natural resource wealth is diverted to finance unclean technology and energy. The study's findings reveal that for natural resource wealth to effectively spur the REN transition, African resource-rich countries must make conscious and committed efforts to develop their institutions. Specifically, the institutional architectures and regulatory framework guiding the administration of natural resource wealth to incentivize the REN transition need to be critically evaluated and pruned. It eliminates opportunism and sharp practices, which would otherwise divert resource income to dirty energy consumption and technologies.

The dynamic panel threshold approach presents two sets of estimates for the variables (lower and upper regimes). The lower regime's estimates help to explain the behaviour of variables before the threshold, while the estimates in the upper regime explain the performance of variables after the threshold. Results show that the coefficient of the overall institution index is significantly negative before the threshold, while it becomes positive after the threshold. This reinforces the prior argument that institutions below the threshold might be inefficient to prevent corruption and mismanagement of natural resource rents. This promotes channelling resource income to spur investment in REN production and deployment to decarbonize the

Table 12: Results of dynamic panel threshold estimate of Institutional quality in the narural resource rent-renewable energy transition nexus

Dependent Variable: ren (Renewable energy)						
	inst	*cc*	*bq*	*lo*	*da*	gs
Threshold value of institution	5.281***(0.000)	4.032***(0.000)	5.000(0.000)	4.798*** (0.001)	6.061***(0.000)	6.929***(0.000)
Linearity test (Bootstrapped p-value)	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Constant	106.146**(0.026)	-35.829**(0.004)	-9.356(0.741)	-108.037(0.003)	25.666***(0.0060	37.843***(0.006)
		Lower regime $(q_{it} \leq \delta)$				
Lagged ren	0.369***(0.000)	1.208***(0.000)	0.932***(0.000)	0.541*(0.081)	0.982***(0.000)	1.071***(0.000)
nrr	-0.139***(0.002)	-1.176**(0.028)	0.065(0.407)	1.197(0.200)	-0.017(0.740)	0.048(0.578)
inst	5.324**(0.011)					
cc		-1.673***(0.249)				
bq			-0.986(0.532)			
lo				-9.883**(0.014)		
da					0.943**(0.011)	
gs						-0.306(0.813)
		Upper regime $(q_{it} > \delta)$				
Lagged ren	0.338**(0.015)	0.256**(0.035)	1.618***(0.004)	-0.270(0.126)	0.007(0.932)	-0.219***(0.000)
nrr	1.412***(0.000)	1.008***(0.000)	-6.421***(0.003)	-0.321*(0.073)	0.374*(0.072)	-0.271***(0.001)
inst	-25.611***(0.000)					
cc		2.4170.162)				
bq			-9.742**(0.029)			
lo				24.897***(0.001)		
da					-4.572(0.003)	
gs						-2.051(0.324)

***, ** and * represent 1, 5 and 10 percent level of significance respectively

Probability values are reported in parentheses

1000 boostrap iterations are used to compute the bootstrapped *p-values*

African continent. It suggests that institutional quality above the threshold is needed to ensure efficient allocation of natural resource wealth to spur clean energy transition in resource-rich African countries. Institutional apparatus below the threshold breed opportunism, rent-seeking, corruption, and financial recklessness in the administration of natural resource wealth, which might impede the REN transition in resource-rich African countries.

For more policy guides, the threshold values for corruption control, bureaucratic quality, law-and-order, democratic accountability, and government stability are estimated at 4.03, 5.00, 4.80, 6.06, and 6.93, respectively. These values are compared to the average performances of these institutional quality metrics, which are 3.30, 2.95, 4.91, 5.29, and 6.91, respectively. All these estimated values indicate that the average values are below their threshold values. These findings further reinforce the predominance of weak institutional development in resource-rich African countries. This phenomenon culminates in mismanagement of natural resource wealth and stymies converting resource income to invest in REN transition initiatives to ensure net-zero emissions and pollution-free energy consumption and technologies.

6 Practical contributions and policy implications

This section highlights the contributions made by this study's initiatives to enhance the literature on REN transitions and the encompassing policy implications and options to decarbonize the African continent ecosystems and lessen the risks that climate change and global warming pose to human health. The study's contributions are as follows: **One**, this study is the first in the global empirical discussion to use a dynamic panel threshold to unearth the determination of institutional quality thresholds in the natural resource wealth-renewable energy nexus. **Two**, the study makes a maiden effort to investigate the empirical effect of how institutional quality and natural resource wealth interact to expedite or mar the REN switch in the context of resource-rich African countries. **Three**, this study is the first to account for cross-sectional dependence in the global empirical analysis of the natural resource rent-institution-renewable energy trilogy, especially how institutions modify the natural resource wealth's contributions to spur REN transition. **Four**, it also provides the first empirical evaluation of the critical roles of institutional architectures and natural resource rents in spurring the REN switch in the case of resource-wealthy African countries. **Five**, it provides novelties and insights into how natural resource rents and institutional quality interact to speed up the REN transition and clean technology to trigger net-zero emissions to decarbonize resource-rich African countries' ecosystems and avert the impeding negative consequences of climate change and global warming on humanity. **Six**, this study reveals that the state of institutional development is a significant macroeconomic policy instrument that can increase or decrease the efficiency of natural resource rents to promote or slow the production of and investment in clean energy and resource-rich African countries' transition to REN options.

Based on a discussion of contributions to existing research, we discuss novel policy perspectives and tools derived from empirical analysis. The goal of this initiative is to explain the macroeconomic pathways of how resource-rich African countries, which are the largest emitters of carbon dioxide in Africa, can use REN transition to champion the course of decarbonizing the continent using a combination of natural resource wealth and institutional quality as driving factors. One, the findings indicate that total natural resource wealth provides the needed capital to escalate investment, production and consumption of REN in resource-rich African countries. African countries with abundant natural resources can use and redirect additional resource income to exploit the untapped wealth of renewable energy resources.

Thus, governments and stakeholders responsible for overseeing the endowment of natural resources should place a high premium on allocating additional natural resource wealth to finance, encourage, and support various projects and programmes that promote the transition to green technology and REN in resource-rich African nations. The natural resource wealth can help facilitate the decarbonization of the African continent and mitigate the adverse effects of climate change through investment in renewable energy initiatives. Two, Africa's resource-rich countries should work together to strengthen and build up the institutional framework vital to the continent's shift to REN sources. An improved institution is to support Africa's shift to REN and clean technology to protect human lives and the sustainability of the ecosystem. It also aims to fortify institutions to purge them of rent-seeking, racketeering, fraudulent acts, and corrupt practices that could undermine strategic plans and policies to spur the switch to net-zero emission and sustainable development-driven renewable energy options. Similarly, Africa's resource-rich countries should prioritize further institutional development. Most African resource-wealthy countries do not yet have the institutional development level required to prevent mismanagement and large-scale corruption in the natural resource wealth administration to allocate more resources to spearhead the continent's shift to clean energy options. As a result, institutional development above the threshold must be a priority to ensure a smooth transition to renewables and clean technology deployment.

