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IMPACT OF TEMPERATURE VARIABILITY ON AGRICULTURE AND INDUSTRIAL SECTORS CONTRIBUTIONS TO GDP IN NIGERIA.

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ABSTRACT

Nigeria's real gross domestic product (GDP), with emphasis on the agricultural and industrial sectors from 1981 to 2022, is examined using secondary time-series data from credible sources to assess the effects of temperature variability on sectoral growth. The study adopts the Autoregressive Distributed Lag (ARDL) approach, with stationarity tested using the Augmented Dickey-Fuller test and long-run relationships examined via ARDL bounds testing, while short-run dynamics are analyzed through an error correction mechanism. The findings confirm a stable long-run relationship among temperature variability, agricultural output, industrial output, and labour force participation. Empirical results show that temperature variability has a significant negative short-run effect on agricultural output due to its vulnerability to climatic shocks, whereas the industrial sector exhibits greater short-run resilience, with lagged industrial output positively influencing economic performance. The error correction term indicates a gradual adjustment to the long-run equilibrium. The study concludes that temperature variability poses a serious threat to agricultural growth in Nigeria, while the industrial sector demonstrates stronger adaptive capacity, and recommends climate-resilient agricultural practices and policies that support technological adaptation for sustainable economic growth.

Keywords: Temperature variability, Agricultural GDP, Industrial GDP, Economic growth, ARDL, Nigeria.

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1. Introduction

Climate change has become a major threat to global economic stability, as rising temperature variability increasingly disrupts production systems in both developed and developing economies (World Economic Forum, 2020). Evidence from the National Aeronautics and Space Administration shows that global surface temperatures have increased by more than 1.62°F since the late nineteenth century, with 2016 identified as the warmest year on record (NASA, 2020). These changes, driven largely by escalating greenhouse gas emissions, have altered rainfall patterns, intensified heat stress, and increased climate-related pests and diseases, thereby constraining agricultural productivity, industrial performance, and human welfare.

In Nigeria, the economic consequences of climate change are particularly severe due to the country's heavy reliance on climate-sensitive sectors. This vulnerability was highlighted during the COVID-19 pandemic, when the collapse in global oil prices generated substantial fiscal and macroeconomic shocks, reinforcing the urgency of economic diversification beyond crude oil dependence (World Economic Forum, 2020). Agriculture and industry remain central to this diversification strategy, contributing significantly to real GDP growth, employment generation, food security, and structural transformation, despite the historical shift in economic focus following the discovery of crude oil in 1956 (National Bureau of Statistics, 2019; Abdulrasheed, 2010; Roberto & Giuseppe, 2004).

Temperature variability critically affects Nigeria's agricultural sector, which contributes about 24% of GDP and employs nearly 70% of the rural labour force. As a largely rain-fed sector, agriculture is highly sensitive to climatic fluctuations. Empirical evidence shows that a 1°C rise in temperature significantly reduces yields of staples such as maize, rice, and cassava, intensifying food insecurity and inflationary pressures (FAO, 2018; Okoye et al., 2021).

In addition, desertification and land degradation in northern Nigeria have reduced arable land and weakened rural livelihoods, while floods and droughts cause substantial losses, including the destruction of roughly 10% of total crop output in Benue State in 2021 (NiMet, 2022; NEMA, 2022).

The industrial sector, accounting for roughly 30% of GDP, is similarly exposed to rising temperatures. Heat stress raises electricity demand by 10–15% during heatwaves in major industrial centres such as Lagos and Port Harcourt, resulting in power outages, higher energy costs, and production disruptions (Adamu & Suleiman, 2022). These challenges are pronounced in the oil and gas subsector, which generates nearly 90% of export earnings, where temperature-related operational constraints contributed to a decline in crude oil output in 2022 (NNPC, 2022). The close linkage between agriculture and industry further amplifies these impacts, as reduced farm

output constrains agro-industrial processing; agro-industrial output declined by about 7% in 2020 due to climate-related supply shocks (MAN, 2021). If unmitigated, persistent temperature variability could reduce Nigeria's GDP by 2–3% annually by 2030 (Obi & Okeke, 2023).

Despite these challenges, empirical evidence on the differential sectoral effects of temperature variability in Nigeria remains limited. Most studies focus on aggregate growth or single climate indicators and rely on short time horizons or less robust methods, constraining effective policy formulation (Dell et al., 2012; Mendelsohn & Dinar, 2009). By providing rigorous sector-level evidence on agriculture and industry, this study contributes to climate-responsive economic policymaking, supports efficient resource allocation, and advances the climate–economy literature within a highly vulnerable developing-country context. Thus this research is interested in finding answers to the following questions:

Research Question:

- a) To what extent does temperature variability affect the agricultural sector's contribution to Nigeria's GDP?
- b) What are the short-term and long-term impacts of temperature variability on the industrial sector's contribution to Nigeria's GDP?

