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Research Report

The impact of climate change on the real sector in the West African Monetary Zone

WAMI Occasional Paper Series, No. 39

Provided in Cooperation with:

West African Monetary Institute (WAMI), Accra

Suggested Citation: Olowofeso, Olorunsola E. et al. (2025) : The impact of climate change on the real sector in the West African Monetary Zone, WAMI Occasional Paper Series, No. 39, West African Monetary Institute (WAMI), Accra

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WEST AFRICAN MONETARY INSTITUTE

WAMI OCCASIONAL PAPER SERIES NO. 39



THE IMPACT OF CLIMATE CHANGE ON THE REAL SECTOR IN THE WEST AFRICAN MONETARY ZONE

DECEMBER 2025



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The Impact of Climate Change on the Real Sector in the West African Monetary Zone¹

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WAMI OCCASIONAL PAPER SERIES 39

DECEMBER 2025

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Abstract

Climate change poses severe risks to developing economies, particularly those in the West African Monetary Zone (WAMZ), where agriculture and climate-sensitive sectors drive growth. Rising temperatures, erratic rainfall, and extreme weather events increasingly disrupt output, fuel inflation, and destabilise exchange rates, undermining both national resilience and regional integration under the ECOWAS single currency agenda. However, empirical evidence on the magnitude and channels of these impacts in the WAMZ remains limited. This study examines the relationship between climate change and real sector performance in the WAMZ Member States using a balanced annual panel dataset from 1974-2024. Temperature is employed as a proxy for climate shocks, alongside key macroeconomic variables: real GDP growth, inflation (GDP deflator), and exchange rates. A Panel Autoregressive Distributed Lag (Panel-ARDL) technique is applied to capture both short- and long-run dynamics. The results suggest that a 1 percent increase in temperature is associated with a 28.8 percent and 0.68 percent increase price index and real GDP growth rate, respectively in the long-run, underscoring climate change's non-trivial macroeconomic effects. Climate change policy analysis indicates that existing climate strategies across WAMZ Member States remain fragmented, weakly coordinated, and insufficiently integrated into macroeconomic frameworks. The study argues for harmonised regional climate policies, climate-smart investment, and resilience-oriented macroeconomic planning aligned with the Sustainable Development Goals. By providing the first panel-based evidence of climate change's macroeconomic effects in the WAMZ, this study highlights the urgent need for coordinated regional responses to safeguard sustainable growth and the monetary integration agenda.

Keywords: *Climate Change, Real Sector, Inflation, Output, Convergence*

JEL Classification: E31, E32, F15, Q54.

1. Introduction

Climate change has emerged as one of the most pressing global challenges of the 21st century, affecting economies, societies, and the environment on an unprecedented scale. It has been identified as an existential threat to humanity due to its rapid, devastating impact on the environment, lives, and the economy (Kumar *et al.*, 2021; Tetteh *et al.*, 2022). Climate change over time has had a significant impact on the real sector, affecting manufacturing, agriculture, infrastructure, mining, production and other real sector activities, influencing GDP and Inflation. WAMZ countries are experiencing varied degrees of climate change effects, including rising temperatures, dry spells, desertification, coastal erosion and flooding, among others, leading to food insecurity from low yields; land degradation; compulsory migration, outbreaks of diseases, etc., thereby attracting the attention of policymakers and researchers. (IPCC, 2022; Niang *et al.*, 2014; Sultan and Gaetani, 2016; Serdeczny *et al.*, 2022). Through the Sustainable Development Goals (SDG), the United Nations has set 2030 for member countries to work towards reducing the impacts of climate change. Specifically, Goal 13 requires countries to “take urgent action to combat climate change and its impacts” (Nilsson *et al.*, 2016). This goal seeks to limit, mitigate, and adapt to climate change for sustainable development. The West African region, particularly the Member States of the West African Monetary Zone (WAMZ), comprising The Gambia, Ghana, Guinea, Nigeria, Liberia, and Sierra Leone, with the desire to form macroeconomic convergence for the adoption of the single currency is especially vulnerable due to its reliance on climate-sensitive sectors such as agriculture, energy, and manufacturing (Niang *et al.*, 2014); Sultan and Gaetani (2016) Rising temperatures, erratic rainfall patterns, flooding, and prolonged droughts have increasingly disrupted economic activities, undermined growth, and exacerbated poverty in the region which not only negatively impact the real sector but also deters the regional integration process (World Bank, 2022).

Understanding the adverse impacts of climate change on the real sector, which forms the backbone of the WAMZ economies, is fundamental for economic growth and regional integration in the region. Fluctuations in agricultural yields, infrastructure damage, and production process disruptions directly affect key economic indicators such as inflation, GDP growth, GDP per capita, and exchange rate stability (Burke *et al.*, 2015). Moreover, the economic burden associated with climate-related shocks imposes additional fiscal challenges on countries already grappling with macroeconomic imbalances and development deficits (Hallegatte *et al.*, 2019). This study focuses on assessing the impact of climate change on the

real sector of the WAMZ countries while estimating its economic costs and proposing policy recommendations to address the associated challenges.

The growing incidence of climate-related events like the flooding in Ghana and Nigeria that has impacted food production and inflation; heat waves and extreme temperatures leading to droughts in the zone effecting rain-fell agriculture and food security; coastal erosion and the rise of sea level in the WAMZ has led to significant disruptions in economic activities and macroeconomic stability thus impeding the WAMZ efforts to meet the convergence criteria for the formation of the monetary union under the ECOWAS Monetary Cooperation Programme (EMCP). Despite the apparent vulnerability of the region, there is a lack of comprehensive analysis on how climate change impacts key economic variables such as inflation, GDP, and exchange rates across the WAMZ countries through vulnerability from the production sector's exposure to climate change effects.

Furthermore, climate change policies in the WAMZ countries remain fragmented and insufficiently coordinated, creating gaps in regional efforts to mitigate its effects (Antwi-Agyei *et al.*, 2018). There is also limited empirical evidence on the monetary value of the adverse effects of climate change within the WAMZ, which is critical for policymaking and resource allocation. Given the Zone's ambition to foster regional integration and achieve macroeconomic convergence, the disproportionate impact of climate change threatens to undermine these efforts unless urgent and coordinated measures are adopted.

In light of these gaps, this study seeks to provide a rigorous analysis of climate change's effects on the real sector of the WAMZ, while offering practical policy recommendations to mitigate its adverse impact and promote sustainable economic development in line with the SDGs.

The broad objective of this study is to assess the impact of climate change on the real sector, given the crucial role it plays in driving economic stability, GDP per capita improvements and low inflation, which are ideal for the convergence in the West African Monetary Zone (WAMZ). Specifically, the study aims to: (a) examine the climate change policies of member countries in the WAMZ; (b) estimate the effect of climate change on inflation and GDP per capita in WAMZ; (c) examine the causal relationship between the climate change variables and the real sector indicators in the WAMZ and the channels through which disruptions are transmitted; and (d) recommend policy initiatives to mitigate the effects of climate change through economic planning in the WAMZ.

