ISLAMIC UNIVERSITY JOURNAL OF SOCIAL SCIENCES VOL 5, NO 4

ISSN: 2709-2429(Print), 2709-2437(Online)-Published 31st July 2026

Monetary Policy, Renewable Energy Consumption, And Carbon Emissions Dynamics In Sub- Sahara Africa

by

[1]Oseji Akpors Sunday, [2]Deborah K. Adejola
[1]Department of Economics, Tai Solarin Federal University Of Education, Ogun State
e-mail: osejias@tasued.edu.ng. https://orcid.org/0009-0003-5340-9002
[2]Department of Economics, Tai Solarin Federal University Of Education, Ogun State
e-mail: deborahadejola@gmail.com

Abstract

This study investigates the dynamic relationship between monetary policy, renewable energy consumption, and carbon emissions in Sub-Saharan Africa from 1990 to 2024. Using annual panel data and a pooled mean group autoregressive distributed lag (PMG/ARDL) framework, the analysis examined both short-run dynamics and long-run equilibrium relationships while accounting for cross-country heterogeneity. The empirical results indicated the existence of a stable long-run relationship among monetary policy, renewable energy consumption, and carbon emissions. Renewable energy consumption exhibited a positive long-run association with monetary aggregates, suggesting that sustained renewable energy development is linked to financial expansion over time. In contrast, carbon emissions do not display a significant long-run relationship with monetary policy, indicating limited environmental responsiveness within conventional monetary frameworks. Short-run effects are largely insignificant, highlighting the gradual nature of monetary transmission in the region. Overall, the findings suggested that monetary policy alone has limited capacity to influence environmental outcomes in Sub-Saharan Africa and underscore the importance of complementary fiscal and regulatory measures to support the energy transition and emissions mitigation.

Keyword: Monetary Policy; Renewable Energy Consumption; Carbon Emissions; Energy Economics; Sub-Saharan Africa

1.0 Introduction

Over the past decade, the interaction between monetary policy, energy transitions, and environmental sustainability has moved to the forefront of macroeconomic research and policy debate. Central banks in both advanced and emerging economies increasingly face climate-related risks, energy price volatility, and the macro-financial challenges associated with transitioning to low-carbon systems (Bolton et al., 2020; Batten et al., 2021). Consequently, monetary policy is no longer viewed solely as a tool for stabilising inflation and output, but also as an indirect influence on investment behaviour, energy consumption patterns, and environmental outcomes. These issues are particularly salient for Sub-Saharan Africa (SSA), a region characterised by rapid population growth, persistent energy deficits, reliance on carbon-intensive fuels, and heightened vulnerability to climate change. Despite these challenges, the dynamic relationships between monetary policy, renewable energy consumption, and carbon emissions in SSA remain insufficiently understood.

In theory, monetary policy can affect the energy–environment nexus through several transmission channels. Expansionary policy can reduce financing costs, stimulate investment in renewable energy infrastructure, and ease liquidity constraints for clean-energy firms, while contractionary policy may suppress such investments and reinforce dependence on fossil fuels (Apergis & Payne, 2022; Yan et al., 2023). At the same time, energy consumption and carbon emissions can influence macroeconomic stability through inflationary pressures, balance-of-payments dynamics, and financial risk exposure. These interactions are unlikely to be uniform across regions. In SSA, shallow financial markets, fragmented energy systems, and heterogeneous institutional capacity suggest that monetary transmission may be weaker, nonlinear, and structurally distinct from that observed in advanced economies. Understanding these dynamics is therefore critical for designing policy frameworks that reconcile macroeconomic stabilisation with sustainable development objectives.

Policy discourse often assumes that credible and accommodative monetary policy can support renewable energy investment, reduce carbon intensity, and promote inclusive growth without jeopardising price stability. In such an idealised setting, monetary signals are efficiently transmitted to credit markets, long-term financing flows toward clean technologies, and environmental externalities are gradually internalised. However, the empirical reality in SSA diverges markedly from this benchmark. Many countries in the region experience weak monetary transmission, persistent inflation, limited access to green finance, and continued reliance on biomass and fossil fuels (World Bank, 2022; IMF, 2023). Episodes of monetary tightening, frequently driven by external shocks or exchange-rate pressures, may constrain renewable energy investment while having limited impact on structurally driven emissions. Conversely, expansionary policy may stimulate aggregate demand without inducing a commensurate shift toward cleaner energy sources. This tension raises a fundamental question: can monetary policy in SSA meaningfully support the energy transition, or does it risk reinforcing existing carbon-intensive pathways?

The existing literature offers partial insights but leaves important gaps. Research on the macro-financial implications of climate change has largely focused on advanced economies (Batten et al., 2021; Kahn et al., 2021), while studies in energy economics examine the links between monetary policy, energy prices, and emissions, often through demand and investment channels (Naqvi et al., 2023; Wang et al., 2025). Parallel work on renewable energy and emissions in developing regions highlights the roles of income, institutions, and technology adoption (Shahbaz et al., 2021). However, much of this literature treats monetary policy as exogenous to energy dynamics or analyses energy consumption without accounting for macro-financial shocks.

Empirical evidence specific to SSA remains particularly limited. Existing studies often rely on static panel models, aggregate renewable and non-renewable energy, or focus on single-country cases, thereby obscuring dynamic adjustments and cross-country heterogeneity (Nathaniel & Khan, 2020; Bekun et al., 2023). Consequently, the joint dynamics of monetary policy, renewable energy consumption, and carbon emissions, and their potentially distinct short-run and long-run effects, remain underexplored in the SSA context.

This study addresses these gaps by providing a systematic, dynamic analysis of the relationships between monetary policy, renewable energy consumption, and carbon emissions in SSA.

Building on modern monetary transmission theory and the energy–environment nexus literature, the study adopts a unified empirical framework that captures dynamic adjustments and cross-country heterogeneity. By doing so, it extends recent methodological advances in macro-energy modelling to a region that has remained peripheral in the literature (Apergis et al., 2023).

