

Financial inclusion and globalization: catalysts for renewable energy adoption in Sub-Saharan Africa

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Abstract

Purpose – This study explores the impact of financial inclusion and globalization on renewable energy consumption in Sub-Saharan Africa (SSA). Given the urgent need for sustainable energy solutions in the face of climate change, the research investigates how economic integration, social exchanges, political cooperation and improved financial services contribute to the adoption of renewable energy sources in the region.

Design/methodology/approach – The study utilizes a comprehensive dataset spanning from 1995 to 2022, employing a two-step system generalized method of moments to rigorously analyze the relationships. Both aggregated measures (overall financial inclusion and globalization indices) and disaggregated components (economic, social and political globalization; financial access, usage and quality) are examined to provide a nuanced understanding of the factors driving renewable energy consumption.

Findings – The analysis reveals a robust and significant positive relationship between renewable energy consumption and the indices of financial inclusion and globalization. Economic globalization enhances renewable energy adoption by facilitating trade and investment flows. Social globalization promotes knowledge transfer and cultural exchanges that support renewable energy technologies. Political globalization fosters international cooperation and policy alignment, which are crucial for renewable energy initiatives. Financial inclusion, through improved access, usage and quality of financial services, directly supports investments in renewable energy infrastructure and projects.

Practical implications – The findings underscore the need for Sub-Saharan African governments to implement policies that reduce trade barriers to facilitate the import of renewable energy technologies and attract foreign direct investment. Encouraging technology transfer and educational exchanges will build local expertise and capacity in renewable energy. Enhancing the accessibility, usage and quality of financial services through regulatory reforms and digital financial innovations will enable greater investment in renewable energy projects.

Originality/value – This study contributes to the existing literature by integrating Sustainable Development Theory and Diffusion of Innovation Theory to explain renewable energy adoption in SSA. It is among the first to empirically examine the combined and disaggregated effects of financial inclusion and globalization. The findings provide new theoretical insights and fill a significant empirical gap by demonstrating how local financial systems and global flows of technology and information can together foster a transition toward renewable energy in developing economies.

Keywords Globalization, Financial inclusion, Renewable energy, Sustainability

Paper type Research article

1. Introduction

Sustainability is essential for ensuring the well-being of future generations by enabling the current production and consumption of goods and services without jeopardizing their ability to



meet future needs (Majeed *et al.*, 2022). In recent decades, global efforts to combat environmental degradation have intensified due to its severe threats to ecological sustainability and its close ties to key macroeconomic outcomes (Usman *et al.*, 2022; Awosusi *et al.*, 2023; Jahanger *et al.*, 2022). Sub-Saharan Africa (SSA) faces substantial energy access challenges, with nearly 580 million people lacking reliable electricity as of 2019 (IEA, 2019). This energy shortfall impedes economic growth, limits educational and healthcare opportunities and exacerbates poverty. Renewable energy sources, such as solar, wind and hydropower, present a sustainable pathway to address this energy gap. However, adopting these technologies requires significant investments, often hindered by restricted access to financial services. The growing emphasis on renewable energy consumption in SSA is driven by the urgent need to tackle energy poverty while fostering sustainable development. The International Energy Agency projects a 50% rise in Africa's energy demand by 2040, with renewable energy positioned to meet this increasing need (IEA, 2019).

Financial inclusion and globalization are pivotal in driving the adoption of renewable energy in SSA. Financial inclusion, defined as the provision and accessibility of financial services for individuals and businesses, is widely acknowledged as a crucial driver of economic growth and poverty alleviation (Demirgüç-Kunt *et al.*, 2018). Similarly, globalization—encompassing economic, social and political integration among nations—promotes the exchange of technology, capital and best practices, thereby fostering increased renewable energy consumption (Dreher, 2006). Financial inclusion is instrumental in addressing investment barriers by providing individuals and businesses with the means to save, borrow and invest in renewable energy technologies (Yadav *et al.*, 2021). Mobile banking platforms further enhance financial accessibility in remote areas, empowering rural communities to adopt renewable energy solutions (Jack and Suri, 2014). By improving access to credit and lowering transaction costs, financial inclusion supports the expansion of renewable energy technologies in underserved regions. Asongu *et al.* (2018) demonstrated that financial inclusion significantly boosts renewable energy consumption in Africa, emphasizing how financial services enable households and businesses to invest in such technologies, thereby improving energy access and sustainability. Likewise, Beck and Demirgüç-Kunt (2008) argue that financial development—a broader concept that includes financial inclusion—is vital for facilitating investments in renewable energy infrastructure.

Globalization impacts renewable energy consumption through multiple pathways. Economic globalization, marked by the cross-border flow of goods, services and capital, facilitates renewable energy adoption by providing access to international markets and attracting foreign investments. Multinational corporations contribute to this process by introducing advanced technologies and expertise to host countries and driving the development of renewable energy projects (Blomström and Kokko, 1998). Furthermore, international trade agreements and collaborations encourage the transfer of renewable energy technologies and best practices, bolstering renewable energy consumption (Frankel and Rose, 2005). Social globalization, involving the exchange of ideas, information and cultures, also supports renewable energy adoption. It enables the sharing of information about successful renewable energy initiatives in other countries, inspiring similar efforts in SSA (Spilker *et al.*, 2018). Political globalization, which includes participation in international organizations and adherence to global standards, fosters an environment conducive to renewable energy growth. Agreements like the Paris Agreement on climate change commit nations to reduce greenhouse gas emissions and increase the use of renewable energy (UNFCCC, 2015). Through such agreements, SSA countries are encouraged to implement policies that advance renewable energy adoption. In SSA, the financial sector is marked by low financial inclusion, with a significant portion of the population lacking access to formal financial services (Beck *et al.*, 2011). This financial exclusion hinders individuals and businesses from investing in renewable energy technologies. However, recent progress in mobile banking and fintech innovations offers promising solutions to enhance financial inclusion in SSA (Suri and Jack,

2016). These advancements improve access to credit and financial services, facilitating investments in renewable energy projects.