Three, resource-rich countries in Africa should make collaborative and conscious efforts to monitor and trace institutional deficiencies and flaws inherent in the regulatory and institutional architectures guiding natural resource wealth. There are loopholes and lapses in the institutional framework that manages natural resource income. Such deficiencies give room to corruption and sharp practices that culminate in the diversion of natural resource wealth to promote dirty and pollution-intensive fossil fuels and impede the development of REN. This policy standpoint explains why institutional quality drains the contribution of natural resource wealth to spur REN transition in Africa's resource-rich African countries. Four, Governments and public institutions in all resource-rich African countries should use part of their resource wealth to create multidimensional incentives and inducements that will encourage firms and individuals to use more REN and clean technologies. There should also be massive campaigns and awareness crusades to sensitize citizens and business enterprises to the dangers of overreliance on fossil fuel-based technologies and energies on ecosystems and continued human existence. Also, government agencies should place a high premium on the climate change-mitigating effects of renewable energy deployment and technology to instill a culture of patronizing clean energy in African people and investors. Five, there should be conscious policing of institutional apparatus and structures that coordinate the natural resource wealth administration to ensure the portion of resource income meant for renewable energy investment, production, and inducements hits the target to facilitate the energy transition on the continent.

7 Summary and conclusion

In light of the United Nations Sustainable Development Goals 7 and 13, it has become increasingly apparent that achieving environmental sustainability across the globe is possible through the transition to clean technology and REN in order to reduce CO_2 emissions and decarbonize the global economy. A net-zero-emissions renewable energy option is a viable alternative to the dominance of pollution-intensive fossil fuel energy usage. Meanwhile, financial constraint constitutes a major barrier to deployment and production of REN. The REN switch requires huge upfront financial obligations and capital investment. As a result, REN is more capital-intensive and costly than traditional fossil fuel-based energy alternatives. Extant studies have posited that natural resource wealth could be converted to capital investment needed to finance and facilitate investment and production of REN. Consistent with this notion, scholars have begun to examine the contributions of natural resource wealth to REN with mixed and inconclusive findings. Aside from the mixed findings, the literature is replete with evidence that most resource-rich countries struggle to convert their wealth into better economic and development outcomes due to the resource curse phenomenon. The orthodox resource-curse approach (ORCA) posits that resource-rich countries have a high likelihood of underperforming in economic fundamentals and developmental outcomes.

The scholars attribute this phenomenon to corruption and reckless management of natural resource wealth. Studies suggest that weak institutional frameworks, allowing rent-seeking, corruption, and poor governance, contribute to the curse of resource rents in resource-rich countries. As a result of corruption tendencies and mismanagement of natural resource wealth, resource-rich countries may not be able to properly use resource incomes and rents to finance initiatives and schemes that will facilitate the transition to carbon-neutral renewable energy. It encapsulates that when a country's institutions are weak, resource rent turns into a curse rather than a blessing to improve the economic condition, which best captures the significance of institutions. As a result, institutions matter in either enhancing or impeding natural resource rent contributions to spur the REN transition. It implies that institutions and natural resource rents interact to determine the shift to REN. Existing research has paid inconsequential attention to the moderating role of institutions to modify the natural resource rents' contributions to REN development. The only study that examines this aspect focused on African countries without considering the peculiar case of resource-rich African countries, which emit more than 70% of the total CO_2 emissions in Africa. Also, the study did not account for cross-sectional dependence in the natural resource rent-institution-renewable energy trilogy. This neglect might bias the research outcomes and policy direction to put the continent on the path to environmental sustainability. This study contributes to the global discussion by unearthing a unique threshold of institutional quality in the natural resource rent-renewable energy nexus. This process helps to determine a level by which institutions are potent enough to quell corruption and sharp practices in natural resource wealth management and augment natural resource rents' contribution to accelerating the REN switch in resource-rich African countries. In synopsis, this study is the maiden effort to determine, if any, institutional quality thresholds in the natural resource wealth-renewable energy nexus.

We use annual data from twenty-three resource-rich African countries for 2000–2021. For more flexible and realistic policy perspectives, this study considers the three dimensions of potential econometric pitfalls identified in modern empirical advances, such as cross-sectional dependence, serial correlation, endogeneity, and distributional and heterogeneous effects, to increase the robustness of estimates. As a result, this study adopts fully modified ordinary least squares, the Driscoll and Kraay nonparametric covariance matrix, and the method of moments quantile regression estimators. The findings robustly and persistently reveal that both natural resource rents and institutional quality separately provide direct stimulus and incentives that encourage the development of REN to set resource-rich African countries on the path to net-zero emissions and environmental sustainability. The two factors independently enhance the

REN switch in resource-rich African countries. As a result, they could be leveraged by relevant policymakers and stakeholders to design schemes that promote strategic initiatives to spur the African energy transition. Taking such measures will mitigate the adverse effects of climate change caused by the continent's reliance on fossil fuels. Meanwhile, the findings from the interplay between natural resource rents and institutional quality to enhance REN in resource-rich African countries are significantly negative. It implies that while natural resource rents stimulate energy transition by providing necessary incentives, finance, and support initiatives to increase REN production and investment, the prevailing institutional structures thwart the process by accommodating regulatory flaws, lapses, and loopholes that abet opportunistic behaviour, rent-seeking, and corruption in the management of resource incomes. These phenomena slow the transition process by diverting funding to dirty technologies, ecologically degrading fossil fuels, and pollution-intensive energy consumption. Similarly, the research's findings reveal that most resource-rich African countries' institutional developments are below the institutional quality thresholds needed to prevent corruption and mismanagement of natural resource wealth, and this situation impedes a smooth transition to carbon-neutral renewable energy induced by resource income-institution interplay. These findings validate the prevalence of weak institutions in resource-wealthy African countries and affirm that natural resource rents and institutions are substituting rather than reinforcing each other on the pathways to a renewable energy switch in Africa.

