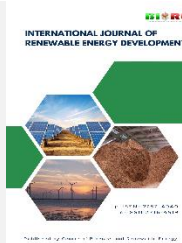




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Research Article

Exploring the impact of financial development on renewable energy consumption within the renewable energy-environmental Kuznets curve framework in Sub-Saharan Africa

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Abstract. Renewable energy usage is deemed a feasible panacea to environmental degradation and energy poverty. In pursuit of carbon neutrality, nations are obligated to formulate strategies that bolster renewable energy initiatives following the Sustainable Development Goals of the United Nations. Given this, this article scrutinises the impact of financial development on the advancement of renewable energy consumption within the renewable energy- environmental Kuznets curve (REKC) framework while controlling for foreign direct investment (FDI), trade openness, governance and urbanisation using a panel of 38 Sub-Saharan African (SSA) nations from 2002-2019. The empirical findings based on the panel corrected standard error (PCSE) and the Feasible Generalized Least Squares (FGLS) models validated the REKC hypothesis for renewable energy consumption in the SSA region. Financial development, economic growth, trade openness, governance, and urbanisation have a substantial and detrimental impact on renewable energy consumption, whereas FDI has a neutral effect. The Dumitrescu-Hurlin causality tests demonstrate a bidirectional (feedback) causality between renewable energy consumption and all its determinants except for trade openness, where a unidirectional causality from renewable energy consumption to trade openness was established. Given these insights, our paper adds to empirical literature and provides incisive suggestions for policy formulation.

Keywords: Financial development, renewable energy, governance, trade openness, foreign capital, economic growth



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1. Introduction

The dire implications of climate change on environmental sustainability have prompted a rising discourse in recent decades over the connection between energy and the environment. Energy consumption reduces environmental quality and promotes climate change, even though it is a crucial factor in economic growth (Wen *et al.*, 2023). The increase in population, enhanced standard of living, increased production, and economic competitiveness have caused a notable growth in energy usage, leading to a substantial rise in greenhouse gas emissions, particularly CO₂ emissions (Prempeh, Yeboah, *et al.*, 2023). Emerging economies have difficulties attaining a sustainable environment. The utilisation of fossil fuels greatly contributes to the amounts of CO₂ emissions in the atmosphere. Approximately 67% of the total worldwide CO₂ emissions result from the combustion of fossil fuels (Progiou *et al.*, 2023). CO₂-driven environmental deterioration has led to climate change originating from floods, changes in rainfall patterns, landslides, and other disasters that have exacerbated economic situations (Martin-Ortega *et al.*, 2024; Udeagha & Breitenbach, 2023). Policymakers and stakeholders became cognizant of these environmental challenges (Sebos *et al.*, 2023), leading to the

enactment of the Kyoto Protocol in 2005, aimed at reducing aggregate emissions of GHGs produced by industrialised nations. Furthermore, the Paris Agreement (COP 21) was forged in 2015 to formulate a comprehensive strategy to steer the world from climate change. The accord aspires to achieve net zero GHG emissions by 2050. To achieve this aim by 2050, an annual emissions reduction of 37 gigatonnes (Gt) is expected. This route to sustainability necessitates a significant shift in the energy use pattern (Akkermans *et al.*, 2023; Kyriakopoulos *et al.*, 2023). Aside from environmental pressures, the overreliance on fossil fuel usage risks the energy security of the importing economies (Eren *et al.*, 2019).

Transitioning to renewable energy usage (REN) is essential for reducing environmental degradation. The possibility of achieving the 2050 goal hinges on making substantial advancements by 2030 to hasten the renewable-based transition, and the proportion of renewable energy in global energy would need to rise to 79% by 2050 (Tan & Uprasen, 2022). A body of literature has acknowledged the beneficial impact of REN in reducing CO₂ emissions, enhancing environmental quality, achieving energy security, and promoting sustainable development (Losada-Puente *et al.*, 2023; Prempeh, 2024). As a result, nations are now making

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substantial efforts to boost the proportion of REN in the overall energy mix and achieve Sustainable Development Goal (SDG) 7. However, cost is one of the primary hurdles toward incorporating renewable energy. Several monetary barriers to address in renewable energy projects include infrastructure, start-up expenses, and operating costs. In this context, the robustness of the financial framework has become critical in promoting renewable energy projects (Prempeh, 2023). A resilient financial framework offers market liquidity, risk management, and a mechanism for price discovery. Also, financial markets enhance the efficiency of capital allocation. Advanced financial systems have the capacity to direct investments towards critical sectors of the economy, whereas underdeveloped financial systems may deter investments. According to sustainable finance theory, the promotion of sustainable investments and financial practices can serve as a powerful catalyst for financial development, thereby contributing to the attainment of the SDGs (Ahmad *et al.*, 2024). Financial development fosters the mobilisation of financial resources, which in turn enables the provision of financing for sustainable developments such as the generation of renewable energy. Financial development may promote green technologies by bolstering research and development (R&D) initiatives and technology transfer to solve urgent issues like GHG emissions and climate change (Yu *et al.*, 2023). Hence, financial development (FD) may have a substantial influence on renewable energy projects in an environment that strongly promotes environmentally sustainable investments.

The International Energy Agency (IEA) in 2022 reported that the total energy demand in SSA grew by an average of 2.4% yearly from 2010 to 2019 and it is projected to rise by an additional 30% from 2020 to 2030. The overall energy demand is expected to rise by 80% by 2040, in line with a twofold increase in population. Although SSA is rich in renewable energy sources, it has one of the lowest levels of renewable energy utilisation globally. In 2021, renewable energy output in SSA was 190.22 billion kWh, whereas Europe generated 1,551.41 billion kWh, Eurasia produced 306.01 billion kWh, Asia and Oceania produced 3,443.75 billion kWh, Central and South America produced 874.18 billion kWh, and North America produced 1,392.68 billion kWh. Financial development in SSA has improved but still lags behind other regions globally. The average annual growth rate of domestic credit to the private sector from 2016 to 2021 was 2.20%, whereas the average yearly growth rate of domestic credit to the private sector extended by banks was 4.35%. During the same time frame, the annual average growth rates for broad money supply, deposit bank assets, and liquid liabilities were 7.20%, 2.10%, and 3.80%, respectively (Diallo & Ouoba, 2023).

An examination of scholarly literature demonstrates that empirical investigations of the association between FD and REN have garnered attention (Anton & Nucu, 2020; Eren *et al.*, 2019; Kwakwa, 2021; Shahbaz *et al.*, 2021; Wu & Broadstock, 2015) with divergent results. For example, according to some studies (Habiba & Xinbang, 2023; Mukhtarov & Mikayilov, 2023; Prempeh, 2023; Wen *et al.*, 2023), FD tends to stimulate REN. This assertion is based on the premise that a well-established financial sector can efficiently put funds towards investments in green energy projects. However, scholars such as Akpanke *et al.* (2023), Skare *et al.* (2023) and X. Zhao *et al.* (2023) demonstrated that FD does not always promote REN and can have an inhibitory impact.