1.1 Research Questions

To achieve the stated objectives, this study seeks to answer the following research questions:

1. What are the existing climate change policies in member countries in the West African Monetary Zone?
2. What is the effect of climate change on key macroeconomic indicators such as inflation and real GDP growth in the West African Monetary Zone?
3. What is the relationship between the climate change variables and the real sector indicators in the WAMZ?
4. What policy initiatives can be recommended to mitigate the adverse effects of climate change in the West African Monetary Zone?

Following this introduction, the rest of the paper is organised as follows. Section 2 presents stylised facts on climate change characteristics and climate change policy in the WAMZ, while Section 3 reviews relevant literature. Section 4 deals with methodology and data description. Section 5 presents and discusses the results, while Section 6 concludes the paper and proposes policy recommendations.

2. Climate Change Policy Context for WAMZ Member States

Climate change stands as one of the most urgent and complex global challenges of the 21st century, with the West African Monetary Zone (WAMZ) member states facing especially acute vulnerabilities due to their dependence on climate-sensitive sectors (Woodward and Smith, 2014). The region has experienced a series of severe climate-related events, including rising average temperatures, erratic rainfall patterns, prolonged droughts, and recurrent flooding, which have together resulted in substantial human and financial costs (Kumar *et al.*, 2021; Tetteh *et al.*, 2022). These impacts are evident in widespread agricultural losses, infrastructure damage, displaced communities, increased incidence of disease, and heightened food insecurity, collectively undermining economic growth and exacerbating poverty across the Zone.

Responding to these threats, WAMZ countries have adopted national climate change policies and regional frameworks aimed at mitigation, adaptation, and climate resilience. Agreements such as the Kyoto Protocol, the Paris Agreement, and the ECOWAS Regional Climate Strategy form the backbone of coordinated interventions, with each member state tailoring its approach to address local priorities in sectors like agriculture, water resources, energy, and health

(UNFCCE COP21, 2015; UNFCCE COP29, 2024; ECOWAS Regional Climate Strategy, 2022). However, the scale and frequency of climate shocks continue to challenge the region's economic stability, underlining the necessity for accelerated policy implementation, improved regional coordination, and enhanced investments in climate adaptation and risk management.

This section provides an overview of the most significant climate events affecting WAMZ member states, quantifies their socio-economic impacts where data allow, and critically examines the policies and institutional responses designed to mitigate these ongoing challenges.

2.1 Policy Development

Most WAMZ countries have formulated national climate change policies and strategies consistent with the Paris Agreement and the ECOWAS Regional Climate Strategy (RCS), which was developed and adopted in 2022 (ECOWAS Regional Climate Strategy, 2022). This strategy includes a vision for 2050 and an action plan for 2022-2030. The climate change policies in the WAMZ countries are part of broader regional initiatives aimed at tackling climate challenges in West Africa (Sorgho *et al.*, 2020). These policies focus on key sectors and thematic areas to strengthen resilience and foster sustainable development in response to climate change. The climate change policies in the WAMZ countries focus on seven primary sectors, including Energy, Agriculture, Water resources, Health, Forestry, Infrastructure, and Education. In addition to the key sectors, the policies also cover eight thematic areas: Community resilience, Disaster risk management, Institutional development, Industry development, Research and development, Policy making, Economic investment, and Partnerships and collaboration.

2.2 Country-Specific Climate Change Policies

Across the West African Monetary Zone, member countries have taken substantial steps to address climate change, guided both by international commitments such as the Paris Agreement and by regional frameworks like the ECOWAS Climate Strategy. However, each nation's approach is shaped by specific vulnerabilities and development priorities, resulting in diverse yet comparable policy landscapes. The Gambia has anchored its climate response in foundational policies, such as the Climate Change National Policy, aimed at mainstreaming climate action into planning, budgeting, and governance processes. A key thrust of Gambian strategy is to strengthen institutional coordination, disaster resilience, and community-level adaptation. This policy is complemented by a long-term national vision, the Climate-Neutral

Development Strategy 2050. This policy targets net-zero greenhouse gas emissions by mid-century (Republic of The Gambia, 2022, 2021b; Han and Kirabaeva, 2024). The strategy sets out concrete measures in energy, agriculture, waste management, transport, and land use, and seeks to mobilise significant investment to support green transitions, including renewable energy adoption, climate-smart agriculture, and coastal management. Together, these complementary frameworks reflect The Gambia's dual focus on national adaptation and global mitigation, aligning local action with international climate agendas while aiming to enhance food security, energy access, and disaster preparedness.

Ghana's policy environment is similarly robust, anchored by the National Climate Change Policy. This framework emphasises the integration of climate considerations into core sectors, like energy, infrastructure, natural resource management, and food security, while also advancing disaster readiness and social development (Republic of Ghana, 2013). To ensure local implementation, Ghana has produced practical guidance for municipal and district authorities, linking climate adaptation with disaster risk reduction. Institutional mechanisms such as the National Development Planning Commission help incorporate climate targets into medium-term development plans, advancing Sustainable Development Goals at the subnational level (UNDP, 2017). These measures demonstrate Ghana's strategy to foster resilience through both top-down policy and bottom-up, community-focused interventions.

Guinea's climate policies reflect an integrated approach, balancing mitigation with adaptation across energy, agriculture, coastal management, and water resources. The National Strategy on Climate Change and the country's internationally determined commitments focus on building resilience, reducing emissions, and raising access to climate finance (Climate Change Laws of the World, 2019). Guinea aims to empower vulnerable communities, especially women and youth, through climate-smart agricultural practices and knowledge diffusion. Public education, capacity building, and access to microcredit constitute important pillars of policy implementation, while partnerships with international agencies support both technology transfer and improved use of meteorological information for risk management.

In Liberia, climate action is structured through a comprehensive national policy and a dedicated gender action plan (Republic of Liberia, 2018). Policy documents emphasise integrating climate considerations into all development planning and seek to ensure gender equity in adaptation and mitigation efforts. Liberia's approach is fundamentally inclusive: sectoral strategies address agriculture, forestry, the coast, energy, and health, while gender mainstreaming expands participation in climate initiatives. The focus on stakeholder

engagement, effective budgeting, and robust monitoring serves to embed climate resilience across all government activities and to decrease disparities in vulnerability and adaptive capacity.

Nigeria operates under a broad suite of climate policies, including a binding National Climate Change Policy and the landmark Climate Change Act (Republic of Nigeria, 2021). Policy objectives include not only emission reductions and adaptation support but also the creation of a climate-resilient, low-carbon economy integrated across sectors. Legal frameworks support the development of a national action plan, institutional coordination through a National Climate Change Council, and the establishment of a climate fund for financing green investments. With the introduction of an ambitious Energy Transition Plan, Nigeria has committed to achieving net-zero emissions between 2050 and 2070, focusing on decarbonisation in power, transport, industry, and cooking. These layered policies are evidence of Nigeria's shift towards comprehensive, cross-sector governance and the mainstreaming of climate targets into national development processes.

Sierra Leone's climate strategy is built around a National Climate Change Policy and an Initial National Adaptation Plan. National objectives centre on building a resilient, climate-compatible economy through adaptation, mitigation, and the systematic integration of climate risk into policymaking. Key priorities include safeguarding agriculture, food security, water resources, coastal management, and social inclusion. Institutional enhancements, such as regulatory and compliance improvements and the establishment of dedicated governmental bodies for climate coordination, underscore Sierra Leone's commitment to effective implementation. Like other WAMZ members, Sierra Leone has prioritised both immediate risk reduction and long-term, low-emission development strategies.

