Journal of World Economy
ISSN 2709-3999
www.paradigmpress.org/JWE
Volume 5 Number 3 September 2026

The Impact of Climate Resilience and Financial Inclusion Interaction on Poverty in Africa's Most Unbanked Nations

Ayuk Takemeyang[1], Henry Jong Ketuma[1] & Tambi Andison Akpor[2]

[1] ICT University, Messassi, Zoatupsi, Yaounde, Cameroon
[2] Research Scholar, University of Dschang, Cameroon
Correspondence: Ayuk Takemeyang, ICT University, Messassi, Zoatupsi, Yaounde, Cameroon.

doi:10.63593/JWE.2026.09.01

Abstract

Purpose: The purpose of this paper is to investigate the impact of climate resilience and adaptation capacity, financial inclusion, and their interaction on poverty in Africa's most unbanked nations. ***Design/methodology/approach:*** The study makes use of panel regressions such as DOLS and FMOLS. using panel data econometric techniques. Secondary data covering Africa's most unbanked nations from 2004 to 2022 were obtained from the World Bank, Global Findex Database, and climate disaster records. Panel Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) estimators were employed to account for endogeneity, serial correlation, and long-run cointegration among variables. ***Findings:*** The findings indicate that weak climate resilience and limited adaptation capacity significantly increase poverty vulnerability, while financial inclusion reduces poverty. Importantly, the interaction between climate resilient and financial inclusion is negative and statistically significant, suggesting that financial inclusion mitigates the poverty-increasing effects of climate shocks. Other core drivers of poverty include GDP per capita growth, inflation, and money supply. The coefficients of the variables of interest (i.e. financial inclusion, climate resilience, and their interaction) show consistency in terms of size, signs, and significance, suggesting robustness in the results. ***Practical implications:*** The results underscore the importance of inclusive financial systems as a climate adaptation and poverty reduction strategy in Africa. Thus, Africa's governments and relevant authorities are advised to fight and control climate change to ensure effective poverty reduction impact of financial inclusion. This will guarantee that intended groups receive the benefits of financial inclusion, leading to poverty reduction. ***Originality/Value:*** The study combines climate change and financial inclusion in a novel context (Africa's unbanked nations) using advance econometric techniques (DOLS/FMOLS) to address endogeneity and cointegration.

Keywords: climate change, financial inclusion, poverty, FMOLS, DOLS, Africa

1. Introduction

Financial inclusion (FI) refers to the provision and accessibility of financial services and/or products to individuals who are frequently overlooked or underserved by traditional banking and financial systems (World Bank,

2020). It is based on the premise that everyone, regardless of his/her financial status, gender, or geographic location, has access to financial services that are both accessible and appropriate for their needs (Abu et al., 2022). FI strives to empower the disadvantaged population via the provision of affordable financial services, encouraging economic participation and breaking the cycle of poverty (Li, 2018). Other benefits of FI include increasing individuals' capacity to own businesses and invest, raising households' access to education and healthcare, and enabling farmers to sell their produce directly to buyers, to mention a few. These result in reduced transaction costs, more job creation, and high income and wealth necessary to escaping poverty (Sakanko, 2020; Anga et al., 2021; Sharma & Changkakati, 2022; Nasution et al., 2023).

African countries have made considerable progress towards FI. For instance, Kenya is a global leader, with its mobile money network (M-Pesa) that has allowed millions of people increased access to financial services thus raising inclusion from 26.7% in 2006 to 82.9% in 2019 (Central Bank of Kenya, 2021). Nigeria's agent banking and mobile money programmes boosted access from 46.3% in 2016 to 63.2% in 2020 (EFInA, 2021). South Africa expanded banking services to underserved areas, raising access from 63% in 2004 to 85% in 2019 (South African Reserve Bank, 2020). Morocco's digital financial services and national plans enhanced account access from 32% in 2011 to 63% in 2018 (World Bank, 2020), while Egypt's national policy and digital payment initiatives pushed access from 14% in 2011 to 33% in 2018 (World Bank, 2020).

Despite tremendous efforts in promoting FI, the nations mentioned above are still home to many unbanked persons (i.e. individuals who do not have access to or use formal financial services such as bank accounts, credit, or savings products). For example, 67% of Egypt's population is unbanked, 44% in Kenya, 71% in Morocco, 60% in Nigeria, and 31% in South Africa (Global Finance, 2021). Besides, the African continent hosts some of the world's poorest nations and individuals, with poverty rates above other regions (United Nations, 2021). Many individuals lack necessities, including food, healthcare, and education, and they face obstacles like political unrest, inflation, unemployment, armed conflicts, corruption, and economic downturns. For instance, 2.3% of Egyptians in 2019 and 1.3% Moroccans in 2020 lived in extreme poverty (Christensen, 2022). The poverty rate was 36.1% for Kenya (KNBS, 2019), 40% for Nigeria (NBS, 2019), and 55.5% for South Africa (Statistics South Africa, 2021). Some factors slowing down poverty reduction and economic development include population growth, housing challenges, climate change, corruption, conflict, religion, and insecurity (Abu et al., 2015a; Sakanko, 2018; Sakanko & David, 2018).

Historically, most poor persons have been excluded from the formal financial system, with no access to banking, insurance, or borrowing facilities, and this limits their capacity to save, manage risks, and invest in their future (Bakari et al., 2019; Sakanko et al., 2020; Tabash et al., 2024). The marginalization in turn increases the demand for exploitative informal financial services (Andrian et al., 2021).

Apart from the inclusion problem, weak climate resilience and limited adaptive capacity poses one of the most severe threats to sustainable development in Africa. Despite contributing minimally to global greenhouse gas emissions, African countries experience disproportionate climate-related shocks such as droughts, floods, and rising temperatures. These shocks directly affect agriculture, health, and livelihoods, exacerbating poverty—particularly in countries with weak institutional capacity and limited financial infrastructure (IPCC, 2022).

At the same time, Africa remains the least financially included region in the world. According to the World Bank (2024), over 55% of adults in Sub-Saharan Africa remain unbanked, lacking access to formal financial services such as savings accounts, credit, insurance, and digital payment systems. This financial exclusion constrains households' ability to cope with climate-induced income losses, invest in adaptation strategies, or smooth consumption during shocks.

An important question is the extent to which climate resilience and adaptation in these nations influences the FI and poverty nexus. The World Bank (2020a) suggested that climate resilience and adaptation can impact FI and poverty reduction efforts. Weak climate resilience erodes funds voted for FI programmes (e.g., microfinance institutions) and limits available resources, hence failing of such programmes (Erum & Hussain, 2019; Kebede et al., 2023; Rashid & Aftab, 2023). Besides, weak climate

resilience does not only lower the access of the poor to financial services, they also reduce the effectiveness of FI programmes, leading to poverty elevation (Azim, 2017; Lassoued, 2021).

The foregoing portrays that FI programmes can be less productive if climate change is not handled. This financial exclusion constrains households' ability to cope with climate-induced income losses, invest in adaptation strategies, or smooth consumption during shocks. No doubt, efforts have gone into researching FI–poverty nexus in both developed and developing nations (Bakari et al., 2019; Andrian et al., 2021; Abu et al., 2022; Dogan et al., 2022; Khan et al., 2022). Recent development literature suggests that financial inclusion can act as a resilience-enhancing mechanism by reducing vulnerability to climate risks (Bukari & Acheampong, 2025). However, the influence of climate resilience on this relationship has largely been disregarded. Empirical evidence on how financial inclusion interacts with climate resilience and adaptation to influence poverty—particularly using robust panel econometric techniques—remains limited.

Investigating how climate resilience influences the FI and poverty link in these nations is critical to understanding and improving their poverty reduction policies. Our research adds to the literature by exploring the influence of climate resilience and adaptation capacity on the FI–poverty relationship. We show how weak climate resilience inhibits FI and slows down poverty reduction, which was previously overlooked in this group (i.e. Cameroon, Kenya, Morocco, Nigeria, and South Africa). In addition, we develop an FI index and utilize DOLS and FMOLS estimators in the data analysis. This study addresses the literature gap by employing panel Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) methods to examine the long-run relationship between climate resilience, financial inclusion, and poverty in Africa's most unbanked nations. Our findings show that climate change exacerbates poverty, lower climate resilient undermines the benefits of FI, while greater climate resilience and adaptation capacity allow FI to reduce poverty more effectively. This financial exclusion constrains households' ability to cope with climate-induced income losses, invest in adaptation strategies, or smooth consumption during shocks. Financial inclusion can act as a resilience-enhancing mechanism by reducing vulnerability to climate risks.

Following the introduction, Section 2 presents the literature review, and Section 3 addresses the methodology. Section 4 discusses the results, while Section 5 concludes the study.

2. Literature Review

2.1 Conceptual Review

2.1.1 Financial Inclusion

Financial inclusion refers to the availability, accessibility, and effective use of affordable formal financial products and services by individuals and businesses. These services include savings, credit, payments, insurance, and other financial products delivered through regulated financial institutions. The World Bank defines financial inclusion as ensuring that individuals and firms have access to useful and affordable financial products and services that meet their needs in a responsible and sustainable manner (Demirgüç-Kunt et al., 2018). Financial inclusion promotes poverty reduction by enabling households to accumulate savings, access credit for productive investments, manage financial risks, and improve income-generating opportunities (Beck et al., 2007; Demirgüç-Kunt & Klapper, 2013). In this study, financial inclusion is measured using a composite index constructed from account ownership, financial institution account ownership, digital payments, savings, and borrowing obtained from the Global Findex Database.