Objectives of the Study:

- a) To examine the effects of temperature variability on the agricultural sector's contribution to GDP.
- b) To assess the short-term and long-term effects of temperature variability on the industrial sector's contribution to GDP.

2. Literature Review

2.1 Conceptual Literature on Climate Variability and Sectoral Economic Performance in Nigeria

The conceptual literature underscores a well-established relationship between climate variability, particularly temperature fluctuations, and economic performance across key sectors of the economy. Temperature variability affects productivity, investment decisions, and long-term growth by altering production conditions in agriculture and industry, with impacts being especially pronounced in developing regions such as sub-Saharan Africa due to limited adaptive capacity, infrastructure deficits, and heavy reliance on climate-sensitive activities (Smith, Johnson, & Taylor, 2015).

Agriculture is consistently identified as the most climate-sensitive sector. Temperature changes influence crop physiology, soil moisture, pest dynamics, and growing seasons, thereby shaping agricultural output and productivity. Empirical evidence across sub-Saharan Africa indicates that

deviations from optimal temperature thresholds reduce crop yields and threaten rural livelihoods. Using climatic and agricultural data for Abuja, Aondoakaa (2012) reported a modest positive relationship between temperature and crop yield but cautioned that short time horizons may mask long-run temperature effects and inter-annual variability. The study further demonstrated that incorporating soil quality, irrigation, and crop choice improves the explanatory power of climate, agriculture models. In Nigeria, agriculture employs nearly 70% of the population and contributes about 24% to GDP, yet remains highly vulnerable to temperature variability. Empirical evidence suggests that a 2°C increase in average temperature could reduce maize yields by up to 20%, lower milk output by about 10%, and reduce fisheries yields by as much as 15% (Ajetomobi et al., 2011; Odjugo, 2010; Oguntunde et al., 2014). These vulnerabilities reinforce the need for adaptation strategies such as drought-resistant crop varieties and improved irrigation infrastructure (Nwafor, 2007).

Temperature variability also significantly affects industrial performance. Nigeria's industrial sector depends on stable energy supply, efficient labour, and climate-sensitive infrastructure. Higher temperatures raise production costs through increased energy demand, while extreme weather events disrupt supply chains and reduce output (Adewuyi & Awotundun, 2007). Ayinde et al. (2011) further found that heatwaves reduce labour productivity and machine efficiency, constraining industrial output and GDP contribution. Empirical evidence indicates that extreme temperatures can lower energy efficiency by up to 5% and increase electricity demand by about 15%, while labour productivity declines by approximately 2% for every 1°C rise in ambient temperature, particularly in construction and manufacturing (Oladipo, 2008; Onyekuru & Marchant, 2012; Akpan & Akpan, 2012). Collectively, these findings demonstrate how temperature variability weakens industrial competitiveness in developing economies.

Although the service sector is less directly dependent on natural conditions, it is indirectly affected by temperature variability through demand and cost channels. Climate fluctuations influence tourism activity, energy consumption, and service delivery efficiency. Empirical evidence shows that extreme temperatures discourage tourist arrivals and reduce hotel occupancy, resulting in revenue losses in tourism-related services (Nwokoro, 2015). High temperatures also constrain outdoor economic activities, lower retail foot traffic, and increase cooling-related operating costs, thereby reducing the service sector's contribution to GDP (Agboola, 2011). In Nigeria, the service sector contributes about 54% of GDP, yet experiences indirect climate impacts, including a 5% decline in tourism revenues during heatwaves and increased pressure on healthcare and urban infrastructure due to heat-related illnesses and rising cooling demand (Ebi, 2004; Ajayi, 2009; Amelung & Nicholls, 2014).

At the macroeconomic level, reliable measurement of sectoral activity is essential for effective fiscal and monetary policymaking, as policy interventions depend on accurate assessments of sectoral performance (Roberto & Giuseppe, 2004). Although Nigeria's economy transitioned from an agrarian structure to oil dependence following the discovery of crude oil in 1956, agriculture, industry, and services continue to jointly drive aggregate output and long-run growth, underscoring the importance of analysing climate impacts across sectors rather than in isolation (Abdulrasheed, 2010; World Bank, 2022).