In summary, while all WAMZ countries address similar vulnerabilities, extreme weather, food insecurity, and resource management, they tailor their policies to national contexts. These frameworks typically feature an interplay of adaptation and mitigation, institutional reforms, financial innovation, and stakeholder engagement, with coordination at national and subnational levels. The varied emphasis in each country, whether on legal mandates, gender inclusivity, or local capacity building, reflects a shared understanding of climate change as a driver of economic and social risk, demanding both coordinated and country-specific responses.

2.3 Policy Documents Comparison

To provide a clear comparison of climate change policies among WAMZ member countries, the essential objectives, sectoral focus areas, and distinctive elements of each national framework are synthesised in the following tables. All content is summarised based on the narrative in Section 2.2.

Table 1a: Climate Change Policy Summary – The Gambia, Ghana, and Guinea

Country	Main Objectives	Key Sectors Targeted	Unique Features
The Gambia	Mainstream integration of climate change into national decisions promotes resilience and reduces disaster risks; target net-zero emissions by 2050	Energy, agriculture, waste, transport, land use	Strong focus on disaster risk reduction, community-based adaptation, and ambitious long-term decarbonization goals
Ghana	Pursue effective adaptation, social development, and mitigation through integrated policies and local implementation	Energy/infrastructure, natural resources, agriculture/food security, disaster response	Emphasises traditional knowledge, research institutions, and guides local governments in climate change adaptation
Guinea	Enhance resilience, lower emissions, build capacity and facilitate finance/technology adoption; integrate climate action into broader policies	Agriculture, water, forestry, and coastal areas	Community empowerment, focus on women/youth, climate-smart agriculture, improved information systems

Table 1b: Climate Change Policy Summary – Liberia, Nigeria, and Sierra Leone

Country	Main Objectives	Key Sectors Targeted	Unique Features
Liberia	Significantly reduce emissions and build resilience through adaptation; integrate gender equality in climate response	Agriculture, forestry, coasts, fisheries, health, transport, industry, energy, waste	Sectoral strategies, stakeholder engagement, gender-focused action, drive to establish a climate innovation centre
Nigeria	Cut emissions, strengthen socio-economic resilience, and achieve net-zero (2050-2070); ensure cross-sector integration	Energy, agriculture, water, and coastal areas	Legal/institutional reforms, central climate council, national climate fund, robust multi-sectoral coordination
Sierra Leone	Decrease emissions in line with set targets and build resilience via adaptation planning	Agriculture, water/energy, coastal, forestry, tourism, mining, infrastructure	Whole-government adaptation, regulatory capacity-building, dedicated national climate authority

These summarised comparisons are entirely based on the synthesised narrative provided in Section 2.2. Overall, all WAMZ countries have at least one climate change policy and address similar core issues. However, each country’s policy reflects its unique national circumstances and priorities in tackling climate change.

3. Methodology and Data Description

This section contains the modelling strategies and the steps followed in the modelling phase. It also presents the description of the dataset used in the empirical estimation.

3.1 Econometric Modelling Strategies

The study sought to examine the impact of climate change on the real sector of the member states in the WAMZ from a quantitative research paradigm. The study involved a balanced panel data consisting of temperature as a proxy for climate change related variables and

macroeconomic indicators, such as price index (GDP deflator), real GDP growth (%) and exchange rate spanning the period 1974-2024. We also used the change in GDP deflator (PI) as a proxy for inflation because of the unavailability of a long series of consumer price index (CPI)-based inflation rates in some Member States, such as Guinea, Liberia, and Sierra Leone. Panel data can be modelled using the Vector Autoregressive (VAR), the Fully Modified Ordinary Least Squares (FMOLS), the Dynamic Ordinary Least Squares (DOLS), and the Autoregressive Distributed Lag (ARDL), with each having its strengths and weaknesses. However, the choice of the best technique to employ depends, among others, on the stationarity of the variables (Pesaran *et al.*, 1999). According to Pesaran *et al.* (1999), the dependent variable should necessarily be integrated at order 1. Our preliminary panel unit root test results in Table 2 show that our real sector indicators were integrated at order 1. We conduct the panel unit root tests for each variable assuming no intercept, individual intercept, and intercept and trend. The Panel Autoregressive Distributed Lag (Panel-ARDL) with the Generalised Method of Moments (GMM) estimator was considered suitable for this study since the stationarity test results revealed that the variables are stationary at level $I(0)$ and first difference $I(1)$. Furthermore, the study seeks to estimate both short-run and long-run dynamic relationships between climate change and real sector variables.

To simplify the model, we defined the variables real GDP growth as $RGDP$, GDP Deflator as PI , Exchange Rate as $EXCH$, and Temperature as $TEMP$. To empirically estimate the impact of climate change ($TEMP$) on real sector indicators (e.g., $RGDP$ and PI) of the member states, we formulate the representation as:

$$PI = f(TEMP, RGDP, EXCH) \quad (1)$$

$$RGDP = f(TEMP, PI, EXCH) \quad (2)$$

Given a panel data set with time periods, $t = 1, 2, 3, \dots, T$, and groups, $i = 1, 2, 3, \dots, N$, we define a Panel – ARDL (p, q_1, q_2, \dots, q_N) model as;

$$y_{it} = \sum_{j=1}^p \lambda_{ij} y_{i,t-j} + \sum_{j=0}^q \delta'_{ij} X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (3)$$

Where:

$X_{i,t-j}$ is the $k \times 1$ vector of explanatory variables (regressors) for group i ,

μ_i represents the fixed effects,

λ_{ij} is the coefficients of the lagged dependent variable are scalars,

δ_{ij} is $k \times 1$ coefficient vector of the disturbance term,

p and q represent the optimal lags of endogenous and explanatory variables, respectively.

We specify the re-parametrisation of Equation 3 as follows:

$$\Delta y_{i,t} = \phi_i y_{i,t-1} + \beta'_i x_{it} + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta y_{i,t-j} + \sum_{j=1}^{q-1} \delta_{ij}^{*'} \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \quad (4)$$

Where;

$$i = 1, 2, 3, \dots, N, \quad t = 1, 2, 3, \dots, T,$$

$$\phi_i = -(1 - \sum_{j=1}^p \lambda_{ij}), \quad \beta_i = \sum_{j=0}^q \delta_{ij}, \quad \lambda_{ij}^* = -\sum_{m=j+1}^p \lambda_{im}, \quad j = 1, 2, 3, \dots, p - 1,$$

$$\text{and} \quad \delta_{ij}^* = -\sum_{m=j+1}^q \delta_{im}, \quad j = 1, 2, 3, \dots, q - 1.$$

Rewriting the above equation with stacking time-series observations for each group, we arrive at Equation (5) as;

$$\Delta y_i = \phi_i y_{i,t-1} + \mathbf{X}_i \beta_i + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta y_{i,t-j} + \sum_{j=1}^{q-1} \delta_{ij}^* \Delta \mathbf{X}_{i,t-j} + \mu_i + \varepsilon_{it} \quad (5)$$