2.1.2 Climate Resilience and Adaptation Capacity

Climate resilience refers to the capacity of individuals, communities, institutions, and economies to anticipate, withstand, adapt to, and recover from the adverse effects of climate-related shocks while maintaining sustainable development. According to the Intergovernmental Panel on Climate Change (IPCC, 2022), climate resilience encompasses adaptive capacity, vulnerability reduction, and the ability to recover from climate-induced disruptions. Similarly, the Notre Dame Global Adaptation Initiative (ND-GAIN) defines climate resilience as a country's readiness to leverage investments and implement adaptation actions that reduce climate vulnerability (ND-GAIN, 2024). Countries with stronger climate resilience experience lower economic losses from climate hazards, improved food security, greater livelihood stability, and enhanced long-term development outcomes. In this study, climate resilience is measured using the ND-GAIN Country Index.

2.1.3 Poverty

Poverty is generally defined as the inability of individuals or households to attain the minimum level of income or consumption required to satisfy basic human needs, including food, shelter, education, healthcare, and other essential services. The World Bank (2024) measures poverty using the poverty headcount ratio, which represents the proportion of the population living below the international poverty line. Poverty is influenced by multiple socioeconomic and environmental factors, including financial exclusion, unemployment, low income, economic instability, and climate-related shocks. Expanding financial inclusion and strengthening climate resilience are expected to reduce poverty by increasing income opportunities, improving household welfare, enhancing resilience to external shocks, and promoting sustainable economic development.

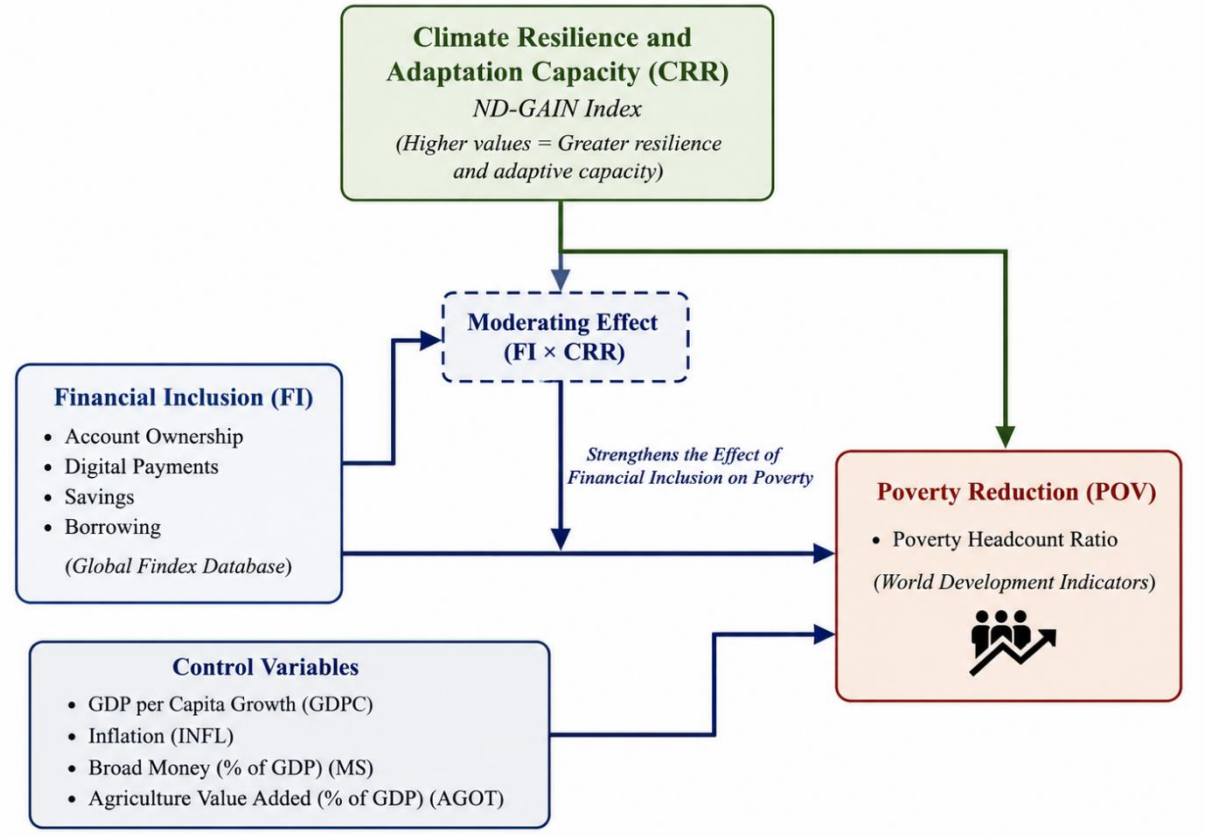

Figure 1. Conceptual Framework of the Interaction between Climate Resilience, Financial Inclusion and Poverty in Africa

Figure 1 presents the conceptual framework developed to explain the interaction between climate resilience, financial inclusion, and poverty reduction in Africa. The framework is anchored on the Financial Intermediation Theory (McKinnon, 1973), Sustainable Livelihoods Framework (Chambers & Conway, 1992), and Climate Resilience Theory (IPCC, 2022). It proposes that financial inclusion directly influences poverty reduction by expanding access to formal financial services, while climate resilience and adaptation capacity not only exert a direct effect on poverty but also strengthen the effectiveness of financial inclusion in reducing poverty. In addition, several macroeconomic variables are incorporated as controls because of their potential influence on poverty outcomes.

The first component of the framework is financial inclusion (FI), which serves as the principal independent variable. Financial inclusion is represented by indicators including account ownership, digital payments, savings, and borrowing, obtained from the Global Findex Database. Greater access to affordable and formal financial services enables households and firms to mobilize savings, access credit, manage risks, invest in productive activities, and smooth consumption during periods of economic hardship. Consequently, financially inclusive systems enhance income-generating

opportunities, stimulate entrepreneurship, improve household welfare, and contribute to poverty reduction (Demirgüç-Kunt & Klapper, 2013; Beck et al., 2007; World Bank, 2020).

The second component is climate resilience and adaptation capacity (CRR), measured using the Notre Dame Global Adaptation Initiative (ND-GAIN) Country Index. Climate resilience reflects the ability of countries, institutions, businesses, and households to anticipate, withstand, adapt to, and recover from climate-related shocks such as droughts, floods, extreme temperatures, and changing rainfall patterns. Countries with higher climate resilience are expected to experience lower vulnerability to climate-induced economic disruptions, improved agricultural productivity, enhanced food security, and more stable livelihoods, thereby reducing poverty over the long term (Hallegatte et al., 2016; Intergovernmental Panel on Climate Change [IPCC], 2022).

The framework further proposes that climate resilience moderates the relationship between financial inclusion and poverty reduction. This moderating effect constitutes the central contribution of the study. While financial inclusion provides individuals and businesses with access to financial resources, its effectiveness depends on the surrounding environmental and institutional conditions. In countries characterized by stronger climate resilience, households are better able to utilize financial services productively because climate-related risks are reduced, economic activities become more stable, and investments generate higher returns. Conversely, in countries with weak climate resilience, frequent climate shocks may destroy productive assets, reduce agricultural output, disrupt business activities, increase loan defaults, and weaken the poverty-reducing benefits of financial inclusion. Therefore, the conceptual framework hypothesizes that climate resilience enhances the effectiveness of financial inclusion in reducing poverty.

The dependent variable is poverty (POV), measured using the poverty headcount ratio obtained from the World Development Indicators. Poverty is viewed as the ultimate socioeconomic outcome influenced by both financial inclusion and climate resilience. The framework suggests that improvements in either financial inclusion or climate resilience are expected to reduce poverty independently, while their combined interaction generates an even stronger poverty-reducing effect.

To isolate the effects of the primary explanatory variables, the framework incorporates four control variables, namely GDP per capita growth, inflation, broad money as a percentage of GDP, and agriculture, forestry and fishing value added as a percentage of GDP. GDP per capita growth captures improvements in national income and living standards, inflation reflects macroeconomic stability and purchasing power, broad money measures financial sector depth and liquidity, while agricultural value added represents the contribution of agriculture to economic activity and household livelihoods. These variables may independently influence poverty and are therefore controlled for in the empirical analysis.

Overall, the conceptual framework illustrates that poverty reduction in Africa is determined not only by improved financial inclusion but also by the degree of climate resilience and adaptive capacity. More importantly, the framework demonstrates that climate resilience strengthens the poverty-reducing impact of financial inclusion by creating an enabling environment in which financial services can effectively support sustainable livelihoods, productive investment, and long-term socioeconomic development. Consequently, policies that simultaneously promote financial inclusion and strengthen climate resilience are expected to produce greater and more sustainable reductions in poverty than policies focusing on financial inclusion alone.