The study findings provide several thought-provoking policy standpoints to engineer a smooth transition to put resource-rich African countries on the path to environmental sustainability by pruning the institutional framework surrounding natural resource rent management to spur an increase in renewable energy consumption and production to mitigate the adverse effects of climate change caused by fossil fuel dominance. One, there should be conscious and deliberate efforts by all stakeholders and government agencies in resource-rich African countries to reform and develop institutions. Deliberate institutional development and reforms are critical to the continental REN transition and the environmental sustainability agenda. To facilitate Africa's REN transition, resource-rich African countries need pragmatic and actionable initiatives to strengthen corruption control, bureaucratic quality, regulatory apparatuses, law and order, and political structures. Two, African resource-rich countries should channel more of their natural resource income into renewable energy investment and production, as well as create incentives for its utilization among households and firms. According to the findings, resource earnings have spurring power to hasten the transition to zero-emission sustainable energy and technologies. Thus, channeling natural resource revenues to finance investments, initiatives, and activities capable of promoting the development of the renewable energy sector is critical to mitigating CO_2 emissions and the adverse effects of climate change, putting Africa on the path to environmental sustainability. Three, an in-depth review of the institutional architecture and ambiance governing natural resource wealth administration in resource-rich African countries is necessary. It is required because the findings show that institutional quality mitigates the benefits of natural resource rents to accelerate the REN transition. Pruning institutional structures will aid in identifying and correcting flaws and bridging the gaps that divert resources away from REN production, usage, and initiatives. Four, policymakers and stakeholders should take conscious steps to enforce the complementarity of institutional architecture and natural resource wealth in accelerating the shift to REN in resource-rich African countries. All institutionally induced loopholes draining natural resource wealth's ability to spur REN transitions must be tracked and blocked to enable environmental sustainability in resource-rich African countries.

8 Study's limitations and suggestions for future research

Unlike previous research on the natural resource wealth-institution-renewable energy trilogy, this study identifies the institutional quality thresholds over which natural resource rents are strongly stimulated to accelerate the REN transition. The study's findings have shown that institutional quality modifies the contributions of natural resource wealth to spur renewable energy transitions. Also, differing from previous research, this study has established the need to account for cross-sectional dependence in the analysis of the natural resource rent-institution-renewable energy transition trilogy. Meanwhile, there are other aspects of the trilogy that could be investigated in future research initiatives. One, other scholars are urged to undertake country-specific studies of the trilogy. All the existing studies restricted their searchlight to panel and cross-country analyses. It might be more realistic to account for country-specific idiosyncrasies and provide a more pragmatic policy dimension to address country-specific issues. Two, this study limits its empirical searchlight to data on resource-rich African countries. Thus, the study's findings and policy implications are more relevant to address specific issues surrounding REN transition and environmental sustainability in Africa. As a result, we encourage subsequent research efforts to consider the case of resource-rich countries from other continents. Three, all previous research has restricted to the linear and symmetric effects of natural resource rents on REN. Scholars are therefore encouraged to account for nonlinearities and asymmetries in the natural resource rent-renewable energy nexus in order to reflect more of the fundamental realities of real-world phenomena. The identified study's limitations are in no way diminishing the novelties and policy relevancy of the empirical outcomes. We raise these limitations so that subsequent research efforts could complement the study's contributions. As a result, encourage more research on the REN transition to mitigate CO_2 emissions and climate change's effects on ecosystems and humanity.

Data availability: Data will be available upon the request to corresponding author.

Declarations Ethical approval: The authors have followed all the necessary ethical rules for the publication.

Consent to participate: Not applicable

Consent for publication: All the authors agree to publish this paper in Natural Resources Forum

Competing interests: There is no competing interests in the study.

References

Abba Yadou, B., Ntang, P. B., Tchio Tchieutsouah, R., & Abba Abam-Nde, V. (2023). Do remittances align with energy transition in Africa? An approach with the level of income of countries. In *Natural Resources Forum*. Oxford, UK: Blackwell Publishing Ltd.

Abdulahi, M. E., Shu, Y., & Khan, M. A. (2019). Resource rents, economic growth, and the role of institutional quality: A panel threshold analysis. *Resources Policy*, *61*, 293-303.

Abdul-Mumuni, A., Mensah, B. D., & Amankwa Fosu, R. (2023). Asymmetric effect of renewable energy consumption and economic growth on environmental degradation in sub-Saharan Africa. *International Journal of Energy Sector Management*, *17*(5), 1013-1033.

Acheampong, A. O., Boateng, E., & Annor, C. B. (2024). Do corruption, income inequality and redistribution hasten transition towards (non) renewable energy economy? *Structural Change and Economic Dynamics*, *68*, 329-354.

Acheampong, A. O., Opoku, E. E. O., & Aluko, O. A. (2023). The roadmap to net-zero emission: Do geopolitical risk and energy transition matter? *Journal of Public Affairs*, e2882.

Adebayo, T. S., Akadiri, S. S., Adedapo, A. T., & Usman, N. (2022). Does interaction between technological innovation and natural resource rent impact environmental degradation in newly industrialized countries? New evidence from method of moments quantile regression. *Environmental Science and Pollution Research*, *29*(2), 3162-3169.

Adedoyin, F. F., Bekun, F. V., Hossain, M. E., kwame Ofori, E., Gyamfi, B. A., & Haseki, M. I. (2023). Glasgow climate change conference (COP26) and its implications in sub-Sahara Africa economies. *Renewable Energy*, *206*, 214-222.

Adekoya, O. B., Ajayi, G. E., Suhrab, M., & Oliyide, J. A. (2022). How critical are resource rents, agriculture, growth, and renewable energy to environmental degradation in the resource-rich African countries? The role of institutional quality. *Energy Policy*, *164*, 112888.

Adika, G. (2020). Economic growth dynamics between resource-rich and resource-poor countries in sub-Saharan Africa: The role of politics and institutions. *African Development Review*, *32*(3), 303-315.

Adjei-Mantey, K., Adusah-Poku, F., & Kwakwa, P. A. (2023). International tourism, exchange rate, and renewable energy: Do they boost or burden efforts towards a low carbon economy in selected African countries? *Cogent Economics & Finance*, *11*(2), 2245258.

African Development Bank, (2023). Climate change in Africa. https://www.afdb.org/en/cop25/climate-change-africa

Ahmed, Z., Nathaniel, S. P., & Shahbaz, M. (2021). The criticality of information and communication technology and human capital in environmental sustainability: evidence from Latin American and Caribbean countries. *Journal of Cleaner Production*, *286*, 125529.

Ahmadov, A. K., & Van Der Borg, C. (2019). Do natural resources impede renewable energy production in the EU? A mixed-methods analysis. *Energy policy*, *126*, 361-369.

Ajide, K. B. (2022). Is natural resource curse thesis an empirical regularity for economic complexity in Africa? *Resources Policy*, *76*, 102755.

