ASSESSING THE EFFECTS OF CLIMATE CHANGE AND HUMAN CAPITAL DEVELOPMENT ON FOOD STABILITY IN NIGERIA

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Abstract
This study examines the effect of climate change and human capital on food stability in Nigeria using annual time-series data covering the period from 1971 to 2023. The study employs the Autoregressive Distributed Lag (ARDL) estimation technique to examine both the short-run and long-run relationships among food stability, CO_2 emissions as a proxy for climate change, human capital, population growth and food exports. The findings indicate that CO_2 emissions have a significant negative effect on food stability, suggesting that climate-related environmental pressures increase fluctuations and disruptions within the food system and weaken the ability to maintain stable food security over time. In contrast, human capital has a positive and statistically significant effect on food stability, indicating that improvements in education, health, skills and knowledge enhance the capacity of individuals and food systems to adapt to and withstand food-related shocks. Population growth also has a significant negative effect, reflecting the increasing pressure of demographic expansion on food resources and the capacity of the food system to maintain stable food conditions. Similarly, food exports exert a negative and significant effect on food stability, suggesting that excessive diversion of domestic food supplies to external markets may increase vulnerability to domestic food shortages and price fluctuations. The study therefore recommends strengthening climate-change adaptation and mitigation strategies, investing in human capital development, improving domestic food production and storage systems, and ensuring that food-export policies are consistent with domestic food-security objectives. These measures are essential for enhancing the resilience and long-term stability of Nigeria's food system.
Keywords: *Climate Change, Human Capital, Food Stability, Nigeria*

JEL Codes: Q54, Q18, O15, O13, O35

1. 1ntroduction

Food security remains a critical development challenge in developing countries, particularly in Sub-Saharan Africa, where environmental, demographic and socioeconomic pressures continue to threaten the sustainability of food systems. Food security is commonly understood through four interconnected dimensions: availability, access, utilization and stability. While availability concerns the physical supply of food and access relates to households' ability to obtain it, food stability refers to the ability of individuals and households to maintain continuous access to sufficient, safe and nutritious food over time, even in the presence of economic, environmental or social shocks (FAO, 2020). Consequently, food stability represents an important dimension of food security because temporary disruptions in production, prices, incomes or distribution can quickly reverse improvements achieve in other dimensions of food security.

In Nigeria, maintaining stable food security has become increasingly difficult due to recurring environmental and socioeconomic disturbances. Climate change is one of the major threats to the stability of the country's food system. Rising temperatures, irregular rainfall, prolonged

droughts, flooding and desertification can disrupt agricultural production and create fluctuations in food supply across seasons and regions (Fraval et al., 2022). Because a substantial proportion of agricultural production depends on rainfall, climatic uncertainty can expose farmers and consumers to repeated production shocks. These disruptions can subsequently generate fluctuations in food prices and household food access, making it difficult for vulnerable populations to maintain stable food consumption over time.

Human capital also plays an important role in strengthening food stability. Education, health, skills and knowledge can enhance the capacity of farmers, households and communities to anticipate, absorb and recover from food-system shocks. Individuals with higher levels of human capital may be better equipped to adopt climate-smart agricultural technologies, diversify livelihoods, access market information and respond effectively to changes in food prices and availability. Conversely, deficiencies in education, healthcare, agricultural extension and technical skills may increase the vulnerability of households and agricultural producers to environmental and economic shocks (Osabohien et al., 2018). Thus, human capital can contribute to the resilience and adaptive capacity required to sustain food security during periods of disruption.

Population growth presents another important challenge to food stability in Nigeria. The country's rapidly expanding population is expected to place increasing pressure on agricultural resources, food production and distribution systems. The United Nations (2020) projects that Nigeria's population will exceed 400 million by 2050, implying a substantial increase in future food requirements. Where food production, infrastructure and household incomes fail to expand sufficiently to accommodate demographic growth, pressure on food supplies may increase, potentially contributing to shortages, higher food prices and greater vulnerability to food-system shocks. In addition, insecurity, land degradation, displacement and restricted access to agricultural land in some parts of the country can further disrupt production and distribution, thereby weakening the stability of the food system (Obayelu et al., 2019).