Due to the conflicting results, which mainly vary across the period, the measure of FD and the econometric strategy employed, further research is needed to examine the factors

that influence the REN to develop practical policy tools to achieve SDG 7 (especially in SSA within the REKC framework). The REKC hypothesis introduced by Yao *et al.* (2019) supports the link between economic growth and renewable energy consumption. The REKC U-shaped hypothesis suggests a negative correlation between REN and economic growth throughout the initial stages of development. During the initial stages of development, the expenses related to using renewable energy are much higher than those of non-renewable energy. As economies grow and reach a certain income threshold, they become more conscious of the environmental effects of using non-renewable energy sources (Prempeh, 2024). Also, through R&D, the costs of using renewable energy tend to fall (Gielen *et al.*, 2019). At this stage, nations increase their utilisation of renewable energy sources to reduce GHG emissions and improve environmental conditions. Sub-Saharan Africa, which is experiencing high levels of energy poverty and is highly vulnerable to climate change, is being overlooked in terms of thorough and empirical research on the impact of FD, economic growth (EG), FDI, trade openness (TOP), governance (GOV) and urbanisation (URB) on its REN.

Following the ongoing debate, this study aims to explore the role of FD in adopting renewable energy sources in SSA nations. The present study contributes to the literature in three folds. First, departing from previous studies (Diallo & Ouoba, 2023; Nabaweesi *et al.*, 2023; Nawaz & Rahman, 2023), this is the first study in the context of the SSA region to explore the role of FD on REN within the renewable energy-environmental Kuznets curve (REKC) framework while controlling for FDI, TOP, GOV and URB. Second, the study uses comprehensive GOV and FD metrics to explore the intricate role of GOV quality and FD on REN in the SSA environment. Lastly, the contribution of this paper lies in the econometric approach adopted. The advantage of this approach is that it is robust to common econometric problems associated with panel data, such as cross-sectional dependence, slope homogeneity, heteroskedasticity and autocorrelation in the model. This paper offers a fresh policy outlook on how financial development, economic growth, FDI, trade openness, governance quality, and urbanisation play crucial roles in the transition to renewable energy usage in Sub-Saharan Africa.

The remainder of the paper is organised as described. Section 2 is the literature review. The methodology used in this study is detailed in the third section. Section 4 showcases and discusses our discoveries. In Section 5, we conclude and offer policy ramifications.

2. Literature review

The burgeoning worldwide discourse on environmental quality is inextricably connected to FD, EG, FDI, GOV, TOP, and URB. The focus primarily falls on renewable energy transition and usage, a major way to mitigate climate change. This literature review explores scholarly works on these subjects, illuminating the complex nature of REN. The review focuses on the role of FD in REN, the impact of EG on REN, the impact of FDI on REN, the nexus between TOP and REN, the impact of GOV on REN and how URB influences REN.

2.1 Nexus between financial development and renewable energy consumption

Numerous regions of the globe have been the subject of an investigation into the association between FD and REN (Anton & Nucu, 2020; Eren *et al.*, 2019; Samour *et al.*, 2022; Shahbaz *et al.*, 2021). Several investigations have shown that countries

endowed with advanced financial sectors are capable of leveraging their financial prowess to advance renewable energy initiatives, thereby contributing to the enhancement of environmental quality (Prempeh, 2024). Developed nations with robust financial frameworks may finance renewable energy initiatives, unlike developing ones with weaker financial systems (Akpanke *et al.*, 2023). Economies with underdeveloped financial structures often rely on non-renewable energy sources, such as fossil fuels, due to their affordability and accessibility, exacerbating climate change.

Empirical investigations have demonstrated that FD exerts a beneficial impact on REN (Deka *et al.*, 2024; Dimnwobi *et al.*, 2022; Mukhtarov & Mikayilov, 2023; Nabaweesei *et al.*, 2023; Prempeh, 2023), among many others. The literature is replete with overwhelming evidence regarding the crucial role that FD plays in the development of sustainable renewable energy projects that aim to accomplish the carbon neutrality agenda. Therefore, by financing renewable energy initiatives, FD indirectly contributes to mitigating global warming and boosting environmental quality. Prempeh (2024) contends that rises in FD and REN result in enhanced ecological quality. However, Assi *et al.* (2021), Lei *et al.* (2022), and Köksal *et al.* (2021) observed that FD has a neutral impact on REN while, Nawaz and Rahman (2023), Kwakwa (2021), and Saadaoui and Chtourou (2023) demonstrate that FD harms REN. A fragile REN and FD characterise the African continent, SSA in particular. In pursuit of enhancing renewable energy initiatives and improving environmental quality, it is imperative that nations identify and implement optimal alternative financing strategies. At the same time, studies such as Wang *et al.* (2021) and Zhe *et al.* (2021) concluded that REN promotes FD.

2.2. Linkage between economic growth and renewable consumption

EG and REN nexus are crucial to scholars and policymakers to develop effective policies. Scholars have explored this subject to better comprehend how EG and REN are associated. Most studies in the literature allude to a positive association between EG and REN (Can & Korkmaz, 2020; Chhabra *et al.*, 2024; Güney, 2021; Ntanos *et al.*, 2018; Sebos *et al.*, 2020). Some studies also concluded that EG drives REN (Alam & Murad, 2020; Ashfaq *et al.*, 2024; EL-Karimi & El-houjjaji, 2022; Gupta & Guha, 2024), among others. Thus far, empirical evidence from the literature supports that a feedback association exists between EG and REN. In addition, the investigations by (Nabaweesei *et al.*, 2023; Nawaz & Rahman, 2023; Yao *et al.*, 2019) validate the REKC hypothesis. They argued that the association between EG and REN is contingent on the level of EG. Therefore, for nations to advance in REN, which may stimulate environmental quality, they should boost EG. However, a contrary viewpoint is presented by Dogan *et al.* (2020), Shahbaz *et al.* (2021) and Prempeh (2023), who establish an inverse association between EG and REN. Pratomo *et al.* (2023) found no significant association between REN and EG.

2.3 FDI and renewable energy consumption

The empirical literature has not extensively analysed the relationship between FDI and REN. Nonetheless, Scholars have shown a keen interest in exploring their association over the past decade. For instance, Tariq *et al.* (2023), Qamruzzaman and Jianguo (2020), and Akpanke *et al.* (2023) found a positive association between FDI and REN. They contended that FDI may promote REN by offering financial resources, technical improvement, and specialist expertise. FDI also facilitates the spread of renewable energy innovations, enhances local

capabilities, and establishes new markets for renewable energy products. Hoa *et al.* (2024) in their study of 60 countries found a bidirectional association between FDI and REN. In the context of BRICS nations, Tan and Uprasen (2022) demonstrated that the effect of FDI on REN is contingent on the level of regulatory stringency, while the results of Yilanci *et al.* (2019) revealed that the impact is contingent on the country under study. Using the panel asymmetric ARDL technique, Qamruzzaman *et al.* (2022) demonstrated that a positive (adverse) shock in FDI substantially increases (decreases) REN. However, Anton & Nucu (2020), Dimnwobi *et al.* (2022), and Nawaz and Rahman (2023), using FDI as a control variable in their investigations, detected no significant association between FDI and REN.