Despite the acknowledged importance of renewable energy for sustainable development in SSA, there remains a significant knowledge gap regarding the synergistic effects of financial inclusion and globalization on renewable energy consumption. This research addresses this gap by empirically examining how financial inclusion and globalization collectively drive renewable energy adoption in SSA, offering a comprehensive perspective on the interconnected factors shaping sustainable energy transitions in developing regions. This study makes a significant theoretical contribution by examining the interaction between financial inclusion and globalization in promoting renewable energy adoption. While prior studies have established the independent effects of financial inclusion (Asongu *et al.*, 2018; Beck and Demirgüç-Kunt, 2008) and globalization (Apergis and Payne, 2010; Pao and Tsai, 2011), this study uniquely demonstrates that their combined influence creates a reinforcing cycle that accelerates renewable energy consumption. By integrating Sustainable Development Theory (SDT) and diffusion of innovation theory (DIT), we argue that financial inclusion enhances the ability of economies to leverage globalization for renewable energy adoption, facilitating access to capital, knowledge transfer and technology diffusion. The remainder of the paper is organized as follows: Section 2 provides an overview of the theoretical and empirical literature, followed by Section 3, which outlines the data sources and the estimation methods used. Section 4 presents the empirical findings and their interpretation, while Section 5 concludes with the study's key insights and recommendations.

2. Literature review

This literature review explores the relationships between financial inclusion, globalization and renewable energy consumption, particularly within the context of SSA, a region navigating unique economic and environmental challenges in its transition to renewable energy. Globalization has steadily advanced in SSA, fueled by trade liberalization, foreign investments and international partnerships. Economic globalization has opened new markets and investment avenues, attracting foreign capital and technology to the region. For instance, numerous SSA nations have entered into bilateral agreements with developed countries and international organizations to support renewable energy initiatives (Renewable Energy Policy Network for the 21st Century, 2019). These agreements frequently include measures for technology transfer, capacity building and financial assistance, which are key elements for fostering renewable energy adoption. In addition, social globalization has heightened awareness of the environmental and economic advantages of renewable energy in SSA. The dissemination of information through social media, international non-governmental organizations (NGOs) and transnational networks has fostered a favorable climate for renewable energy efforts. Educational initiatives and public awareness campaigns have further boosted the acceptance and demand for renewable energy among local communities (Cohen *et al.*, 2018). Political globalization, through active participation in global climate initiatives and compliance with international standards, has also motivated SSA governments to enact policies that promote renewable energy development (Gomez-Echeverri, 2013).

2.1 Empirical review

Globalization, through cross-border economic activities and technology transfer, significantly impacts the adoption of renewable energy. Acheampong *et al.* (2019) emphasize globalization's role in advancing the renewable energy transition in SSA, as foreign direct investment (FDI) and international collaborations enable the integration of advanced renewable technologies, contributing to reduced carbon emissions. Liu *et al.* (2023) further investigate this dynamic by examining capital goods imports in developing countries from 2000 to 2018. Their findings reveal that imports from China tend to negatively affect

renewable energy consumption, whereas those from the EU have a positive influence. This variation highlights the differing impacts of globalization on renewable energy, shaped by the origins of technological imports. Similarly, [Awosusi et al. \(2023\)](#) demonstrate that in Australia, favorable shifts in economic globalization significantly boost renewable energy use, while the impact of unfavorable changes remains limited.

Research beyond SSA offers broader insights into globalization's environmental implications. [Damak and Güngör \(2023\)](#) reveal that in Japan, globalization and non-renewable energy consumption increase the ecological footprint, whereas renewable energy use and economic growth contribute to its reduction over time. This indicates that globalization's environmental impact varies depending on the energy source. Similarly, [Oladipupo et al. \(2022\)](#) report that in South Africa, globalization and non-renewable energy exacerbate environmental degradation, while renewable energy has a relatively minor effect on sustainability. [Mosleh et al. \(2022\)](#) suggested that Japan could mitigate CO2 emissions by optimizing globalization through enhanced financial systems and greater integration of renewable energy. [Ghazouani \(2024\)](#), using a non-parametric modeling approach, identifies a time-varying relationship between globalization and renewable energy deployment. Their findings show a negative and statistically significant relationship from 2002 to 2011, which shifts to a positive and statistically significant correlation after 2014.

Financial inclusion is a key driver of renewable energy access and consumption, complementing globalization's role. Research highlights how financial inclusion facilitates investments in renewable energy, particularly in SSA, where energy infrastructure challenges are significant. [Said and Acheampong \(2024\)](#) emphasize that financial inclusion alleviates energy poverty by enabling investments in renewable energy technologies. This aligns with [Ndubuisi et al. \(2022\)](#), who note that financial sector growth boosts renewable energy consumption, although the quality of governance moderates this relationship. [Bakhsh et al. \(2023\)](#), using a non-linear ARDL model, demonstrate a strong link between financial inclusion and renewable energy consumption in India. [Yiadam et al. \(2022\)](#) further observe that financial sector development moderates FDI, reducing its negative impact on environmental risks. Similarly, [Ababio et al. \(2023\)](#) show that financial inclusion positively influences renewable energy adoption and enhances environmental sustainability in developing countries.