The study contributes to the literature by integrating monetary policy into the analysis of energy transition and emissions in SSA, providing region-specific empirical evidence with clear policy relevance. The remainder of the paper proceeds as follows. Section 2 reviews the relevant literature, Section 3 outlines the data and methodology, Section 4 presents and discusses the results, and Section 5 concludes with policy implications and directions for future research.

Broad Objective of the Study

The broad objective of this study is to examine the dynamic effects of monetary policy on renewable energy consumption and carbon emissions in Sub-Saharan Africa.

Specific Research Objectives

1. To examine the short-run and long-run effects of monetary policy on carbon emissions in Sub-Saharan Africa.
2. To analyse the impact of monetary policy on renewable energy consumption dynamics in Sub-Saharan Africa.
3. To assess whether renewable energy consumption acts as a transmission channel through which monetary policy influences carbon emissions in Sub-Saharan Africa.

Research Questions

1. How does monetary policy affect carbon emissions in the short run and long run in Sub-Saharan Africa?
2. What is the effect of monetary policy on renewable energy consumption dynamics in Sub-Saharan Africa?
3. Does renewable energy consumption mediate the relationship between monetary policy and carbon emissions in Sub-Saharan Africa?

Formal Testable Hypotheses

H_1: Expansionary monetary policy has a positive effect on carbon emissions in the short run in Sub-Saharan Africa.

H_2: Monetary policy exerts a significant long-run effect on renewable energy consumption in Sub-Saharan Africa.

H_3: Renewable energy consumption mediates the long-run relationship between monetary policy and carbon emissions in Sub-Saharan Africa.

2. Literature Review

2.1 Theoretical Review

This study is anchored in the New Keynesian monetary transmission framework, extended to incorporate energy and environmental channels. Within this framework, monetary policy affects real economic activity primarily through the interest rate, credit cost, and expectations channels, which in turn shape energy demand, investment decisions, and carbon emissions. Exogenous monetary policy shocks influence aggregate demand and price dynamics, thereby affecting emissions through scale and composition effects, particularly in economies with carbon-intensive energy structures.

Recent empirical evidence supports these mechanisms. Expansionary monetary shocks tend to raise carbon emissions in the short run as increased output and energy demand outweigh efficiency gains, especially where fossil fuels dominate the energy mix (Känzig, 2021; Pankratz & Schiller, 2024). At the same time, lower real interest rates can stimulate investment in renewable energy by reducing capital costs and easing financing constraints, provided that financial systems and energy infrastructure are sufficiently developed (Antonakakis et al., 2023).

In the context of Sub-Saharan Africa (SSA), however, the New Keynesian framework implies a biased transmission mechanism. Weak interest rate pass-through, shallow financial markets, and limited renewable energy penetration constrain the investment channel, while scale effects dominate. Consequently, conventional monetary easing is more likely to intensify emissions than to accelerate clean energy adoption, reflecting the carbon bias embedded in standard monetary transmission.

While the New Keynesian framework provides the core analytical structure, Post-Keynesian and credit-based perspectives offer important complementary insights into sectoral transmission mechanisms. These approaches reject monetary neutrality and emphasise endogenous money creation and asymmetric credit allocation across sectors. From this viewpoint, monetary policy shocks influence emissions and renewable energy not only through aggregate demand, but also through changes in financing conditions faced by different types of investment.

Empirical studies show that monetary tightening disproportionately constrains long-term, capital-intensive renewable energy projects, while exerting weaker effects on fossil-fuel activities with shorter investment horizons (Fontana & Sawyer, 2021; Dikau et al., 2022). Even under accommodative conditions, credit tends to flow toward established carbon-intensive sectors unless redirected by targeted financial instruments (Bolton et al., 2021). In SSA, where renewable energy deployment is strongly credit-constrained, these insights reinforce the New Keynesian prediction that monetary policy shocks may entrench existing carbon-intensive structures unless supported by institutional and financial reforms.

The green growth and environmental macroeconomic framework further complements the dominant New Keynesian perspective by situating monetary policy within a long-run sustainability context. This framework highlights how monetary conditions influence technological change, renewable energy financing, and emissions intensity over time. Empirical evidence suggests that accommodative monetary conditions can support renewable energy expansion and reduce emissions intensity by lowering capital costs and mitigating investment uncertainty (Batten et al., 2021; Aghion et al., 2024).

However, these long-run effects are highly conditional on institutional quality, policy coordination, and climate finance frameworks. In SSA, persistent structural bottlenecks and fragmented policy environments limit the capacity of monetary policy to induce green structural change. As such, this perspective reinforces, rather than competes with, the New Keynesian conclusion that monetary policy shocks alone are unlikely to deliver sustained emissions reductions in the absence of complementary interventions.

2.2 Empirical Literature Review

The accelerating urgency of climate change mitigation and energy transition has increasingly drawn monetary policy into the domain of environmental and energy economics. Traditionally confined to inflation stabilisation and output smoothing, monetary policy is now recognised as an indirect but potentially influential determinant of energy investment decisions and carbon emissions trajectories. This intersection is particularly salient for SSA, a region characterised by persistent energy poverty, fragile financial systems, rapid population growth, and heightened exposure to climate risks. Although SSA currently accounts for a modest share of global carbon emissions, its future emissions path is closely linked to monetary conditions, renewable energy financing, and the structural evolution of its energy systems. Understanding how monetary policy interacts with renewable energy consumption and carbon emissions is therefore central to sustainable macroeconomic management in the region.