Food exports may also have implications for food stability when domestic production is unable to adequately satisfy internal demand. Although agricultural exports generate foreign exchange and provide income for producers, excessive diversion of food commodities toward external markets may reduce domestic supplies during periods of production shortages. This can contribute to domestic price pressures and increase the vulnerability of households to food insecurity. Similarly, inadequate storage facilities, poor transportation networks and weak food-distribution systems can amplify the effects of temporary production shocks by preventing food from moving efficiently from surplus to deficit areas.

Against this background, this study examines the impact of climate change and human capital on food stability in Nigeria, using annual time-series data covering the period from 1971 to 2023. The study employs the Autoregressive Distributed Lag (ARDL) approach to investigate both the short-run and long-run relationships between climate change, human capital and food stability, while accounting for other relevant determinants, including population growth, food exports and domestic food production. By focusing specifically on the stability dimension of food security, the study seeks to provide empirical evidence on the factors that determine Nigeria's capacity to maintain reliable food security in the face of environmental and socioeconomic shocks. The findings are expected to provide useful evidence for the formulation of policies aimed at strengthening climate resilience, human capital, agricultural productivity and the overall stability of Nigeria's food system. The remainder of the paper is

structured as follows: Section 2 presents the relevant literature; Section 3 discusses the methodology; Section 4 presents and discusses the empirical results; while Section 5 provides the conclusion and policy recommendations.

2. Literature Review

2.1 Conceptual Literature

This section defines and interlinks the core concepts of climate change, human capital development (HCD), and food stability within the Nigerian context, and as they are used in the study.

2.1.1 Climate Change

Climate change denotes long-term changes in temperature, precipitation regimes, and the frequency or intensity of extreme events such as droughts, floods, and heatwaves. In Nigeria these appear as rising mean temperatures, highly variable rainfall, northern desertification, and southern orcoastal flooding. Because the majority of Nigerian agriculture depends on rainfall, these changes can reduce crop yields, degrade soil, increases post-harvest losses, and disrupt production cycles (Adebayo et al., 2022; Oyabambi et al., 2025).

2.1.2 Food Stability

Food stability is one of the internationally recognised pillars of food security. The Food and Agriculture Organization (FAO) defines food security as the condition in which “all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.” The other pillars include; Availability, Access and utilization.
Stability is undermined when climate shocks cause sudden production shortfalls, price spikes, or supply-chain interruptions. In Nigeria, temperature rises, rainfall irregularity and extreme events have been shown to erode the stability of maize, rice and root-and-tuber supplies, thereby generating food-price inflation and seasonal hunger (Adebayo et al., 2022).

2.1.3 Human Capital Development

Human capital development (HCD) comprises the stock of knowledge, skills, health and competencies that raise individual and collective productivity. In agriculture it includes formal education, technical training in climate-smart practices, access to extension services, research capacity and physical health that sustains labour. Higher HCD enables farmers to adopt improved varieties, irrigation, soil-conservation techniques and livelihood diversification, thereby buffering climate impacts on food production and access (Okechukwu & Ikeije, 2025).

2.2 Theoretical Literature

Several complementary theories underpin the joint analysis of climate change, human capital development and food stability. The most relevant frameworks are outlined below.

2.2.1. Malthusian Theory of Population

Malthus (1798) argued that population increases at a geometric rate, whereas food production expands at an arithmetic rate, creating the possibility of food shortages when population growth outpaces food supply. Although advances in agricultural technology and production techniques have challenged some aspects of the original Malthusian argument, persistent population growth in developing countries such as Nigeria can exert pressure on food production and contribute to instability in food markets. Consequently, the Malthusian perspective provides the theoretical foundation for developing the econometric model of this study, which examines the contribution of population growth, climate change, human capital, and food exports to food stability in Nigeria.