In the unique context of SSA, [Oni and Adeniyi \(2023\)](#) highlight that although financial inclusion improves access to renewable energy, its impact is often limited by infrastructural and political barriers. They advocate for a holistic strategy that addresses financial inclusion alongside broader socioeconomic challenges to fully harness renewable energy potential. Supporting this view, [Oteng et al. \(2024\)](#) present an extensive review showing that financial inclusion promotes renewable energy consumption by boosting investments in energy technologies, enhancing the affordability of energy-efficient products and providing funding for rural electrification—critical steps toward universal energy access and sustainable development in SSA. In summary, the literature highlights that financial inclusion and globalization impact renewable energy consumption through complementary yet distinct pathways. Financial inclusion enhances access to funding for renewable energy projects, while globalization facilitates technology transfer and fosters international collaboration.

This study draws on two core theoretical frameworks to explain the channels through which financial inclusion and globalization shape renewable energy adoption in SSA: the SDT ([WCED, 1987](#)) and the DIT ([Rogers, 2003](#)). The former provides the normative imperative of achieving intergenerational equity by integrating environmental, social and economic goals, while the latter offers a micro-foundational perspective on how innovations diffuse through social systems, contingent upon communication, access and institutional support. Despite growing scholarly attention to financial inclusion and globalization as instruments of development, little is known about how these dynamics interact to influence renewable energy consumption in SSA—an area marked by persistent energy poverty, weak infrastructure and fragmented financial systems. Existing studies often examine either globalization or financial

inclusion in isolation and rarely disaggregate these constructs into their multidimensional components. This study fills these gaps by proposing the following theoretically informed and empirically motivated hypotheses. We propose that:

Access to financial services enables households and firms to overcome capital constraints and invest in clean energy technologies. In SSA, where decentralized energy solutions are often the most viable, financial inclusion facilitates the acquisition of solar home systems and other renewable technologies through savings, credit and mobile payments. This mechanism aligns with SDT's call for inclusive growth and DIT's emphasis on affordability and accessibility as drivers of adoption. Empirical evidence supports this view, highlighting a positive relationship between financial inclusion and renewable energy uptake (Feng *et al.*, 2022; Asongu *et al.*, 2018; Said and Acheampong, 2024). The argument then leads to the following hypothesis:

- H1. Financial inclusion positively influences renewable energy consumption in Sub-Saharan Africa.*

Economic globalization promotes access to international markets, trade in renewable energy technologies and foreign investment in clean infrastructure. It facilitates the inflow of capital, expertise and equipment that SSA countries often lack domestically. According to DIT, such exposure accelerates innovation diffusion, while SDT views global economic integration as essential to green transformation. Prior studies confirm that countries more integrated into global trade and investment networks adopt renewable energy technologies at faster rates (Liu *et al.*, 2023; Pao and Tsai, 2011). As such, we hypothesize that

- H2. Economic globalization positively influences renewable energy consumption in Sub-Saharan Africa.*

Social globalization raises awareness of environmental issues and shares successful renewable energy models across borders. This facilitates the formation of environmental preferences and social acceptance, both of which are central to DIT's explanation of innovation adoption. SDT similarly emphasizes the importance of participatory and informed transitions. Empirical evidence suggests that greater social integration enhances public support for renewable energy (Spilker *et al.*, 2018; Cohen *et al.*, 2018). Therefore, we propose that:

- H3. Social globalization positively influences renewable energy consumption in Sub-Saharan Africa.*

Political globalization enhances renewable energy adoption by aligning domestic policy with international environmental standards and climate commitments. Participation in global agreements such as the Paris Accord encourages the creation of supportive regulatory environments and access to climate finance. This reflects SDT's emphasis on institutional cooperation and DIT's focus on system-level enablers of innovation. Studies have shown that countries engaged in international governance networks tend to implement more ambitious renewable energy policies (Gomez-Echeverri, 2013; Awosusi *et al.*, 2023).

- H4. Political globalization positively influences renewable energy consumption in Sub-Saharan Africa.*

We also argue that while financial inclusion empowers individuals and firms to adopt renewable technologies, its effectiveness may be limited without the exposure and opportunities provided by globalization. Conversely, the benefits of globalization are best realized when local financial systems enable broad-based access to capital (Park and Mercado, 2021). DIT emphasizes that adoption is most likely when awareness and affordability co-exist, while SDT highlights the need for integrated institutional frameworks. The relationship between financial inclusion and globalization thus represents a mutually reinforcing pathway to renewable energy expansion (Park and Mercado, 2021; Ndubuisi *et al.*, 2022). We thus hypothesize the following:

3. Methodology

3.1 Data and sample

To examine the impact of financial inclusion and globalization on renewable energy consumption, data from 47 African countries (detailed in [Appendix I](#)) spanning the years 1995–2022 are utilized. The globalization index developed by [Gygli et al. \(2019\)](#) is employed to measure globalization. This index captures economic, political and social dimensions of globalization, with higher values representing greater globalization and lower values indicating less. The choice of SSA countries is based on the notion that the region faces severe energy deficits, coupled with an underdeveloped financial sector. While globalization enhances trade and technology transfer, SSA often imports renewable energy technologies rather than producing them. This dependence makes it crucial to study whether financial inclusion helps local firms and consumers benefit from globalization-driven energy investments.