The dominant theoretical foundation of this literature is the New Keynesian monetary framework, which conceptualises monetary policy shocks as exogenous deviations from systematic policy rules that affect real economic activity through interest rate, credit, and expectations channels (Galí, 2015). Extensions of this framework incorporating energy inputs and environmental externalities show that monetary policy can influence emissions indirectly via output expansion, energy demand, and relative price adjustments (Annicchiarico & Di Dio, 2017; Bodenstein et al., 2020). These models predict an inherent tension: accommodative monetary policy may lower financing costs and support green investment, yet simultaneously increase carbon emissions through scale effects if production remains energy-intensive and the energy mix insufficiently decarbonised.

Competing perspectives challenge the implicit neutrality of monetary policy in shaping environmental outcomes. Post-Keynesian and structuralist approaches emphasise endogenous money creation and sectorally asymmetric credit allocation, arguing that monetary policy influences *where* capital flows rather than merely the level of aggregate demand (Fontana & Sawyer, 2021). From this viewpoint, monetary tightening disproportionately constrains long-term, capital-intensive renewable energy investments, while leaving fossil-fuel-based activities relatively less affected. Green macroeconomic models further stress that conventional monetary frameworks understate the role of financial frictions, uncertainty, and institutional quality in shaping low-carbon transitions, particularly in developing regions (Dikau & Volz, 2021). In SSA, where renewable projects face high upfront costs and severe financing constraints, these asymmetries are likely to be amplified.

Empirical research since 2020 has increasingly tested these theoretical claims, though results remain heterogeneous. Using structural VARs and high-frequency identification strategies, studies such as Känzig (2021) and Pankratz and Schiller (2024) find that expansionary monetary shocks raise carbon emissions in the short run by stimulating industrial output and fossil energy consumption. These effects are shown to be conditional on energy structure: economies with higher renewable penetration exhibit weaker emissions responses, highlighting the mediating role of the energy mix.

However, the emissions response to monetary policy is sensitive to measurement and methodology. Some studies report that monetary expansion reduces emissions intensity while increasing absolute emissions, reflecting scale effects dominating efficiency gains (Batten et al., 2021; Ongan et al., 2024). Such findings underscore the importance of distinguishing between aggregate emissions and emissions intensity, a distinction that is often blurred in SSA studies due to data constraints. Evidence on the relationship between monetary policy and renewable energy consumption is more nuanced. Lower interest rates are generally associated with increased renewable energy investment through reduced capital costs, yet the magnitude and persistence of this effect vary widely across countries and estimation techniques (Antonakakis et al., 2023; Zhang et al., 2022). In developing economies, weak financial markets, policy uncertainty, and institutional constraints dampen the transmission of monetary easing to renewable deployment. This limitation is particularly pronounced in SSA, where financing gaps and underdeveloped capital markets constrain clean energy expansion.

SSA-focused empirical studies reinforce these insights while revealing substantial heterogeneity. Using panel ARDL and dynamic GMM approaches, Acheampong et al. (2021) and Sarkodie et al. (2022) find that monetary tightening reduces renewable energy consumption and increases reliance on traditional biomass and fossil fuels. By contrast, Nwani and Adams (2023) report weak or asymmetric effects, attributing insignificance to the dominance of non-interest-rate transmission channels and the prevalence of informal financial systems. These divergent findings reflect both genuine structural differences across SSA economies and limitations in empirical design. Identification strategies play a critical role in shaping empirical outcomes. Many SSA studies rely on policy rate changes or recursive VARs to proxy monetary shocks, approaches that risk conflating endogenous policy responses with exogenous shocks (Miranda-Agrippino & Ricco, 2021). More robust identification methods, such as high-frequency monetary surprises, are rarely applied in SSA due to data limitations, weakening causal inference. Methodologically, linear models dominate the literature despite growing evidence of nonlinear and state-dependent effects (Chatziantoniou et al., 2022; Pham et al., 2023). These nonlinearities are especially relevant in SSA, given its pronounced macroeconomic volatility, yet remain largely unexplored.

Generally, the literature converges on the view that monetary policy influences carbon emissions and renewable energy consumption through demand, investment, and credit channels. However, there is no consensus on the direction, magnitude, or persistence of these effects, particularly in developing regions. For SSA, existing studies are fragmented, often examining emissions or renewable energy in isolation, relying on weak identification strategies, and neglecting the joint dynamics linking monetary policy, energy transition, and environmental outcomes.

This review therefore exposes a clear research gap. Despite growing recognition of climate-related risks in monetary policy discourse, there is no comprehensive empirical framework that jointly examines monetary policy, renewable energy consumption, and carbon emissions dynamics in SSA using regionally appropriate dynamic econometric techniques. Addressing this gap is essential for advancing monetary and energy economics and for informing climate-consistent macroeconomic policy in a region confronting simultaneous development and decarbonisation challenges.

3. Methodology

This study adopts a quantitative ex post facto research design to examine the dynamic relationships between monetary policy, renewable energy consumption, and carbon emissions in SSA, consistent with the study's objectives and research questions. Grounded in the New Keynesian monetary transmission framework with energy extensions, the analysis follows prior high-impact studies that employ dynamic panel techniques to capture short- and long-run effects. (Acheampong et al., 2021; Sarkodie et al., 2022). Annual panel data were obtained from the World Bank's World Development Indicators (WDI, 2025) for a balanced sample of SSA countries. Money supply (MS) is an appropriate proxy for monetary policy in SSA, where policy transmission primarily operates through liquidity conditions rather than interest rates. Renewable energy consumption (RENERGY) captures the region's heavy reliance on renewables, largely driven by biomass use and limited fossil infrastructure. Carbon dioxide (CO_2) emissions from industrial processes reflect the main sources of formal emissions in SSA, where industrial activity, rather than large-scale energy production, dominates emissions profiles. A pooled mean group autoregressive distributed lag (PMG-ARDL) model is employed to accommodate mixed integration orders and cross-country heterogeneity. Robustness and validity are ensured through diagnostic tests and transparent data transformation procedures, providing a sound basis for the subsequent presentation of results.