Where; $i = 1, 2, 3, \dots, N, t = 1, 2, 3, \dots, T$

$$\begin{aligned} \Delta \ln PI_{i,t} &= \phi_{0i} + \beta_{1i} \ln PI_{i,t-1} + \beta_{2i} \ln TEMP_{i,t-1} + \beta_{3i} RGDP_{i,t-1} + \beta_{4i} \ln EXCH_{i,t-1} \\ &+ \sum_{j=0}^p \lambda_{ij} \Delta \ln PI_{i,t-j} + \sum_{j=0}^q \delta_{1ij} \Delta \ln TEMP_{i,t-j} + \sum_{j=0}^{q1} \delta_{2ij} \Delta RGDP_{i,t-j} \\ &+ \sum_{j=0}^{q2} \delta_{3ij} \Delta \ln EXCH_{i,t-j} + \mu_i + \varepsilon_{it} \end{aligned} \quad (6)$$

$$\begin{aligned} \Delta RGDP_{i,t} &= \phi_{0i} + \beta_{1i} RGDP_{i,t-1} + \beta_{2i} \ln TEMP_{i,t-1} + \beta_{3i} \ln PI_{i,t-1} + \beta_{4i} \ln EXCH_{i,t-1} \\ &+ \sum_{j=0}^p \lambda_{ij} \Delta RGDP_{i,t-j} + \sum_{j=0}^q \delta_{1ij} \Delta \ln TEMP_{i,t-j} + \sum_{j=0}^{q1} \delta_{2ij} \Delta \ln PI_{i,t-j} \\ &+ \sum_{j=0}^{q2} \delta_{3ij} \Delta \ln EXCH_{i,t-j} + \mu_i + \varepsilon_{it} \end{aligned} \quad (7)$$

Where: $i = 1, 2, 3, \dots, N$; $t = 1, 2, 3, \dots, T$.

Following the recommendations by Pesaran *et al.* (1999), we estimated the pooled mean group (PMG) to critically determine the effects of climate change on the economies of the member states. We relied on the Akaike information criterion (AIC), Bayesian information criterion (BIC), and Hannan-Quinn information criterion (HQIC) to determine the best model for each real sector indicator, after employing a stepwise modelling procedure. The study further employs the normality and standardised residual test to assess the fitness of the models and the estimates in line with Wooldridge (2020), Greene (2018), and Gujarati and Porter (2009). Also, Wooldridge (2020) recommends the procedure of adding or removing control variables to test for the robustness of a model.

3.2 Steps in Estimating Panel ARDL

The econometric estimation began with the conduct of the unit root tests, followed by the determination of the maximum lag, cointegration test, and long-run and short-run test for both the panel data and each member state. We also performed the Granger causality test and residual analysis.

3.3 Data Description and Sources

Data for the study comprised temperature and real sector variables for the six (6) member states of the WAMZ spanning the period 1974-2024. Temperature data were obtained from the Africa Data Hub, while real sector indicators such as real GDP growth rate (annual, %), GDP deflator/Price Index (PI, base year varying by country), and exchange rate (LCU per US\$, period average) were sourced from the IMF's World Economic Outlook (WEO) and WAMI databases. The results in Table 2 reveal varied macroeconomic experiences across the WAMZ despite relatively uniform climatic conditions.

The Gambia records a high and stable average temperature of 27.31°C (SD = 0.42), reflecting minimal climatic variation. Real GDP growth averages 3.72 percent (SD = 3.55), with fluctuations ranging from -8.13 to 12.39 percent, indicating moderate volatility. The PI averages 56.47 (SD = 57.67), suggesting significant inflationary pressures and variation over time. The exchange rate averages 21.06 (SD = 18.74), pointing to a gradual depreciation trend, though without the hyper-volatility observed elsewhere in the bloc. Ghana's climate is similarly stable, with a mean temperature of 27.03°C (SD = 0.41). Real GDP growth averages 3.95 percent (SD = 4.34), with wide swings from -12.43 to 14.05 percent, reflecting exposure to

external shocks and structural adjustments. Inflation, proxied by the PI, is relatively high (mean = 59.63, SD = 100.70), highlighting episodes of both hyperinflation and relative stability, consistent with periods of commodity booms, macroeconomic reforms, and cedi re-denominations. The exchange rate averages 1.70 (SD = 2.95), low due to re-denominations, but the standard deviation indicates sustained episodes of depreciation.

Guinea's mean temperature of 27.30°C (SD = 0.44) is in line with the regional profile. Real GDP growth averages 4.02 percent (SD = 2.55), one of the most stable in the bloc. Inflation is moderate (mean PI = 64.14, SD = 74.92), though subject to periodic surges. The exchange rate, however, is highly depreciated, averaging 3,178.95 (SD = 3,548.78) and peaking near 9,763.72, reflecting chronic currency weakness and persistent external imbalances. Liberia records the coolest average temperature at 26.59°C (SD = 0.73). Real GDP growth averages 1.43 percent but with extraordinary volatility (SD = 20.77), swinging between -51.03 and 106.28 percent, underscoring post-conflict fragility and exposure to commodity cycles. Inflation (mean PI = 47.89, SD = 35.21) has been unstable, and the exchange rate averages 71.29 (SD = 44.01), reflecting consistent depreciation and shallow foreign exchange market dynamics.

Nigeria has the lowest mean temperature (26.01°C, SD = 0.42). Real GDP growth averages 3.14 percent (SD = 5.35), reflecting modest but relatively stable expansion for the region's largest and most diversified economy. Inflation is high and volatile (mean PI = 70.01, SD = 93.99), driven by oil price shocks, fiscal dominance, and exchange rate adjustments. The exchange rate averages 140.07 (SD = 252.67), with extremes up to 1,612.64, indicating persistent depreciation pressures despite Nigeria's larger foreign exchange market. Sierra Leone exhibits a mean temperature of 27.24°C (SD = 0.54). Real GDP growth averages 2.65 percent (SD = 7.54), with sharp fluctuations ranging from -20.49 to 26.52 percent, reflecting conflict, Ebola, and commodity shocks. Inflation is the highest in the bloc (mean PI = 118.22, SD = 166.20), indicating severe price instability. The exchange rate averages 3.34 (SD = 4.98), low due to re-denominations, but volatile over the long term.

At the WAMZ regional level, the mean temperature of 26.91°C (SD = 0.69) underscores broad climatic stability. However, real GDP growth averages 3.15 percent (SD = 9.58), indicating modest expansion alongside considerable volatility. Inflation (mean PI = 69.39, SD = 99.16) remains divergent across countries, and exchange rates (mean = 569.40, SD = 1855.84) highlight severe heterogeneity, with persistent depreciation and volatility concentrated in Guinea, Nigeria, and Liberia.