2.2.2 Climate Vulnerability Theory

Vulnerability is conceptualised as a function of exposure to climatic hazards, sensitivity of the socio-ecological system, and adaptive capacity. Climate change acts as a threat multiplier that interacts with existing socio-economic weaknesses. In Nigeria the theory has been applied to demonstrate that temperature variability exerts the strongest negative effect on food security, followed by extreme weather and precipitation changes; northern regions are more sensitive to temperature and drought, southern regions to rainfall extremes. Limited adaptive capacity (low education, weak institutions) magnifies the impact (Oyabambi et al., 2025).

2.2.3 Amartya Sen's Entitlement and Capability Approaches

Sen's entitlement theory (1981) shifts the focus from aggregate food availability to the legal and economic means by which individuals command food (production-based, trade-based, labour-based or transfer entitlements). Climate shocks erode production entitlements; human capital strengthens labour and knowledge entitlements, expanding capabilities to secure food. The broader capability approach links food security to human development: inadequate nutrition impairs cognitive and physical development, reducing future human capital and perpetuating insecurity. This framework underpins the UNDP human-development approach to food security (UNDP Africa, n.d.).

2.2.4 Human Capital Theory

Originating with Becker, the theory treats education, training and health as investments that raise productivity. In agriculture, higher human capital accelerates technology adoption, improves resource allocation and enhances resilience to environmental stress. Empirical applications in Nigeria and comparable settings confirm that HCD exerts both direct positive effects on food security and indirect effects channeled through agricultural technology adoption and skills (Abba, 2024; Okechukwu & Ikeije, 2025).

2.3 Empirical Literature

Several studies have examined the determinants of food utilization and the broader dimensions of food security across different regions.

Firdaus, *et al* (2019) argue that climate change affects food stability as well as availability, access and utilization. Their review shows that temperature extremes, irregular rainfall and climate-related disasters generate fluctuations in production, prices and household access to

food over time. Because stability refers to the ability to maintain adequate food consumption despite shocks, climate variability can reverse short-term gains in other food-security dimensions. The authors observe that stability remains less researched than availability and therefore require more empirical work on how environmental shocks propagate through food systems. This perspective is directly relevant to Nigeria, where rain-fed agriculture and recurring droughts or floods can produce persistent instability in food supply and prices.

Fagbemi, *et al* (2024) examine the effect of carbon dioxide emissions on food production in Nigeria using ARDL and vector error-correction techniques. They find that CO_2 emissions are a significant determinant of food production and that higher emissions are associated with more severe food shortages. The study also reports bidirectional causality between emissions and food production in the long run, suggesting that unsustainable agricultural practices can raise emissions while climate pressure further weakens production. Although the dependent variable is food production rather than price volatility, the results have clear implications for food stability: production shortfalls induced by climate-related emissions can generate supply disruptions, price fluctuations and reduced reliability of domestic food systems. The paper therefore provides recent Nigerian evidence that CO_2-related climate pressure threatens the continuity of food supply.

Ogundipe, *et al* (2020) assess environmental degradation and food security in Nigeria over the period 1970–2017 using Johansen cointegration and vector error-correction analysis. Drawing on Malthusian theory, they find that environmental degradation reduces food production, while population growth raises demand for food without a matching increase in output. These dynamics imply greater pressure on food systems and a higher likelihood of shortages. For food stability, the relevant implication is that environmental stress and demographic pressure can make food supply and prices more vulnerable to shocks. The study therefore supports the inclusion of climate-related environmental indicators and population growth in models of food stability in Nigeria.