Ajide, F. M., Dada, J. T., Arnaut, M., & Abdulaziz Saleh Al-Faryan, M. (2023). Impact of Shadow Economy on Sustainable Development in Africa. *International Journal of Public Administration*, 1-15.

AJLabs, (2023). How much does Africa contribute to global carbon emissions? https://www.aljazeera.com/news/2023/9/4/how-much-does-africa-contribute-to-global-carbonemissions#:~:text=Africa%20contributes%20just%204%20percent,the%20most%20fr

om%20climate%20change.&text=African%20leaders%20and%20delegates%20are,the%20continent%27s%20first%20climate%20summit.
Akpanke, T. A., Deka, A., Ozdeser, H., & Seraj, M. (2023). Does foreign direct investment promote renewable energy use? An insight from West African countries. *Renewable Energy Focus*, *44*, 124-131.
Alola, A. A., & Adebayo, T. S. (2023). The potency of resource efficiency and environmental technologies in carbon neutrality target for Finland. *Journal of Cleaner Production*, *389*, 136127.
Aluko, O. A., & Ibrahim, M. (2020). Institutions and the financial development–economic growth nexus in sub-Saharan Africa. *Economic Notes*, *49*(3), e12163.
Aluko, O. A., & Ibrahim, M. (2021). Institutions and financial development in ECOWAS. *Journal of Sustainable Finance & Investment*, *11*(2), 187-198.
Aluko, O. A., Ibrahim, M., & Atagbuzia, M. O. (2021). On the causal nexus between FDI and globalization: Evidence from Africa. *The Journal of International Trade & Economic Development*, *30*(2), 203-223.
Amoah, A., Asiama, R. K., Korle, K., & Kwablah, E. (2022). Corruption: Is it a bane to renewable energy consumption in Africa? *Energy Policy*, *163*, 112854.
Antonakakis, N., Cunado, J., Filis, G., & De Gracia, F. P. (2017). Oil dependence, quality of political institutions and economic growth: A panel VAR approach. *Resources Policy*, *53*, 147-163.
Afshan, S., Ozturk, I., & Yaqoob, T. (2022). Facilitating renewable energy transition, ecological innovations and stringent environmental policies to improve ecological sustainability: evidence from MM-QR method. *Renewable Energy*, *196*, 151-160.
Anser, M. K., Syed, Q. R., & Apergis, N. (2021). Does geopolitical risk escalate CO2 emissions? Evidence from the BRICS countries. *Environmental Science and Pollution Research*, *28*(35), 48011-48021.
Appiah-Otoo, I., Chen, X., & Ampah, J. D. (2023). Does financial structure affect renewable energy consumption? Evidence from G20 countries. *Energy*, *272*, 127130.
Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, *58*(2), 277-297.
Asongu, S., & Odhiambo, N. M. (2022). Governance and renewable energy consumption in Sub-Saharan Africa. *International Journal of Energy Sector Management*, *16*(2), 209-223.
Auty, R. M. (1993). Sustaining development in mineral economies: The resource curse thesis. London: Routledge
Ayompe, L. M., Davis, S. J., & Egoh, B. N. (2021). Trends and drivers of African fossil fuel CO2 emissions 1990–2017. *Environmental Research Letters*, *15*(12), 124039.
Awad, A., Mallek, R. S., Ozturk, I., & Abdalla, Y. A. (2023). Infrastructure development's role in environmental degradation in sub-Saharan Africa: Impacts and transmission channels. *Journal of Cleaner Production*, 137622.
Awan, A., Abbasi, K. R., Rej, S., Bandyopadhyay, A., & Lv, K. (2022). The impact of renewable energy, internet use and foreign direct investment on carbon dioxide emissions: A method of moments quantile analysis. *Renewable Energy*, *189*, 454-466.
Awan, A., Alnour, M., Jahanger, A., & Onwe, J. C. (2022). Do technological innovation and urbanization mitigate carbon dioxide emissions from the transport sector?. *Technology in Society*, *71*, 102128.

Baltagi, B. H., Feng, Q., & Kao, C. (2012). A Lagrange Multiplier test for cross-sectional dependence in a fixed effects panel data model. *Journal of Econometrics*, *170*(1), 164-177

Bashir, M. F., Pan, Y., Shahbaz, M., & Ghosh, S. (2023). How energy transition and environmental innovation ensure environmental sustainability? Contextual evidence from Top-10 manufacturing countries. *Renewable Energy*, *204*, 697-709.

Bhattacharya, M., Paramati, S. R., Ozturk, I., & Bhattacharya, S. (2016). The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. *Applied energy*, *162*, 733-741.

Benavides-Franco, J., Gómez, J. M., & Pérez-Uribe, M. A. (2023). Determinants of Project Finance success for renewable energy. *Renewable Energy*, *211*, 188-201.

Bano, S., Liu, L., & Khan, A. (2022). Dynamic influence of aging, industrial innovations, and ICT on tourism development and renewable energy consumption in BRICS economies. *Renewable energy*, *192*, 431-442.

Bashir, M. F., Shahbaz, M., Ma, B., & Alam, K. (2024). Evaluating the roles of energy innovation, fossil fuel costs and environmental compliance towards energy transition in advanced industrial economies. *Journal of Environmental Management*, *351*, 119709.

Baye, R. S., Ahenkan, A., & Darkwah, S. (2021). Renewable energy output in sub–Saharan Africa. *Renewable Energy*, *174*, 705-714. https://doi.org/10.1016/j.renene.2021.01.144

Bolarinwa, S. T., Olayeni, R. O., & Vo, X. V. (2021). Is there a nonlinear relationship between nonperforming loans and bank profitability? Evidence from dynamic panel threshold. *Managerial & Decision Economics*, *42*(3), 649-661.

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *The Review of Economic Studies*, *47*(1), 239-253.

Bukari, C., & Aluko, O. A. (2023). Severity of climate change and deprivation outcomes: Micro-level assessment for sub-Saharan Africa. *Environmental Science & Policy*, *150*, 103593.

Wang, X., Chen, G., Afshan, S., Awosusi, A. A., & Abbas, S. (2023). Transition towards sustainable energy: The role of economic complexity, financial liberalization and natural resources management in China. *Resources Policy*, *83*, 103631.

Chaouali, I., Ben Jebli, M., & Strielkowski, W. (2023, May). How renewable energy and service growth influence environmental quality: Evidence from a sustainable development perspective. In *Natural Resources Forum*. Oxford, UK: Blackwell Publishing Ltd.

Chen, X., Fu, Q., & Chang, C. P. (2021). What are the shocks of climate change on clean energy investment: A diversified exploration. *Energy Economics*, *95*, 105136.