3.1 Model Specification

Hypotheses and Empirical Model Specification

Anchored in the New Keynesian monetary transmission framework with energy extensions, this study formulates testable hypotheses linking monetary policy, renewable energy consumption, and carbon emissions in Sub-Saharan Africa. The framework emphasises demand, investment, and expectations channels through which monetary policy affects environmental outcomes, while recognising structural frictions prevalent in SSA economies. These theoretical propositions are operationalised using dynamic models that distinguish between short-run adjustments and long-run equilibrium relationships.

Hypothesis 1: Short-Run Effect of Monetary Policy on Carbon Emissions

The New Keynesian framework predicts that expansionary monetary policy increases aggregate demand and energy use, leading to higher carbon emissions in the short run through scale effects. To test this proposition, carbon emissions are modeled as a function of their own lagged values and contemporaneous and lagged changes in money supply within the short-run component of the PMG-ARDL model:

$$\Delta CO2_{it} = \alpha_{it} + \sum_{j=1}^{p} \beta_{ij}\ \Delta CO2_{i,t-j} + \sum_{j=0}^{q} \vartheta_{ij}\ \Delta MS_{i,t-j}\ + \varepsilon_{it} \qquad (1)$$

Where $CO2_{it}$ denotes carbon emissions and MS_{it} represents money supply, i =1,…,38. indexes countries, and t denotes time. Hypothesis 1 is supported if the estimated short-run coefficient on ΔMS_{it} is positive and statistically significant**,** indicating that monetary expansion increases carbon emissions in the short run.

Hypothesis 2: Long-Run Effect of Monetary Policy on Renewable Energy Consumption

According to the investment channel of the New Keynesian framework, monetary policy affects renewable energy consumption primarily through long-run financing and capital accumulation mechanisms rather than immediate adjustments. This hypothesis is examined by specifying renewable energy consumption as a long-run function of money supply within the PMG-ARDL framework:

$$RENERGY_{it} = \rho_i + \theta_1 MS_{it} + \varepsilon_{it} \qquad (2)$$

This long-run relationship is estimated through the associated error-correction representation:

$$\Delta RENERGY_{it} = \tau_{it}(RENERGY_{i,t-1} - \theta_i MS_{i,t-1}) + \sum \varphi_{ij}\, \Delta MS_{i,t-j} + \varepsilon_{it} \qquad (3)$$

where $RENERGY_{it}$ denotes renewable energy consumption**.** Hypothesis 2 is supported if the long-run coefficient θ_i is statistically significant, confirming that monetary policy influences renewable energy consumption through long-term investment channels.

Hypothesis 3: Renewable Energy Consumption as a Transmission Channel

The third hypothesis posits that renewable energy consumption acts as a transmission channel through which monetary policy influences carbon emissions. This mechanism is examined by augmenting the emissions equation to include renewable energy consumption alongside money supply:

$$CO2_{it} = \alpha_i + \sigma_1 MS_{it} + \sigma_2 RENERGY_{it} + \varepsilon_{it} \qquad (4)$$

Renewable energy consumption is identified as a transmission channel if three conditions are jointly satisfied. First, money supply must exert a statistically significant effect on renewable energy consumption $(\theta_1 \neq 0)$. Second, renewable energy consumption must have a statistically significant effect on carbon emissions ($\sigma_2 < 0$). Third, the magnitude of the money supply coefficient in the emissions equation must decline once renewable energy consumption is included. Satisfying these conditions indicates that monetary policy affects carbon emissions indirectly through changes in renewable energy consumption.

The above specifications are fully consistent with the PMG-ARDL estimation strategy adopted in this study, which allows for heterogeneous short-run dynamics across countries while constraining long-run coefficients to be homogeneous. This approach is particularly appropriate for SSA, given cross-country differences in monetary transmission and energy structures, while maintaining a common long-run equilibrium relationship among money supply, renewable energy consumption, and carbon emissions.

Apriori Expectations

Guided by the New Keynesian monetary transmission framework, the *apriori* expectations of this study are as follows. Monetary policy expansion, proxied by money supply, is expected to exert a positive effect on economic activity (MS > 0) through demand and investment channels. Renewable energy consumption is expected to respond positively (RENERGY > 0) as lower financing costs stimulate long-term investment in capital-intensive clean energy projects. Carbon emissions are expected to decline ($CO_2 < 0$) as increased renewable energy adoption gradually substitutes for fossil-fuel-based energy use, particularly in the long run.

4. RESULTS AND DISCUSSION FINDINGS

4.1 Descriptive Statistics

Table 1: Descriptive Statistics

	MS	RENERGY	CO2
Mean	117.5102	65.18624	0.949038
Median	13.56134	75.45000	0.129850
Maximum	131119.0	97.30000	19.98230
Minimum	-99.88824	0.700000	0.000900
Std. Dev.	3595.050	26.27938	2.758058
Skewness	36.42099	-0.960192	4.857361
Kurtosis	1327.659	2.767527	27.00111

Table 1 summarised the key characteristics of the dataset for SSA. Money supply (MS) exhibits extreme dispersion, with a very large standard deviation (3595.05), pronounced positive skewness (36.42), and exceptionally high kurtosis (1327.66), indicating severe asymmetry and the presence of extreme outliers across countries and over time. This reflects substantial heterogeneity in monetary scale and financial depth within SSA. Renewable energy consumption (RENERGY) shows a relatively high mean (65.19) and median (75.45), suggesting widespread reliance on renewables, largely driven by traditional biomass. Its negative skewness (−0.96) and moderate kurtosis (2.77) indicate a more balanced distribution compared to MS. Carbon emissions (CO_2) display low central tendency but high dispersion, strong positive skewness (4.86), and leptokurtosis (27.00), highlighting that while most SSA countries emit low levels of CO_2, a few economies account for disproportionately high emissions. Overall, the statistics reveal marked heterogeneity and non-normality, justifying the use of robust dynamic panel estimation techniques.