Table 2: Descriptive Statistics

Country	Variable	Obs	Mean	Min	Max	SD
The Gambia	Temperature	51	27.31	26.46	28.33	0.4242
	RGDP Growth	51	3.72	-8.13	12.39	3.5458
	PI	51	56.47	1.27	193.00	57.6724
	Exchange rate	51	21.06	1.71	67.66	18.7480
Ghana	Temperature	51	27.03	26.00	27.89	0.4056
	RGDP Growth	51	3.95	-12.43	14.05	4.3389
	PI	51	59.63	0.00	373.58	100.7049
	Exchange rate	51	1.70	0.00	14.18	2.9453
Guinea	Temperature	51	27.30	26.18	28.10	0.4386
	RGDP Growth	51	4.02	-3.35	10.82	2.5475
	PI	51	64.14	0.94	251.57	74.9185
	Exchange rate	51	3178.95	1.71	9763.72	3548.7788
Liberia	Temperature	51	26.59	25.04	27.75	0.7306
	RGDP Growth	51	1.43	-51.03	106.28	20.7728
	PI	51	47.89	9.06	116.65	35.2058
	Exchange rate	51	71.29	23.72	191.52	44.0102
Nigeria	Temperature	51	26.01	25.06	26.75	0.4221
	RGDP Growth	51	3.14	-13.13	15.33	5.3512
	PI	51	70.01	0.10	400.62	93.9927
	Exchange rate	51	140.07	0.55	1612.64	252.6685
Sierra Leone	Temperature	51	27.24	26.07	28.07	0.5407
	RGDP Growth	51	2.65	-20.49	26.52	7.5432
	PI	51	118.22	0.01	688.39	166.2037
	Exchange rate	51	3.34	0.00	22.59	4.9793
WAMZ	Temperature	306	26.91	25.04	28.33	0.6907
	RGDP Growth	306	3.15	-51.03	106.28	9.5810
	PI	306	69.39	0.00	688.39	99.1587
	Exchange rate	306	569.40	0.00	9763.72	1855.8414

Source: WAMI Staff computations; Min – Minimum, Max – Maximum, PI – Price Index; SD – Standard Deviation, Obs–Observations

4 Empirical Results and Discussions

The empirical analysis involves the conduct of the unit root tests, followed by the determination of the maximum lag, cointegration test, and long-run and short-run test for both the panel data and each member state. We also perform the Granger causality test and residual analysis.

4.1 Cross-Sectional Dependence Test

To begin the econometric modelling, we explore the stationarity of the panel data to determine the order of integration for each variable. Kunst (2016), Barbieri (2006), and De Hoyos *et al.* (2006) recommend the first-generation panel unit root test (assuming cross-sectional independence) and the second-generation panel unit root test (assuming cross-sectional dependence) for testing stochastic properties in a dataset. Before this, we conducted the panel cross-sectional dependence tests, including the Breusch-Pagan LM, the Pesaran scaled LM, and the Pesaran CD tests to determine the most appropriate generation framework to employ. The results in Table 3 reveal that there is a cross-sectional dependence (correlation) in the residuals of the variable, since the p-values are less than the significance level of 0.05. This suggests that the second-generation panel unit root test is appropriate to conduct the stationarity test.

Table 3: Residual Cross-Sectional Dependence Test

Test	Statistic	Df	P-value
Breusch-Pagan LM	458.03	15	0.0000
Pesaran scaled LM	80.89		0.0000
Pesaran CD	19.99		0.0000

*Source: WAMI staff computation; ***, **, * indicate statistical significance at the 1%, 5% and 10% levels.*

4.2 Panel Unit Root Test

We apply the second-generation panel unit root test before estimating the econometric models. It is essential to examine the time-series properties of the variables to avoid spurious regression outcomes. Table 4 presents the results of the panel unit root tests using both the Panel Analysis of Non-stationarity in Idiosyncratic and Common Components (PANIC) and the Cross-Sectionally Augmented Im, Pesaran, and Shin (CIPS) procedures. These second-generation tests are particularly appropriate in the present context, given their ability to accommodate cross-sectional dependence and common factor structures, which are often pervasive in macroeconomic panels involving countries within regional blocs.

The results reveal a mixed order of integration across the variables. Specifically, temperature anomalies (TEMP) and real GDP (RGDP) are found to be stationary in levels under both PANIC and CIPS, thereby exhibiting an $I(0)$ process. This suggests that these variables revert to their long-run means without the need for differencing. In contrast, price instability (PI) and the exchange rate (EXCH) are non-stationary at levels, but attain stationarity after first differencing, implying that they follow an $I(1)$ process. While the PANIC test could not be computed for the exchange rate series due to data limitations or computational restrictions, the CIPS test confirms its integration at order one. The presence of variables integrated of different orders ($I(0)$ and $I(1)$) underscores the importance of adopting econometric techniques that can accommodate such heterogeneity. Notably, the mixture of $I(0)$ and $I(1)$ variables rules out the use of standard panel regression approaches that assume homogeneity in stationarity properties. Instead, it justifies applying panel cointegration methodologies, which are robust to such combinations and allow for the identification of long-run equilibrium relationships among the variables despite their different stochastic properties.

Table 4: Panel Unit Root Test

	PANIC		CIPS		Remarks
	Levels	First Difference	Levels	First Difference	
TEMP	-1.75*	-	-4.87***	-	$I(0)$
RGDP	-3.97***	-	-3.97***	-	$I(0)$
PI	0.69	5.36***	-1.09	4.01***	$I(1)$
EXCH	N/A	N/A	1.89	-4.14***	$I(1)$

Note: ***, **, and * for 1%, 5% and 10%, respectively. PANIC = Panel Analysis of Non-stationarity in Idiosyncratic and Common Components. CIPS = Cross-Sectionally Augmented Im, Pesaran, and Shin test.

4.3 Impact of Climate Variables on Inflation in the WAMZ

This study estimated a Panel ARDL (1,3,3,3) model using the Pooled Mean Group (PMG) estimator to examine the long- and short-run determinants of price index (inflation), measured as the log-difference of the price index (DLOG(PI)), for six WAMZ Member States over the period 1977-2024 (see Table 5). The key explanatory variables include the log of temperature (LOG(TEMP)), real GDP (RGDP), and the log of the exchange rate (LOG(EXCH)). The specification allows for heterogeneous short-run dynamics across countries while constraining the long-run relationship to be the same. The long-run coefficients reveal three notable drivers of price changes (PI). The estimated coefficient (28.80, $p = 0.0186$) suggests that a 1 percent increase in temperature is associated with a 28.8 percent rise in PI growth in the long-run. This large, significant effect underscores the inflationary risks of climate change. Persistently higher

temperatures can disrupt agricultural productivity, reduce food supply, raise energy costs, and generate sustained cost-push pressures on prices. Also, the coefficient (-0.0739, $p < 0.05$) indicates that stronger economic growth is associated with lower inflation in the long-run. This result is consistent with supply-side effects, expansion in productive capacity, improved efficiency, and currency stability, which can offset demand-driven price pressures. The coefficient (0.7465, $p < 0.0001$) points to a strong and highly significant exchange rate pass-through effect. Currency depreciation raises the cost of imported goods and inputs, which feeds directly into domestic prices. Given the high import dependence of the sample economies, this effect is both large and persistent.