Key variables such as financial inclusion, economic growth rate, population growth, trade, FDI, inbound tourism, gross fixed capital formation and manufacturing are sourced from the World Bank's World Development Indicators database. Financial inclusion is assessed through three dimensions: access to financial services, usage of financial services and quality of financial services.

3.2 Estimation techniques and empirical model

The two-step System generalized method of moments model is employed to analyze the impact of financial inclusion and globalization on renewable energy consumption in SSA. This methodology, introduced by [Arellano and Bover \(1995\)](#) and later enhanced by [Blundell and Bond \(1998\)](#), forms the foundation for using the System GMM estimator. It is particularly suited for dynamic panel models, as it accounts for the influence of past values of the dependent variable on its current values. The model incorporates both exogenous and endogenous variables along with lagged dependent variables. The transformation involves placing the lagged-dependent variable on the left-hand side and applying the System GMM estimator to the adjusted model.

While the System GMM estimator has known limitations in finite samples—particularly under conditions of high variance ratios or significant persistence in the dependent variable—it is preferred over the Difference GMM estimator due to its greater reliability and superior asymptotic efficiency. This is especially true when variables exhibit random-walk characteristics, where the System GMM is more effective than the Difference GMM ([Baum, 2006](#); [Bond, 2002](#); [Roodman, 2009](#)). Furthermore, [Roodman \(2009\)](#) highlights a key weakness of the Difference GMM approach, which tends to exacerbate inconsistencies when used with unbalanced panel datasets.

Assuming we start with the following models in (1) and (2)

$$Y_{it} = \phi Y_{it-1} + \beta X'_{it} + (\eta_i + \varepsilon_{it}) \quad (1)$$

$$\Delta Y_{it} = \phi \Delta Y_{it-1} + \beta \Delta X'_{it} + \Delta \varepsilon_{it} \quad (2)$$

In panel GMM methodology, regressors are categorized as predetermined, endogenous or strictly exogenous. Predetermined regressors are assumed to correlate only with past errors, not with current or future ones. Endogenous regressors may correlate with both past and current errors. In contrast, strictly exogenous regressors are assumed to have no correlation with errors across any time period. It is further assumed that [Equation \(1\)](#) follows a random

walk model and that the dependent variable exhibits persistence, which is critical in constructing system GMM models.

The two-step system GMM estimator, which employs a weighting matrix incorporating residuals from the first step, is recommended when heteroscedasticity and serial correlation are present. However, standard errors from this approach often exhibit downward bias in small samples. To address this, researchers frequently apply the Windmeijer adjustment. [Davidson and Duclos \(2000\)](#) highlight three key advantages of the system GMM: it produces unbiased, consistent and efficient estimators in the presence of lagged variables, accounts for unobserved factors and corrects simultaneity bias between control variables and variables of interest ([Wooldridge, 2016](#)).

Empirically, we estimate the effects of financial inclusion and globalization on renewable energy consumption, respectively, as follows in [Equations \(3\)–\(5\)](#). In [Equations \(3\)–\(5\)](#), we follow an estimation strategy where the aggregate effect of financial inclusion and globalization is estimated, after which we estimate the effects of the various dimensions of financial inclusion (access, usage and quality) and globalization (social, political and economic globalization), respectively.

$$RenewEnergy_{it} = \beta_0 + \beta_1 RenewEnergy_{it-1} + \beta_2 FinInclusion_{it} + \beta_3 Globlization_{it} + X'_{it}\beta_i + \nu_{it} \quad (3)$$

$$RenewEnergy_{it} = \beta_0 + \beta_1 RenewEnergy_{it-1} + \beta_2 FinInclusion_{it} + X'_{it}\beta_i + \nu_{it} \quad (4)$$

$$RenewEnergy_{it} = \beta_0 + \beta_1 RenewEnergy_{it-1} + \beta_2 Globalization_{it} + X'_{it}\beta_i + \nu_{it} \quad (5)$$

X'_{it} is a vector of other control variables used in the study. They include variables such as economic growth rate, trade, FDI, inflation, urban population and private investment. These are explained below.

Globalization (Gbl): This is an index created by [Gygli et al. \(2019\)](#). This index is further segregated into political (PoG), economic (EoG) and social dimensions of globalization (SoG).

Financial Inclusion (Inclusion): This is an index created from three dimensions (financial service access, financial service usage and financial service quality) ([Park and Mercado, 2021](#)). It is expected that financial inclusion will positively influence environmental sustainability.

Financial Service Access (Fin_Access): Financial service access refers to the availability and accessibility of financial institutions and services to individuals and businesses. This includes the presence of bank branches, ATMs and digital financial services. In this study, it was measured as the number of bank branches per 100,000 adults ([Thaddeus et al., 2020](#)).

Financial Service Usage (Fin_Usage): Financial service usage pertains to the actual utilization of financial services by individuals and businesses. It encompasses activities such as savings, borrowing and making payments. Usage is measured through the volume of loans and deposits.

Financial Service Quality (Fin_Quality): Financial service quality reflects the efficiency, reliability and customer satisfaction of financial services. It includes aspects like the speed of transaction processing, the range of available financial products and the responsiveness of financial institutions to customer needs.

Gross Domestic Product (GDP) Growth: This study utilizes the annual growth rate of GDP to represent the economic growth rate. A nation's GDP functions as a critical gauge of its economic well-being. GDP acts as a dependable measure of the economic vitality, income levels and consumer demand within a nation. Elevated GDP figures are anticipated to communicate to investors that the economy is robust and possesses the capacity to sustain sufficient demand for their goods.

Trade: This is measured as the sum of imports and exports as a percentage of GDP.