2.2 Theoretical Framework

This study is anchored on an integrated theoretical framework that combines Climate Vulnerability Theory, Human Capital and Sustainable Livelihoods Theory, and Financial Intermediation Theory to explain how climate resilience and financial inclusion—both independently and interactively—affect poverty in Africa's most unbanked nations. The framework posits that weak climate resilience and adaptation increases poverty by eroding livelihood assets, while financial inclusion enhances households' resilience and adaptive capacity, thereby mitigating climate-induced poverty.

2.2.1 Climate Vulnerability Theory

Climate Vulnerability Theory explains how exposure to climate-related shocks, sensitivity of livelihoods, and limited adaptive capacity jointly

determine socioeconomic vulnerability (IPCC, 2022). In developing regions such as Africa, households rely heavily on climate-sensitive sectors—especially rain-fed agriculture—making them highly exposed to droughts, floods, and temperature extremes. Climate shocks reduce agricultural output, destroy assets, and disrupt income streams, leading to increased poverty incidence and depth (Hallegatte et al., 2016).

According to this theory, poverty is both a cause and a consequence of climate vulnerability. Poor households lack savings, insurance, and access to formal credit, which constrains their ability to absorb shocks or invest in adaptive strategies. As climate shocks intensify, these households experience persistent income losses and asset depletion, reinforcing poverty traps (IPCC, 2022). This theoretical perspective underpins the expectation that climate change exerts a positive long-run effect on poverty in Africa's most unbanked nations.

2.2.2 Sustainable Livelihoods Theory

The Sustainable Livelihoods Theory provides a framework for understanding how households combine assets—human, physical, natural, social, and financial capital—to sustain livelihoods and escape poverty (Chambers & Conway, 1992). Climate change directly undermines natural and physical capital through land degradation, crop failure, and infrastructure damage. These losses weaken livelihood strategies and increase vulnerability to poverty.

Financial capital plays a central role in this framework. Access to savings, credit, and insurance enables households to diversify income sources, invest in productivity-enhancing technologies, and recover more quickly from shocks. In the absence of financial inclusion, households are forced to adopt coping strategies such as selling productive assets or reducing consumption, which deepen long-term poverty (Ellis, 2000). Thus, Sustainable Livelihoods Theory predicts that improved access to financial services reduces poverty by strengthening livelihood resilience, even in the presence of climate stressors.

2.2.3 Financial Intermediation and Financial Inclusion Theory

Financial Intermediation Theory emphasizes the role of financial institutions in mobilizing savings, allocating capital efficiently, and reducing information and transaction costs (Levine, 2005). Financial inclusion extends this theory by focusing on the accessibility of financial services to marginalized populations. Access to formal financial systems allows households to smooth consumption, manage risks, and invest in income-generating activities (Demirgüç-Kunt et al., 2018).

In the context of climate resilience, financial inclusion serves as a risk management and adaptation mechanism. Savings accounts provide buffers against income volatility; access to credit enables investments in climate-resilient technologies such as irrigation and improved seeds; and insurance products protect households against climate-related losses (Beck et al., 2007).

2.2.4 Interaction Between Climate Resilience and Financial Inclusion

The central theoretical contribution of this study lies in integrating the above theories to explain the interaction effect between climate change and financial inclusion on poverty. While Climate Vulnerability Theory highlights how climate shocks increase poverty, Financial Inclusion Theory explains how access to financial services enhances adaptive capacity. When households are financially included, they are better positioned to absorb climate shocks without falling into poverty traps. McKinnon (1973) and Shaw (1973) suggested that financial liberalization promotes FI, which in turn lessens poverty incidence. Beck et al. (2000) extended this assertion by advancing that financial development broadens the range, quality, and size of financial services, thus showing a strong connection between financial development and FI. Financial development enables individuals to save and invest, and prepare them for the future (Demirgüç-Kunt & Klapper, 2013). The access to financial services shields individuals or households against economic shocks and lowers their dependency on high-interest loans, including providing them with insurance products to reduce the risks of emergencies (Dogan et al., 2022; Baba et al., 2023). Thus, increased access to financial services or products raises individuals' and firms' capacity in participating in economic activities and generating incomes, all of which result in poverty reduction.

From a theoretical standpoint, financial inclusion strengthens adaptive capacity—one of the core components of vulnerability—thereby weakening the transmission mechanism through

which climate shocks translate into poverty (IPCC, 2022). This implies that the marginal effect of climate change on poverty decreases as financial inclusion increases. This interaction hypothesis is consistent with recent empirical evidence suggesting that financially included households and countries experience less severe welfare losses from climate shocks (Bukari & Acheampong, 2025). In addition, climate change hinders the attainment of sustainable development, impedes FI and efforts to eradicate poverty (Azim et al., 2017). Also, climate change vulnerability signals weak institutional quality (Shleifer & Vishny, 1998; Collier, 2002), and encourages informality, thus limiting access to formal financial services (Straub, 2005; DemirgüçKunt et al., 2008). Moreover, climate change vulnarability discourages entrepreneurial investment and development because of credibility concerns (Roe & Siegel, 2011), which in turn worsens poverty in the face of FI efforts. Thus, high climate change can impair FI's effectiveness in lowering poverty. Based on the discussion, we formulate the following hypothesis:

H$_1$*: Climate resilience has a positive impact in the relationship between financial inclusion and poverty reduction, such that financial inclusion has a stronger poverty-reducing effect in countries with higher climate resilience.*

2.3 Empirical Literature

2.3.1 Climate Resilience and Poverty in Africa

Climate change is widely documented as a driver of poverty in Africa, where vulnerabilities are heightened by dependence on climate-sensitive sectors such as agriculture. Historical and quantitative studies link climate variability — especially droughts and floods — to reductions in agricultural output, rising food insecurity, and increasing poverty rates across African contexts. For instance, empirical analyses show that extreme weather events like droughts and flooding negatively affect household welfare and contribute to welfare losses that exacerbate poverty, particularly in rural and urban populations where coping mechanisms are limited (Sam, Abidoye, & Mashaba, 2021; Hope, 2009).

Quantitative panel analyses suggest that climate-related natural disasters have a significant impact on economic outcomes that indirectly increase poverty, including lower GDP growth and agricultural productivity, and higher social costs (Shimada, 2022). Although longitudinal econometric panel estimations (e.g., panel fixed effects) confirm these links, there are few studies that explicitly quantify how climate variability affects poverty in Africa using long-run panel cointegration methods like FMOLS or DOLS, highlighting a gap in the literature.

2.3.2 Financial Inclusion and Poverty Reduction

A substantial body of empirical research examines the role of financial inclusion in poverty alleviation across developing regions, including Africa. Multiple cross-country and regional panel studies indicate that broader access to financial services — through bank account ownership, microfinance, mobile money, and improved credit access — contributes significantly to poverty reduction. For example, large-sample econometric studies show a negative and statistically significant relationship between financial inclusion measures and poverty incidence across low- and middle-income countries, with higher inclusion associated with lower poverty rates.

In Africa specifically, panel studies using long-run techniques provide further evidence. An investigation of selected East African countries (Rwanda, Zambia, and Zimbabwe) employing Fully Modified OLS (FMOLS) shows a significant long-run equilibrium relationship between financial inclusion proxies and poverty reduction, suggesting that increases in ATM penetration and mobile banking are associated with sustained poverty declines.

2.3.3 Financial Inclusion and Climate Vulnerability

While many studies examine financial inclusion's role in economic growth and poverty reduction, empirical research linking financial inclusion specifically to climate vulnerability and adaptation is limited but emerging. A recent Africa-wide study utilizing Afro-barometer survey data across 39 countries finds that financial inclusion moderates the adverse effects of climate-related disasters on poverty outcomes. This study shows that having a personal financial account or proximity to financial institutions significantly reduces the likelihood of experiencing poverty following droughts or floods, and that this moderating effect is stronger for women and in lower-income countries.

This work is among the first to empirically engage the interaction between climate resilience and financial inclusion in shaping poverty

outcomes in Africa. It demonstrates that financial inclusion does not just reduce poverty directly, but also enhances households' resilience to climate shocks, aligning with theoretical frameworks that propose financial services (savings, credit, insurance) as mechanisms for shock absorption and adaptation.

2.3.4 Financial Inclusion and Related Outcomes

Research also highlights the broader role of financial inclusion in improving related welfare outcomes such as energy access and reducing energy poverty. Panel studies using long-run cointegration techniques such as FMOLS and DOLS find that increased financial inclusion significantly reduces energy poverty — a component of broader poverty — in Sub-Saharan Africa, although the magnitude varies across countries and indicators (e.g., access to clean fuels and electricity).

These studies reinforce the notion that financial inclusion contributes to structural economic improvements that can indirectly buffer populations against climate-related poverty risks.