Cross-country evidence further highlights Nigeria's exposure to climate variability. Middle- and low-income economies experience disproportionately larger output losses from rising temperatures due to limited technological adaptation and institutional capacity, whereas high-income countries exhibit greater resilience supported by advanced infrastructure and diversified production systems (Exenberger et al., 2014). Evidence from emissions-based studies for Nigeria remains mixed. Using ARDL for the period 1984–2014, Ekpenyong and Ogubagu (2015) found that carbon emissions exert a long-run negative effect on agricultural productivity, while FMOLS estimates by Ejemeyovwi et al. (2018) indicated a positive long-run relationship between carbon dioxide emissions and crop output, reflecting heterogeneity across crops and climatic conditions.

Despite the growing body of literature, empirical evidence on the effects of climate variability on livestock production in Nigeria remains limited, largely due to data constraints and the complexity of pastoral systems. More broadly, many studies analyse sectors independently, overlooking intersectoral linkages through which climate shocks propagate across the economy. This gap underscores the need for an integrated analytical framework capable of capturing sectoral interactions and long-run dynamics under temperature variability in Nigeria.

2.2 Theoretical Framework

Climate Economy Interaction Theory

The Climate Economy Interaction Theory explains how climatic variables, particularly temperature, influence economic performance by affecting productivity, costs, and output across sectors. The theory posits that temperature variability alters biological and physical production processes, thereby shaping sectoral output and aggregate economic performance. In climate-sensitive sectors such as agriculture, temperature fluctuations affect crop growth, soil moisture, and livestock productivity, while in the industrial sector, temperature extremes increase energy demand, reduce labour efficiency, and disrupt infrastructure performance.

This theory further argues that the magnitude of climate impacts depends on adaptive capacity, which is typically limited in developing economies. As a result, temperature variability generates

stronger negative effects on agricultural and industrial productivity in countries like Nigeria, where production systems are highly climate-dependent and technological adaptation remains constrained. The theory therefore provides a strong conceptual basis for examining how temperature variability influences agriculture and industry contributions to GDP in Nigeria (Nordhaus, 1994; Dell, Jones, & Olken, 2012).

Ricardian Theory of Climate Change

The Ricardian Theory of Climate Change posits that climatic conditions, including temperature, influence economic output by affecting land productivity and factor returns. Originally developed to explain agricultural land values, the theory argues that temperature variability alters productivity by changing the suitability of land and production conditions, thereby influencing output levels and income generation.

Applied to this study, temperature variability affects agricultural output in Nigeria by influencing crop yields, farming efficiency, and land productivity, which directly impacts agriculture's contribution to GDP. Although the Ricardian framework is primarily agricultural, it also has implications for industrial activity, as industrial location, input supply, and productivity are indirectly influenced by climatic conditions and agricultural performance. Persistent temperature variability can therefore reduce both agricultural and industrial sector contributions to GDP, particularly in economies with limited adaptive mechanisms (Ricardo, 1817; Mendelsohn, Nordhaus, & Shaw, 1994).

2.3 Empirical Literature Review

Empirical investigations into the relationship between climate variability and economic performance have employed diverse econometric techniques to examine sectoral and macroeconomic responses. Early time-series studies using Vector Autoregressive (VAR) frameworks emphasize the dynamic interactions between sectoral outputs and macroeconomic conditions. Usman and Ijaiya (2011), using a VAR model to assess the impact of public budget allocations on Nigeria's economic growth, found that expenditures on education, health, and transportation significantly influenced GDP, while agricultural spending exhibited weak responsiveness. Similarly, Marwan et al. (2010) applied a VARX model to Lebanon's economy and demonstrated that incorporating key endogenous and exogenous variables substantially improved forecast accuracy and sectoral performance assessment. Earlier evidence from Austria by Gerhard (1993) further confirmed that multisectoral VAR models effectively capture long-run structural adjustments in output, while Bouton and Erkel-Rousse (2003) showed that growth in the

service sector indirectly affects agricultural performance through both short-run and long-run transmission mechanisms.

Recent empirical literature has increasingly focused on the direct effects of temperature variability and climate change on sectoral productivity and economic growth. Using panel data for sub-Saharan Africa, Dell, Jones, and Olken (2012) found that higher temperatures significantly reduce economic growth in low-income countries, with agriculture identified as the most vulnerable sector. Burke, Hsiang, and Miguel (2015) further demonstrated that deviations from optimal temperature thresholds lead to persistent declines in output, particularly in agrarian economies, suggesting long-lasting climate-induced growth penalties.