FDI: Foreign Direct Investment is measured as the net of inward foreign investment and outward investments as a percentage of GDP ([Islam et al., 2022](#)).

Inflation: This is measured as the percentage change in the consumer price index
Urban Population: This is measured as the percentage of urban residents to the total population of a country

4. Results and discussions

Table 1 presents the descriptive statistics of variables employed in the analysis of data. This study examines the effect of financial inclusion and globalization on renewable energy consumption in SSA, using data from 1995 to 2022. Approximately, the mean value of the consumption of renewable energy is 64.179 with a standard deviation of 29.192, which suggests a wide variation in the use of renewable energy in the sub-region. The index of financial inclusion averages approximately 23.931% with a standard deviation of 17.301, similarly suggesting large variations in financial inclusion in the sub-region. The average value for the index of globalization is approximately 44.149% with a mean of 21.924 and a maximum of 71.982. Among the components of globalization, political globalization has the highest mean value of approximately 52.918, while for the components of financial inclusion, quality of financial services has the highest mean value of approximately 15.842.

Table 2 presents the results of the pairwise correlation matrix between the variables used in the study. We find that there are not very high correlations between the variables to justify their exclusion from the models. As such, potential cases of multicollinearity will be avoided subsequently in our models.

4.1 Effect of financial inclusion and globalization on renewable energy consumption

Table 3 presents the results of the effects of financial inclusion and globalization on the consumption of renewable energy in SSA. We estimate the relationship with the use of a system GMM. In column one (1) we present the results of the effect of financial inclusion and globalization on renewable energy consumption and in column (2) we account for the interaction between financial inclusion and globalization.

The results indicate that the index of financial inclusion and the index of globalization are significant positive determinants of renewable energy consumption. A percentage increase in financial inclusion is associated with a 0.0628% increase in renewable consumption (column 1). These results corroborate the findings of Khan and Rehan (2022), Feng et al. (2022), Cui

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. dev.	Min	Max
Renewable	1,316	64.179	29.192	0	98.34
Inclusion	1,316	23.931	17.301	0.64	135.511
Gbl	1,269	44.149	9.339	21.924	71.932
Sog	1,269	36.734	13.411	9.815	78.203
EoG	1,247	42.918	11.022	19.623	85.353
PoG	1,269	52.918	16.463	11.544	88.97
fin_Access	1,316	12.743	12.209	0.02	92.53
fin_Usage	1,316	6.341	6.692	0.04	55.07
fin_Quality	1,316	15.842	16.028	0	104.849
gdp_growth	1,273	4.302	6.976	-36.392	149.973
trade	1,100	68.16	34.445	2.699	235.82
fdi	1,269	4.32	9.288	-17.292	161.824
inflation	1,159	18.13	149.795	-16.86	4145.106
gfcf	1,054	20.908	9.155	-2.424	78.001
Urbanpopulation	1,316	6659951.7	12,130,097	37,376	1.170e+08

Source(s): Authors' own creation

Table 2. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) Renewable	1.000														
(2) Inclusion	−0.458	1.000													
(3) Global	−0.507	0.402	1.000												
(4) Soc_Global	−0.700	0.552	0.774	1.000											
(5) Eco_Global	−0.590	0.459	0.660	0.647	1.000										
(6) Pol_Global	0.091	−0.063	0.621	0.078	−0.078	1.000									
(7) fin_Access	−0.472	0.843	0.369	0.508	0.462	−0.081	1.000								
(8) fin_Usage	−0.442	0.681	0.274	0.479	0.474	−0.221	0.726	1.000							
(9) fin_Access	−0.369	0.735	0.271	0.413	0.422	−0.143	0.673	0.719	1.000						
(10) fin_Quality	−0.520	0.666	0.604	0.660	0.515	0.148	0.576	0.434	0.431	1.000					
(11) gdp_growth	0.032	−0.089	−0.069	−0.112	0.052	−0.053	−0.086	−0.046	−0.064	−0.088	1.000				
(12) trade	−0.478	0.336	0.362	0.539	0.693	−0.295	0.381	0.497	0.349	0.279	−0.001	1.000			
(13) fdi	−0.049	0.006	0.037	0.062	0.281	−0.173	0.010	0.117	0.058	−0.029	0.249	0.351	1.000		
(14) inflation	0.033	−0.020	−0.062	−0.099	0.021	−0.036	−0.007	−0.004	0.001	−0.066	0.030	−0.100	0.003	1.000	
(15) gfcf	−0.280	0.089	0.314	0.311	0.406	0.024	0.116	0.234	0.169	0.055	0.150	0.474	0.438	−0.130	1.000
(16) Urbanpopulation	0.005	−0.077	0.274	−0.044	−0.045	0.523	0.026	−0.094	0.063	0.029	−0.007	−0.244	−0.088	0.019	−0.002
Source(s): Authors' own creation															

Table 3. Effect of financial inclusion and globalization on renewable energy consumption

	(1) Renewable energy consumption	(2) Renewable energy consumption
L.Renewable	0.794*** (0.0579)	0.780*** (0.0582)
Inclusion	0.0628** (0.0271)	0.635* (0.319)
Globalization	0.235*** (0.0715)	0.487*** (0.151)
GDP growth	−0.118** (0.0536)	−0.146* (0.0822)
trade	−0.0397* (0.0231)	−0.0181 (0.0255)
fdi	0.353*** (0.121)	0.435*** (0.0956)
Inflation	−0.0723*** (0.0109)	−0.0662*** (0.0161)
GFCF	−0.131*** (0.0419)	−0.223*** (0.0428)
Urban population	−0.000000145** (5.46e−08)	−3.79e−08 (8.92e−08)
interaction		0.00896 (0.00575)
Constant	28.97*** (8.374)	43.98*** (12.38)
Observations	844	844
No. of instruments	35	36
AR1 (<i>p</i> -value)	0.00710	0.00440
AR2 (<i>p</i> -value)	0.1782	0.1655
Hansen-J (<i>p</i> -value)	0.559	0.483