The State of Food Security and Nutrition in the World 2023 report (FAO, IFAD, UNICEF, WFP & WHO, 2023) provides the standard international framework for food security and documents how conflict, climate extremes and economic shocks continue to undermine progress towards ending hunger. The report emphasises that food stability is an essential dimension of food security because temporary disruptions in production, markets or incomes can quickly erode gains in availability, access and utilization. It also highlights that climate extremes and price shocks remain major drivers of food insecurity, particularly in countries with weak infrastructure, high import dependence and limited social protection. These official findings justify treating food stability as a distinct outcome and examining how climate pressure, demographic change and trade-related food movements affect Nigeria's capacity to maintain reliable food conditions over time.

Mendez et al. (2017) also studied food security and stability in rural Guatemala, focusing on the relationship between agricultural practices and food stability. They found that crop diversification and improved storage techniques were essential for ensuring food stability throughout the year. This was particularly important in areas prone to seasonal food shortages.
Firat (2022) investigated the effects of international food price fluctuations on food stability in sub-Saharan Africa. Their study concluded that the volatility of global food prices contributed to erratic food availability in the region, disproportionately affecting low-income households. They recommended increasing the resilience of local food systems and stockpiling key commodities to protect food security during global price surges. Finally, Zhang et al. (2023)

examined food stability in East Asia and found that international trade policies and food production policies played a significant role in stabilizing food availability. Countries with more open trade policies and robust food safety nets were able to maintain food stability even during global disruptions.

The reviewed studies demonstrate that food stability is influenced by food price volatility, climate variability, agricultural practices, trade policies, global supply-chain disruptions, government interventions and food-system shocks. However, the literature reveals a significant gap in understanding the combined effects of climate change and human capital on food stability in Nigeria. Most existing studies focus on individual factors such as climate variability, food prices, trade policies or agricultural interventions, while limited attention has been given to the role of human capital in strengthening households' and food systems' capacity to withstand and recover from food-related shocks. Moreover, much of the existing evidence is drawn from other African countries and developing regions, with relatively limited empirical evidence based on long-term Nigerian time-series data. The interaction between environmental pressures and socioeconomic capacity, particularly how human capital can mitigate the adverse consequences of climate change on food stability, remains insufficiently explored. This study therefore fills this gap by examining the effects of climate change and human capital on food stability in Nigeria, while accounting for other relevant factors such as population growth, food exports and domestic food production using annual time-series data and the ARDL approach.

3. Methodology

3.1. Types and Sources of Data

The dependent variable for this study is the fourth dimension of food security, food stability. Food stability refers to the ability to sustain consistent and dependable levels of food availability, accessibility, and utilization over time. It also reflects the capacity of the food system to withstand and recover from various shocks, including climate-related disturbances, economic instability, and conflict. In this study, food stability is represented by food price volatility, which indicates the extent to which food prices fluctuate over time and, consequently, reflects the ability of an economy to sustain relatively stable food prices. The data for the food stability indicator are obtained from the FAO (2024) database. The principal explanatory variables comprise population growth, climate change, and human capital, which are considered important factors influencing food stability. Population growth is measured by the annual percentage change in population and captures the demand-side pressure that changing population size can impose on the food system. Climate change is represented by carbon dioxide (CO_2) emissions, measured in metric tons per capita, as an indicator of environmental pressure associated with climate change. Human capital represents the quality of education and health embodied in a population and is constructed as a composite index using Principal Component Analysis (PCA) based on two underlying variables. Data for these human capital indicators are obtained from the World Bank (2024) database. The individual indicators are standardized and subjected to PCA, with the resulting components used to construct the Human Capital Index (HCI).

3.2 Theoretical Framework

This study is grounded in the Malthusian theory of population, which provides the theoretical basis for examining the effects of climate change and human capital on food stability in Nigeria. The framework is extended beyond the traditional emphasis on population dynamics

to accommodate other factors that may influence food stability. In particular, climate change represents the environmental dimension, human capital captures the socioeconomic dimension, while food export is incorporated as a control variable. Malthus (1798) argued that population increases at a geometric rate, whereas food production expands at an arithmetic rate, creating the possibility of food shortages when population growth outpaces food supply. Although advances in agricultural technology and production techniques have challenged some aspects of the original Malthusian argument, persistent population growth in developing countries such as Nigeria can exert pressure on food production and contribute to instability in food markets. Consequently, the Malthusian perspective provides the theoretical foundation for developing the econometric model of this study, which examines the contribution of population growth, climate change, human capital, and food exports to food stability in Nigeria.