The short-run results highlight slower and more muted price change responses. The negative and significant coefficient (-0.0628, $p = 0.0445$) confirms the existence of a long-run equilibrium relationship. The magnitude implies that only about 6.3 percent of any deviation from equilibrium is corrected each quarter, pointing to sluggish price adjustment due to structural rigidities. Contemporaneous temperature changes have a marginally significant negative effect (-1.97, $p < 0.1$), while the first and second lags are significantly negative (-2.56 and -1.87). This suggests that short-term weather variations may temporarily ease inflation, possibly through improved harvests or reduced energy demand, before the longer-run adverse effects dominate. Short-run coefficients for GDP and exchange rate changes are insignificant across lags, implying that their immediate impact on inflation is weak, with effects emerging primarily over longer horizons.

Table 5: Long-run Impacts of Climate Change on Price Index (PI) in the WAMZ

Variable	Coefficient	Std. Error	t-Statistic	P-value
<i>Long-run Equation</i>				
LOG(TEMP)	28.7994**	12.16	2.37	0.0186
RGDP	-0.0739**	0.03	-2.49	0.0132
LOG(EXCH)	0.7465***	0.07	10.28	0.0000
<i>Short-run Equation</i>				
COINTEQ	-0.0629**	0.03	-2.02	0.0445
DLOG(TEMP)	-1.9723*	1.04	-1.90	0.0583
DLOG(TEMP(-1))	-2.5589***	0.86	-2.99	0.0030
DLOG(TEMP(-2))	-1.8710***	0.68	-2.75	0.0063
D(RGDP)	0.0008	0.001	0.59	0.5546
D(RGDP(-1))	0.0021	0.002	1.25	0.2129
D(RGDP(-2))	0.0004	0.0012	0.31	0.7570
DLOG(EXCH)	-0.0046	0.09	-0.05	0.9595
DLOG(EXCH(-1))	0.0395	0.07	0.59	0.5534
DLOG(EXCH(-2))	0.0561	0.05	1.14	0.2541
C	-5.6961*	2.90	-1.96	0.0504

Source: WAMI staff computation; ***, **, * indicate statistical significance at the 1%, 5% and 10% levels.

Furthermore, the results of the ARDL bounds testing procedure for the six WAMZ Member States are presented in Table 6. The computed F -statistics are evaluated against the corresponding finite-sample critical bounds from Table 7 for a sample size of approximately 50 observations. At the 5 percent significance level, the lower bound $[I(0)]$ and upper bound $[I(1)]$ critical values are 3.500 and 4.700, respectively. The decision rule, following Pesaran, Shin, and Smith (2001), is that if the calculated F -statistic exceeds the upper bound, the null hypothesis of no long-run relationship is rejected; if it falls below the lower bound, the null cannot be rejected; and if it lies between the bounds, the result is inconclusive. To strengthen inference, the associated t -statistics for the lagged error correction term (ECT) are compared against the asymptotic critical values, with significance indicated when the t -statistic is more negative than the $I(1)$ bound.

The empirical results reveal heterogeneity in the existence of long-run cointegrating relationships across countries. In the case of Nigeria, the F -statistic (6.139) exceeds the upper

bound at the 5 percent level, and the associated t-statistic (-4.34) is more negative than the $I(1)$ critical value (-3.78), providing robust evidence in favour of a stable long-run relationship among the model variables. This result indicates that deviations from the long-run equilibrium in Nigeria are corrected at a statistically significant rate, consistent with economic theory and policy dynamics that anchor short-run fluctuations to a long-run path. For Ghana and Guinea, the computed F -statistics (8.299 and 7.284, respectively) exceed the 1 percent upper bound, suggesting the presence of long-run cointegration. However, the associated t-statistics (-0.07 for Ghana and 0.92 for Guinea) are far less negative than the $I(0)$ and $I(1)$ thresholds, implying that while the bounds test identifies a long-run relationship, the speed of adjustment back to equilibrium is not statistically significant. This divergence between the F - and t -statistic results may reflect weak error correction dynamics, possibly due to high structural volatility, partial adjustment mechanisms, or omitted structural breaks that dilute the ECT's significance. In contrast, The Gambia, Liberia, and Sierra Leone record F -statistics (2.728, 2.497, and 1.868, respectively) below the 10 percent lower bound, thereby failing to reject the null hypothesis of no cointegration. Moreover, their t -statistics (-3.14, -1.44, and -1.99, respectively) do not provide compelling evidence of a significant error correction mechanism. These findings suggest that in these economies, the macroeconomic variables under consideration do not share a stable long-run equilibrium relationship over the sample period, and adjustments in one variable are unlikely to systematically influence the long-run trajectory of the others.

Table 6: Bound Test

Countries	Obs.	F-Stat	t-Stat
Gambia, The	48	2.73	-3.14
Ghana	48	8.30	-0.07
Guinea	48	7.28	0.92
Nigeria	48	6.14	-4.34
Liberia	48	2.50	-1.44
Sierra Loene	48	1.87	-1.99

Table 7: Bound test critical

	10%		5%		1%	
	<i>I</i> (0)	<i>I</i> (1)	<i>I</i> (0)	<i>I</i> (1)	<i>I</i> (0)	<i>I</i> (1)
Sample Size	<i>F-Statistic</i>					
45	2.89	3.98	3.54	4.73	4.98	6.42
50	2.87	3.97	3.50	4.70	4.87	6.36
Asymptotic	2.72	3.77	3.23	4.35	4.29	5.61
	<i>t-Statistic</i>					
Asymptotic	-2.57	-3.46	-2.86	-3.78	-3.43	-4.37

* *I*(0) and *I*(1) are respectively the stationary and non-stationary bounds.

4.4 Impact of Climate Change on Real GDP in the WAMZ

The long-run coefficients provide evidence of how climate variables and macroeconomic fundamentals affect real GDP (RGDP) once equilibrium is restored. The estimates in Table 8 indicate that temperature (LOG(TEMP)) exerts a positive and highly significant effect on RGDP (0.678, $p = 0.0021$). At first glance, this result appears counterintuitive, given the predominantly negative perception of climate change impacts. However, it can be interpreted through the lens of short- to medium-term productivity effects. Moderate increases in temperature may initially stimulate agricultural yields in certain crops, extend the growing season in selected regions, or reduce heating costs. These transitional gains, however, are unlikely to be sustainable, as prolonged warming trends are expected to erode productivity and undermine growth in the longer term (Burke *et al.*, 2015; Dell *et al.*, 2012).

By contrast, the exchange rate (LOG(EXCH)) displays a negative and statistically significant coefficient (-0.312, $p < 0.05$), underscoring the contractionary effects of currency depreciation on output. Persistent depreciation not only fuels inflation but also raises the cost of imported intermediate goods and capital equipment, constraining investment and production in the real sector. Real GDP growth in WAMZ economies, heavily reliant on imported machinery, refined petroleum, and industrial inputs, is thus highly vulnerable to exchange rate volatility. The coefficient for inflation (PI) is also negative (-0.046, $p < 0.1$), consistent with macroeconomic theory that excessive price instability erodes purchasing power, increases production costs, and disrupts investment planning. Inflationary pressures, especially when driven by climate shocks to agriculture and food security, therefore translate into significant output losses.