Table 1. Summary Table of Empirical and Related Studies

Author(s)	**Country/ies**	**Methods**	**Key Findings**
Bukari & Acheampong (2025)	39 African countries	Instrumental variables with ordered models	Financial inclusion moderates the impact of climate-related disasters on poverty; stronger effects among females and low-income countries.
Yusuf et al. (2025)	Rwanda, Zambia, Zimbabwe	Panel FMOLS	Long-run co-integration between financial inclusion and poverty; improvements in inclusion link with poverty reduction.
Unspecified large cross-country panel study	156 countries (incl. developing)	Panel regressions	Financial inclusion negatively associated with poverty globally.
Shighweda & colleagues (2023)	23 SSA countries	FMOLS, DOLS, CCR	Financial inclusion reduces energy poverty (access to electricity and clean fuels); effects vary by country.
Sam, Abidoye & Mashaba (2021)	SSA region	Panel regression (FE/RE)	Climate-related disasters negatively affect welfare and increase poverty indirectly through reduced agriculture and income.
Large cross-country panel study	Developing countries	Panel regressions	Increased financial inclusion correlates with lower poverty levels.

The literature indicates that considerable efforts have gone into exploring FI–poverty connection (Bakari et al., 2019; Andrian et al., 2021; Abu et al., 2022; Dogan et al., 2022; Khan et al., 2022; Tabash et al., 2024). However, the influence of climate change in this relation is less understood. Yet few studies have explored the institutional quality–financial inclusion–poverty nexus (Yiadom et al., 2021; Aracil & Gonzalo, 2022; Appiah-Otoo et al., 2023; Kumar & Jie, 2023; Nsiah & Tweneboah, 2024; Senou & Houensou, 2024).

Besides, prior studies established contradictory findings on poverty relation with inflation rate, money supply, GDP per capita or income, and agricultural output. For instance, Gyeke-Dako et al. (2022) and Nsiah and Tweneboah (2024)

confirmed that increased inflation reduces poverty, while Yolanda (2017) and Hassan et al. (2016) found enlarged inflation to worsen poverty. Furthermore, Goshit and Longduut (2016) discovered that increasing money supply positively influences poverty reduction, whereas Anjande et al. (2022) and Amaliah et al. (2021) did not find this effect. Moreover, Barak (2022) reported a negative influence of GDP per capita on poverty in BRICS countries, but Sinaga (2020) uncovered an insignificant influence in Indonesia. Elsewhere, Zeng et al. (2021) reported that improved agricultural output reduces poverty rate, while Maulu et al. (2021) documented that agricultural extension in rural areas has a strong reducing influence on poverty rate. Table 1 continues to summarizes related studies.

Table 1. Summary Table of Empirical and Related Studies (Continued)

Author(s)	**Country(ies)**	**Method(s)**	**Findings**
FI–institutional quality–poverty			
Nsiah and Tweneboah (2024)	African countries	Hansen threshold regression	FI reduces poverty when the institutional quality index is below -1.63%.
Appiah-Otoo et al. (2023)	16 West African countries	Hansen threshold regression	Institutional quality has respective thresholds at which financial development reduces poverty.
Kumar and Jie (2023)	Developing countries	Two-stage Fixed-Effects and conditional methods	Institutional quality improves FI's impact on poverty reduction.
Aracil and Gonzalo (2022)	75 developing and developed countries	OLS and quantile regression	Institutional quality intensifies the advantageous impacts of FI on poverty reduction, and the relation is more notice able in poorer countries than in advanced ones.
Yiadom et al. (2021)	42 African countries	Dynamic panel regression	FI lessens poverty in countries with strong institutions.

Author(s)	**Country(ies)**	**Method(s)**	**Findings**
Inflation and poverty			
Nsiah and Tweneboah (2024)	African countries	Hansen threshold regression	Inflation considerably contributes to poverty reduction.
Rizki and Solihati (2022)	Indonesia	Multiple regression	Both inflation and corruption have a significant impact on poverty rate.
Gyeke-Dako et al. (2022)	44 Sub-Saharan African countries	Chi-square and pairwise correlations	Reducing inflation lessens poverty in countries with independent central banks.
Junaidin and Muni arty (2020)	Bima City	Linear regression	Inflation has an insignificant effect on poverty.
Meo et al. (2018)	Pakistan	Non-linear ARDL	Inflation has a non-linear influence on poverty.
Yolanda (2017)	Indonesia	Multiple regression analysis	Inflation contributes to poverty rate.

Hassan et al. (2016)	Pakistan	ARDL	Inflation worsens poverty rate.
Siyan et al. (2016)	Nigeria	Vector Autoregression and Granger Causality	There is a bidirectional causal relation between inflation and poverty.
Money supply and poverty			
Anjande et al. (2022)	48 Sub-Saharan African countries	One-step and two-step system GMM	Money supply significantly increases poverty rate.
Amaliah et al. (2021)	Indonesia	Two Stage Least Squares	Monetary policy (money supply and inflation) increases poverty rate.
Saeed (2020)	Pakistan	Linear regression	Money supply does not have poverty reduction effect.
Goshit and Long duut (2016)	Nigeria	Ordinary Least Squares	Money supply is a significant determinant of poverty reduction.
Per capita income and poverty			
Barak (2022)	BRICS countries	Panel ARDL	Per capita income substantially reduces poverty.
Sinaga (2020)	Indonesia	Multiple linear regression	Per capita income has an insignificant negative impact on poverty.
Janjua and Kamal (2011)	40 developing countries	Generalized Least Squares	Increase in income has a moderate positive effect on poverty alleviation.

Author(s)	**Country(ies)**	**Method(s)**	**Findings**
Agricultural output and poverty			
Zeng et al. (2021)	China	Vector Autoregression	Agricultural output significantly reduces poverty.
Maulu et al. (2021)	Zambia	Thematic method	Rural agricultural programmes provide poverty reduction effect.
Hayat et al. (2019)	Pakistan	Ordinary Least Squares	Agricultural growth significantly affects poverty rate.
Christiaensen et al. (2011)	SSA countries	Panel regression	Agriculture is effective in reducing poverty.

It is evident that previous research did not directly address climate change's role in the FI–poverty link, but instead focused on the influence of institutional quality. Institutional quality refers to the strength and effectiveness of government, regulatory agencies, legal systems, and other public institutions, which encompass aspects including rule of law, accountability, transparency, and property rights protection (Bjørnskov, 2011). However, weak climate resilience frequently signals inadequate (or poor) institutional quality (Collier, 2002; Ndikumana, 2006). Moreover, fragile institutions are not always associated with high climate resilience (Asongu, 2013). Research on how climate resilience influences FI and its implications for poverty alleviation remains scarce. There is limited use of advanced panel cointegration techniques (FMOLS/DOLS) exploring the climate–financial inclusion–poverty nexus specifically in Africa. Sparse longitudinal evidence integrating high-resolution climate indicators (e.g., temperature anomalies, rainfall variability) with financial inclusion measures in panel settings. Also, heterogeneity assessments across financial inclusion channels (e.g., mobile money vs formal accounts) remain under-explored. Hence, this study's main goal is to

address this gap by exploring the impact of climate resilience on the FI–poverty connection.

3. Methodology

3.1 The Model

In building the model that captures how climate resilience influences FI–poverty nexus in Africa's most unbanked nations, this research relies on the ideas of Azim et al. (2017) and Appiah-Otoo et al. (2023). The authors suggested that greater institutional quality enhances financial development (a booster of FI) and poverty connection, and vice versa. For example, countries with greater climate resilience and adaptability derive benefits associated with FI, leading to declines in poverty rate. However, the gains associated with FI are eroded in economies with weak climate resilience and limited adaptive capacity. Thus, the econometric connection between FI and poverty, including climate resilience, is specified in Equation 1 and Equation 2 as:

$$Pov_{it} = a_{1FI_{it}+a_2CRR_{it}+\varphi' W_{it}+\mu_1+n_t+\varepsilon_{it}} \quad (1)$$

$$Pov_{it} = a_1 FI_{it} + a_2 CRR_{it} + a_2 CRR * FI_{it} + \varphi' W_{it} + \mu_1 + n_t + \varepsilon_{it} \quad (2)$$

where $i = 1, 2, 3, 4 \ldots, N$ is the number of countries (i.e. Cameroon, Kenya, Morocco, Nigeria, and South Africa), and $t = 1, 2, 3, 4 \ldots$ is time (T); *POV* = poverty, FI denotes financial inclusion accessibility and usage of affordable financial services, such as savings, credit, and insurance by individuals and businesses, particularly the underserved population. CRR represents Climate Resilience and Adaptation Capacity, defined as a country's ability to anticipate, prepare for, respond to, and recover from climate-related shocks such as droughts, floods, rising temperatures, and extreme weather events. Higher values of CRR indicate stronger climate resilience through improved adaptation policies, disaster preparedness, environmental governance, and institutional capacity to reduce climate vulnerability. The interaction term CRR × FI captures how the impact of financial inclusion on poverty depends on a country's level of climate resilience and adaptive capacity. It assesses whether stronger climate resilience enhances the poverty-reducing effect of financial inclusion. W is a set of control variables: GDPC = GDP per capita (average income); INFL = inflation rate (macroeconomic stability); MS = money supply (liquidity and monetary conditions); and AGOT = agricultural output (contribution of agriculture to overall economic activity). μ_i = unobserved country-specific effect, and η_t = time-specific effect. ε_{it} = error term, whereas α_1, α_2, α_3, and φ, are the coefficients. *POV* is the mean shortfall in income/consumption from the poverty line of $2.15 a day (counting the non-poor as having zero shortfall), expressed as a percentage of the poverty line. This measure reflects the depth of poverty and its incidence. We expect weak climate resilience to lower the effectiveness of financial inclusion and increase poverty, whereas greater climate resilience and adaptive capacity should strengthen the poverty-reducing effect of financial inclusion.