3.3 Method of Estimation

Prior to estimating the model, preliminary time-series diagnostic procedures are performed to establish the statistical properties of the variables. Since the study relies on time-series data, examining the stationarity of the variables is necessary to minimize the possibility of obtaining spurious regression results. Accordingly, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests are employed to determine the order of integration of the variables. Following the unit root analysis, a cointegration test is conducted to establish whether the variables share a stable long-run equilibrium relationship. The existence of cointegration implies that although individual variables may be non-stationary in their levels, a linear combination of them can be stationary, thereby indicating the presence of a meaningful long-run relationship. To investigate this possibility, the Autoregressive Distributed Lag (ARDL) bounds testing approach developed by Pesaran et al. (2001) is adopted.

Once evidence of a long-run relationship is established, the ARDL and Error Correction Model (ARDL-ECM) frameworks are employed to estimate the long-run and short-run dynamics among the variables. The ARDL approach is considered appropriate for the present study because of its methodological flexibility and suitability for time-series analysis. In particular, the approach can be applied when the regressors are a mixture of variables integrated at level, I(0), and first difference, I(1), provided that none of the variables is integrated of order two, I(2). This feature distinguishes the ARDL approach from conventional cointegration techniques that generally require stronger assumptions concerning the integration properties of the variables. Another important advantage of the ARDL framework is its suitability for relatively small samples. Pesaran et al. (2001) demonstrate that the bounds-testing procedure provides a useful framework for investigating long-run relationships where the sample size is limited. The technique also allows the short-run adjustment process and long-run equilibrium relationship to be estimated within a unified modelling framework. These characteristics make the ARDL approach particularly suitable for examining the dynamic relationship between climate change, human capital and food utilization in Nigeria. Accordingly, the ARDL bounds-testing procedure is applied to determine whether a long-run equilibrium relationship exists among the variables included in the food utilization model. Where cointegration is established, the associated error correction representation is subsequently estimated to capture both the short-run effects and the speed at which deviations from long-run equilibrium are corrected.

3.4 Models Specification

Drawing from the propositions of the Malthusian theory of population, the functional form of the baseline model is specified as follows:

$$FST_t = f(POPG_t) \quad (1)$$

Where FST represents Food Stability, measured in terms of fluctuations or volatility in food prices, while POPG denotes Population Growth, measured as the annual percentage growth rate of the population. Consistent with previous related research, particularly Boege (2020), this study broadens the Malthusian framework by incorporating additional environmental and socioeconomic determinants of food stability. Climate change is represented by carbon dioxide emissions (CO_2), human capital is captured by the Human Capital Index (HCI), while food export (FEX) is introduced as a control variable. The inclusion of these variables provides a broader perspective on the factors that may influence food stability in Nigeria. Accordingly, the baseline model is extended as follows:

$$FST_t = f(POPG_t,\ CO2_t,\ HCI_t, FEX_t) \quad (2)$$

Where FST = Food Stability, POPG = Population Growth, CO_2 = Carbon Dioxide Emissions, HCI = Human Capital Index, and FEX = Food Export. The corresponding econometric specification is expressed as:

$$FST_t = \gamma_0 + \gamma_1 POPG_t + \gamma_2 CO2_t + \gamma_3 HCI_t + + \gamma_4 FEX_t + \varepsilon_t \quad (3)$$