In the short-run dynamics, the error correction term (ECT) is negative and significant (-0.071, $p < 0.05$), indicating that approximately 7 percent of deviations from the long-run equilibrium are corrected each period. This adjustment speed, although moderate, implies that climate and

macroeconomic shocks have persistent effects, with economies requiring multiple periods to revert to equilibrium output paths. Short-run coefficients for contemporaneous changes in temperature and exchange rate are weakly significant, suggesting that their immediate effects on RGDP are less pronounced, with stronger impacts materialising over longer horizons.

Table 8: Impact of Climate Change on RGDP in the WAMZ

Variable	Coefficient	Std. Error	<i>t</i> -Statistic	<i>p</i> -value
<i>Long-run Equation</i>				
LOG(TEMP)	0.678***	0.22	3.10	0.0021
LOG(PI)	0.510***	0.19	2.74	0.0066
LOG(EXCH)	0.010	0.11	0.09	0.9296
<i>Short-run Equation</i>				
COINTEQ	-0.777***	0.12	-6.25	0.0000
DLOG(TEMP)	12.348	22.34	0.55	0.5809
DLOG(TEMP(-1))	75.211	95.62	0.79	0.4322
DLOG(TEMP(-2))	45.614	46.37	0.98	0.3261
DLOG(TEMP(-3))	80.381***	14.29	5.63	0.0000
DLOG(PI)	-0.304	3.95	-0.08	0.9387
DLOG(PI(-1))	-1.367	8.43	-0.16	0.8712
DLOG(PI(-2))	6.265	4.29	1.46	0.1462
DLOG(PI(-3))	-8.912	6.74	-1.32	0.1869
DLOG(EXCH)	10.754	11.41	0.94	0.3468
DLOG(EXCH(-1))	-17.731	16.05	-1.10	0.2704
DLOG(EXCH(-2))	6.479	9.30	0.70	0.4865
DLOG(EXCH(-3))	0.059	4.22	0.01	0.9888

Source: WAMI staff computation; ***, **, * indicate statistical significance at the 1%, 5% and 10% levels.

Table 9 presents the results of the ARDL bounds test for the existence of long-run cointegration relationships between real GDP and the selected regressors across the six WAMZ member countries. The decision rule follows Pesaran, Shin, and Smith (2001), where the computed *F*-statistic is compared against the lower bound (*I*(0)) and upper bound (*I*(1)) critical values. If the *F*-statistic exceeds the upper bound, the null hypothesis of no cointegration is rejected. In addition, the significance of the *t*-statistic on the lagged error correction term provides further confirmation of the existence of long-run relationships. The

results indicate strong evidence of cointegration in The Gambia, Guinea, Nigeria, and Sierra Leone. In each of these countries, the computed F -statistics (12.01, 14.01, 6.73, and 8.33, respectively) are well above the upper bound critical values at the 1 percent significance level, while the corresponding t -statistics (ranging from -4.95 to -7.41) are more negative than the 1 percent $I(1)$ critical threshold. This suggests the presence of a stable long-run relationship between real GDP and the explanatory variables in these economies.

For Ghana, the F -statistic of 3.16 lies between the lower and upper bounds at the 5 percent level, while the t -statistic (-3.45) is close to the 5 percent $I(1)$ threshold. This provides borderline evidence of cointegration, implying that the existence of a long-run equilibrium relationship is plausible but relatively weak compared to the stronger cases. By contrast, Liberia fails to show evidence of cointegration. The F -statistic of 1.81 falls below the 10 percent lower bound, and although the t -statistic (-2.30) is more negative than the $I(0)$ bound, it does not breach the $I(1)$ threshold. This suggests that the macroeconomic variables considered do not form a stable long-run equilibrium relationship in Liberia.

Table 9: Bound Test

Country	Obs.	F -Stat	t -Stat
Gambia, The	47	12.01	-6.92
Ghana	47	3.16	-3.45
Guinea	47	14.01	-7.41
Nigeria	47	6.73	-4.95
Liberia	47	1.81	-2.30
Sierra Loene	47	8.33	-5.67

Table 10: Bound text critical

	10%		5%		1%	
	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$
Sample Size	F -Statistic					
45	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
Asymptotic	2.01	3.10	2.45	3.63	3.42	4.84
	t -Statistic					
Asymptotic	-1.62	-3.00	-1.95	-3.33	-2.58	-3.97

* $I(0)$ and $I(1)$ are respectively the stationary and non-stationary bounds.

4.5 Robustness and Diagnostic Tests

As indicated earlier, we rely on model diagnostic analyses recommended by Wooldridge (2020) and others. This is guaranteeing the accuracy and validity of the panel ARDL models, as well as the stability of the estimated parameters. To check the robustness of our results, we perform different specifications for the impact of temperature of RGDP with TEMP and EXCH as the regressors. In the diagnostic model in Table 11, both temperature (LOG(TEMP)) and exchange rate (LOG(EXCH)) are statistically significant in the long-run, with coefficients of 0.77 and 0.27 respectively. This suggests that both variables play a meaningful role in driving RGDP over time. In contrast, the main model in Table 5 identifies temperature (LOG(TEMP)) and price index (LOG(PI)) as the key long-run determinants of RGDP, both significant at the 1 percent level, with coefficients of 0.678 and 0.510 respectively. However, the exchange rate (LOG(EXCH)) is not significant in the long run ($p = 0.9296$), indicating that its contribution to long-run growth dynamics in the WAMZ is negligible once climate variables are included.

In both models, the error correction term (COINTEQ) is negative and highly significant, with a magnitude of around -0.77. This indicates a strong and rapid convergence back to equilibrium (about 77% adjustment each period), which is a classic sign of model robustness and stability. The model is robust in the long run, with consistent and significant effects of temperature on RGDP.

Table 11: Diagnostic Test Results

Variable	Coefficient	Std. Error	<i>t</i> -Statistic	p-value
<i>Long-run Equation</i>				
LOG(TEMP)	0.77	0.13	5.71	0.0000
LOG(EXCH)	0.27	0.07	3.62	0.0003
<i>Short-run Equation</i>				
COINTEQ	-0.77	0.12	-6.24	0.0000
DLOG(TEMP)	13.52	12.48	1.08	0.2796
DLOG(TEMP(-1))	44.31	65.91	0.67	0.5019
DLOG(TEMP(-2))	9.98	38.19	0.26	0.7940
DLOG(EXCH)	8.63	8.16	1.06	0.2911
DLOG(EXCH(-1))	-12.99	13.09	-0.99	0.3221
DLOG(EXCH(-2))	1.26	1.74	0.73	0.4680

Source: WAMI staff computation; ***, **, * indicate statistical significance at the 1%, 5% and 10% levels.