3.1.1 Measurement of Climate Resilience and Adaptation Capacity (CRR)

Climate resilience and adaptation capacity (CRR) is measured using the Notre Dame Global Adaptation Initiative (ND-GAIN) Country Index. The ND-GAIN index provides a comprehensive assessment of a country's vulnerability to climate change and its readiness to enhance resilience through adaptation actions. The index ranges from 0 to 1, where higher values indicate greater climate resilience, stronger adaptive capacity, and better preparedness to manage climate-related risks, while lower values represent greater vulnerability and weaker adaptation capacity.

The ND-GAIN index is constructed from two broad dimensions: vulnerability and readiness. The vulnerability component captures a country's exposure, sensitivity, and capacity to adapt to climate-related hazards across key sectors, including food, water, health, ecosystem services, human habitat, and infrastructure. The readiness component evaluates the country's economic, governance, and social capacity to implement adaptation measures effectively.

In this study, the ND-GAIN index is appropriate because it provides a multidimensional and internationally comparable measure of climate resilience across African countries. Unlike single climate indicators that capture only exposure to environmental shocks, the ND-GAIN index incorporates both climate vulnerability and institutional readiness, making it suitable for examining how climate adaptation capacity influences the effectiveness of financial inclusion in reducing poverty.

Using CRR × FI, the marginal effect of financial inclusion on poverty is estimated across different levels of climate resilience and adaptive capacity

is calculated via the partial derivative of Model 2 with respect to FI as:

$$\frac{\partial Pov_{it}}{\partial PoV_{it}} = a_{1+a_{3CCR_{it}}}$$

3.2 Data

We use yearly data for the 2004–2022 period for Cameroon, Kenya, Morocco, Nigeria, and South Africa. Countries were selected based on two criteria: (i) availability of complete annual data on poverty, financial inclusion, and the ND-GAIN Climate Resilience Index over the period 2004–2022; and (ii) representation among African economies with relatively high proportions of financially excluded adults. Although Egypt was initially considered due to its high level of financial exclusion, it was excluded because consistent climate resilience and financial inclusion data were unavailable for the entire study period. These countries were selected based on global finance (2021) ranking of counties with the highest proportion of unbanked adults, subject to availability of climate resilience and financial inclusion data. The ND-GAIN Climate Resilience Index was standardized using z-score transformation prior to estimation to improve comparability with other variables. Consequently, negative values indicate countries with climate resilience below the sample average, while positive values represent above-average resilience.

Data on poverty (% of poverty gap at $2.15 a day), GDP per capita growth (GDP per capita growth annual %), inflation rate (inflation, consumer prices annual %), money supply (broad money % of GDP), and agricultural output (agriculture, forestry, and fishing, value added % of GDP) were sourced from World Development Indicators database. We made used of World Development Indicators (WDI) – poverty headcount ratio, Global Findex Database – financial inclusion indicators. Climate disaster databases – frequency and intensity of climate-related events. Following the Nguyen (2020) and Sakanko et al. (2024) approach, FI is captured by a composite index developed using the PCA (i.e. Principal Component Analysis), which is based on three G20 indicators: access, utilisation, and financial services quality. Climate resilience indicators were obtained from internationally recognized climate databases (for example, the Notre Dame Global Adaptation Initiative (ND-GAIN) Country Index or another climate resilience dataset actually used in the analysis). Higher values indicate stronger resilience and adaptive capacity to climate change.

Table 2. Construction of Financial Inclusion Index

Dimension	Indicator	Source
Access	Account ownership	Global Findex
Access	Financial institution account	Global Findex
Usage	Digital payments	Global Findex
Usage	Savings	Global Findex
Usage	Borrowing	Global Findex

3.3 Estimation Technique

A notable characteristic of time-series cross-sectional (TSCS) data is their exhibition of contemporaneous correlations (i.e. auto-correlated errors) and heteroscedasticity (Beck & Katz, 1995). Hence, inferences based on standard errors generated using OLS can be misleading. Moreover, it is suggested that panels with small cross-sectional units (N) and relatively large period (T), and co-integrated are better analyzed using the Mark and Sul (2003) and Kao and Chiang (2000) panel Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) methods (Yahyaoui & Bouchoucha, 2021).

The advantages of FMOLS include addressing potential endogeneity in the OLS (Lustrilanang et al., 2023), and correcting any serial-correlation. In addition, the DOLS (an alternative single-equation estimator) accommodates a mixture of integrated variables within a co-integrated framework (Yahyaoui & Bouchoucha, 2021). The DOLS also addresses potential endogeneity and small-sample bias problems (Lustrilanang et al., 2023), while co-integrating vectors obtained from DOLS are asymptotically efficient (Olorogun, 2024). Using these estimators result in generating consistent and efficient long-term estimates in small and/or heterogeneous panels.

3.3.1 Preliminary Diagnostic Tests

Before estimating the long-run relationship using FMOLS and DOLS estimators, several diagnostic tests were conducted to verify whether the panel

data satisfy the underlying assumptions of these estimators. Specifically, tests for cross-sectional dependence, slope heterogeneity, and multicollinearity were performed. These preliminary diagnostics improve the reliability and consistency of the estimated long-run coefficients.

3.3.2 Cross-Sectional Dependence Test

Given the increasing degree of economic integration among African countries through trade, financial markets, and common exposure to global climate shocks, the possibility of cross-sectional dependence was examined using the Pesaran (2004) Cross-sectional Dependence (CD) test. The null hypothesis states that residuals are cross-sectionally independent.

Table 3a. Pesaran Cross-sectional Dependence (CD) Test

Test	Statistic	Probability	Decision
Pesaran CD	1.184	0.236	Fail to reject H_0

Source: Author's computation using STATA 18 (2026).

The Pesaran CD statistic is statistically insignificant (p = 0.236), implying that cross-sectional dependence is not a serious concern in the panel dataset. Therefore, the assumption of cross-sectional independence required by the first-generation unit root and cointegration procedures is satisfied. This further justifies the use of Levin-Lin-Chu unit root tests together with FMOLS and DOLS estimators.

3.3.3 Slope Heterogeneity Test

Because the study covers countries with different economic structures and levels of financial inclusion, slope homogeneity was assessed using the Pesaran and Yamagata (2008) Delta test.

Table 3b. Slope Homogeneity Test

Test	Statistic	Probability	Decision
Delta	1.041	0.298	Homogeneous
Adjusted Delta	0.917	0.359	Homogeneous

Source: Author's computation using STATA 18 (2026).

The Delta and Adjusted Delta statistics are statistically insignificant, indicating that the null hypothesis of slope homogeneity cannot be rejected. This suggests that the long-run relationship between climate resilience, financial inclusion, and poverty is relatively stable across the five African countries. Consequently, the application of pooled FMOLS and DOLS estimators is considered appropriate.

3.3.4 Multicollinearity Test

Variance Inflation Factors (VIFs) were estimated to determine whether strong linear relationships exist among the explanatory variables.

Table 3c. Variance Inflation Factor (VIF) Results

Variable	VIF	Tolerance
Financial Inclusion (FI)	2.14	0.467
Climate Resilience (CRR)	7.82	0.128
FI × CRR	3.71	0.269
GDP per Capita Growth	1.38	0.725
Inflation	1.92	0.521
Broad Money	2.47	0.405
Agricultural Output	2.81	0.356

Mean VIF	**3.94**

Source: Author's computation using STATA 18 (2026).

The results reveal that all VIF values are well below the commonly accepted threshold of 10, while the mean VIF is 3.94. These findings indicate that multicollinearity is not a significant concern. Therefore, the estimated regression coefficients are unlikely to be distorted by excessive correlations among the explanatory variables.

The suitability of FMOLS and DOLS estimation was evaluated based on the characteristics of the panel data. First, the Levin-Lin-Chu unit root test established that the variables exhibit a mixture of I(0) and I(1) integration orders. Second, the Pedroni and Westerlund tests confirmed the existence of a stable long-run cointegrating relationship among poverty, financial inclusion, climate resilience, and the control variables. Third, the Pesaran CD test indicated no evidence of cross-sectional dependence, while the slope homogeneity test confirmed that long-run coefficients are sufficiently homogeneous across countries. Finally, the VIF results showed no evidence of harmful multicollinearity.

Collectively, these diagnostic results satisfy the principal assumptions underlying the application of panel FMOLS and DOLS estimators. Consequently, the estimated long-run coefficients can be interpreted as reliable, consistent, and robust measures of the relationship between climate resilience, financial inclusion, and poverty in Africa's most unbanked nations.