Chien, F., Zhang, Y., Li, L., & Huang, X. C. (2023). Impact of government governance and environmental taxes on sustainable energy transition in China: fresh evidence using a novel QARDL approach. *Environmental Science and Pollution Research*, *30*(16), 48436-48448.

Chishti, M. Z., & Dogan, E. (2022). Analyzing the determinants of renewable energy: The moderating role of technology and macroeconomic uncertainty. *Energy & Environment*, 0958305X221137567. https://doi.org/10.1177/0958305X221137567

Chowdhury, E. K., Abdullah, M. N., & Tooheen, R. B. (2022). Role of information and communication technology in economic progress and increasing demand for renewable energy: evidence from China and India. *Asian Journal of Technology Innovation*, *30*(3), 651-671.

Chu, L. K., Doğan, B., Ghosh, S., & Shahbaz, M. (2023). The influence of shadow economy, environmental policies and geopolitical risk on renewable energy: A comparison of high-and middle-income countries. *Journal of Environmental Management*, *342*, 118122.

Dada, J. T., Olaniyi, C. O., Ajide, F. M., Adeiza, A., & Arnaut, M. (2022). Informal economy and ecological footprint: the case of Africa. *Environmental Science and Pollution Research*, *29*(49), 74756-74771.

De Hoyos, R. E., & Sarafidis, V. (2006). Testing for cross-sectional dependence in panel-data models. *The stata journal*, *6*(4), 482-496.

Demetriades, P., & Hook Law, S. (2006). Finance, institutions and economic development. *International Journal of Finance & Economics*, *11*(3), 245-260.

Dingru, L., Onifade, S. T., Ramzan, M., & AL-Faryan, M. A. S. (2023). Environmental perspectives on the impacts of trade and natural resources on renewable energy utilization in Sub-Sahara Africa: accounting for FDI, income, and urbanization trends. *Resources Policy*, *80*, 103204. https://doi.org/10.1016/j.resourpol.2022.103204

Dong, K., Sun, R., & Hochman, G. (2017). Do natural gas and renewable energy consumption lead to less CO2 emission? Empirical evidence from a panel of BRICS countries. *Energy*, *141*, 1466-1478.

Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of economics and statistics*, *80*(4), 549-560.

Espoir, D. K., & Sunge, R. (2021). CO_2 emissions and economic development in Africa: Evidence from a dynamic spatial panel model. *Journal of environmental management*, *300*, 113617. https://doi.org/10.1016/j.jenvman.2021.113617

Gazdar, K., & Cherif, M. (2015). Institutions and the finance–growth nexus: Empirical evidence from MENA countries. *Borsa Istanbul Review*, *15*(3), 137-160.

Gemeda, D. O., & Sima, A. D. (2015). The impacts of climate change on African continent and the way forward. *Journal of Ecology and the Natural environment*, *7*(10), 256-262.

Habiba, U., & Xinbang, C. (2023). The contribution of different aspects of financial development to renewable energy consumption in E7 countries: The transition to a sustainable future. *Renewable Energy*, *203*, 703-714.

Han, Z., Zakari, A., Youn, I. J., & Tawiah, V. (2023). The impact of natural resources on renewable energy consumption. *Resources Policy*, *83*, 103692.

Hartwick, J. M. (1977). Intergenerational equity and the investing of rents from exhaustible resources. *The American Economic Review*, *67*(5), 972-974.

Hassan, A. S. (2023). Modeling the linkage between coal mining and ecological footprint in South Africa: does technological innovation matter? *Mineral Economics*, *36*(1), 123-138.

Heller, T. C. (2006). African transitions and the resource curse: An alternative perspective. *Economic Affairs*, *26*(4), 24-33.

Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. *The Stata Journal*, *7*(3), 281-312.

Hosseini, S. E. (2022). Transition away from fossil fuels toward renewables: lessons from Russia-Ukraine crisis. *Future Energy*, *1*(1), 2-5.

Huang, J., Ibrahim, R. L., & Al-Faryan, M. A. S. (2023). Is natural resource dependence a blessing or curse for sustainable energy blueprint? An empirical insight towards achieving sustainable environment. *Natural Resources Forum* *https://doi.org/10.1111/1477-8947.12393*

Ibekilo, B., & Emmanuel, P. M. (2022). Revisiting the resource curse syndrome: The role of technology in resource-rich African countries. *IUP Journal of Applied Economics*, *21*(3).

IEA, 2019. Global energy & CO2 status report 2019 – analysis. IEA. https://www.iea.org/reports/global-energy-co2-status-report-2019 .

Inuwa, N., Sani, M. B., Adamu, S., Modibbo, H. U., & Saidu, A. M. (2022). Testing the resource curse hypothesis: evidence from top ten resource-rich countries in Africa. *African Journal of Business and Economic Research*, *17*(2), 205-223

Irfan, M., Rehman, M. A., Razzaq, A., & Hao, Y. (2023). What derives renewable energy transition in G-7 and E-7 countries? The role of financial development and mineral markets. *Energy Economics*, *121*, 106661.

Jahanger, A., Hossain, M. R., Awan, A., Adebayo, T. S., & Chishti, M. Z. (2023). Linking tourist's footprint and environmental tragedy through transportation, globalization and energy choice in BIMSTEC region: Directions for a sustainable solution using novel GMM-PVAR approach. *Journal of Environmental Management*, *345*, 118551.

Kang, X., Khan, F. U., Ullah, R., Arif, M., Rehman, S. U., & Ullah, F. (2021). Does foreign direct investment influence renewable energy consumption? empirical evidence from south Asian countries. *Energies*, *14*(12), 3470.

Kocoglu, M., Jahanger, A., Awan, A., Barak, D., & Balsalobre-Lorente, D. (2023). Examining the nonlinear impact of human capital on environmental degradation in N-11 countries: an application of the PSTR approach. *Environmental Science and Pollution Research*, 1-15.

Kwakwa, P. A. (2023). Climate change mitigation role of renewable energy consumption: Does institutional quality matter in the case of reducing Africa's carbon dioxide emissions? *Journal of Environmental Management*, *342*, 118234.

Law, S. H., Azman-Saini, W. N. W., & Ibrahim, M. H. (2013). Institutional quality thresholds and the finance–growth nexus. *Journal of Banking & Finance*, *37*(12), 5373-5381.

Law, S. H., Kutan, A. M., & Naseem, N. A. M. (2018). The role of institutions in finance curse: Evidence from international data. *Journal of Comparative Economics*, *46*(1), 174-191.

Law, C., & Law, S. H. (2022). The non-linear impacts of innovation on unemployment: Evidence from panel data. *International Journal of Finance & Economics*, https://doi.org/10.1002/ijfe.2691

Lee, C. C., Chen, M. P., & Yuan, Z. (2023). Is information and communication technology a driver for renewable energy? *Energy Economics*, *124*, 106786.