2.4. Trade openness and renewable energy consumption

Regarding the TOP-REN nexus, Alam and Murad (2020) found TOP to be a significant driver of REN in 25 OECD countries. Similarly, Farzana *et al.* (2023) validated the promoting effect of TOP on REN using a panel of South Asian nations covering 1991-2020. Ibrahim and Hanafy (2021) supported the role of TOP in driving REN using data from North African economies. Zhang *et al.* (2021) found that TOP promoted REN up to a certain threshold, beyond which the effects became inhibiting using a sample of 35 OECD nations. In the case of Tunisia, Saadaoui and Omri (2023) documented a deleterious impact of TOP on REN, which they attributed to the proliferation of national fossil resources and the rise in energy requirements, resulting in fossil fuel imports for several decades. Studies conducted by Zhao *et al.* (2020) for China, Dingru *et al.* (2023) for SSA, and Nabaweesei *et al.* (2023) for East African Community countries affirm the deleterious impact of TOP on REN. However, using a panel of 43 economies, Uzar (2020) found no significant association between TOP and REN.

2.5 Governance and renewable energy consumption

Governance quality has been argued to be a significant factor in REN promotion in developed and emerging economies (Ganda, 2024; Murshed, 2024; Simionescu, 2023; Ye & Chaiyapa, 2024). For instance, Huang *et al.* (2022), using panel data from 5 ASEAN nations, concluded that GOV has a considerable positive impact on REN. Similar results were obtained by Belaid *et al.* (2021) and Awijen *et al.* (2022) for the MENA region. In the case of Africa, Dossou *et al.* (2023) revealed that GOV positively influences REN in SSA. Contrary to Dossou *et al.*'s (2023) findings, Asongu and Odhiambo (2022) confirmed that GOV does not influence REN in SSA nations favourably. Therefore, they concluded that GOV hurts REN, which hinders its consistent growth. The negative impact of GOV on REN in African countries is supported by Pan *et al.* (2023) and Nawaz and Rahman (2023). In comparison, the works of Kolawole *et al.* (2024) and Nabaweesei *et al.* (2023) demonstrate that GOV has a neutral influence on REN. However, Onuoha *et al.* (2023) highlighted that the impact of GOV on REN is dependent on the measure of GOV using a panel of 26 SSA nations from 1996-2020.

2.6 Urbanisation and renewable energy consumption

Numerous studies have recognised URB's pivotal function in influencing energy consumption (Fan *et al.*, 2023; Liu *et al.*, 2022; Yan *et al.*, 2024; Yang *et al.*, 2019). However, few studies have focused on the role of URB on REN. For instance, Yin and Qamruzzaman (2024), using the CS-ARDL and NARDL techniques, concluded that URB adversely influences REN

within the BIMSTEC nations. Islam et al. (2022) unveiled that URB negatively impacts REN but drives non-REN in Bangladesh. In the context of SSA economies, Dingru et al. (2023) indicated that a rise in URB is associated with a decline in REN. The negative impact of URB on REN is supported by studies conducted by Fang et al. (2022) for BICS nations, Asghar et al. (2024) for nine newly industrialised countries (NICs) and Pata et al. (2023) for G7 nations. Conversely, using a large panel of 116 nations, Su et al. (2022) documented that URB is a key driver of REN, and this finding is affirmed by Shahbaz et al. (2022), Tan & Uprasen (2022), and Chen et al. (2023) as they provide similar evidence from various economies, which indicate URB promotes REN. On the other hand, Han et al. (2022), using the panel quantile regression approach, established a neutral impact of URB on REN in China.

Previous studies have examined the discrete elements of these linkages in isolation. Nevertheless, there is a dearth of research examining the combined impacts of these variables on REN in this particular domain. Notwithstanding the mounting acknowledgement of the critical role of REN in enhancing environmental quality and rising attention towards FD, FDI, EG, TOP, GOV, and URB, there exists a dearth of empirical studies that explicitly examine the interrelationships and interconnections among these variables within the REKC framework in the specific context of economies in SSA. The paper fills this void by providing a more nuanced and thorough comprehension of the interplay between FD, FDI, EG, TOP, GOV, URB, and REN within the REKC framework in the economies of SSA. Furthermore, by addressing these knowledge gaps, the study aims to elucidate the specific mechanisms and connections that support or impede REN within this domain. This research can offer valuable policy insights for stakeholders in SSA nations.

3. Methodology

3.1. Theoretical framework

The study aims to reveal the linkage between FD and REN in SSA nations. For this purpose, following Yao et al. (2019) and Nabaweesi et al. (2023), the theoretical model employed in this

paper is grounded on the REKC. The universal model for estimating the numerous EKC hypotheses (see Figure 1) is as follows:

$$EQ = f(EG, EGSQ, X) \quad (1)$$

EQ represents environmental quality, EG symbolises gross domestic product, $EGSQ$ denotes gross domestic product squared, and X denotes other regressors. In the REKC model, EQ is substituted with REN; thus, the REKC is represented as follows:

$$REN = f(EG, EGSQ, FD, FDI, TOP, GOV, URB) \quad (2)$$

In this context, REN denotes renewable energy consumption, FD indicates financial development, FDI indicates foreign direct investment, TOP indicates trade openness, GOV indicates governance, and URB indicates urbanisation. To facilitate interpretation and reduce the occurrence of heteroscedasticity, all variables are normalised to their natural logarithm ($\ln$) form. Consequently, Equation (2) is rewritten as follows:

$$\ln REN_{it} = \sigma_{it} + \varphi_1 \ln EG_{it} + \varphi_2 \ln EGSQ_{it} + \varphi_3 \ln FD_{it} + \varphi_4 \ln FDI_{it} + \varphi_5 \ln TOP_{it} + \varphi_6 \ln GOV_{it} + \varphi_7 \ln URB_{it} + \varepsilon_{it} \quad (3)$$

where σ is the constant, i denotes the nations (number of cross sections), and t indicates the period. ε_{it} denotes the error term. The REKC is validated when $\varphi_1 < 0$ and $\varphi_2 > 0$, that is, the coefficients shift from negative to positive values. Therefore, the U-shaped REKC hypothesis, as stipulated in Equation (3), would be confirmed by the significant negative (-) and positive (+) coefficients of EG and $EGSQ$, respectively.