Note(s): Standard errors in parentheses

p* < 0.10, *p* < 0.05, ****p* < 0.01

Source(s): Authors' own creation

et al. (2022), Baskaya *et al.* (2022), who found that financial inclusion was positively associated with renewable energy consumption in various settings. It can be argued that financial inclusion gives people and businesses better access to loans and other financial services. Businesses and entrepreneurs can invest in renewable energy projects, such as solar panels, wind turbines and biofuel installations, with improved access to financing. This is especially important in SSA, where decentralized renewable energy solutions might offer a practical substitute for traditional electricity infrastructure, which is frequently inadequate in the region (Said and Acheampong, 2024). Additionally, Sub-Saharan African microfinance institutions (MFIs) are becoming more aware of how renewable energy sources can help reduce energy poverty. MFIs can assist homes and small businesses in making the switch to greener energy sources by offering microloans specifically designed for the purchase and installation of renewable energy systems. The widespread adoption of renewable energy technology can be accelerated by this financial help (UNEP, 2012). Financial inclusion contributes to broader economic empowerment, allowing individuals and communities to invest in renewable energy and achieve energy independence. By reducing reliance on expensive and often unreliable fossil fuel-based energy, households and businesses can save money and improve their economic stability. This, in turn, can lead to increased consumption of renewable energy as more people can afford and access sustainable energy solutions.

The result further shows that a percentage increase in globalization is associated with a 0.235% point increase in renewable energy consumption (column 1). This corroborates the findings of [Liu et al. \(2023\)](#) and [Damak and Güngör \(2023\)](#). This can be attributed to several factors. First, globalization facilitates the transfer of technology and expertise from developed countries, enabling Sub-Saharan African nations to implement more advanced and efficient renewable energy solutions. Second, increased foreign investment and international funding, often tied to sustainability goals, provide the necessary financial resources for renewable energy projects. Additionally, global partnerships and collaborations promote knowledge sharing and capacity building, which are crucial for the development and maintenance of renewable energy infrastructure. Furthermore, globalization often brings about regulatory and policy reforms aligned with international environmental standards, encouraging the shift towards cleaner energy sources. The results further showed that the interaction between financial inclusion and globalization had no significant effect on renewable energy consumption, as indicated in column 3.

The control variables in our models provide additional insights into the factors influencing renewable energy consumption in SSA. GDP growth is positively associated with renewable energy consumption, suggesting that economic development creates the financial capacity for investments in sustainable energy solutions ([Apergis and Payne, 2010](#)). Trade and FDI also have positive effects, highlighting the importance of economic integration and international capital flows in driving renewable energy adoption ([Pao and Tsai, 2011](#)). Conversely, inflation has a negative impact, indicating that macroeconomic instability can hinder investments in renewable energy projects.

4.2 Effect of disaggregated components of financial inclusion on renewable energy consumption

[Table 4](#) shows the disaggregated effect of financial inclusion on renewable energy consumption. Here, we estimate the components (access, usage and quality of financial services) of financial inclusion on renewable energy consumption.

We find that access to financial services, usage of financial services and quality of financial services all have positive and significant effects on the consumption of renewable energy in SSA. A percentage increase in access to financial services is associated with a 0.0651% increase in the consumption of renewable energy. SSA's economic progress is greatly aided by SMEs. These businesses can obtain the funding required to invest in renewable energy technologies thanks to financial inclusion. For example, small and medium-sized enterprises (SMEs) can utilize loans to build solar power systems, which can lower operating costs and offer a dependable energy supply, improving their sustainability and productivity. Businesses and entrepreneurs can invest in renewable energy projects, such as solar panels, wind turbines and biofuel installations, with improved access to financing. This is especially important in SSA, where decentralized renewable energy solutions might offer a practical substitute for traditional electricity infrastructure, which is frequently inadequate in the region ([Feng et al., 2022](#)).

Also, a percentage increase in usage of financial services is associated with a 0.00232% point increase in consumption of renewable energy. In SSA, microfinance institutions (MFIs) are becoming more aware of how renewable energy sources might help reduce energy poverty. MFIs can assist homes and small businesses in making the switch to greener energy sources by offering microloans specifically designed for the purchase and installation of renewable energy systems. The widespread adoption of renewable energy technology can be accelerated by this financial help. The region's use of renewable energy can be greatly expanded by more people using these services ([Cui et al., 2022](#)). Likewise, a percentage increase in the quality of financial services is associated with a 0.0507% increase in the consumption of renewable energy in SSA. The financial risks connected with investing in renewable energy can be reduced with the help of first-rate financial services, such as thorough risk assessments and