In Equation (3), the constant term (γ_0) represents the intercept of the model and indicates the expected level of food stability (FST) when all the explanatory variables are held at zero. The respective coefficients ($\gamma_1, \gamma_2, \gamma_3 and\ \gamma_4$) capture the effects of population growth (POPG), carbon dioxide emissions (CO_2), human capital (HCI), and food export (FEX) on food stability. Each coefficient indicates the expected change in food stability associated with a one-unit or one-percentage-point change in the corresponding explanatory variable, conditional on the other variables remaining constant. The subscript t denotes the time period, while ε represents the error term. The error term captures the effects of other unobserved factors, random shocks, and disturbances that may influence food stability but are not explicitly accounted for in the model

The ARDL bounds-testing model for food stability is therefore specified as follows:

$$\Delta FST_t = \alpha_0 + \alpha_1 FST_{t-1} + \alpha_2 POPG_{t-1} + \alpha_3 CO2_{t-1} + \alpha_4 HCI_{t-1} + \alpha_5 FEX_{t-1} + \sum_{i=1}^{p} \beta_1 \Delta FUT_{t-i} + \sum_{j=0}^{q1} \beta_2 \Delta POPG_{t-j} + \sum_{j=0}^{q2} \beta_3 CO2_{t-j} + \sum_{j=0}^{q3} \beta_4 \Delta HCI_{t-j} + \sum_{j=0}^{q4} \beta_5 \Delta FEX_{t-j} + \mu_t$$

Where i and j denote the lags ($i = 1, 2 \ldots p; j = 0, 1, 2, \ldots, q$ and t represents time); FST_t is the dependent variable, and POPG, CO2, HCI and FEX are the explanatory variables; β_1 is the short-run coefficient of the lagged dependent variable; β_2 to β_5 represent the short-run coefficients of the lagged explanatory variables, α_1 to α_5 represent the long-run coefficients of the explanatory variables Lastly, $\boldsymbol{\mu_t}$ shows the error-term. The error correction form of model (4) was specified as follows:

$$\Delta FST_t = \alpha_0 + \sum_{i=1}^{p} \beta_1 \Delta FST_{t-i} + \sum_{j=0}^{q1} \beta_2 \Delta POPG_{t-j} + \sum_{j=0}^{q2} \beta_3 CO2_{t-j} + \sum_{j=0}^{q3} \beta_4 \Delta HCI_{t-j} + \sum_{j=0}^{q4} \beta_5 \Delta FEX_{t-j} + ECT_{t-1} + \mu_t \quad (5)$$

In equation (5), the Error Correction Term (ECT_{t-1}) captures the extent of deviation from the long-run equilibrium relationship among food stability (FST), population growth (POPG), CO_2 emissions, human capital index (HCI), and food export (FEX) in the previous period. It represents the lagged residuals from the cointegrating equation and reflects how much the actual value of food availability diverged from its long-run level. A key feature of the ECT is its coefficient, which is expected to be negative and statistically significant, indicating the speed at which any short-run disequilibrium is corrected over time.

3.5 Variable Description and measurement

Table 1: Variables Description, Measurement

Codes	Variables Description and Measurement	Sign	Sources
FST	Food Stability (Food Price Volatility)	N/A	FAO (2024)
POPG	Population growth (annual %)		World Bank (2024)
CO2	Carbon dioxide (CO2) emissions per capita (t CO2e/capita)	-	World Bank (2024)
HCI	Human Capital Index	-	World Bank (2024)
FEX	Food Export (annual %)	-	World Bank (2024)

Note: NA = Not applicable Source: Researcher's compilations (2026)

4. Results and Discussion

4.1 Results of Unit Root Tests

This section presents the results of unit root tests conducted to examine the stationarity properties of the variables. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were used to examine the stationarity of each variable and the results are presented in Table 4.2.

Table 4.2: Results of Unit Root Tests (ADF and PP)

Variables	ADF		Order of integration	PP		Order of integration
	Level t-Statistic	1st Difference t-Statistic		Level t-Statistic	1st Difference t-Statistic	
FST	-0.701	-8.743***	I(1)	-0.366	-11.162***	I(1)
CO2	-5.169***	----------	I(0)	-5.18***	----------	I(0)
HCI	-3.006	-3.897**	I(1)	-2.689	-3.889**	I(1)
POPG	-2.157	-4.999***	I(1)	-2.314	-5.257***	I(1)
FEX	-4.643***	----------	I(0)	-6.234***	----------	I(0)

Notes: Both ADF and PP tests are conducted with intercept and trend. Asterisks (***) and (**) indicate significance at 1% and 5% level, respectively.
Source: Researcher's computation (2026), using E-Views 13.