3.2. Data description

This paper covers 38 Sub-Saharan African countries (see Appendix Table A1) from 2002 to 2019. The availability of data mainly influenced both the duration of the study and the number of countries. The dependent variable (REN) is quantified as a percentage of the total energy usage. Renewable energy consumption (% of total energy usage) is a commonly

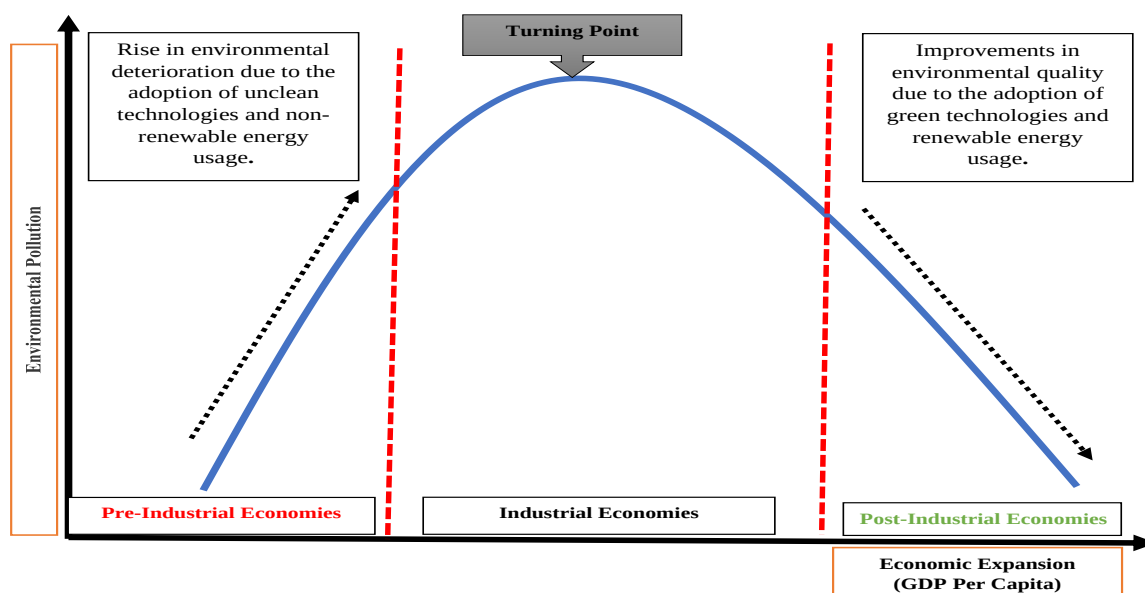


Fig 1. Environmental Kuznets Curve (Source: Figure created by Authors)

Table 1
Principal component analysis

Principal component	Eigenvalue	Proportion of variance extracted	Cumulative proportion of variance extracted
Comp1	5.060	0.843	0.843
Comp2	0.356	0.059	0.903
Comp3	0.303	0.050	0.953
Comp4	0.147	0.025	0.978
Comp5	0.069	0.012	0.989
Comp6	0.065	0.011	1.000

Source: Authors' computation

used proxy to evaluate REN in contemporary scholarly literature (Dogan *et al.*, 2020; Wen *et al.*, 2023).

The main explanatory variable is FD. FD is measured by an FD index computed by the International Monetary Fund (IMF). This FD index measures the depth, access and efficiency of a nation's financial markets and institutions. The FD index has been employed in various studies to measure and evaluate FD (Ahmad *et al.*, 2024; Prempeh, Kyeremeh, *et al.*, 2023). *A priori*, a positive association between FD and REN is expected as a developed financial sector may stimulate investments in renewable energy projects.

The study also captured other critical determinants of REN to deal with issues arising from omitted variable bias. These variables include EG, FDI, GOV, URB, and TOP. Economic growth (EG) was quantified by GDP per capita (constant 2015 US\$) (Jahanger *et al.*, 2023; Jianguo *et al.*, 2022). The EG was squared (EGSQ) to explore the presence of the renewable energy EKC hypothesis. The study anticipates a U-shaped association between EG, EGSQ, and REN.

Foreign capital inflow was measured by net FDI inflows (% of GDP) (Prempeh, 2022; Yue *et al.*, 2019). A positive link between FDI and REN is expected as FDI is deemed to facilitate the transfer of technology into SSA, which may include environmentally-friendly technologies such as REN.

At the country level, governance (GOV) is measured using six major indicators: government effectiveness, regulatory quality, control of corruption, political stability and absence of violence/terrorism, rule of law, and voice and accountability. These GOV indicators are interconnected and intrinsically linked (Nabaweesi *et al.*, 2023). Accordingly, these GOV measures complement one another to guarantee the general

development of a nation's governance. Thus, analysing them individually may not provide the aggregate implications of the GOV framework on REN in SSA. Given the aforementioned rationales, a composite GOV index was formulated using principal component analysis (PCA) (Kassi *et al.*, 2020; Nabaweesi *et al.*, 2023). The PCA results are reported in Table 1. One principal component of GOV with an eigenvalue of 5.06, which is greater than 1 and accounts for 84.3% of the variance in the selected measures of GOV was chosen. This facilitated our investigation of the aggregate influence of GOV on REN. It is envisaged that GOV and REN would be positively correlated. Urbanisation (URB) is conceptualised as the proportion of the total population residing in urban areas. It is measured by urban population (% of total population) (Georgescu & Kinnunen, 2023; Li *et al.*, 2022). URB and REN are anticipated to have a positive correlation since grid-based power is mostly accessible in urban regions of SSA. Lastly, trade openness (TOP), as quantified by trade as a percentage of GDP (Hu *et al.*, 2022; Qamruzzaman & Jianguo, 2020), is predicted to have a favourable (+) impact on REN by facilitating the acquisition of such technologies, hence possibly stimulating their adoption.

Data on REN, EG, FDI, URB, and TOP were obtained from the World Development Indicators (WDI) database. Data on FD and GOV were gleaned from the International Monetary Fund (IMF) and World Governance Indicators (WGI) databases, respectively. All variables were transformed to their natural logarithms to facilitate interpretation and comparison prior to data analysis. The findings are then presented in the form of elasticities. The presence of multicollinearity will render the outcome of multiple regression unreliable as they are based on inaccurate estimates. Therefore, we examined the series for the

Table 2
Summary statistics

Variables	Mean	Std. Dev.	Min	Max
<i>ln</i> REN	4.002	0.846	-0.342	4.588
<i>ln</i> FD	-2.156	0.636	-3.633	-0.523
<i>ln</i> FDI	0.815	1.358	-6.168	4.030
<i>ln</i> EG	7.162	0.953	5.599	9.726
<i>ln</i> TOP	4.115	0.452	2.727	5.403
<i>ln</i> GOV	4.133	0.724	1.712	5.240
<i>ln</i> URB	3.613	0.438	2.161	4.497

Source: Author's computation

Table 3
Correlation matrix

	<i>ln</i> REN	<i>ln</i> FD	<i>ln</i> FDI	<i>ln</i> EG	<i>ln</i> TOP	<i>ln</i> GOV	<i>ln</i> URB
<i>ln</i> REN	1.000						
<i>ln</i> FD	-0.639	1.000					
<i>ln</i> FDI	-0.192	0.100	1.000				
<i>ln</i> EG	-0.715	0.717	0.172	1.000			
<i>ln</i> TOP	-0.537	0.376	0.453	0.536	1.000		
<i>ln</i> GOV	-0.495	0.645	0.131	0.465	0.348	1.000	
<i>ln</i> URB	-0.386	0.278	0.313	0.591	0.449	0.189	1.000