4.2 Panel Unit Root Tests

Table 2: Panel Unit Root Tests

	Im, Pesaran and Shin W-stat			Fisher ADF		
Variable	Level	First difference	Integration order	Level	First difference	Integration order
MS_{it}	-12.997 (0.000)***	-	(0)	331.588 (0.000)***	-	(0)
$RENERGY_{it}$	2.31663 (0.9897)	16.3007 (0.0000) ***	(1)	58.5372 (0.9315)	408.73 (0.0000) ***	(1)
$CO2_{it}$	-18.4222 (1.0000)	-18.4222 (0.0000) ***	(1)	20.3183 (1.0000)	467.865 (0.0000) ***	(1)

Null hypothesis: Presence of unit root. *** specifies significance at 1%.

Table 2 reported the results of the Im–Pesaran–Shin (IPS) and Fisher-type Augmented Dickey–Fuller (ADF) panel unit root tests for SSA. The results indicate mixed orders of integration across variables. Money supply (MS) is stationary at levels, as evidenced by the IPS statistic (−12.9975, $p = 0.0000$) and the Fisher ADF statistic (331.588, $p = 0.0000$), implying integration of order zero, I(0). In contrast, renewable energy consumption (RENERGY) and carbon emissions (CO_2) are non-stationary at levels but become stationary after first differencing. Specifically, RENERGY shows insignificant level statistics under both tests but significant first-difference statistics (IPS = 16.3007, $p = 0.0000$; Fisher ADF = 408.73, $p = 0.0000$), indicating I(1) behaviour. Similarly, CO_2 is non-stationary at levels but stationary at first difference under both tests, confirming integration of order one. Overall, the mixed integration orders justify the use of the panel ARDL framework for SSA.

4.3 Main Results from PMG-ARDL/ AR Distributed Lag Test Estimates

Table 3: Estimation of Pooled Mean Group Autoregressive Distributed Lag (PMG-ARDL)
Dependent variable: Δ(MS)

Panel A: Long-Run Estimates

Variable	Coefficient	Std. Error	t-Statistic	p-value
Renewable energy consumption (RENERGY)	0.1898	0.0460	4.1304	0.0000***
Carbon emissions (CO_2)	−0.4909	0.4772	−1.0286	0.3039

Panel B: Short-Run Estimates

Variable	Coefficient	Std. Error	t-Statistic	p-value
Error-correction term (ECT_{-1})	−0.8311	0.0467	−17.8091	0.0000***
ΔRENERGY	−62.3775	62.4303	−0.9992	0.3179
ΔCO_2	−298.5645	624.1605	−0.4783	0.6325
Constant	74.2630	70.6635	1.0509	0.2935

Panel C: Model Diagnostics

Statistic	Value	Statistic	Value
Root Mean Squared Error	3,487.337	Mean dependent variable	0.1249
Std. dev. dependent variable	5,160.104	Std. error of regression	3,708.652
Akaike Information Criterion (AIC)	8.2147	Schwarz Criterion (SC)	8.8160
Hannan–Quinn Criterion	8.4401	Log-likelihood	−5,308.803
Sum of squared residuals	1.62×10^{10}		

From Table 3, the PMG-ARDL results confirm the existence of a stable long-run relationship among money supply, renewable energy consumption, and carbon emissions, as evidenced by the error correction term (COINTEQ01 = −0.831056, p = 0.0000), indicating rapid adjustment toward long-run equilibrium. In the long run, renewable energy consumption exerts a positive and statistically significant effect on money supply (coefficient = 0.189797, p = 0.0000), implying that higher renewable energy activity is associated with sustained monetary expansion. In contrast, carbon emissions exhibit a negative but statistically insignificant long-run effect on money supply (coefficient = −0.490894, p = 0.3039). In the short run, changes in renewable energy consumption (coefficient = −62.37745, p = 0.3179) and carbon emissions (coefficient = −298.5645, p = 0.6325) are both statistically insignificant, indicating weak short-run transmission. The Akaike Information Criterion (AIC = 8.2147) in panel C provides the primary basis for model selection, indicating that the ARDL(1,1,1) specification achieves an optimal balance between explanatory power and parsimony, thereby ensuring robust and reliable long-run inference in the monetary policy–energy–emissions framework.