The results of ADF and PP unit root tests in Table 4.2 indicate that, most of the variables are non-stationary at level but become stationary after first differencing, suggesting they are integrated of order one, I(1). For instance, Food Stability (FST), Human Capital Index (HCI), Population Growth (POPG), and Local Food Production (FPRO), all show non-stationarity at level but reject the null hypothesis of unit root at the first difference. However, Carbon Dioxide Emissions (CO_2), and Food Export (FEX) are found to be stationary at level, indicating they are I(0).

4.2 Results of ARDL Bounds Test for Co-Integration

Having established the order of integration of the variables and ensure their stationarity property, which confirmed that the variables are either integrated of order zero I(0) or order one I(1), the next step is to conduct co-integration test to determine whether long run (equilibrium) relationship exist between food stability and explanatory variables in the model. Table 4.2 presents the results of the ARDL bounds test for the model. The F-statistic and critical values are used to determine the presence of a long-run (cointegration) relationship among the variables.

Table 4.2: Result of ARDL Bounds Tests

Test Statistic			Critical Values	
	Value	Significance	I(0)	I(1)
F-statistic	7.541***	5%	3.12	4.25
K	5	1%	3.93	5.23

*Note. k = no. of independent variables, *** and ** denotes a rejection of the null hypothesis of no co-integration at 1% and 5% significance level respectively.*
Source: Researcher's computation (2026), using E-Views 13.

The result of the ARDL bounds test for co-integration presented in Table 4.2 provide critical insights into the long-run relationships between food stability and the explanatory variables. The test uses the F-statistic to compare with the critical value bounds at 5% and 1% significance levels. If the F-statistic exceeds the upper bound (I(1)) at a given significance level, the null hypothesis of no co-integration is rejected, indicating the presence of a long-run equilibrium relationship. The result show that, the F-statistic (7.541) exceeds the critical values at both 1% (5.72) and 5% (4.57) significance levels, strongly rejecting the null hypothesis. This result confirms the existence of a co-integrating relationship between food stability and the explanatory variables in the long run.

4.3 Results of the Estimated Coefficients

This section presents the results of the estimated coefficients for the Food Stability Model, which investigates the effects of key variables on food stability in Nigeria. Food stability, in this context, reflects the consistent availability and accessibility of food over time. The model incorporates population growth (POPG), carbon dioxide emissions ($LNCO_2$), human capital index (HCI), and food exports (FEX). The long-run results presented in Table 4.3 reveal significant relationships. Population growth (POPG) has a negative and highly significant effect on food stability (coefficient = −0.629, p = 0.000), suggesting that as population increases, food systems may become more vulnerable to instability due to rising demand and decrease on resources. Similarly, carbon dioxide emissions (CO_2) are negatively associated

with food stability (coefficient = −0.393, p = 0.034), indicating that climate change risks proxied by CO_2 emissions undermine the resilience of the food system.

Table 4.3: Results of ARDL Estimated Coefficients

Panel A: Long-run				
Variable	Coefficient	Std. Error	t-Statistic	p-Value
POPG	-0.629	0.145	-4.335	0.000
LNCO2	-0.655	0.163	-4.014	0.000
HCI	0.393	0.175	2.247	0.034
FEX	-0.320	0.151	-2.110	0.045
Panel B: Short-run				
C	-16.286	2.820	-5.775	0.000
ΔFST_{t-1}	0.470	0.127	3.687	0.001
$\Delta POPG$	-3.465	4.749	-0.730	0.470
$\Delta POPG_{t-1}$	-0.470	0.140	-3.356	0.002
$\Delta LNCO2$	-0.470	0.140	-3.356	0.002
ΔHCI	2.180	1.692	1.288	0.206
ΔFEX	-3.115	7.306	-0.426	0.672
ΔFEX_{t-1}	-13.759	5.550	-2.479	0.018
ECT_{t-1}	-0.885	0.162	-5.465	0.000
R-squared	0.595			
Adjusted R-squared	0.577			