Source: Authors' computation

presence of multicollinearity. All parameter variance inflation factors (VIFs) are less than 10 (refer to Table A2 in the Appendix), indicating that the study is devoid of multicollinearity issues. Table 2 reports the summary statistics. EG recorded the highest mean (7.162). GOV (4.133), TOP (4.115), REN (4.002), URB (3.613) and FDI (0.815) followed, while FD recorded the lowest mean (-2.156). There are no outliers, as indicated by the low standard deviation values for the variables. The minimum and maximum values for the variables are as follows: the minimum and maximum for REN are -0.342 and 4.588, respectively. FD ranges from -3.633 to -0.523, while FDI varies from -6.168 to 4.030. The minimum EG value is 5.599 and the maximum is 9.726. Also, TOP has a minimum of 2.727 and a maximum of 5.403, while GOV varies from 1.712 to 5.240. Finally, URB ranges from 2.161 to 4.497 across SSA over the period under consideration. The correlation matrix is presented in Table 3. A negative correlation ranging from very weak to strong exists between REN and all the regressors.

3.3 Empirical estimation framework

Figure 2 presents the chart of the econometric strategy of the study. Each stage of the estimation strategy is elaborately detailed in the following sections.

3.3.1. Cross-sectional dependence test

Due to the interconnectedness of countries and regional blocs, cross-sectional dependence (CSD) is a prevalent phenomenon in panel data. Consequently, estimating strategies disregarding CSD may provide erroneous findings (Prempeh, Yeboah, *et al.*, 2023). For this reason, CSD analysis of panel data is crucial. The paper employs the CSD test devised by Pesaran (2004) to investigate CSD in the variables. The CSD test is specified as:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \right) \rightarrow N(0,1) \quad (4)$$

where T indicates the sample period, N denotes the sample size, and $\hat{\rho}_{ij}$ is the correlation coefficient of the disturbances. Equation (4) is asymptotically distributed as standard normal if the H_0 of cross-section independence considers $T \rightarrow \infty$ and $N \rightarrow \infty$.

3.2.2. Slope homogeneity test

The problem of slope homogeneity across nations is investigated after the CSD analysis, including the potential variations in economic, socio-economic, and demographic dynamics across different countries. The slope homogeneity test developed by Pesaran and Yamagata (2008) is used for this purpose. The slope homogeneity test equations are specified as follows:

$$\widetilde{\Delta}_{SH} = (N)^{\frac{1}{2}} (2K)^{\frac{1}{2}} \left(\frac{1}{2} \tilde{S} - k \right) \quad (5)$$

$$\widetilde{\Delta}_{ASH} = (N)^{\frac{1}{2}} \left(\frac{2k(T-k-1)}{T+1} \right)^{\frac{1}{2}} \left(\frac{1}{2} \tilde{S} - K \right) \quad (6)$$

where the delta tilde is denoted by $\widetilde{\Delta}_{SH}$ and the delta tilde adjusted by $\widetilde{\Delta}_{ASH}$.

3.3.3. Panel unit root tests

In the presence of CSD and slope homogeneity in the panel data, first-generation panel unit root tests (i.e., Levin-Lin Chu (LLC), Augmented Dickey-Fuller, Im, Pesaran, and Shin (IPS), Phillips-Perron (PP) panel unit root tests) results may be invalid due to their stringent assumption of cross-section independence. Therefore, we rely on second-generation panel unit root tests, which account for CSD. In this paper, we addressed the issue of CSD by using Cross-sectional augmented

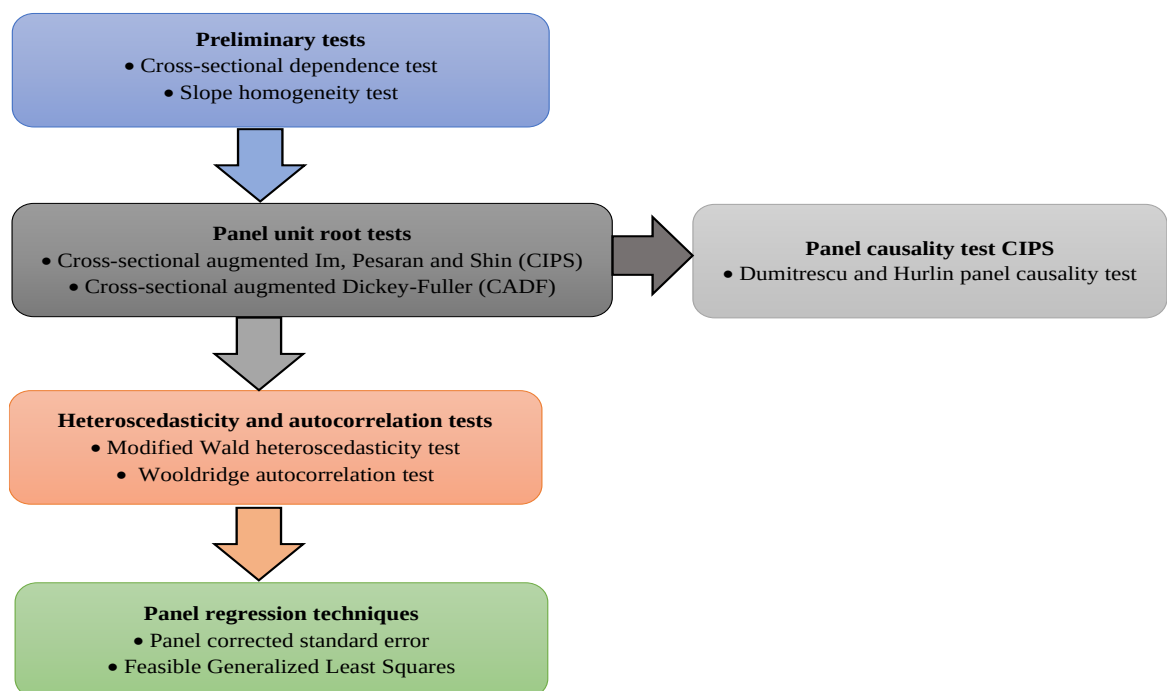


Fig 2. Chart of the empirical strategy

Im, Pesaran and Shin (CIPS), and Cross-sectional augmented Dickey-Fuller (CADF). These tests developed by Pesaran (2007) are robust to CSD. The CADF model is expressed as:

$$\Delta y_{it} = \vartheta_i + \mu_i y_{it-1} + \rho_i \bar{y}_{t-1} + \sum_{j=0}^p \pi_{ij} \Delta \bar{y}_{t-j} + \sum_{j=1}^p \varphi_{ij} \Delta y_{i,t-j} + \varepsilon_{it} \tag{7}$$

where $\bar{y}_{t-1}$ and $\Delta \bar{y}_{t-j}$ specify the averages for the first difference and lags for each cross-section. Once the CADF statistics are obtained, the CIPS statistics can be computed as follows:

$$CIPS = \frac{1}{N} \sum_{i=1}^N t_i(N, T) \tag{8}$$

where $t_i(N, T)$ represents the CADF test statistic as defined by Equation (7).