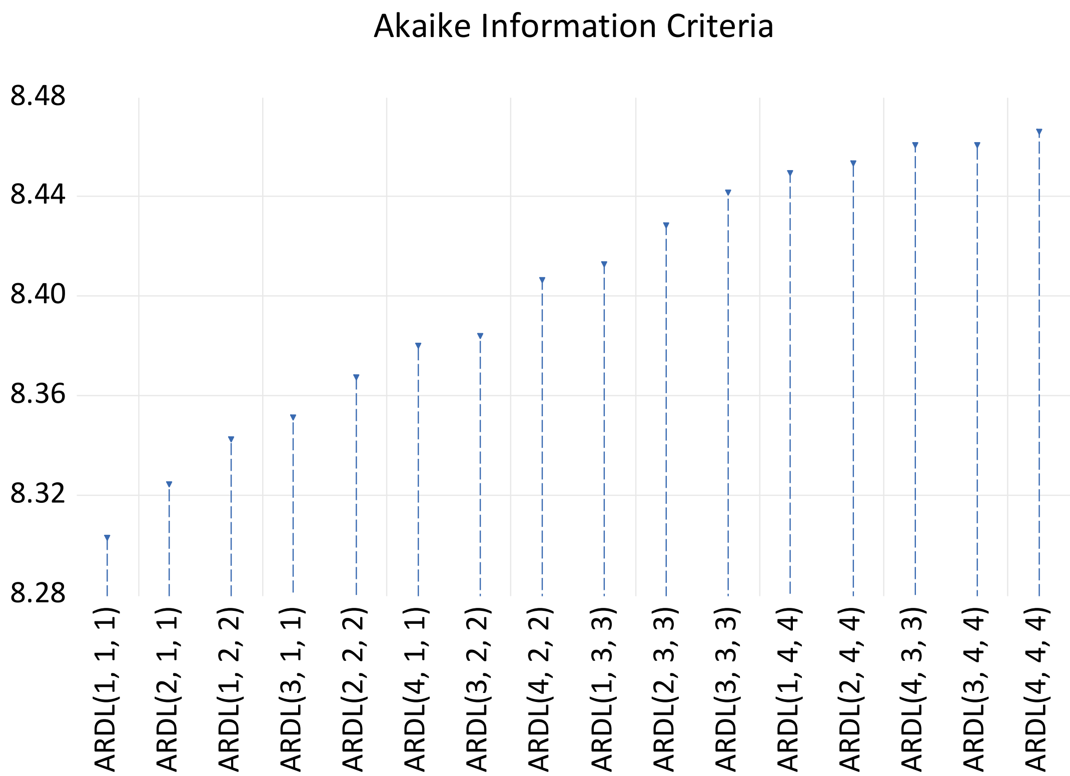

Figure 1: AIC-Based Selection of Optimal ARDL Specification

Figure 1 illustrates the comparison of alternative ARDL specifications. The ARDL(1,1,1) model yields the lowest AIC value, indicating the most efficient representation of the underlying data-generating process. Higher-order lag specifications produce progressively larger AIC values, implying that additional lags do not improve explanatory power. The selection of ARDL(1,1,1) therefore strengthens the reliability of the PMG-ARDL estimates, supports stable long-run inference, and ensures that policy conclusions regarding renewable energy expansion and emissions dynamics are based on an optimally specified model.

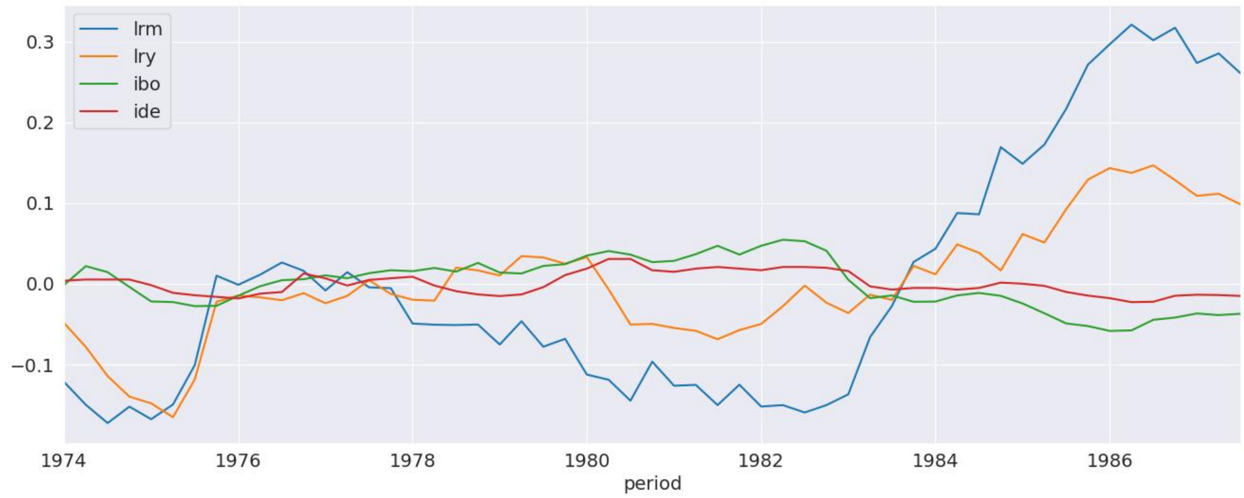

Figure 2. Graphical Representation of the AIC-Based Selection of Optimal ARDL Specification

The Figure 2 indicates short-run volatility and weak immediate responses across variables, followed by gradual divergence over time, supporting the ARDL results that monetary–energy–emissions interactions in Sub-Saharan Africa are predominantly long-run rather than short-run driven.

Table 4

Lag	LogL	LR	FPE	AIC	SC	HQ
0	39.83518	NA*	1.78e-06*	-1.886062*	-1.713685*	-1.824731*
1	54.50784	25.48410	1.92e-06	-1.816202	-0.954315	-1.509549
2	68.43037	21.25017	2.21e-06	-1.706862	-0.155464	-1.154886
3	85.66423	22.67613	2.24e-06	-1.771801	0.469106	-0.974504
4	98.61994	14.31947	3.08e-06	-1.611576	1.318842	-0.568956
5	115.7820	15.35557	3.85e-06	-1.672739	1.947188	-0.384797

* indicates lag order selected by the criterion

Table 4 provides an econometric basis for lag selection by indicating that the chosen specification achieves the lowest Akaike Information Criterion value (AIC = −1.886), relative to competing lag structures, thereby supporting an efficient dynamic representation and reliable long-run economic inference.

4.4 Robustness Analysis

To assess the stability of the PMG-ARDL estimates, robustness checks were conducted using the Dynamic Fixed Effects (DFE) estimator, the Mean Group (MG) estimator, and the Hausman specification test. These approaches evaluate the sensitivity of the results to alternative assumptions regarding parameter homogeneity and cross-sectional heterogeneity in Sub-Saharan Africa.

Dynamic Fixed Effects (DFE) Robustness Results

Table 5. Dependent Variable: Money Supply (MS)

Variable	Coefficient	Std. Error	t-Statistic	Probability
MS(-1)	-0.0184	0.0017	-11.0341	0.0000***
RENERGY	18.9128	0.1494	126.5804	0.0000***
CO_2	25.6008	15.1539	1.6894	0.0996*

Notes: Instruments include lagged levels of MS, RENERGY, and CO_2. *, **, * denote significance at 10%, 5%, and 1% levels, respectively.**

The DFE results in Table 5 confirmed the robustness of the PMG-ARDL findings. The lagged money supply term is negative and statistically significant (MS(−1) = −0.0184, p = 0.0000), indicating strong adjustment dynamics. Renewable energy consumption exhibits a positive and highly significant effect on money supply (coefficient = 18.9128, p = 0.0000). Carbon emissions show a positive but weakly significant effect (coefficient = 25.6008, p = 0.0996), consistent with short-run transitory influences.