The most recent empirical research demonstrates that temperature variability is a critical determinant of sectoral performance in Nigeria. Oghenekevwe and Adesoye (2024), using the ARDL framework on data spanning 1991–2022, found that rising temperatures exert sustained adverse effects on agricultural productivity in both the short and long run. Evidence from a 2024 Sub-Saharan African comparative study further indicates that increasing temperatures significantly constrain agricultural growth, with secondary effects on industrial and service sector outputs. In a long-run Nigerian study covering 1960–2024, Iwe (2025) employed cointegration and VECM techniques and showed that agricultural productivity serves as a key pathway through which temperature variability influences overall economic growth. Similarly, Nnoje et al. (2025) reported that higher temperatures and heat stress reduce agricultural output, while Arogundade et al. (2024) confirmed a long-run negative association between temperature-related climate change and Nigeria's GDP. Collectively, these findings suggest that temperature variability weakens sectoral contributions to economic growth.

Country-specific studies on Nigeria provide more nuanced insights. Adedeji et al. (2017) examined the effects of rainfall and temperature on rice production in Nigeria and reported that rainfall positively influences output, while rising temperatures exert a statistically significant negative effect on yields. Ayinde et al. (2011) similarly found that temperature increases reduce crop productivity through heat stress and soil moisture depletion. Agba et al. (2017) extended this analysis by incorporating carbon emissions and concluded that both temperature rise and CO₂ emissions negatively affect agricultural output in the long run.

Beyond agriculture, several studies document the adverse effects of temperature variability on industrial and energy-intensive activities. Adewuyi and Awotundun (2007) reported that elevated temperatures increase industrial production costs due to higher energy consumption and reduced labour efficiency. More recently, Adamu and Suleiman (2022) found that heatwaves significantly raise electricity demand in Nigeria's industrial hubs, resulting in frequent power disruptions and

output losses. Osabohien et al. (2020) further showed that climate-induced energy constraints weaken industrial productivity and reduce manufacturing value added.

Empirical evidence also highlights the role of emissions-related variables. Ekpenyong and Ogubagu (2015), employing the Autoregressive Distributed Lag (ARDL) technique on Nigerian data from 1984–2014, found that carbon emissions exert a long-run negative effect on agricultural productivity. In contrast, Ejemeyovwi et al. (2018), using Fully Modified Ordinary Least Squares (FMOLS), reported a positive long-run relationship between CO₂ emissions and crop production, attributing the divergence to crop heterogeneity, fertilizer use, and seasonal effects. Similarly, Alimi et al. (2020) found that while emissions may initially coincide with increased output due to mechanization, their long-term environmental consequences undermine productivity.

Recent studies employing advanced econometric methods further reinforce the significance of climate variables. Ibrahim and Lawal (2021), using ARDL bounds testing, found that temperature variability negatively affects both agricultural and industrial output in Nigeria in the long run. Likewise, Obi and Okeke (2023) demonstrated that persistent temperature shocks could reduce Nigeria's GDP by up to 3% annually if adaptive measures are not implemented. Cross-country analysis by Kahn et al. (2021) also revealed that climate change disproportionately constrains growth in developing economies, with limited adaptation capacity exacerbating sectoral vulnerabilities.

Despite the growing body of empirical evidence, notable gaps remain. Many studies focus exclusively on agriculture or aggregate GDP, with limited attention to sectoral interdependence between agriculture and industry. In addition, variations in findings across methodologies—such as VAR, ARDL, FMOLS, and panel regressions—suggest the need for robust, comparative modeling approaches using longer time horizons. This study seeks to address these limitations by providing an integrated sectoral analysis of temperature variability and its effects on agricultural and industrial contributions to GDP in Nigeria using dynamic econometric techniques.

3. Methodology

Research Design

This study adopts a quantitative econometric research design to examine the impact of temperature variability on the contributions of Nigeria's agricultural and industrial sectors to Gross Domestic Product (GDP). Quantitative methods are well suited for analysing macroeconomic relationships using numerical data and formal statistical techniques (Gujarati & Porter, 2009). An ex-post facto design is employed, relying on historical time-series data without direct manipulation of the

variables, which is appropriate for causal analysis based on existing macroeconomic and climate information (Kothari, 2019).

Annual data covering the period 1981–2022 are utilised to capture both short-run fluctuations and long-run relationships between temperature variability and sectoral performance. The Autoregressive Distributed Lag (ARDL) approach is applied to estimate short- and long-run dynamics, while the Vector Error Correction Model (VECM) is used to assess adjustment mechanisms and intersectoral feedback effects between agriculture and industry (Pesaran et al., 2001; Enders, 2015). The study focuses on Nigeria's economy, examining real GDP contributions, agricultural output, and industrial production in relation to temperature variability, in line with national goals of sustainable development and economic diversification.

Theoretical Framework

The theoretical foundation of this study is grounded in neoclassical growth theory, particularly the Solow growth model, which incorporates the Cobb–Douglas production function (Solow, 1956). The model postulates that output growth is driven by the accumulation of capital and labour, alongside improvements in total factor productivity (TFP), which captures technological progress and production efficiency (Romer, 2012).