3.3.4. Heteroscedasticity and autocorrelation tests

Panel regression models may provide spurious results if the residuals are autocorrelated or heteroscedastic. Therefore, verifying the occurrence of these problems is essential. This paper employed the Modified Wald test for group-wise heteroscedasticity (Baum, 2001) and Wooldridge (2002) test for autocorrelation in panel data to test for the presence of heteroscedasticity and autocorrelation in the residuals, respectively. Whereas the Woolridge test is based on the *F*-distribution, the Wald test adheres to the Chi-square distribution. In contrast to the Lagrange Multiplier and the conventional Wald test, the Wald test functions appropriately when the supposition of normality of errors is breached and adheres to the asymptotic property (Baum, 2001). In addition, the Woolridge test yields reliable results when there are no breaks in the time series for both balanced and unbalanced panel data (Nawaz & Rahman, 2023). The Woolridge test evaluates whether there is a first-order autocorrelation.

3.3.5. Panel regression technique

The panel corrected standard error (PCSE) and the Feasible Generalized Least Squares (FGLS) were employed because of the prevalence of CSD heteroscedasticity, slope heterogeneity and autocorrelation in the model. Issues relating to autocorrelation, CSD, and heteroscedasticity are corrected using these methods to get reliable results (Nsanyan *et al.*, 2021). Nawaz and Rahman (2023) and Nuță *et al.* (2024) have also employed these techniques in analogous studies to deal

with comparable problems. The PSCE model is specified as follows:

$$y_{it} = \beta_i + \varphi X_{it} + \varepsilon_{it} \tag{9}$$

where y_{it} denotes REN; β_i signifies the intercept; the vector of parameters to be calculated is denoted by φ ; X_{it} is the matrix of regressors; ε_{it} represents the stochastic error term.

The FGLS is also computed using Equation (10):

$$y_{it} = \vartheta X_{it} + \varepsilon_{it} \tag{10}$$

where y_{it} denotes REN; the vector of parameters to be calculated is denoted by ϑ ; X_{it} is the matrix of regressors; ε_{it} represents the stochastic error term.

3.3.6. Panel causality test

To investigate the path of causality between variables, the paper employs the Dumitrescu and Hurlin (2012) panel causality test as it considers CSD and yields reliable results in large and small heterogenous panels. For this test, cointegration is not a prerequisite. The Dumitrescu and Hurlin panel causality test can be expressed as follows:

$$y_{it} = \tau_i + \sum_{k=1}^K \lambda_i^{(k)} y_{it-k} + \sum_{k=1}^K \beta_i^{(k)} x_{it-k} + \varepsilon_{it} \tag{11}$$

where y_{it} and x_{it} are stationary variables observed for *N* nations (cross-sections) in *T* duration. τ_i is the fixed effect, and *K* is the lag order, which is constant for all cross-sections. $\lambda_i^{(k)}$ is the autoregressive coefficient and $\beta_i^{(k)}$ is the regression coefficient which varies between cross-sections.

4. Empirical results and discussion

A CSD test is essential to diagnostics since its presence or absence determines the subsequent estimating procedure. The CSD test results are reported in Table 4. The Pesaran scaled LM and Pesaran CD tests reject the null hypothesis of no CSD at the 1% level. We confirm the existence of spatial effects across the panel of 38 SSA countries on the basis of this result. Given that the dataset contains CSD, our following estimate techniques account for this characteristic.

The slope homogeneity test results are provided in Table 5. The results demonstrate that the data are heterogeneous across nations (cross-sections). This further supports our decision to employ second-generation econometric techniques

Table 4
Outcome of CSD tests

Test	Test statistic	p-value
Pesaran scaled LM	57.781	0.000
Pesaran CD	4.109	0.000

Source: Authors' computation

Table 5
Outcome of slope coefficient homogeneity test

Test	Test statistic	p-value
$\bar{\Delta}$	10.408	0.000
$\bar{\Delta}_{adj.}$	13.963	0.000

Source: Authors' computation

that mitigate the common effect.

Table 6
Outcome of CIPS and CADF unit root tests

Variable	CIPS		CADF		Decision
	Level	Δ	Level	Δ	
<i>lnREN</i>	-1.850	-3.664***	-1.765	-2.732***	<i>I</i> (1)
<i>lnFD</i>	-2.371***	-3.969***	-2.005**	-2.723***	<i>I</i> (0)
<i>lnFDI</i>	-2.756***	-5.041***	-2.125***	-3.020***	<i>I</i> (0)
<i>lnEG</i>	-1.161	-3.293***	-1.349	-2.652***	<i>I</i> (1)
<i>lnTOP</i>	-1.854	-3.901***	-1.707	-2.786***	<i>I</i> (1)
<i>lnGOV</i>	-1.691	-3.972***	-1.455	-2.527***	<i>I</i> (1)
<i>lnURB</i>	-1.884	-2.255**	-1.646	-2.723***	<i>I</i> (1)

Note: *** and ** denote statistically significant levels at 1% and 5%, respectively. *t*-bar statistics for the CADF tests are reported.

Source: Authors' computation

Table 7
Outcome of heteroscedasticity and autocorrelation tests

Test	Test statistic	<i>p</i> -value	Conclusion
Modified Wald test for group-wise heteroscedasticity	15106.62	0.000	Heteroscedastic
Wooldridge test for autocorrelation	65.120	0.000	Autocorrelated

Source: Authors' computation

Subsequently, the variables' stationarity is then investigated using second-generation panel unit root tests. Table 5 provides the results of the panel cointegrating unit root tests, i.e., CIPS and CADF, for the variables used in this study. The results show that at level, all the variables except FD and FDI are stationary for both the CIPS and the CADF. However, all variables attained stationarity following the first differencing. This indicates that none of the variables is *I*(2), which might lead to erroneous results.

We examined the model at this stage to check if it was free from issues relating to heteroscedasticity and autocorrelation using the Wald and Wooldridge tests, respectively. The results in Table 6 suggest that heteroscedasticity and autocorrelation are present in the model. Therefore, it is appropriate to employ estimation approaches that address heteroscedasticity, autocorrelation, and CSD issues.