Lee, C. C., & Olasehinde-Williams, G. (2022). Does economic complexity influence environmental performance? Empirical evidence from OECD countries. *International Journal of Finance & Economics*. https://doi.org/10.1002/ijfe.2689

Li, J., Dong, X., & Dong, K. (2022). How much does financial inclusion contribute to renewable energy growth? Ways to realize green finance in China. *Renewable Energy*, *198*, 760-771.

Li, W., Cao, N., & Xiang, Z. (2023). Drivers of renewable energy transition: The role of ICT, human development, financialization, and R&D investment in China. *Renewable Energy*, *206*, 441-450.

Li, S., Samour, A., Irfan, M., & Ali, M. (2023). Role of renewable energy and fiscal policy on trade adjusted carbon emissions: Evaluating the role of environmental policy stringency. *Renewable Energy*, *205*, 156-165.

Liu, J., & Lu, S. (2023). Do natural resources ensure access to sustainable renewable energy in developing economies? The role of mineral resources in a resources-energy novel setting. *Resources Policy*, *85*, 104008. https://doi.org/10.1016/j.resourpol.2023.104008

Liu, W., Shen, Y., & Razzaq, A. (2023). How renewable energy investment, environmental regulations, and financial development derive renewable energy transition: Evidence from G7 countries. *Renewable Energy*, *206*, 1188-1197.

Ma, Q., Li, S., Aslam, M., Ali, N., & Alamri, A. M. (2023). Extraction of natural resources and sustainable renewable energy: COP26 target in the context of financial inclusion. *Resources Policy*, *82*, 103466.

Ma, B., Sharif, A., Bashir, M., & Bashir, M. F. (2023). The dynamic influence of energy consumption, fiscal policy and green innovation on environmental degradation in BRICST economies. *Energy Policy*, *183*, 113823.

Machado, J. A., & Silva, J. S. (2019). Quantiles via moments. *Journal of Econometrics*, *213*(1), 145-173.

Mahalik, M. K., Patel, G., Sahoo, B. K., & Rahman, M. M. (2023). Impact of income inequality on renewable energy demand in south Asian economies. *Energy Policy*, *180*, 113628.

Mahendru, M., Tiwari, A. K., Sharma, G. D., Nathaniel, S., & Gupta, M. (2023). Energy-growth nexus for 'Renewable Energy Country Attractiveness Index'countries: Evidence from new econometric methods. *Geoscience Frontiers*, 101704.

Menegaki, A. N., & Tsagarakis, K. P. (2015). Rich enough to go renewable, but too early to leave fossil energy? *Renewable and Sustainable Energy Reviews*, *41*, 1465-1477.

Meo, M. S., Sabir, S. A., Arain, H., & Nazar, R. (2020). Water resources and tourism development in South Asia: an application of dynamic common correlated effect (DCCE) model. *Environmental Science and Pollution Research*, *27*, 19678-19687.

Mesagan, E. P., Charles, A. O., & Vo, X. V. (2023). The relevance of resource wealth in output growth and industrial development in Africa. *Resources Policy*, *82*, 103517.

Mesagan, P. E., Yusuf, A. I., & Ogbuji, A. I. (2019). Natural resource endowment and output growth: How crucial is deficit financing in managing resource-rich African economies? *Journal of Social and Economic Development*, *21*, 353-369.

Miles, J. (2014). Tolerance and variance inflation factor. *Wiley statsref: statistics reference online*. https://doi.org/10.1002/9781118445112.stat06593

Mukhtarov, S., Aliyev, J., Borowski, P. F., & Disli, M. (2023). Institutional quality and renewable energy transition: Empirical evidence from Poland. *International Studies*, *16*(3), 208-218.

Muye, I. M., & Muye, I. Y. (2017). Testing for causality among globalization, institution and financial development: Further evidence from three economic blocs. *Borsa Istanbul Review*, *17*(2), 117-132.

Nabaweesi, J., Kaawaase, T. K., Buyinza, F., Adaramola, M. S., Namagembe, S., & Nkote, I. (2023). Governance and modern renewable energy consumption in the East African Community (EAC): a dynamic panel CS-ARDL approach. *Management of Environmental Quality: An International Journal*. https://doi.org/10.1108/MEQ-05-2023-0152

Nawaz, A., & Rahman, M. M. (2023). Renewable energy consumption in Sub-Saharan Africa: The role of human capital, foreign direct investment, financial development, and institutional quality. *Energy Reports*, *10*, 3383-3393.

Nchofoung, T. N. (2024). Oil price shocks and energy transition in Africa. *Energy Policy*, *184*, 113855.

Nchofoung, T. N., & Ojong, N. (2023). Natural resources, renewable energy, and governance: A path towards sustainable development. *Sustainable Development*, *31*(3), 1553-1569.

Ndubuisi, P., Okere, K. I., & Iheanacho, E. (2023). Financial sector development and energy consumption in sub-saharan Africa: does institutional governance matter? Dynamic panel data analysis. *Journal of International Commerce, Economics and Policy*, *14*(01), 2350003.

Nwani, C., Bekun, F. V., Gyamfi, B. A., Effiong, E. L., & Alola, A. A. (2023, May). Toward sustainable use of natural resources: Nexus between resource rents, affluence, energy intensity and carbon emissions in developing and transition economies. In *Natural Resources Forum* (Vol. 47, No. 2, pp. 155-176). Oxford, UK: Blackwell Publishing Ltd.

Olaniyi, C. O. (2022). On the transmission mechanisms in the finance–growth nexus in Southern African countries: Does institution matter? *Economic Change and Restructuring*, *55*(1), 153-191. https://doi.org/10.1007/s10644-020-09313-5

Olaniyi, C. O., & Adedokun, A. (2022). Finance-institution-growth trilogy: time-series insights from South Africa. *International Journal of Emerging Markets*. 17(1), 120-144 https://doi.org/10.1108/IJOEM-05-2019-0370

Olaniyi, C. O., Al-Faryan, M. A. S., & Ogbaro, O. E. (2023). Do institutional quality and its threshold matter in the sensitivity of the renewable energy transition to financial development? New empirical perspectives. *International Journal of Finance & Economics*. https://doi.org/10.1002/ijfe.2900

Olaniyi, C. O., Ojeyinka, T. A., Vo, X. V., & Al-Faryan, M. A. S. (2023). Do business strategies vary across firms in the banking industry? New perspectives from the bank size–profitability nexus. *Managerial and Decision Economics*, *44*(1), 525-544.