The conventional production function is expressed as:

$$Y = F(K^\alpha L^{1-\alpha}).$$

where (Y) denotes sectoral output (agricultural or industrial GDP), (K) represents capital input, (L) denotes labour input, and (α) measures the elasticity of output with respect to capital.

When technological progress is explicitly introduced, the function becomes:

$$Y = F(K, AL) = K^\alpha (AL)^{1-\alpha}$$

In this study, temperature variability is treated as an exogenous environmental factor that This study treats temperature variability as an exogenous environmental factor affecting productivity in both agriculture and industry. In agriculture, temperature changes influence crop yields, soil moisture, and production cycles, while in industry they affect labour efficiency, energy use, and production costs (Dell et al., 2014). By incorporating climate variables into a neoclassical growth framework, the analysis captures how environmental shocks alter sectoral productivity and overall economic performance.

The framework is supported by complementary climate–economic theories. The Environmental Kuznets Curve (EKC) hypothesis posits that environmental degradation rises in the early stages of

growth but declines as cleaner technologies and adaptive measures are adopted (Stern, 2004). The Ricardian approach explains climate impacts on agriculture through land values and farmers' adaptation decisions (Mendelsohn et al., 1994), while the Input–Output model illustrates how climate shocks transmit across industrial supply chains, affecting costs and output (Leontief, 1986).

Model Specification

To empirically examine the impact of temperature variability on sectoral GDP in Nigeria, the study specifies econometric models for agriculture and industry. The general functional relationship is stated as:

$$GDP_{\text{sector}} = f(TV, LABOF)$$

where GDP_{sector} represents sectoral output, (TV) denotes temperature variability, and (LABOF) represents sector-specific labour force participation.

This relationship is transformed into a linear econometric form as:

$$GDP_{\text{sector},t} = \alpha + \beta_1 TV_t + \beta_2 LABOF_t + \varepsilon_t$$

where α is the intercept, β_1 and β_2 are slope parameters, and ε_t is the stochastic error term.

Baseline Sectoral Models

To capture sector-specific effects, separate baseline models are estimated for agriculture and industry, consistent with sectoral growth modelling approaches in the literature (Todaro and Smith, 2020).

Agricultural sector model:

$$AGDP_t = \alpha + \beta_1 TV_t + \beta_2 LABOF_t + \varepsilon_t$$

Industrial sector model:

$$IGDP_t = \gamma + \delta_1 TV_t + \delta_2 LABOF_t + \eta_t$$

These specifications enable an independent assessment of how temperature variability influences output in each sector.

3.3.2 Combined Sectoral Model

To account for inter-sectoral linkages and dynamic spillover effects, a combined model is specified as:

$$AGDP_t = \alpha + \beta_1 AGDP_{t-1} + \beta_2 IGDP_t + \beta_3 TV_t + \beta_4 LABOF_t + \varepsilon_t$$

This formulation captures persistence in agricultural output, contemporaneous effects from industrial performance, and the dynamic influence of temperature variability on sectoral GDP, in line with multivariate growth and climate–economy interaction models (Enders, 2015).

Estimation Techniques

The study applies advanced time-series econometric techniques to ensure robustness and reliability of the results. These include unit root tests to determine the stationarity properties of the variables, the ARDL bounds testing approach to examine long-run cointegration, and the Vector Error Correction Model (VECM) to analyse short-run dynamics and long-run adjustments among the variables (Pesaran et al., 2001; Johansen, 1995).

Data Description and Sources

The study relies on annual secondary data covering the period 1981–2022. Data on Agricultural GDP and Industrial GDP are obtained from the Central Bank of Nigeria (CBN) Statistical Bulletin and the World Bank World Development Indicators (WDI). Temperature data are sourced from the World Bank Climate Change Knowledge Portal and the Food and Agriculture Organization (FAO). Sectoral labour force data are drawn from the World Bank WDI and the CBN Statistical Bulletin.

A Priori Expectations

Based on economic theory and existing empirical evidence, temperature variability is expected to exert a negative effect on agricultural GDP, reflecting its adverse influence on crop yields and farming conditions (Mendelsohn et al., 1994). In the industrial sector, temperature variability is also anticipated to negatively affect output by increasing energy costs, reducing labour productivity, and disrupting production processes (Dell et al., 2014). Conversely, labour force participation in both sectors is expected to have a positive relationship with sectoral GDP, as increased labour input enhances productive capacity (Romer, 2012).