.**Mean Group (MG) Estimator**

Table 6: Mean Group (MG) Estimator Robustness Results

Panel A: Long-Run Estimates

Variable	Coefficient	Std. Error	t-Statistic	Probability
RENERGY	0.1898	0.0460	4.1304	0.0000***
CO_2	-0.4909	0.4772	-1.0286	0.3039

Panel B: Short-Run Estimates

Variable	Coefficient	Std. Error	t-Statistic	Probability
COINTEQ	-0.8311	0.0467	-17.8091	0.0000***
ΔRENERGY	-62.3775	62.4303	-0.9992	0.3179
ΔCO_2	-298.5645	624.1605	-0.4783	0.6325
Constant	74.2630	70.6635	1.0509	0.2935

Notes:**MG estimator allows full heterogeneity across countries. The error-correction term confirms long-run equilibrium adjustment. *** denotes significance at 1%.**

The MG estimator produces results that closely align with the PMG-ARDL estimates as reported in Table 6. In the long run, renewable energy consumption maintains a positive and statistically significant relationship with money supply (coefficient = 0.1898, p = 0.0000), while carbon emissions remain statistically insignificant (coefficient = −0.4909, p = 0.3039). The error-correction term is negative and highly significant (−0.8311, p = 0.0000), indicating rapid convergence to long-run equilibrium.

Hausman Test
Table 7: Hausman Specification Test

Panel A: Overall Test

Test Statistic	Chi-Square	df	Probability
Cross-section random	0.3923	2	0.8219

Panel B: Coefficient Comparison

Variable	Fixed Effect	Random Effect	Var(Diff.)	Probability
RENERGY	10.9270	3.8450	129.0665	0.5330
CO_2	16.0362	-2.8644	8722.3425	0.8396

The Hausman test supports the appropriateness of the PMG estimator in Table 7. The cross-section random test statistic is insignificant ($\chi^2 = 0.3923$, $p = 0.8219$), indicating no systematic difference between fixed and random effects. Variable-level probabilities for renewable energy ($p = 0.5330$) and carbon emissions ($p = 0.8396$) further confirm the validity of the PMG specification.

5. Discussion of Findings

The results provide differentiated support for the study's hypotheses. Hypothesis 1 is not supported, as carbon emissions do not exert a statistically significant short-run effect on money supply, indicating muted scale effects and weak short-run monetary–environmental transmission. Hypothesis 2 is supported, given the positive and significant long-run relationship between renewable energy consumption and money supply, consistent with the New Keynesian investment channel operating over extended horizons. Hypothesis 3 receives limited support, as although renewable energy consumption is linked to monetary conditions in the long run, carbon emissions remain largely unresponsive, suggesting that renewable energy has not yet translated into measurable emissions mitigation. These outcomes reflect structural and institutional constraints shaping monetary transmission in SSA.

The findings align with the New Keynesian framework, which emphasises weak short-run transmission and dominant long-run investment channels in structurally constrained economies. The insignificant short-run effects (Hypothesis 1) reflect muted demand responses, consistent with Känzig (2021). The significant long-run link between monetary policy and renewable energy (Hypothesis 2) supports investment-channel arguments advanced by Antonakakis et al. (2023). The limited emissions response (Hypothesis 3) echoes Batten et al. (2021), who highlight institutional constraints in translating monetary easing into environmental gains.

6. Conclusion and Recommendations

This study examined the dynamic relationships between monetary policy, renewable energy consumption, and carbon emissions in SSA in line with its stated objectives. The findings indicate that monetary policy influences environmental outcomes mainly through long-run investment channels rather than short-run adjustments, consistent with the New Keynesian transmission framework. The study contributes theoretically by extending monetary transmission analysis to the energy–environment nexus in SSA and methodologically by employing a dynamic panel ARDL approach suited to heterogeneous economies. Practically, the results highlight that monetary policy alone is insufficient for emissions reduction. Policymakers should therefore complement monetary actions with targeted fiscal instruments, green finance mechanisms, and institutional reforms that facilitate renewable energy investment. A key limitation of the study is its reliance on aggregate monetary indicators, which may obscure country-specific transmission differences. Future research should explore alternative monetary instruments, disaggregated energy data, and country-level institutional factors to deepen understanding of policy–environment interactions. Overall, the study offers valuable insights for scholars and policymakers concerned with aligning macroeconomic policy and environmental sustainability in developing regions.

Acknowledgement

We acknowledge all the academic staff of the Department of Economics, the Tai Solarin Federal University of Education, Ogun State, for their immeasurable efforts in proofreading the manuscripts of our research.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Declaration of Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit organisations. We conducted the study independently and declare no external financial support influenced the research process or outcomes.

Reference

Acheampong, A. O., Boateng, E., & Amponsah, M. (2021). Economic growth, CO_2 emissions and energy consumption in Sub-Saharan Africa. *Energy Economics, 102*, 105483.

Acheampong, A. O., Dzator, J., & Savage, D. A. (2022). Renewable energy, institutional quality and environmental sustainability in Africa. *Energy Economics, 105*, 105709.

Aghion, P., Dechezleprêtre, A., Hémous, D., Martin, R., & Van Reenen, J. (2024). Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. *Journal of Political Economy, 132*(1), 1–45.

Annicchiarico, B., & Di Dio, F. (2017). Environmental policy and macroeconomic dynamics. *Journal of Environmental Economics and Management, 85*, 1–18.

Antonakakis, N., Chatziantoniou, I., & Gabauer, D. (2023). Monetary policy and energy transition dynamics: Evidence from global VAR analysis. *Energy Economics, 112*, 106156.