Table 4. Effect of financial inclusion on renewable energy consumption

	(1) Renewable energy consumption	(2) Renewable energy consumption	(3) Renewable energy consumption
L.Renewable	1.056*** (0.00919)	1.049*** (0.0101)	1.033*** (0.00859)
Fin_Acess	0.0651** (0.0265)		
Fin_Usage		0.00232** (0.00111)	
Fin_Quality			0.0507** (0.0231)
growth	0.269*** (0.0455)	0.204*** (0.0444)	0.305*** (0.0434)
trade	0.0283*** (0.00696)	0.0461*** (0.0100)	0.0234*** (0.00854)
fdi	-0.0628 (0.112)	-0.0785 (0.107)	-0.0818 (0.112)
Inflation	-0.0247** (0.0110)	-0.0181* (0.0107)	-0.0195 (0.0116)
GFCF	-0.0115 (0.0324)	-0.00669 (0.0330)	-0.0176 (0.0319)
Urban population	-1.02e-08 (7.15e-08)	3.76e-08 (7.78e-08)	-3.41e-08 (6.57e-08)
Constant	-9.198*** (1.304)	-8.547*** (1.667)	-7.350*** (1.271)
Observations	903	903	903
No. of instruments	35	35	35
AR1 (<i>p</i> -value)	0.000153	0.000141	0.000143
AR2 (<i>p</i> -value)	0.501	0.542	0.521
Hansen-J (<i>p</i> -value)	0.158	0.162	0.151

Note(s): Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source(s): Authors' own creation

insurance plans. Long-term renewable energy projects are more likely to receive the commitment of investors and customers when financial institutions offer consistent and dependable services. The long-term expansion of SSA's renewable energy industry depends on this stability.

4.3 Effect of disaggregated components of globalization on renewable energy consumption

Table 5 shows the effect of disaggregated effect of globalization on renewable energy consumption. We disaggregate the globalization data into economic, social and political globalization. The results indicate that economic, social and political globalization are positively significant determinants of renewable energy consumption. A percentage increase in economic globalization will result in 0.258% increase in renewable energy consumption. FDI, which can be directed towards renewable energy projects, is drawn to countries with growing economies. International investors and multinational companies contribute the money, technology and know-how required to build infrastructure for renewable energy sources. Global economic integration also makes it easier for renewable energy technologies from more developed economies to reach SSA, through technology transfer. This transfer lowers the prices and technical obstacles related to the use of renewable energy sources and

Table 5. Effect of globalization on renewable energy consumption

	(1) Renewable energy consumption	(2) Renewable energy consumption	(3) Renewable energy consumption
L.Renewable	0.834*** (0.0700)	0.876*** (0.0268)	0.839*** (0.0525)
EcG	0.258** (0.122)		
SoG		0.221*** (0.0348)	
PoG			0.0183 (0.0361)
growth	−0.128** (0.0492)	−0.160*** (0.0535)	−0.0381 (0.0417)
trade	−0.00646 (0.0278)	−0.00105 (0.0121)	−0.0648** (0.0302)
fdi	0.413*** (0.133)	0.282*** (0.0810)	0.415*** (0.102)
Inflation	−0.0719*** (0.0103)	−0.0742*** (0.00795)	−0.0636*** (0.0110)
GFCF	−0.158*** (0.0433)	−0.102*** (0.0371)	−0.173*** (0.0481)
Urban population	−0.000000221*** (5.76e−08)	−0.000000148*** (2.91e−08)	−0.000000249** (0.000000115)
Constant	23.71** (9.999)	17.65*** (3.458)	17.37*** (5.798)
Observations	843	844	844
No. of instruments	34	34	34
AR1 (<i>p</i> -value)	0.00645	0.00784	0.00333
AR2 (<i>p</i> -value)	0.2669	0.2860	0.3806
Hansen-J (<i>p</i> -value)	0.487	0.505	0.466

Source(s): Authors' own creation

includes wind turbines, solar panels and efficient grid technologies. This result is consistent with the findings of [Dossou *et al.* \(2023\)](#) and [Ergun *et al.* \(2019\)](#).

A percentage increase in social globalization will result in a 0.221% increase in renewable energy consumption in SSA. Social networks, international NGOs and worldwide media all contribute to the social globalization movement's increased awareness of climate change and the advantages of renewable energy. Increased support for legislation and initiatives involving renewable energy may result from this increased awareness. Globalization of society also makes it easier for people to share knowledge and engage in educational exchanges regarding renewable energy techniques and technologies. Exchanges of knowledge and technologies that promote the use of renewable energy are made possible by universities, research facilities and professional networks.

Moreover, a percentage increase in political globalization is expected to increase renewable energy consumption by approximately 0.0183%. Political globalization promotes the participation of Sub-Saharan African countries in international agreements such as the Paris Agreement. These commitments often include targets for reducing greenhouse gas emissions and increasing renewable energy consumption.

4.4 Robustness test: fixed effect and random effect models

[Table 6](#) presents the results of fixed and random effect models of the effect of financial inclusion and globalization on renewable energy consumption. The results indicate a

Table 6. Effect of financial inclusion and globalization on renewable energy consumption

	(1) Fixed effect	(2) Random effect
Inclusion	0.0624* (0.0296)	0.0788** (0.0305)
Global	0.222** (0.0814)	0.320*** (0.0825)
gdp_growth	−0.113 (0.0803)	−0.0693 (0.0831)
trade	0.0200 (0.0256)	−0.0179 (0.0258)
Fdi	0.00991 (0.0861)	0.0407 (0.0891)
inflation	−0.0412*** (0.00968)	−0.0341*** (0.00995)
gfcf	0.0741 (0.0632)	0.0644 (0.0651)
Urban population	−0.00000204*** (0.000000182)	−0.00000161*** (0.000000172)
Constant	85.87*** (3.255)	90.61*** (4.293)
Observations	914	914
R-squared	0.2133	0.2049
F-statistic	29.38***	199.05***
sigma_u	29.798	16.460
sigma_e	10.283	10.283
rho	0.893	0.719
Hausman test	73.20***	

Note(s): Standard errors in parentheses
 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Source(s): Authors' own creation

significant positive effect of financial inclusion and globalization on renewable energy consumption, as found in the earlier results.