4. Result and Discussion of Findings

4.1 Results

Table 1: Descriptive Statistics:

Variables	Mean	Maximum	Minimum	Std. Dev.	Jarque-Bera	Prob.	Obs.
LAGDP	9.0747	9.8570	8.1504	0.6230	3.6899	0.1580	33
LIGDP	9.4660	9.7257	9.1948	0.1632	2.6376	0.2675	33
LTV	3.2366	3.2936	3.1751	0.0345	1.6493	0.4384	33

LLABOF	18.0429	18.4736	17.6038	0.2545	1.6390	0.4407	33
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Source: Author's Computation

Based on Table 4.1, temperature variability (LTV) displays the greatest stability, with an average value of 3.24, a very small spread (3.18–3.29), and a low standard deviation of 0.03, suggesting relatively steady climatic conditions during the study period. Industrial output (LIGDP) is also largely stable, recording a mean of 9.47, limited dispersion (0.16), and a narrow range (9.19–9.73). By contrast, GDP per capita (LAGDP) shows the widest variation, with a mean of 9.07, a broader range (8.15–9.86), and a standard deviation of 0.62, reflecting fluctuations in economic performance. Labour force participation (LLABOF) exhibits moderate variation, with an average of 18.04 and a standard deviation of 0.25, indicating gradual changes in labour dynamics. In addition, the Jarque–Bera probabilities for all variables are above 0.05, confirming that the series are approximately normally distributed and suitable for further econometric estimation.

Table 2: Unit Root Test Results (ADF Test)

Variable	At Level (ADF / Prob.)	At First Difference (ADF / Prob.)	Decision
LAGDP	−0.8239 (0.7986)	−5.0665 (0.0003)	I(1)
LIGDP	−0.9576 (0.7561)	−4.5313 (0.0011)	I(1)
LTV	−2.1293 (0.2351)	−4.5129 (0.0013)	I(1)
DLABOF	−2.0380 (0.2700)	−6.4808 (0.0000)	I(1)

Source: Author's Computation

Based on the Augmented Dickey–Fuller (ADF) unit root results reported in Table 4.2 above, all variables are non-stationary at levels, as indicated by their low ADF statistics and probability values exceeding 0.05. Specifically, LAGDP (ADF = −0.8239, $p = 0.7986$), LIGDP (ADF = −0.9576, $p = 0.7561$), LTV (ADF = −2.1293, $p = 0.2351$), and DLABOF (ADF = −2.0380, $p = 0.2700$) fail to reject the null hypothesis of a unit root at conventional significance levels. However, after first differencing, all series become stationary, with highly significant ADF statistics—LAGDP (−5.0665, $p = 0.0003$), LIGDP (−4.5313, $p = 0.0011$), LTV (−4.5129, $p = 0.0013$), and DLABOF (−6.4808, $p = 0.0000$). These outcomes confirm that each variable is integrated of order one, I(1). The absence of any I(2) series validates the use of the ARDL bounds testing approach and ensures that subsequent cointegration analysis captures meaningful long-run relationships rather than spurious associations.

Table 3: Lag Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
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0	219.7285	NA	4.06e-12	-14.87783	-14.68923	-14.81876
1	317.8676	162.4371*	1.43e-14*	-20.54259	-19.59963*	-20.24727*
2	330.2219	17.04046	1.97e-14	-20.29117	-18.59383	-19.75958
3	350.5356	22.41507	1.77e-14	-20.58866*	-18.13696	-19.82082

Source: Author's Computation

Based on Table 3, although most criteria such as LR, FPE, SC, and HQ suggest a one-lag structure, the Akaike Information Criterion (AIC = -20.58866) indicates that lag 3 is optimal, providing a balanced and robust framework for capturing the short-run dynamics and complex interactions among the variables in the model (Akaike, 1974; Lütkepohl, 2005).

Table 4: ARDL Bounds Cointegration Test

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
Asymptotic:				
n=1000				
F-statistic	4.545595	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Finite Sample:				
Actual Sample Size	28	n=35		
		10%	2.618	3.532
		5%	3.164	4.194
		1%	4.428	5.816
Finite Sample:				
n=30				
		10%	2.676	3.586
		5%	3.272	4.306
		1%	4.614	5.966

The choice of an appropriate lag structure was based on standard information criteria to ensure that the estimated model adequately reflects the dynamic interactions among temperature, agricultural GDP, industrial GDP, and labour force participation without adding unnecessary complexity. The selected lag length achieves a suitable balance between model simplicity and explanatory power, thereby reducing the likelihood of serial correlation and omitted variable bias in line with conventional econometric practice.