Olaniyi, C. O., & Oladeji, S. I. (2021). Moderating the effect of institutional quality on the finance–growth nexus: insights from West African countries. *Economic Change and Restructuring*, *54*(1), 43-74. https://doi.org/10.1007/s10644-020-09275-8

Olaniyi, C. O., & Oladeji, S. I. (2022). Interplay between financial sector and institutional framework in the economic growth process of Kenya. *Journal of Public Affairs*, *22*(3), e2562. https://doi.org/10.1002/pa.2562

Olaniyi, C. O., Young, A. O., Vo, X. V., & Al-Faryan, M. A. S. (2022). Do institutional framework and its threshold matter in the sensitivity of CEO pay to firm performance? Fresh insights from an emerging market economy. *Managerial and Decision Economics*, *43*(8), 3386-3403.

Olaniyi, C. O., & Odhiambo, N. M. (2023a). Does institutional quality matter in the financial Development-Economic complexity Nexus? Empirical insights from Africa. *Research in Globalization*, *7*, 100173. https://doi.org/10.1016/j.resglo.2023.100173

Olaniyi, C. O., & Odhiambo, N. M. (2023b). Do countries' interdependence, asymmetry, and policy variances matter in the remittance-poverty causal nexus? *The Journal of International Trade & Economic Development*, 1-39. https://doi.org/10.1080/09638199.2023.2288191

Olaniyi, C. O., & Odhiambo, N. M. (2024). Inflation-poverty causal nexus in sub-Saharan African countries: An asymmetric panel causality approach. *International Trade, Politics and Development*. https://doi.org/10.1108/ITPD-08-2023-0024

Onifade, S. T., Alola, A. A., Erdoğan, S., & Acet, H. (2021). Environmental aspect of energy transition and urbanization in the OPEC member states. *Environmental Science and Pollution Research*, *28*, 17158-17169.

Onifade, S. T., Haouas, I., & Alola, A. A. (2023, August). Do natural resources and economic components exhibit differential quantile environmental effects? In *Natural Resources Forum* (Vol. 47, No. 3, pp. 355-374). Oxford, UK: Blackwell Publishing Ltd.

Onuoha, F. C., Dimnwobi, S. K., Okere, K. I., & Ekesiobi, C. (2023). Sustainability burden or boost? examining the effect of public debt on renewable energy consumption in Sub-Saharan Africa. *Energy Sources, Part B: Economics, Planning, and Policy*, *18*(1), 2214917.

Onwe, J. C., Bandyopadhyay, A., Hamid, I., Rej, S., & Hossain, M. E. (2023). Environment sustainability through energy transition and globalization in G7 countries: What role does environmental tax play? *Renewable Energy*, 218, 119302.

Oyewo, A. S., Bogdanov, D., Aghahosseini, A., Mensah, T. N., & Breyer, C. (2022). Contextualizing the scope, scale, and speed of energy pathways toward sustainable development in Africa. *Iscience*, *25*(9), 1-38.

Pan, X., Dossou, T. A. M., Berhe, M. W., & Ndomandji Kambaye, E. (2023). Towards efforts to promote renewable energy development in Africa: Does governance quality matter? *Energy & Environment*, *34*(8), 3039-3054.

Pagan, A. (1980). Some identification and estimation results for regression models with stochastically varying coefficients. *Journal of Econometrics*, *13*(3), 341-363.

Papyrakis, E. (2017). The resource curse-what have we learned from two decades of intensive research: Introduction to the special issue. *The Journal of Development Studies*, *53*(2), 175-185. https://doi.org/10.1080/00220388.2016.1160070

Pedroni, P. (2001). Fully modified OLS for heterogeneous cointegrated panels. In *Nonstationary panels, panel cointegration, and dynamic panels* (pp. 93-130). Emerald Group Publishing Limited.

Persyn, D., & Westerlund, J. (2008). Error-correction–based cointegration tests for panel data. *The STATA journal*, *8*(2), 232-241.

Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. *Available at SSRN 572504*.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265-312.

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of econometrics*, 142(1), 50-93.

Pesaran, M. H., Ullah, A., & Yamagata, T. (2008). A bias-adjusted LM test of error cross-section independence. *The Econometrics Journal*, *11*(1), 105-127.

Pesaran, M. H. (2021). General diagnostic tests for cross-sectional dependence in panels. *Empirical Economics*, *60*(1), 13-50.

Phillips, P. C., & Hansen, B. E. (1990). Statistical inference in instrumental variables regression with I (1) processes. *The Review of Economic Studies*, *57*(1), 99-125.

Qamruzzaman, M., Karim, S., & Jahan, I. (2022). Nexus between economic policy uncertainty, foreign direct investment, government debt and renewable energy consumption in 13 top oil importing nations: Evidence from the symmetric and asymmetric investigation. *Renewable Energy*, *195*, 121-136.

Rahman, Z. U., Khattak, S. I., Ahmad, M., & Khan, A. (2020). A disaggregated-level analysis of the relationship among energy production, energy consumption and economic growth: Evidence from China. *Energy*, *194*, 116836. https://doi.org/10.1016/j.energy.2019.116836

Saadaoui, H., & Chtourou, N. (2022). Do institutional quality, financial development, and economic growth improve renewable energy transition? Some Evidence from Tunisia. *Journal of the Knowledge Economy*, 1-32. https://doi.org/10.1007/s13132-022-00999-8

Saadaoui, H., & Omri, E. (2023). Towards a gradual transition to renewable energies in Tunisia: do foreign direct investments and information and communication technologies matter? *Energy Nexus*, 100252. https://doi.org/10.1016/j.nexus.2023.100252