The authors believe that the panel-corrected standard errors (PCSE) and feasible generalised least squares (FGLS) models are most appropriate for estimating the model after validating the presence of slope heterogeneity, heteroskedasticity, CSD, and autocorrelation in the data. The results from several model estimates are shown in Table 8. Model 1 accounts for heteroskedasticity with cross-sectional correlation and a common *AR*(1) coefficient for all panels, whereas Model 2 considers heteroscedasticity within panels with panel-specific *AR*(1). Considering the estimates from the PCSE (Model 1), it was demonstrated that a 1% increase in EG decreases REN by 3.76%, whereas a 1% rise in EGSQ raises REN by 0.29%. The REKC hypothesis, illustrated by the association between EG, EGSQ and REN, is confirmed. To be precise, the U-shaped REKC was observed for the selected SSA countries. This suggests that at the early stages of economic growth, REN drops as non-renewable, especially as fossil fuel consumption increases. This is because policymakers focus more on industrial and economic growth and less on environmental quality. However, after attaining a certain threshold of development, policymakers become more concerned about the environment and the dire impact of environmental degradation on the health of citizens. Thus, nations have begun to shift towards ecologically friendly energy sources to help mitigate greenhouse gas emissions that are hazardous to the environment. These findings accord with the EKC hypothesis (Kuznets, 1963). These findings further confirm the discoveries of Yao *et al.* (2019) for developed and emerging nations, Nawaz

and Rahman (2023) for selected SSA nations, and Nabaweesi *et al.* (2023) for EAC countries. Thus, besides boosting EG, SSA governments should support efforts to increase REN. Instead of using fossil fuels and other non-renewable energy sources that harm the environment and human health, governments should support the cost of renewable energy sources and make them available to businesses and households at affordable prices.

It was discovered that FD adversely and significantly influences REN in SSA. Thus, a 1% enhancement in FD will result in a 0.08% reduction in REN. This suggests that the financial systems of SSA states support non-REN funding. This result aligns with the findings of Kwakwa (2021) and Saadaoui and Chtourou (2023). However, this discovery contradicts studies by Mukhtarov *et al.* (2022) and Prempeh (2023), who argue that enormous investments are necessary for renewable energy generation. Consequently, a robust and well-structured financial system facilitates countries' transition from non-renewable to renewable energy sources. Therefore, funds from the financial sector to the renewable energy sector in SSA will boost the accessibility of clean energy to the inhabitants of that region. This action effectively mitigates the impacts of global warming while also attaining the carbon neutrality objective set out by the United Nations.

FDI has a neutral impact on REN in the selected SSA nations. This suggests that the transmission of green technology is not facilitated by FDI inflows into SSA. The technology transfer hypothesis, positing that a nation's economy will gain access to certain skills, technologies, and expertise upon opening up, failed to find empirical support in our study. FDI may result in technical innovation and inter-firm investment, both of which may increase energy efficiency and decrease dependency on renewable energy sources. Therefore, it is not implausible that this is the case. Similar results were also reported by Dimnwobi *et al.* (2022) and Nawaz and Rahman (2023). The variations in results across various studies may be accounted for by the distinct economic circumstances prevalent in different countries. Thus, in keeping with previous research showing that FDI positively affects REN (Akpanke *et al.*, 2023; Tariq *et al.*, 2023), we advise SSA nations to capitalise on incoming FDI to advance REN. Increased FDI inflows will aid in the expansion of renewable energy projects.

GOV significantly reduces REN in SSA. It is observed that a 1% rise in GOV quality leads to a 0.11% decline in RE.

Table 8
Outcomes of PCSE and FGLS analyses.

Variables	PCSE		FGLS	
	Model Coefficient (Std. err.)	Model 2 Coefficient (Std. err.)	Model 3 Coefficient (Std. err.)	Model 4 Coefficient (Std. err.)
<i>lnEG</i>	-3.758*** (0.370)	-3.014*** (0.585)	-3.478*** (0.200)	-2.758*** (0.215)
<i>lnEGSQ</i>	0.285*** (0.026)	0.233*** (0.043)	0.266*** (0.013)	0.219*** (0.014)
<i>lnFD</i>	-0.079*** (0.021)	-0.049*** (0.016)	-0.071*** (0.012)	-0.030*** (0.012)
<i>lnFDI</i>	-0.002 (0.004)	-0.001 (0.002)	-0.002 (0.002)	-0.0003 (0.001)
<i>lnGOV</i>	-0.109*** (0.021)	-0.089*** (0.015)	-0.101*** (0.011)	-0.075*** (0.011)
<i>lnTOP</i>	-0.077*** (0.022)	-0.061*** (0.015)	-0.079*** (0.012)	-0.051*** (0.012)
<i>lnURB</i>	-0.106*** (0.029)	-0.121*** (0.019)	-0.131*** (0.024)	0.116*** (0.058)
Constant	-7.070*** (1.276)	-4.414** (1.946)	-5.987*** (0.757)	-4.268*** (0.776)
R-squared	0.936	0.9951		
Rho(s)	0.863	0.775		
Wald chi2(7)	1231.82	577.99	6207.96	1270.14
Prob > chi2	0.0000	0.0000	0.0000	0.0000
Number of observations	684	684	684	684
Number of groups	38	38	38	38

Note: *** and ** denote statistically significant levels at 1 and 5, respectively. Standard errors (Std. err) in brackets (#)

Source: Authors' computation

Table 9
Dumitrescu & Hurlin Granger non-causality test outcomes

Null Hypothesis	W-Stat.	Zbar-Stat.	Prob.	Causality
<i>lnFD</i> ≠> <i>lnLREN</i>	3.657	2.439	0.015	Yes
<i>lnREN</i> ≠> <i>lnFD</i>	3.417	1.956	0.050	Yes
<i>lnFDI</i> ≠> <i>lnREN</i>	3.418	1.958	0.050	Yes
<i>lnREN</i> ≠> <i>lnFDI</i>	4.106	3.342	0.001	Yes
<i>lnNEG</i> ≠> <i>lnREN</i>	5.708	6.566	0.000	Yes
<i>lnREN</i> ≠> <i>lnEG</i>	3.468	2.060	0.039	Yes
<i>lnTOP</i> ≠> <i>lnREN</i>	3.051	1.220	0.222	No
<i>lnREN</i> ≠> <i>lnTOP</i>	4.685	4.507	0.000	Yes
<i>lnGOV</i> ≠> <i>lnREN</i>	3.635	2.396	0.017	Yes
<i>lnREN</i> ≠> <i>lnGOV</i>	4.749	4.636	0.000	Yes
<i>lnURB</i> ≠> <i>lnREN</i>	6.873	8.909	0.000	Yes
<i>lnREN</i> ≠> <i>lnURB</i>	9.546	14.286	0.000	Yes

Note: The sign ≠> indicates no causality between the specified variables.

Source: Author's computation

This suggests that the governments of the SSA nations are still unable to facilitate the region's energy transition. Within the current context, our findings are comparable with the outcome of Nawa and Rahman (2023) and Asongu and Odhiambo (2022) for SSA countries. However, our finding contradicts the finding of Huang *et al.* (2022), who contend that nations with effective governance support development initiatives to guarantee energy supply and lessen demand-supply disparities. Additionally, they claimed that government interventions use renewable energy sources for energy production to address the issue of energy shortfall. We emphasise that good governance impedes corruption, thereby enabling businesses to operate without bottlenecks, with fewer time-consuming bureaucratic processes, no detrimental consequences of red tape, no rent-seeking behaviour, and no attempt to procure government resources to reduce the high initial cost of renewable energy projects; this stimulates the production and utilisation of renewable energy (Rahman & Sultana, 2022).