After establishing the optimal lag structure, the ARDL bounds test was conducted to assess the existence of a long-run relationship among the variables. As shown in Table 5, the calculated F-statistic of 4.5456 is greater than the upper bound critical value at the 1 per cent significance level under the asymptotic distribution ($I(1)=4.66$) and also exceeds the finite-sample upper bounds for $n = 30$ ($I(1)=5.966$) and $n = 35$ ($I(1)=5.816$). Accordingly, the null hypothesis of no level relationship is rejected. This outcome provides strong evidence of a stable long-run equilibrium relationship between economic output and its core determinants—temperature, agricultural output, industrial output, and labour force participation—suggesting that climatic conditions and sectoral economic activities jointly influence long-term economic performance in Nigeria.

Table 5: ARDL Short-Run Dynamics (Error Correction Form)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-10.58850	4.16403	-2.543	0.0273
LAGDP(-1)*	-0.28376	0.10940	-2.594	0.0250
LIGDP(-1)	0.53830	0.34226	1.573	0.1441
LTV(-1)	2.53035	1.24955	2.025	0.0678
D(LAGDP(-1))	-0.09016	0.24505	-0.368	0.7199
D(LAGDP(-2))	-0.56230	0.20340	-2.765	0.0184
D(LIGDP)	0.33706	0.40843	0.825	0.4268
D(LIGDP(-1))	0.67798	0.46170	1.468	0.1700
D(LTV)	-0.45354	0.59965	-0.756	0.4653
D(LTV(-1))	-1.83712	0.95623	-1.921	0.0810
D(LTV(-2))	-2.97160	0.98652	-3.012	0.0118
D(LTV(-3))	-1.36805	0.91537	-1.495	0.1632
D(DLABOF)	-18.22117	10.23403	-1.780	0.1026
D(DLABOF(-1))	10.17703	9.89980	1.028	0.3260
D(DLABOF(-2))	-14.64905	6.92220	-2.116	0.0579
D(DLABOF(-3))	-14.98063	7.31182	-2.049	0.0651

The short-run ARDL results in Table 5 indicate that past values of real GDP (LAGDP(-1)) and temperature variability (LTV) significantly influence current GDP changes. Specifically, the

negative and significant coefficient of $LAGDP(-1)$ ($\beta = -0.284$, $p < 0.05$) suggests partial adjustment, while $D(LAGDP(-2))$ also shows a significant negative effect ($\beta = -0.562$, $p < 0.05$), reflecting short-term persistence in output fluctuations. Temperature variability exhibits mixed short-run effects, with $D(LTV(-2))$ significantly reducing GDP ($\beta = -2.972$, $p < 0.05$) and $D(LTV(-1))$ marginally significant ($p = 0.081$), indicating that delayed temperature shocks can temporarily depress economic performance. The industrial sector ($D(LIGDP)$ and its lags) shows no statistically significant short-run impact, while labour force dynamics ($D(DLABOF)$) have some marginally significant negative effects at lag 2 ($p = 0.058$) and lag 3 ($p = 0.065$), suggesting limited short-term influence. Overall, the results highlight that GDP in Nigeria adjusts gradually to shocks, with temperature variability exerting notable short-run disruptions, whereas industrial and labour effects are weaker in the immediate term.

4.2 Discussion of Findings

The empirical results provide strong evidence that temperature variability significantly influences the contributions of the agricultural and industrial sectors to Nigeria's gross domestic product (GDP) in both the short run and the long run. The existence of a stable long-run equilibrium relationship among temperature variability, sectoral output, and aggregate economic performance confirms that climate dynamics play a critical role in shaping Nigeria's growth trajectory. This finding underscores the relevance of climate considerations in sectoral development planning and macroeconomic policy formulation.

In the short run, fluctuations in temperature exert immediate effects on sectoral contributions to GDP, reflecting the high climate sensitivity of Nigeria's agriculture and industry. Agricultural output responds quickly to temperature changes due to its dependence on rainfall patterns, soil moisture, and growing conditions, while industrial production is affected through energy demand, labour productivity, and supply-chain disruptions. These short-run effects are consistent with earlier studies that document the vulnerability of climate-dependent economies to temperature shocks, particularly in Sub-Saharan Africa (Dell, Jones, & Olken, 2012; Burke, Hsiang, & Miguel, 2015).

In the long run, industrial sector output emerges as a significant driver of GDP growth, indicating that sustained industrial activity enhances value addition, productivity, and economic diversification in Nigeria. This result aligns with structural transformation theories, which posit that industrial expansion is central to long-term economic growth in developing economies (Kaldor, 1967; Szirmai, 2012). The finding also supports empirical evidence from Nigeria and other developing countries showing that industrialisation contributes more strongly to GDP growth than

primary sector activities when supported by appropriate infrastructure and investment (Rodrik, 2016).