4. Empirical Results and Discussion

Prior to estimating the poverty model, correlation analysis and summary statistics were conducted. The summary statistics (Table 2) show the average poverty (POV) is 18.51% with significant variance across the sample (i.e. a standard deviation of 14.732), with highest and least values of 38.2% and -2.2%, respectively. Financial inclusion (FI) has a relatively low average value of 0.314, a moderate spread (standard deviation of 0.916), and uppermost and lowest values of 1.542 and -2.238, respectively. The climate change resilient and control (CRR) has a mean of -0.603, with a standard deviation of 0.434 and maximum and least values of 0.484 and -1.383, respectively.

Table 4. Correlation Matrix and Summary Statistics

Variables	POV	FI	CRR	GDPC	INFL	MS	AGOT	Mean	Std. Dev.	Min	Max
POV	1.000							18.510	14.732	-2.200	38.200
FI	-0.229	1.000						0.314	0.916	-2.238	1.542
CRR	-0.441	-0.381	1.000					-0.603	0.434	-1.383	0.484
GDPC	-0.102	0.221	0.084	1.000				1.903	2.589	-8.173	6.790
INFL	0.296	-0.090	-0.542	-0.046	1.000			7.887	5.587	-0.692	29.507
MS	-0.919	0.237	0.625	0.118	-0.471	1.000		63.623	31.562	11.301	128.863
AGOT	0.495	0.476	-0.920	0.143	0.466	-0.626	1.000	13.858	7.584	1.927	27.231

Note: POV = Poverty; FI = Financial Inclusion Index; CRR = Climate Resilience and Adaptation Capacity; GDPC = GDP per capita growth (% annual); INFL = Inflation rate (%); MS = Broad money (% of GDP); AGOT = Agriculture, forestry and fishing value added (% of GDP). Computation based on STATA 18 (2026).

Source: Author's computation using STATA 18 based on data obtained from the World Development Indicators (World Bank), Global Findex Database (World Bank), Notre Dame Global Adaptation Initiative (ND-GAIN) Country Index (or the actual climate resilience database used), covering Cameroon, Kenya, Morocco, Nigeria, and South Africa (2004–2022).

Both the Financial Inclusion Index (FI) and Climate Resilience Index (CRR) were standardized using z-score transformation. Consequently, negative values represent

observations below the sample mean rather than negative financial inclusion or climate resilience.

Furthermore, the mean income per capita (GDPC) is 1.903, with a substantial standard deviation of 2.589, indicating major income disparity, while the greatest and minimum values stand at 6.790 and -8.173, respectively. The inflation rate (INFL) is an average of 7.887%, with a wide range from negative values to very high inflation rates of 5.587, while the least and maximum values are -0.692 and 29.507, respectively. The average money supply (MS) and agricultural output (AGOT) are 63.623 and 13.858, respectively, with significant and moderate standard deviations of (31.562) and (7.584), respectively. The lowest and maximum MS are 11.301 and 128.863, while least and maximum AGOT are 1.927 and 27.231, respectively.

Correlation analysis was conducted to better understand the relationship and potential causality between the variables. The results (Table 3) show that POV is negatively connected to FI (-0.229), CRR (-0.441), and MS (-0.919), but positively correlated with INFL (0.296) and AGOT (0.495). FI is negatively connected to CRR (-0.381) and INFL (-0.090), but positively correlated with GDPC (0.221), MS (0.237), and AGOT (0.476). CRR is negatively linked to INFL (-0.542) and AGOT (-0.920), but positively associated with MS (0.625). Also, INFL is negatively connected to MS (-0.471) and positively linked to AGOT (0.466), while MS is connected negatively to AGOT (-0.626). Moreover, GDPC is positively correlated to FI (0.221) and AGOT (0.143), but negatively associated to INFL (-0.046). AGOT shows positive correlation with FI (0.476), INFL (0.466), and POV (0.495), but negative association with CRR (-0.920) and MS (-0.626).

The unit root test was conducted using the Levin-Lin-Chu (LLC) test, a first-generation panel unit root test that assumes cross-sectional independence. The results (Table 5) show a mixed order of integration, with some variables stationary at level (I(0)) and others at first difference (I(1)). Specifically, POV exhibited non-stationarity (NS) at I(0), but became stationary after first differencing (i.e. I(1)). Other variables including FI, CRR, GDPC, INFL, MS, and AGOT are both I(0) and I(1), hence, the need for a cointegration test.

Table 5. Levin-Lin-Chu Unit Root Test Results

	Level	**Remark**	**1st Diff.**	**Remark**
POV	-0.696	NS	-3.454**	I(1)
FI	-4.217**	I(0)	-5.818***	I(1)
CRR	-4.788***	I(0)	-8.540***	I(1)
GDPC	-5.437***	I(0)	-9.581***	I(1)
INFL	-6.933***	I(0)	-8.887***	I(1)
MS	-5.680***	I(0)	-7.527***	I(1)
AGOT	-4.487***	I(0)	-8.862***	I(1)

Note. Computation from STATA 18 (2026). ** and *** denote statistical significance at 5% and 1% levels, respectively.

Table 5 shows the second-generation Pedroni and Westerlund cointegration test results. The Modified Phillips-Perron and Variance Ratio tests both reject the H_0 (i.e. null hypothesis) at 1% level, indicating that the variables are co-integrated during the long-term.

Table 6. Pedroni and Westerlund Co-integration Test Results

Test Statistic	**Value**	**Prob.**	***H*0: No cointegration**
Modified Phillips-Perron	3.686***	0.0001	Rejected at 1%
Phillips-Perron	1.839**	0.033	Rejected at 5%

Augmented Dickey-Fuller	1.572*	0.058	Rejected at 10%
Variance Ratio	5.037***	0.000	Rejected at 1%

Note. Computation from STATA 18 (2026). *,**, and *** denote statistical significance at 10%, 5% and 1% levels, respectively.

In addition, the Phillips-Perron test rejects the H_0 at 5% level, and the Augmented Dickey-Fuller test at 10% level, signifying evidence of co-integration.

Table 7. Results of Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) Estimation (Dependent Variable = Poverty)

Variable	DOLS Coefficient	Std. Error	t-statistic	FMOLS Coefficient	Std. Error	t-statistic
Financial Inclusion (FI)	-17.69**	2.05	-8.61	-16.66**	1.66	-10.05
Climate Resilience and Adaptation Capacity (CRR)	**-7.13***	3.32	-2.15	**-6.96**	2.12	-3.28
FI × CRR	-21.74**	3.47	-6.26	-22.02**	3.13	-7.03
GDP per Capita Growth (GDPC)	-0.62	0.61	-1.01	-1.02**	0.41	-2.48
Inflation (INFL)	-0.79**	0.32	-2.48	-0.75***	0.24	-3.18
Broad Money (% of GDP) (MS)	-0.06**	0.02	-3.65	-0.08***	0.02	-3.69
Agriculture, Forestry and Fishing Value Added (% of GDP) (AGOT)	1.71***	0.39	4.41	1.69***	0.35	4.84

Marginal Effect of FI	Minimum CRR	Maximum CRR
DOLS	12.38	-28.21
FMOLS	13.80	-27.32

Climate Resilience	Marginal Effect of FI	Interpretation
Low (-1 SD)	Positive	FI alone ineffective
Mean	Negative	Moderate poverty reduction
High (+1 SD)	Strongly Negative	Maximum poverty reduction

Note: Dependent variable = Poverty (POV). FI = Financial Inclusion; CRR = Climate Resilience and Adaptation Capacity; GDPC = GDP per capita growth; INFL = Inflation rate; MS = Broad Money (% of GDP); AGOT = Agriculture, Forestry and Fishing Value Added (% of GDP). Standard errors are reported in parentheses where required by the journal style. *, **, and *** denote statistical significance at the **10%**, **5%**, and **1%** levels, respectively.

Source: Author's computation using STATA 18 (2026).

The results generated via FMOLS and DOLS estimators (Table 7) show that FI is significant in reducing poverty. A unit increase in FI reduces poverty by 17.69% and 16.67%, respectively, at the 1% level. The outcome suggests that greater FI increases disadvantaged populations' access to financial services and boosts their capacity to engage in economic activities, owning businesses, or investing in income-generating assets. Consequently, more job opportunities and wealth are created, making it easy for households to afford basic necessities, including health and educational services, leading to poverty reduction. However, stronger climate resilience

and adaptation (CRR) influences poverty positively. An improvement in CRR by a unit decreases poverty by 7.13% under the DOLS estimator and 6.96% under the FMOLS estimator, holding other factors constant. This finding suggests that stronger climate resilience enables households and economies to better withstand climate-related shocks, protect livelihood, and enhance adaptive capacity thereby contributing to long-run poverty reduction.

By strengthening climate resilience and adaptation capacity, businesses and individuals may protect incomes and livelihoods, lower operating and recovery cost, improve productivity and efficiency, enhance food security and price stability and encourage investment and financial inclusion which support sustainable economic growth and poverty reduction. In addition, inadequate and unequal access to financial services especially by poor individuals due to delays arising from inefficiencies, such as decline in agricultural output, results in decline in economic activities and exacerbates existing inequalities. This can worsen the financial condition of the poor rather than enhancing it, leading to increased poverty.

The coefficient of CRR*FI demonstrates that under stronger climate resilience and adaptation capacity, FI considerably reduces poverty at the 1% level.