TOP had a substantial adverse effect on REN, as displayed in Table 8. Technically, a 1% rise in TOP drops REN by 0.08%. The detrimental consequences of TOP stem from the fact that most imported renewable technology entering Sub-Saharan Africa is counterfeit, discouraging using such energy sources. Consequently, SSA officials must establish standardised criteria for importing renewable energy goods. However, this finding supports the findings of Nabaweesi *et al.* (2023) and Tiwari *et al.* (2022) but disagrees with Alam and Murad (2020) and Farzana *et al.* (2023).

The results show that URB has a substantial and detrimental impact on REN. A 1% improvement in URB will decrease REN by 0.11%. This suggests that urbanisation in SSA economies does not contribute to the growth of REN. It shows that urban households rely on relatively cheaper and dirty sources of energy (i.e., charcoal and fossil fuels) because they are conscious of saving money for their precautionary motive. This finding corroborates the findings of Fang *et al.* (2022) and

Voumik *et al.* (2023). They concluded that per capita energy consumption has declined because many urban residents dwell in congested areas. However, our finding disagrees with the findings of Tan and Uprasen (2022) and Zhao and Qamruzzaman (2022).

Comparing the estimations of Model 2 and Model 1, it is evident that both models yielded identical significant elasticities and signs. Concerning the FGLS (Models 3 and 4), the generated estimates corroborated the estimations from the PSCE with respect to the path and impacts. However, the magnitudes of the impacts exhibited variability.

To ascertain the direction of causality between REN and its determinants in Sub-Saharan African countries, the Dumitrescu-Hurlin Granger causality test was employed, and the outcomes are presented in Table 9. The results suggest a bidirectional (feedback) causality between REN and all its determinants except for TOP, where a unidirectional causality from REN to TOP was established in SSA nations. Therefore, changes in FD and EG cause a shift in REN and vice versa.

5. Conclusion and policy implication

5.1. Conclusion

Numerous empirical studies exist on the determinants of renewable energy consumption. However, how financial development influences renewable energy consumption within the REKC framework is somewhat ignored, specifically in the context of SSA. The transition to renewable energy is critical in this region due to its acute susceptibility to both energy poverty and the grave impacts of climate change. To address this lacuna, the paper extends the literature by exploring the impact of financial development on renewable energy consumption within the REKC framework while controlling for FDI, trade openness, governance and urbanisation in 38 Sub-Saharan African nations from 2002-2019.

The empirical findings validate the presence of the U-shaped REKC hypothesis in the SSA region. The U-shaped curve illustrates that economic expansion initially results in decreased renewable energy consumption in the overall energy mix. Nevertheless, after a certain level of development is reached, there is a subsequent rise in the percentage of renewable energy. Financial development is found to harm the use of renewable energy, which demonstrates that the chosen nations' financial systems have some deficiencies with regard to green finance. Moreover, trade openness, governance and urbanisation substantially negatively impact renewable energy consumption, whereas FDI is not a significant determinant. The panel causality test results further revealed a bidirectional (feedback) causality between renewable energy consumption and its determinants, except for TOP, which exhibits a unidirectional causality from REN to TOP.

5.2. Policy ramifications

Based on the empirical findings, we delineate the subsequent policy ramifications. First, the detrimental effect of financial development on renewable energy consumption informs that its potential to stimulate the adoption of renewable energy and reduce energy poverty in SSA is ephemeral, and that the monetary systems of SSA nations have not emphasised green financing. The area may fall short of attaining the United Nations Sustainable Development Goals (SDGs), particularly goal 7, by the designated timeframe of 2030 if the requisite measures are not implemented. To promote green finance, it is imperative that financial sector authorities raise awareness

among the operators of various financial institutions. The relevant authorities should increase education and understanding of the need to support renewable energy projects and usage among financial institutions.

Second, in the light of the continuous urbanisation in the Sub-Saharan Africa (SSA) region, policymakers must promote collaboration among the private sector players, local authorities, and international organisations to leverage resources and expertise to develop renewable energy. By fostering income-generating initiatives and increasing awareness of the benefits of renewable energy, this partnership may enable urban residents to enhance their economic status and access renewable energy options. Third, notwithstanding the empirical evidence indicating that governance negatively affects the use of renewable energy, the research proposes further enhancements in the quality and efficacy of governance within SSA. Countries with politically stable institutions, effective enforcement of laws, the absence of violence or terrorism, and acceptable regulatory standards would be advantageous in promoting renewable energy generation while simultaneously fulfilling their economic and social goals. Since corruption control is notably lax in SSA, a concerted effort to improve the quality of governance in SSA nations may have positive repercussions for producing and utilising renewable energy.

Finally, for renewable energy consumption to reap the advantages of FDI and trade openness, the credibility and certainty of liberalisation policies must be enhanced. Implementing foreign investment laws to safeguard the rights and interests of foreign investors, as well as formalising trade agreements and protocols with other countries to foster mutually beneficial economic relationships, might help accomplish this objective. These agreements may decrease tariffs and quotas while guaranteeing compliance with quality requirements for renewable energy products traded within the region. The investment climate requires improvement concerning corruption, mismanagement, and terrorism. Creating a conducive investment climate has the potential to enhance foreign direct investment (FDI) and trade openness and reverse the adverse effects of FDI and trade openness on the adoption of renewable energy.

5.3 Limitations and future directions

Despite its pertinence, our study identifies limitations that need attention in further studies. Future research might enhance this investigation by examining how governance quality influences the relationship between financial development and renewable energy usage in emerging economies. Furthermore, future studies might explore the ramifications of financial development on different renewable energy sources in cases where data allows, given that emerging economies are endowed with many such sources. The article included a limited number of drivers of renewable energy consumption; further research should consider including other factors that may potentially impact renewable energy consumption. Another shortcoming of the study is the dependence on quantitative data from SSA economies, which may not apply to other economies globally. Prospective studies should incorporate a more varied range of nations for a larger generalizability.

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Availability of Data and materials

In this investigation, we exclusively used secondary data from public sources. Therefore, in this study, no new data is used or produced.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing Interest

The authors declare that they have no conflict of interest.

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Appendix**Table A1**

List of sample nations

Angola	Congo, Rep.	Mauritania	Sudan
Benin	Cote d'Ivoire	Mauritius	Tanzania
Botswana	Eswatini	Mozambique	Togo
Burkina Faso	Gabon	Namibia	Uganda
Burundi	Gambia, The	Niger	Zambia
Cabo Verde	Ghana	Nigeria	
Cameroon	Guinea	Rwanda	
Central African Republic	Guinea-Bissau	Senegal	
Chad	Kenya	Seychelles	
Comoros	Madagascar	Sierra Leone	
Congo, Dem. Rep.	Mali	South Africa	

Table A2

Multicollinearity test outcome

Variable	VIF	1/VIF
LFD	2.92	0.34
LFDI	1.33	0.75
LEG	3.41	0.29
LTO	1.78	0.56
LGOV	1.76	0.57
LURB	1.79	0.56
Mean VIF	2.16	

Source: Authors' computation