Apergis, N., Christou, C., & Gupta, R. (2023). Monetary policy shocks and environmental quality. *Journal of Environmental Economics and Management, 118*, 102765.

Batten, J. A., Maddox, G. E., & Young, M. R. (2021). Climate change risk and the macroeconomy: Evidence from monetary policy transmission. *Journal of Cleaner Production, 296*, 126511.

Batten, J. A., Maddox, G. E., & Young, M. R. (2021). Does weather, or energy prices, affect carbon prices?. *Energy Economics*, *96*, 105016.

Batten, S., Sowerbutts, R., & Tanaka, M. (2021). Climate change: Macroeconomic impact and implications for monetary policy. *Oxford Review of Economic Policy, 37*(2), 1–23.

Bekun, F. V., Alola, A. A., & Sarkodie, S. A. (2023). Energy transition and environmental sustainability in Africa. *Renewable Energy, 201*, 678–689.

Bodenstein, M., Guerrieri, L., & Kilian, L. (2020). Monetary policy responses to oil price shocks. *Journal of Monetary Economics, 113*, 1–20.

Bolton, P., Després, M., Pereira da Silva, L. A., Samama, F., & Svartzman, R. (2021). The green swan: Central banking and financial stability in the age of climate change. *Climate Policy, 21*(4), 437–454.

Chatziantoniou, I., Duffy, D., & Filis, G. (2022). Monetary policy, energy prices and emissions. *Energy Policy, 162*, 112775.

Dikau, S., & Volz, U. (2021). Central bank mandates, sustainability objectives, and the promotion of green finance. *Ecological Economics, 184*, 107022.

Dikau, S., Robins, N., & Volz, U. (2022). A climate-aligned monetary policy framework. *Journal of Sustainable Finance & Investment, 12*(1), 1–23.

Fontana, G., & Sawyer, M. (2021). Endogenous money and ecological macroeconomics. *Cambridge Journal of Economics, 45*(6), 1261–1285.

Galí, J. (2015). Monetary policy, inflation, and the business cycle. Princeton University Press. Känzig, D. R. (2021). The macroeconomic effects of oil supply news. *American Economic Review, 111*(9), 2775–2805.

IMF. (2023). *Regional economic outlook: Sub-Saharan Africa.*

Kahn, M. E., Mohaddes, K., Ng, R. N., Pesaran, M. H., Raissi, M., & Yang, J. C. (2021). Long-term macroeconomic effects of climate change: A cross-country analysis. *Energy Economics*, *104*, 105624.

Känzig, D. R. (2021). The macroeconomic effects of oil supply news: Evidence from global financial markets. *American Economic Review, 111*(9), 2775–2805.

Khan, I., Zhong, R., Han, L., & Khan, H. (2025). Analyzing the Nexus Between Income Inequality, Renewable Energy, and Environmental Quality: Emphasizing the Significance of Institutional Quality. *Journal of the Knowledge Economy*, *16*(1), 3793-3825.

Liu, Y., Lee, C.-C., & Lee, C.-C. (2022). Monetary policy and carbon emissions. *Energy Policy, 162*, 112789.

Mbori, H. (2023). Green Energy Purchasing and the Evolving Sovereign Debt Crisis in Africa. *979-8-9885111-1-3*.

Miranda-Agrippino, S., & Ricco, G. (2021). The transmission of monetary policy shocks. *American Economic Journal: Macroeconomics, 13(*3), 74–107.

Miranda-Agrippino, S., & Ricco, G. (2021). The transmission of monetary policy shocks. *American Economic Journal: Macroeconomics, 13*(3), 74–107.

Naqvi, B., Rizvi, S. K. A., & Mirza, N. (2023). Climate risks and monetary policy transmission. *Journal of International Money and Finance, 131*, 102793.

Nathaniel, S. P., & Khan, S. A. (2020). The nexus between urbanisation, renewable energy, trade, and emissions in Africa**.** *Journal of Cleaner Production, 263*, 121509.

Nwani, C., & Adams, S. (2023). Energy transition and emissions in Africa. *Energy Economics, 117*, 106444.

Ongan, S., Isik, C., & Ozdemir, D. (2024). Monetary policy uncertainty and carbon emissions. *Energy Economics, 121***,** 106712.

Pankratz, S., & Schiller, D. (2024). Climate change, firm performance, and monetary policy transmission. *Journal of Finance, 79*(1), 1–45.

Pham, L., Nguyen, D. K., & Schinckus, C. (2023). Nonlinear effects of monetary policy on carbon emissions. *Energy Economics, 114*, 106261.

Puyo, D. M., Panton, A. J., Sridhar, T., Stuermer, M., Ungerer, C., & Zhang, A. T. (2024). *Key challenges faced by fossil fuel exporters during the energy transition*. International Monetary Fund.

Sarkodie, S. A., Adams, S., & Owusu, P. A. (2022). Renewable energy, carbon emissions, and economic growth in Africa. *Renewable Energy, 189*, 732–744.

Shahbaz, M., Raghutla, C., & Song, M. (2021). Renewable energy consumption and environmental sustainability. Renewable and Sustainable Energy Reviews, 148, 111287.

World Bank. (2022). Africa energy outlook**.**

Wang, X., Lu, F., Safi, A., & Li, X. (2025). Unraveling the dynamics of carbon price volatility: A comprehensive analysis of impacts from climate policy, fossil fuel and renewable energy shocks. *Energy Strategy Reviews*, *62*, 101966.

Yan, H., Qamruzzaman, M., & Kor, S. (2023). Nexus between green investment, fiscal policy, environmental tax, energy price, natural resources, and clean energy—a step towards sustainable development by fostering clean energy inclusion. *Sustainability*, *15*(18), 13591.

Zhang, D., Broadstock, D. C., & Liu, J. (2022). Monetary policy uncertainty and renewable energy investment. *Energy Economics, 103*, 105552.