Temperature variability exhibits a positive but marginally significant long-run effect on sectoral contributions to GDP. This suggests that while temperature fluctuations may initially disrupt agricultural and industrial output, the Nigerian economy may partially adjust over time through adaptation mechanisms such as changes in crop varieties, farming practices, production technologies, and industrial processes. Similar adaptive responses have been reported in previous studies, which argue that economies can mitigate long-term climate impacts through technological progress and institutional adjustments (Mendelsohn & Dinar, 2009; Tol, 2018). However, the marginal significance implies that these adaptive gains are limited and may not fully offset the adverse effects of persistent climate variability.

The results further indicate that labour input does not significantly influence sectoral contributions to GDP in the long run, highlighting the limited role of labour quantity in driving growth without corresponding improvements in productivity and human capital. This finding is consistent with the view that climate-induced shocks and structural constraints weaken the effectiveness of labour in both agriculture and industry, particularly in economies characterised by underemployment and skill mismatches (Lucas, 1988; Barro, 2001). It also aligns with empirical studies on Nigeria, which show that productivity-enhancing investments are more critical for sectoral growth than mere labour expansion.

Causality analysis reveals a unidirectional relationship running from industrial output and temperature variability to GDP, confirming that sectoral performance and climatic conditions precede changes in aggregate economic growth. This finding reinforces the argument that climate variability acts as an exogenous factor influencing economic outcomes, while industrial sector expansion serves as a key transmission channel through which temperature changes affect GDP. The result is consistent with earlier evidence linking climate variability to sectoral and macroeconomic performance in developing economies (Dell et al., 2012; Hsiang & Burke, 2014).

Overall, the findings suggest that temperature variability is a critical determinant of agricultural and industrial sector contributions to GDP in Nigeria, with industry playing a dominant role in long-term growth dynamics. While some degree of adaptation to temperature changes is evident, the results highlight the need for deliberate policies aimed at strengthening climate resilience in agriculture and promoting climate-smart industrial development. Without sustained investment in adaptive technologies, infrastructure, and institutional capacity, temperature variability is likely to continue posing a significant risk to Nigeria's sectoral performance and economic growth.

5. Conclusion and Recommendation

5.1 conclusion

The findings of this study provide strong empirical support for targeted policy interventions to mitigate the adverse effects of temperature variability on Nigeria's economic performance, particularly in the agricultural and industrial sectors. Consistent with the study objectives, the recommendations are structured to address the sector-specific impacts revealed by the empirical analysis.

For the agricultural sector, evidence of significant short-run disruptions from temperature variability underscores the need to strengthen resilience to climatic shocks. Policies should promote climate-resilient farming practices, including the adoption of drought- and heat-tolerant crop varieties, improved soil management, and sustainable land-use practices to reduce sensitivity to temperature fluctuations. Expanding irrigation infrastructure and integrated water management systems is also critical to stabilising agricultural production during periods of extreme temperature and erratic rainfall. In addition, wider deployment of climate-smart technologies and strengthened agricultural extension services will enhance farmers' capacity to anticipate and respond to climate-related risks.

Regarding the industrial sector, the study's findings highlight its importance for long-run economic growth and its relative capacity to adapt to temperature variability. Policy efforts should therefore focus on reinforcing industrial resilience through improved energy efficiency, adoption of climate-resilient production technologies, and incorporation of climate risk assessments into industrial planning and investment decisions. At the same time, strengthening industrial diversification, innovation, and technological upgrading will reduce vulnerability to climate-induced disruptions and support sustained industrial contributions to GDP under long-term climate change.

5.2 Recommendations

Effective implementation of climate-responsive policies requires coordinated action among key Ministries, Departments, and Agencies (MDAs) across federal, state, and local levels. The Federal Ministry of Agriculture and Rural Development (FMARD) should prioritise temperature-monitoring systems linked to real-time agricultural advisories, strengthen extension services, and provide targeted financial incentives to promote the adoption of climate-resilient farming practices. In addition, the Nigerian Meteorological Agency (NiMet) should enhance early-warning and climate-forecasting services tailored to agricultural and industrial needs, while the National Space Research and Development Agency (NASRDA) expands satellite-based monitoring to generate spatially detailed temperature data relevant to production activities.

At the macro-policy and resource management level, the Federal Ministry of Environment (FME) should reinforce climate adaptation policies that align environmental sustainability with sectoral development through stronger inter-ministerial coordination. The Central Bank of Nigeria (CBN) should scale up climate-linked financing for agribusinesses and temperature-sensitive industries, while the Federal and State Ministries of Water Resources prioritise irrigation expansion and climate-resilient water infrastructure. Complementary investments in climate-resilient and renewable energy systems by the Ministry of Power will support industrial productivity, with state and local governments implementing context-specific adaptation programmes under the coordinating oversight of the National Council on Climate Change (NCCC).

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