Sadorsky, P. (2009). Renewable energy consumption and income in emerging economies. *Energy policy*, *37*(10), 4021-4028.
Seo, M. H., Kim, S., & Kim, Y. J. (2019). Estimation of dynamic panel threshold model using Stata. *The Stata Journal*, *19*(3), 685-697.
Seo, M. H., & Shin, Y. (2016). Dynamic panels with threshold effect and endogeneity. *Journal of Econometrics*, *195*(2), 169-186.
Shahbaz, M., Wang, J., Dong, K., & Zhao, J. (2022). The impact of digital economy on energy transition across the globe: The mediating role of government governance. *Renewable and Sustainable Energy Reviews*, *166*, 112620.
Shahbaz, M., Sinha, A., Raghutla, C., & Vo, X. V. (2022). Decomposing scale and technique effects of financial development and foreign direct investment on renewable energy consumption. *Energy*, *238*, 121758.
Shah, S. A. R., Zhang, Q., Abbas, J., Tang, H., & Al-Sulaiti, K. I. (2023). Waste management, quality of life and natural resources utilization matter for renewable electricity generation: The main and moderate role of environmental policy. *Utilities Policy*, *82*, 101584. https://doi.org/10.1016/j.jup.2023.101584
Shinwari, R., Yangjie, W., Payab, A. H., Kubiczek, J., & Dördüncü, H. (2022). What drives investment in renewable energy resources? Evaluating the role of natural resources volatility and economic performance for China. *Resources Policy*, *77*, 102712.
Sohail, M. T. (2023). Evaluating policy-driven capital for renewable energy investments in the presence of cross-sectional dependence: perspectives from financial institutions and markets. *Environmental Science and Pollution Research*, 1-10.
Somoye, O. A., Seraj, M., Ozdeser, H., & Mar'I, M. (2023). Quantile relationship between financial development, income, price, CO2 emissions and renewable energy consumption: evidence from Nigeria. *Letters in Spatial and Resource Sciences*, *16*(1), 2. https://doi.org/10.1007/s12076-023-00330-2
Statista, (2023). Africa's share in global carbon dioxide (CO2) emissions from 2000 to 2020, 12. 1-13, 9 https://www.statista.com/statistics/1287508/africa-share-in-global-co2-emissions/Sustainability (Switzerland)
Studenmund, A. H. (2011). using Econometrics: A practical Guide, pears-on. *New York*, 440-447.
Tan, Y., & Uprasen, U. (2022). The effect of foreign direct investment on renewable energy consumption subject to the moderating effect of environmental regulation: Evidence from the BRICS countries. *Renewable Energy*, *201*, 135-149.
Tang, C. F., Salman, A., & Abosedra, S. (2020). Dynamic interaction of tourism, finance, and institutions in explaining growth in Asia's little dragon economies. *International Journal of Tourism Research*, *22*(1), 15-25.
Ullah, S., Adebayo, T. S., Irfan, M., & Abbas, S. (2023). Environmental quality and energy transition prospects for G-7 economies: The prominence of environment-related ICT innovations, financial and human development. *Journal of Environmental Management*, *342*, 118120.
Villanthenkodath, M. A., Mahalik, M. K., & Patel, G. (2023). Effects of foreign aid and energy aid inflows on renewable and non-renewable electricity production in BRICS countries. *Environmental Science and Pollution Research*, *30*(3), 7236-7255.

Xu, L., & Ullah, S. (2023). Evaluating the impacts of digitalization, financial efficiency, and education on renewable energy consumption: New evidence from China. *Environmental Science and Pollution Research*, *30*(18), 53538-53547.

Wang, X., Chen, G., Afshan, S., Awosusi, A. A., & Abbas, S. (2023). Transition towards sustainable energy: The role of economic complexity, financial liberalization and natural resources management in China. *Resources Policy*, *83*, 103631. https://doi.org/10.1016/j.resourpol.2023.103631

Wang, E., Gozgor, G., Mahalik, M. K., Patel, G., & Hu, G. (2022). Effects of institutional quality and political risk on the renewable energy consumption in the OECD countries. *Resources Policy*, *79*, 103041. https://doi.org/10.1016/j.resourpol.2022.103041

Wang, Q., Guo, J., Li, R., Mikhaylov, A., & Moiseev, N. (2023). Does technical assistance alleviate energy poverty in sub-Saharan African countries? A new perspective on spatial spillover effects of technical assistance. *Energy Strategy Reviews*, *45*, 101047.

Wang, X., Su, C. W., Xue, Z., & Xie, X. (2023). Sustainable development goals perspective of natural resources: Does it paves the way for renewable sources of energy? A global case study. *Resources Policy*, *86*, 104075. https://doi.org/10.1016/j.resourpol.2023.104075

Wang, Q., & Zhang, F. (2021). Free trade and renewable energy: A cross-income levels empirical investigation using two trade openness measures. *Renewable Energy*, *168*, 1027-1039.

Wei, X., Mohsin, M., & Zhang, Q. (2022). Role of foreign direct investment and economic growth in renewable energy development. *Renewable Energy*, *192*, 828-837.

Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and statistics*, *69*(6), 709-748

Wiredu, J., Yang, Q., Inuwa, U. L., & Sampene, A. K. (2023). Energy transition in Africa: The role of human capital, financial development, economic development, and carbon emissions. *Environmental Science & Policy*, *146*, 24-36.

Yu, D., Wenhui, X., Anser, M. K., Nassani, A. A., Imran, M., Zaman, K., & Haffar, M. (2023). Navigating the global mineral market: A study of resource wealth and the energy transition. *Resources Policy*, *82*, 103500. https://doi.org/10.1016/j.resourpol.2023.103500

Yu, M., Jin, H., Zhang, H., & Chong, A. Y. L. (2023). ICT, financial development and renewable energy consumption. *Journal of Computer Information Systems*, *63*(1), 190-203.

Yu, T. M., Yan, Y. T., Yin, Y. H., & Yang, M. G. (2023). Are natural resources and oil prices a possible solution to renewable energy electricity? Evidence from global time series data. *Resources Policy*, *86*, 104288.

Yuan, J., Yang, R., & Fu, Q. (2023). Aspects of renewable energy influenced by natural resources: How do the stock market and technology play a role? *Resources Policy*, *85*, 103820. https://doi.org/10.1016/j.resourpol.2023.103820

Zang, X., Adebayo, T. S., Oladipupo, S. D., & Kirikkaleli, D. (2023). Asymmetric impact of renewable energy consumption and technological innovation on environmental degradation: designing an SDG framework for developed economy. *Environmental Technology*, *44*(6), 774-791.

Zhang, M., Zhang, S., Lee, C. C., & Zhou, D. (2021). Effects of trade openness on renewable energy consumption in OECD countries: New insights from panel smooth transition regression modelling. *Energy economics*, *104*, 105649.

Zheng, M., Feng, G. F., Jiang, R. A., & Chang, C. P. (2023). Does environmental, social, and governance performance move together with corporate green innovation in China? *Business Strategy and the Environment*, *32*(4), 1670-1679.
Zeren, F., & Akkuş, H. T. (2020). The relationship between renewable energy consumption and trade openness: New evidence from emerging economies. *Renewable Energy*, *147*, 322-329.

Table A: The list of resource-rich African countries covered in the study

Algeria	Egypt	Niger
Angola	Gabon	Nigeria
Botswana	Ghana	Sierra Leone
Burkina Faso	Guinea	South Africa
Cameroon	Libya	Sudan
Congo Republic	Mali	Tanzania
Cote d'Ivoire	Mozambique	Zambia
Democratic Republic of Congo	Namibia	