The residual diagnostic results presented in Figure 1 provide important insights into the validity of the estimated model. The histogram of the residuals shows that they are broadly centred around zero, confirming that the model is unbiased on average. Most of the residuals lie within the range of -0.2 to 0.2, although some extreme observations are visible in the tails, indicating the presence of outliers. The descriptive statistics reveal that the mean of the residuals is approximately zero (0.000) and the median is also close to zero (-0.0106), both of which are desirable properties of a well-specified model. The standard deviation of 0.108 suggests a moderate spread around the mean. However, the skewness statistic (1.37) is positive, indicating a longer right tail, while the kurtosis statistic (11.92) is substantially greater than the normal benchmark of 3, suggesting a leptokurtic distribution with fat tails. The Jarque-Bera normality test strongly rejects the null hypothesis of normally distributed residuals (JB = 1044.51, $p = 0.0000$). This implies that although the residuals are mean-reverting around zero, they deviate significantly from normality due to skewness and excess kurtosis. In practice, this means that while the parameter estimates remain consistent and asymptotically valid given the large sample size (288 observations), the reported standard errors may not be fully efficient.

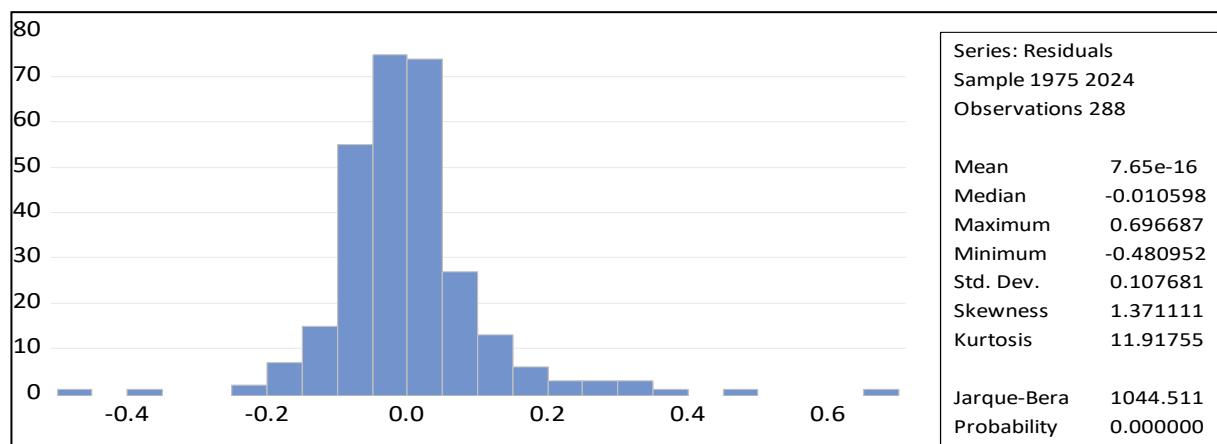


Figure 1: Plot of residual values

4.6 Discussion of Findings

The results show that climate change, proxied by temperature, has a long-run inflationary effect. A 1 percent rise in temperature is associated with a nearly 29 percent increase in the price index. This underscores the vulnerability of WAMZ Member States to climate-induced supply shocks, especially food and energy, which threaten price stability. In the short run, however, temperature fluctuations sometimes ease inflation, reflecting seasonal agricultural harvests before longer-term pressures dominate. Real GDP responds positively to long-run temperature changes and moderate inflation, suggesting that adaptation strategies and short-

term sectoral shifts can temporarily boost growth. However, this is fragile, since sustained high inflation undermines convergence.

The study also finds a strong and persistent exchange rate pass-through effect on inflation. Depreciations significantly increase domestic prices, reflecting the high import dependence of WAMZ Member States. This result implies that without exchange rate stability, achieving inflation convergence under a common currency will be difficult. Exchange rate changes, however, do not exert a robust long-run influence on real GDP. This suggests that structural bottlenecks and rigidities mute the growth benefits of currency movements, further complicating external adjustment under a monetary union.

Evidence of long-run cointegration exists for Nigeria, Ghana, and Guinea, but not for The Gambia, Liberia, and Sierra Leone. This indicates uneven macroeconomic adjustment capacity and differences in structural fundamentals. Nigeria shows the strongest adjustment to long-run equilibrium, while Ghana and Guinea display weak or insignificant error-correction dynamics despite cointegration. This heterogeneity suggests asymmetric shocks will be a challenge for convergence. Smaller economies (Gambia, Liberia, Sierra Leone) fail to exhibit stable long-run relationships among inflation, exchange rate, and GDP, indicating persistent volatility and weak policy anchors. The high sensitivity of prices to both climate shocks and exchange rate movements means WAMZ countries are unlikely to maintain single-digit inflation targets simultaneously. Similarly, persistent depreciation in Guinea and Liberia, combined with Nigeria's inflation volatility, makes it difficult to achieve the exchange rate stability required under a monetary union.

5 Conclusion and Policy Recommendations

5.1 Conclusion

The study examined the dynamic relationship between climate change, proxied by temperature, and real sector performance in the WAMZ using a Panel ARDL-PMG framework. The results demonstrate that climate variability has significant macroeconomic implications for the region. First, higher temperatures exert strong inflationary pressures in the long run by disrupting agricultural productivity, reducing food supply, and raising energy costs. Exchange rate depreciation further amplifies price instability, while stronger real GDP growth helps dampen inflation through expanded supply capacity. Second, real GDP growth in the WAMZ responds positively to temperature in the long run, reflecting possible adaptation mechanisms, sectoral

shifts, and resilience strategies. However, this result may mask long-term vulnerabilities, since delayed climate shocks could undermine productivity, food security, and structural stability. Third, exchange rate movements do not significantly influence long-run growth, although their inflationary pass-through is large and persistent.

The country-level analysis reveals heterogeneity in adjustment dynamics. Nigeria, Ghana, and Guinea show evidence of long-run cointegration between climate and real sector variables, whereas The Gambia, Liberia, and Sierra Leone display weaker equilibrium relationships, reflecting structural fragility, policy inconsistencies, and heightened vulnerability to shocks. Overall, the findings underscore that climate change is not just an environmental challenge but a macroeconomic one that could hinder price stability, growth sustainability, and macroeconomic convergence within the WAMZ.

5.2 Policy Recommendations

1. **Strengthen Fiscal Discipline and Policy Coordination:** Establish binding fiscal rules (e.g., debt and deficit thresholds) at the WAMZ level, supported by credible enforcement mechanisms. Furthermore, introduce regional fiscal stabilisation funds to cushion against asymmetric shocks and reduce procyclical fiscal behaviour.
2. **Enhance Monetary and Exchange Rate Convergence:** Gradually harmonise monetary policy frameworks and strengthen coordination among central banks before the adoption of a single currency. Introduce a pre-union exchange rate mechanism to align national currencies and minimise volatility.
3. **Deepen Structural and Real Sector Convergence:** Promote economic diversification and industrialisation to reduce reliance on commodity exports and improve resilience. Also, enhance regional trade integration through the removal of non-tariff barriers, improved infrastructure, and digital connectivity.
4. **Strengthen Regional Institutions and Governance:** Enhance the capacity, independence, and credibility of regional institutions such as WAMI, WAMA, and ECOWAS Commission in monitoring compliance and coordinating policies. Improve transparency, peer review, and sanctions for non-compliance to ensure credibility of the convergence process.
5. **Promote Social and Political Buy-In:** Strengthen public communication and engagement strategies to build trust, ownership, and support among citizens, businesses, and policymakers. Also, foster political commitment at the highest levels to reduce the risk of policy reversals and maintain credibility.

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