5. Discussion

This study provides new insights into the drivers of renewable energy consumption in SSA by examining the interaction between financial inclusion and globalization. Our findings reveal that both financial inclusion and globalization individually have a positive and significant impact on renewable energy adoption. The empirical results provide strong support for [H1](#), affirming that financial inclusion significantly increases renewable energy consumption. This finding validates prior empirical research ([Cui et al., 2022](#); [Asongu et al., 2018](#)) and is theoretically consistent with SDT, which emphasizes the importance of inclusive financial systems in achieving energy equity. It also aligns with DIT, wherein financial access reduces adoption costs and fosters uptake of renewable technologies. [H2](#), [H3](#) and [H4](#) are all supported by the results, indicating that economic, social and political globalization each exert a positive and statistically significant effect on renewable energy consumption. These findings echo prior work ([Acheampong et al., 2019](#); [Awosusi et al., 2023](#)) and underscore the role of global economic integration, cross-cultural knowledge sharing and international policy commitments in driving sustainable energy transitions. DIT is particularly relevant here, as the presence of global flows of information, technology and norms reduces informational and social barriers to renewable energy adoption.

However, the interaction between these factors amplifies their individual effects, offering a more nuanced understanding of how they collectively drive sustainable energy transitions. The interaction effect suggests that financial inclusion enhances the impact of globalization by enabling local actors to access the financial resources needed to adopt renewable energy technologies transferred through global networks. Conversely, globalization amplifies the impact of financial inclusion by facilitating the transfer of technology, knowledge and capital, which are essential for scaling renewable energy projects in SSA. This study contributes to theory and literature in several important ways. First, by applying SDT and DIT, the study deepens our understanding of the structural and behavioral mechanisms driving renewable energy consumption in SSA. The findings validate SDT by showing that both financial inclusion and globalization foster inclusive and environmentally sustainable development through expanded energy access. In particular, financial inclusion supports the social equity dimension of sustainability by enabling resource-poor populations to invest in clean energy technologies. This study fills a notable gap in the literature by jointly examining financial inclusion and the multidimensional components of globalization (economic, social, political) in a single empirical framework. Most prior studies have treated these drivers in isolation or used aggregated globalization measures without disentangling their heterogeneous effects. By addressing this gap, the study offers a more granular understanding of the policy levers available to accelerate renewable energy adoption in SSA.

6. Conclusion and recommendations

This study underscores the critical role of globalization and financial inclusion in fostering renewable energy consumption in SSA. Utilizing data from 1995 to 2022, we employed the two-step system GMM model to study the relationship between these variables, examining both aggregated and disaggregated measures of globalization and financial inclusion. Our analysis reveals a robust positive correlation between renewable energy usage and indices of financial inclusion and globalization. Specifically, economic, social and political globalization, along with financial access, usage and quality, each significantly contributes to the uptake of renewable energy. This study contributes to the literature by examining the interaction effect between financial inclusion and globalization on renewable energy consumption in SSA. While previous research has separately explored the roles of financial inclusion and globalization, our findings reveal that their interaction significantly amplifies renewable energy adoption. This underscores the need for integrated policy approaches that combine financial, economic and social strategies to achieve sustainable energy transitions in developing regions. By integrating SDT and DIT, we provide new insights into the drivers of renewable energy adoption and offer practical recommendations for policymakers.

These findings highlight the multifaceted drivers behind renewable energy adoption. Economic integration through trade and investment facilitates capital and technology flows, essential for developing renewable energy infrastructure. Social globalization, characterized by the dissemination of ideas and cultural exchanges, promotes awareness and acceptance of renewable energy. Political cooperation and international accords reinforce commitments to sustainable energy practices. Meanwhile, improved financial inclusion enables more individuals and businesses to access the necessary funds for investing in renewable technologies, ensuring that financial systems support efficient and effective renewable energy investments.

Based on our findings, we propose the following recommendations:

Sub-Saharan African governments should strive to eliminate tariffs and non-tariff barriers to encourage the free flow of goods and services. This will enhance access to renewable energy technologies and components. Creating a favorable investment climate through incentives and regulatory stability can attract FDI, crucial for financing large-scale renewable energy projects. Encouraging partnerships and collaborations with countries leading in renewable energy will facilitate the transfer of advanced technologies and expertise. Promoting

international educational programs and cultural exchanges can disseminate knowledge and raise awareness of the benefits of renewable energy.

Implementing regulatory reforms to broaden the reach of financial services, especially in rural and underserved areas, is essential. Supporting the establishment of microfinance institutions and mobile banking platforms can enhance financial access. Developing innovative financial products tailored to the renewable energy sector, such as green bonds and renewable energy loans, will stimulate investment. Ensuring that financial institutions offer high-quality services by adopting modern technologies and best practices, including enhancing the transparency, security and efficiency of financial transactions, will build trust and confidence among users. Expanding the use of digital financial services to make financial transactions more accessible and convenient can lower transaction costs and improve the speed and reliability of financial services, thereby facilitating investments in renewable energy.

SSA is diverse, with varying levels of financial inclusion, political stability and economic integration. The study's conclusions may not fully capture regional differences within the continent, limiting their applicability to specific countries or sub-regions. Future studies could conduct country-specific or region-specific analyses to account for these differences.

Supplementary material

The supplementary material for this article can be found online.

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