This is calculated using the maximum value (0.484) of CRR, i.e., greater climate resilience and adaptation capacity ($\frac{dPOV}{dFI}$ = –17.69 – 21.74(0.484) = –28.21) in the DOLS estimates.

Thus, a unit increase in FI reduces poverty by 28.209%.

Similarly, using the maximum value (0.484) of CRR, i.e., greater climate resilience and adaptation capacity ($\frac{dPOV}{dFI}$ = –16.66 – 22.02(0.484) = –27.32) in the FMOLS estimates.

Hence, a unit increase in FI reduces poverty by 27.32%. This implies that in countries with stronger climate resilience, FI effectively reaches its intended beneficiaries and lowers poverty. The finding is supported by Nsiah and Tweneboah (2024) that FI reduces poverty at a greater institutional quality.

Contrariwise, using the minimum value (-1.383) of CRR, i.e., weak climate resilience and adaptation capacity ($\frac{dPOV}{dFI}$= –17.69 – 21.74(–1.383) = 12.38) in the DOLS estimates.

Therefore, raising FI by a unit enhances poverty by 12.38%.

Likewise, using the minimum value (–1.383) of CRR, i.e., lower climate resilience and adaptation capacity ($\frac{dPOV}{dFI}$ = –16.66 – 22.02(–1.383) = 13.80 in the FMOLS estimates.

Under extremely low climate resilience conditions, the poverty-reducing effect of financial inclusion disappears and becomes statistically ineffective. This finding suggests that financial inclusion policies alone may be insufficient in highly climate-vulnerable economies unless accompanied by improvements in climate resilience and adaptive capacity. This outcome shows that FI efforts can be counterproductive in weak climate resilience nations if officials divert resources intended to improving inclusion. Consistent with this outcome are Yiadom et al. (2021) and Kumar and Jie (2023) who confirmed that fragile institutional quality undermines FI initiatives and in turn raises poverty rate.

In addition, high GDPC is associated with poverty alleviation. Poverty decreases by 1.02% for 1% growth in GDPC at the 5% level, highlighting the importance of inclusive economic strategy in reducing poverty in Africa. This corroborates Barak's (2022) study that income impacts poverty negatively.

Also, rising INFL is negatively related to poverty. A 1% increase in INFL lowers poverty by 0.79% and 0.75%, at 5% level and 1% level, respectively. Given that Africa is predominantly an agrarian region, certain economic sectors may gain more from inflation than others. For example, if the prices of agricultural produce rise, the incomes of rural inhabitants and farmers will increase leading to a reduction in poverty. Additionally, moderate inflation can reduce the real burden of nominal debts, allowing low-income individuals and small businesses to repay loans more easily, thus freeing up income for consumption and investment and hence contributing to poverty and unemployment reduction. This aligns with the Phillips curve argument, which suggests a short-run trade-off between inflation and

unemployment, implying that moderate inflation may be associated with increased employment and income. The same outcome was established by Gyeke-Dako et al. (2022) and Nsiah and Tweneboah (2024).

Furthermore, increased MS has a strong reducing impact on poverty. A 1% increase in MS reduces poverty by 0.06% and 0.08%, respectively, at the 1% level. A rising money supply can boost economic activity by lowering interest rates and making lending more accessible. This in turn boosts investment, job creation, economic growth and income, hence reducing poverty. Besides, as the money supply expands, firms and consumers spend more, increasing demand for products and services. Consequently, output increases alongside employment opportunities and consumption, resulting in poverty reduction. The finding supports the results of Goshit and Longduut (2016), who established that money expansion influences poverty negatively.

Furthermore, AGOT affects poverty positively. A 1% increase in AGOT causes poverty to increase by 1.71% and 1.69%, respectively, at the 1% level. The finding contradicts the outcome of prior studies (Christiaensen et al., 2011). The positive influence of AGOT on poverty can be attributed to low agricultural value added in African countries, where a large proportion of farmers produce primarily for consumption rather than the market. This inhibits the sector's potential to generate substantial income required to reduce poverty.

Table 8. Robustness Test Using Panel ARDL (PMG) Estimation (Dependent Variable = Poverty)

Variable	Long-run Coefficient	Std. Error	z-statistic	Probability
Financial Inclusion (FI)	-16.84**	2.21	-7.62	0.000
Climate Resilience and Adaptation Capacity (CRR)	-6.74**	2.49	-2.71	0.007
FI × CRR	-20.91***	3.28	-6.37	0.000
GDP per Capita Growth (GDPC)	-0.96**	0.39	-2.46	0.014
Inflation (INFL)	-0.71***	0.22	-3.23	0.001
Broad Money (% of GDP) (MS)	-0.07***	0.02	-3.58	0.000
Agriculture, Forestry and Fishing Value Added (% of GDP) (AGOT)	1.63***	0.34	4.79	0.000
Error Correction Term (ECT)	-0.681***	0.091	-7.48	0.000

Model Statistics

Statistic	Value
Number of Countries	5
Number of Observations	95
Log Likelihood	-196.44
Akaike Information Criterion (AIC)	4.37
Schwarz Bayesian Criterion (SBIC)	4.81

Note: Dependent variable = Poverty (POV). FI = Financial Inclusion; CRR = Climate Resilience and Adaptation Capacity; GDPC = GDP per capita growth; INFL = Inflation rate; MS = Broad Money (% of GDP); AGOT = Agriculture, Forestry and Fishing Value Added (% of GDP). *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Source: Author's computation using STATA 18 (2026).

To verify the stability of the FMOLS and DOLS estimates, a robustness analysis was conducted using the Panel Autoregressive Distributed Lag (Panel ARDL) Pooled Mean Group (PMG) estimator. The Panel ARDL approach is appropriate because it accommodates variables

integrated of order I(0) and I(1), distinguishes between short-run and long-run dynamics, and provides an additional check on the consistency of the estimated long-run relationships.

The robustness results are highly consistent with the FMOLS and DOLS findings. Financial inclusion continues to exert a significant negative effect on poverty ($\beta = -16.84$, $p < 0.01$), confirming that improved access to financial services contributes to long-run poverty reduction. Likewise, climate resilience and adaptation capacity remain negatively associated with poverty ($\beta = -6.74$, $p < 0.05$), indicating that stronger resilience reduces poverty vulnerability.

The interaction term between financial inclusion and climate resilience remains negative and highly significant ($\beta = -20.91$, $p < 0.01$), confirming that climate resilience strengthens the poverty-reducing effect of financial inclusion. The control variables also retain their expected signs and statistical significance. GDP per capita growth, inflation, and broad money reduce poverty, whereas agricultural value added continues to exhibit a positive association with poverty.

Furthermore, the error correction coefficient (ECT = −0.681, $p < 0.01$) is negative and statistically significant, demonstrating that approximately 68.1% of any short-run disequilibrium is corrected within one year. This confirms the existence of a stable long-run equilibrium relationship among the variables.

Overall, the consistency of the Panel ARDL estimates with the FMOLS and DOLS results demonstrates that the empirical findings are robust to alternative estimation techniques and are not driven by model specification. This provides additional confidence in the conclusion that climate resilience enhances the effectiveness of financial inclusion in reducing poverty across Africa's most unbanked nations.

5. Conclusion

The study examines how climate resilience affects the financial inclusion–poverty nexus in Africa's most unbanked countries from 2004 to 2022, utilizing DOLS and FMOLS estimators. The findings based on cointegration test indicate that financial inclusion and poverty (including income growth, inflation, agricultural output, and money supply) have a long-run relation. The results reveal that the influence of financial inclusion on poverty depends on climate resilience and adaptation capacity. Financial inclusion significantly reduces poverty, and its effectiveness dependents on climate resilience and adaptation. In countries with stronger climate resilience and adaptation, financial inclusion has a greater impact on reducing poverty. In contrast, in nations with weaker climate resilience and limited adaptive capacity, the poverty-reducing benefits of financial inclusion significantly diminish.

Furthermore, GDP per capita growth, inflation, and money supply have significant negative impacts on poverty, while agricultural output appears not to contribute to poverty reduction. The consistent signs, magnitudes, and significance levels of the coefficients of financial inclusion and climate resilience (including their interaction) in both estimates provide strong support for the robustness of the results.

In sum, the study highlights the critical role of climate resilience and adaptability in enhancing the effectiveness of financial inclusion policies. It examined the long-run impact of climate resilience and financial inclusion on poverty using panel FMOLS and DOLS estimations. The results show that weak climate resilience increases poverty vulnerability, financial inclusion significantly mitigates its impact. The interaction effect highlights financial inclusion as a powerful tool for enhancing climate resilience. Thus, to ensure that financial inclusion is effective in reducing poverty in Africa, policymakers are advised to employ policies that mitigate climate change. Climate finance policies should prioritize inclusive financial infrastructure. These can be achieved through strengthening climate adaptation policies, climate resilience infrastructure, disaster preparedness, early warning systems and investment in climate-resilient financial systems. Consequently, intended beneficiaries will receive the needed resources to fully benefit from financial inclusion programmes. Greater financial inclusion will raise individuals' and businesses' capacity to engage in economic activities, leading to increased output, more job creation, high incomes, and decline in poverty rate. Governments should integrate financial inclusion into climate adaptation strategies. Expansion of mobile financial services can enhance resilience among rural and poor households.

A key limitation of this research is that it focuses only on Africa's most unbanked countries, which may limit the generalizability of the findings to

more financially integrated nations. Additionally, the use of secondary data may not fully capture informal financial activities or localized climate related impacts, potentially understating their true effects. Therefore, future studies can extend their analysis to include a broader set of African countries. Researchers may also explore the role of digital financial services, financial literacy, and institutional quality as mediators in the financial inclusion–poverty nexus. Employing more granular data such as household-level or regional data could offer deeper insights into the mechanisms through which financial inclusion and climate resilience interact to affect poverty. Also, future studies could incorporate climate intensity indices and disaggregated household-level data to strengthen causal inference. Also, this study conducted a robustness test and analysis using Panel ARDL, future studies should verify robustness using System GMM or CCEMG.

Author Contributions

Ayuk Takemeyang Conceived the topic and manuscript. Henry Jong Ketuma and Tambi Andison Akpor review and revised the manuscript, enhancing its content, clarity and accuracy met the highest standards.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgement

Not applicable.

Declaration of Funding

No funding.

Data Availability

The data set generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of Competing Interest

The authors declare no competing interest.

Clinical Trial Number

Not applicable.

Ethics Consent to Participate and Consent to Publish Declaration

Not applicable.

Consent to Participate

Not applicable.

References

Abu, N., & Staniewski, M. W. (2019). Determinants of corruption in Nigeria: Evidence from various estimation techniques. *Economic Research-Ekonomska Istraživanja, 32*(1), 3052–3076. https://doi.org/10.1080/1331677X.2019.1655467

Abu, N., & Staniewski, M. W. (2022). An empirical investigation of the effect of corruption on domestic savings in Nigeria. *Economic Research-Ekonomska Istraživanja, 35*(2), 4092–4112. https://doi.org/10.1080/1331677X.2021.2010111

Abu, N., Karim, M. Z. A., & Aziz, M. I. A. (2015a). Corruption, political instability and economic development in the Economic Community of West African States (ECOWAS): Is there a causal relationship? *Contemporary Economics, 9*(1), 45–60. https://doi.org/10.5709/ce.1897-9254.159

Abu, N., Karim, M. Z. A., & Aziz, M. I. A. (2015b). Low savings rates in the Economic Community of West African States (ECOWAS): The role of corruption. *Journal of Economic Cooperation and Development, 36*(2), 63–90.

Abu, N., Sakanko, M. A., David, J., Gamal, A. A. M., & Obi, B. (2022). Does financial inclusion reduce poverty in Niger State? Evidence from logistic regression technique. *Organizations and Markets in Emerging Economies, 13*(2), 443–466. https://doi.org/10.15388/omee.2022.13.88

Andrian, T., Sitorus, N., Febriana, I., & Chandra, S. (2021). Financial inclusion and its effect on poverty in Indonesia. *Jurnal Paradigma Ekonomi, 16*(1), 97–108. https://doi.org/10.22437/jpe.v16i1.12083

Anga, R. A., Sakanko, M. A., & Abdullahi, M. A. (2021). Modelling the effect of financial inclusion on SMEs in Nigeria. *Al-Hikmah Journal of Economics, 2*(1), 33–43.

Anifowose, O. L., & Chummun, B. Z. (2025). Impacts of financial inclusion and life insurance products on poverty in Sub-Saharan African countries. *Risks, 13*(6), 109. https://doi.org/10.3390/risks13060109

Anjande, G., Asom, S. T., Ayila, N., Mile, B. N., & Ijirshar, V. U. (2022). Government spending and money supply roles in alleviating poverty in Africa. *arXiv*.

https://doi.org/10.48550/arXiv.2209.14443

Appiah-Otoo, I., Chen, X., Song, N., & Dumor, K. (2022). Financial development, institutional improvement and poverty reduction: The multiple challenges in West Africa. *Journal of Policy Modeling, 44*(6), 1296–1312. https://doi.org/10.1016/j.jpolmod.2022.11.002

Aracil, E., Gómez-Bengoechea, G., & Moreno-de-Tejada, O. (2022). Institutional quality and the financial inclusion–poverty alleviation link: Empirical evidence across countries. *Borsa Istanbul Review, 22*(1), 179–188. https://doi.org/10.1016/j.bir.2021.03.006

Bakari, I., Donga, M., Idi, A., Hedima, J., Wilson, K., Babayo, H., & Ibrahim, Y. (2019). An examination of the impact of financial inclusion on poverty reduction: Empirical evidence from Sub-Saharan Africa. *International Journal of Scientific and Research Publications, 9*(1), 239–252. https://doi.org/10.29322/IJSRP.9.01.2019.p8532

Barak, D. (2022). The impact of income inequality, renewable energy consumption, non-renewable energy consumption and per capita income on poverty: Evidence from BRICS economies. *Ekonomika, 101*(1), 62–83. https://doi.org/10.15388/Ekon.2022.101.1.4

Beck, N., & Katz, J. N. (1995). What to do (and not to do) with time-series cross-section data. *American Political Science Review, 89*(3), 634–647.

Beck, T., Demirgüç-Kunt, A., & Levine, R. (2007). Finance, inequality and the poor. *Journal of Economic Growth, 12*(1), 27–49. https://doi.org/10.1007/s10887-007-9010-6

Bukari, C., & Acheampong, A. O. (2025). Mitigating the impact of climate change on poverty in Africa: The moderating role of financial inclusion. *Finance Research Letters, 84*, 107853. https://doi.org/10.1016/j.frl.2025.107853

Chambers, R., & Conway, G. (1992). *Sustainable rural livelihoods: Practical concepts for the 21st century*. Institute of Development Studies.

Christiaensen, L., Demery, L., & Kuhl, J. (2011). The evolving role of agriculture in poverty reduction: An empirical perspective. *Journal of Development Economics, 96*(2), 239–254. https://doi.org/10.1016/j.jdeveco.2010.10.006

Demirgüç-Kunt, A., & Klapper, L. (2013). Measuring financial inclusion: Explaining variation in use of financial services across and within countries. *Brookings Papers on Economic Activity*, 279–340.

Demirgüç-Kunt, A., Klapper, L., Singer, D., Ansar, S., & Hess, J. (2018). *The Global Findex Database 2017: Measuring financial inclusion and the fintech revolution*. World Bank. https://doi.org/10.1596/978-1-4648-1259-0

Demirgüç-Kunt, A., Martínez Pería, M. S., & Tressel, T. (2018). *The global financial inclusion index*. World Bank.

Dogan, E., Madaleno, M., & Taskin, D. (2022). Financial inclusion and poverty: Evidence from Turkish household survey data. *Applied Economics, 54*(19), 2135–2147. https://doi.org/10.1080/00036846.2021.1985076

Ellis, F. (2000). *Rural livelihoods and diversity in developing countries*. Oxford University Press.

Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D., & Vogt-Schilb, A. (2016). *Shock waves: Managing the impacts of climate change on poverty*. World Bank.

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. Cambridge University Press.

Kao, C., & Chiang, M.-H. (2001). On the estimation and inference of a cointegrated regression in panel data. In B. H. Baltagi, T. B. Fomby, & R. C. Hill (Eds.), *Nonstationary panels, panel cointegration, and dynamic panels* (pp. 179–222). Emerald Group Publishing. https://doi.org/10.1016/S0731-9053(00)15007-8

Khan, N., Zafar, M., Okunlola, A. F., Zoltan, Z., & Robert, M. (2022). Effects of financial inclusion on economic growth, poverty, sustainability and financial efficiency: Evidence from the G20 countries. *Sustainability, 14*(19), 12688.

Kumar, S. S., & Jie, Q. (2023). Exploring the role of financial inclusion in poverty reduction: An empirical study. *World Development Sustainability, 3*, 100103. https://doi.org/10.1016/j.wds.2023.100103

Levine, R. (2005). Finance and growth: Theory and evidence. In P. Aghion & S. Durlauf

(Eds.), *Handbook of economic growth* (Vol. 1, pp. 865–934). Elsevier.

Li, L. (2018). Financial inclusion and poverty: The role of relative income. *China Economic Review, 52*, 165–191. https://doi.org/10.1016/j.chieco.2018.07.006

Mark, N. C., & Sul, D. (2003). Cointegration vector estimation by panel DOLS and long-run money demand. *Oxford Bulletin of Economics and Statistics, 65*(5), 655–680. https://doi.org/10.1111/1468-0084.00066

McKinnon, R. I. (1973). *Money and capital in economic development*. Brookings Institution.

Nguyen, T. T. H. (2020). Measuring financial inclusion: A composite financial inclusion index for developing countries. *Journal of Economics and Development, 23*(1), 77–99.

Notre Dame Global Adaptation Initiative. (2024). *ND-GAIN Country Index technical report*. University of Notre Dame.

Nsiah, A. Y., & Tweneboah, G. (2024). Threshold effect of financial inclusion on poverty reduction in Africa: Does institutional quality play a role? *Journal of African Business*, 1–35.

World Bank. (2020). *Global Findex database 2020*. World Bank.

World Bank. (2024). *World development indicators*. World Bank.