Note: Both constant and trend are used in estimating the model, and optimal lags automatically selected by AIC criterion (2,2,1,3,2)
Source: Researcher's computation (2026), using E-Views 13.

In contrast, the human capital index (HCI) exerts a positive and significant influence (coefficient = 0.655, p = 0.000), implying that improvements in health, education, and general human development enhance the food system's stability by enabling better management of resources and shocks. Notably, food exports (FEX) exhibit a positive and statistically significant coefficient (3.107, p = 0.002), indicating that increased food exports are associated with greater food instability in Nigeria. This result suggests that as more domestically produced food is exported, less is available for local consumption, thereby increasing volatility and reducing the reliability of food supply within the country. It reflects a trade-off where economic gains from exports come at the cost of domestic food security, particularly in a context where local production may not be sufficient to meet internal demand.

The short-run dynamics of the Food Stability Model, presented in Panel B, Table 4.3, reveal how fluctuations in key variables impact food stability. The lagged dependent variable (ΔFSTt-1) is positive and significant (0.470, p = 0.001), indicating a level of persistence in food stability from one period to the next. Population growth in its first lag (ΔPOPGt-1) and current carbon emissions (ΔLNCO2) both exert significant negative impacts on food stability

in the short run. Notably, food exports (ΔFEXt-1) continue to negatively affect food stability (–13.759, p = 0.018), reinforcing the long-run findings that increased food exports may contribute to domestic instability by reducing local availability. Meanwhile, the dummy variable (ΔDUM) remains positive and statistically significant (13.759, p = 0.006), suggesting that recent policy changes or interventions during the study period have had a short-run stabilizing effect. The error correction term (ECTt-1) is negative and statistically significant (–0.885, p = 0.000), confirming the presence of a stable short-run adjustment toward long-run equilibrium. The overall model fit, with an R-squared of 0.595, implies that the explanatory variables account for approximately 60% of the variation in food stability in the short term.

4.5 Results of Post-Estimation Tests

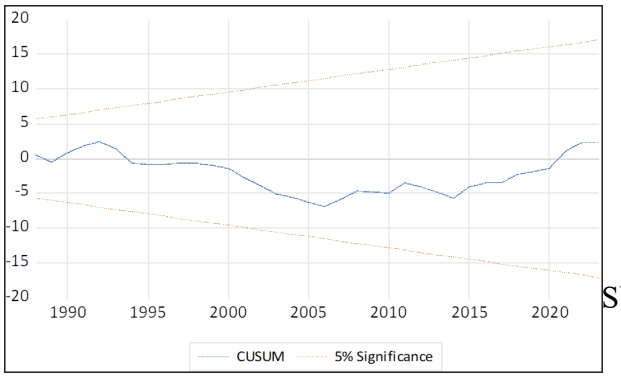
The results of post-estimation diagnostic tests, as presented in Table 4.4, confirm the robustness and reliability of the estimated model. The Jarque-Bera test indicates that the residuals are normally distributed, with p-values well above the 0.05 threshold. Similarly, there is no evidence of serial correlation, as shown by the high p-values in the Breusch-Godfrey LM test across all models. The heteroscedasticity tests also reveal no significant issues, confirming the assumption of constant variance of the residuals. Lastly, the Ramsey RESET test for functional form shows that all models are correctly specified, with p-values exceeding 0.05. These results collectively suggest that the model meet the key classical linear regression assumptions, enhancing the credibility of the study's findings and policy implications.

Table 4.4: Results of Residual Diagnostic Tests

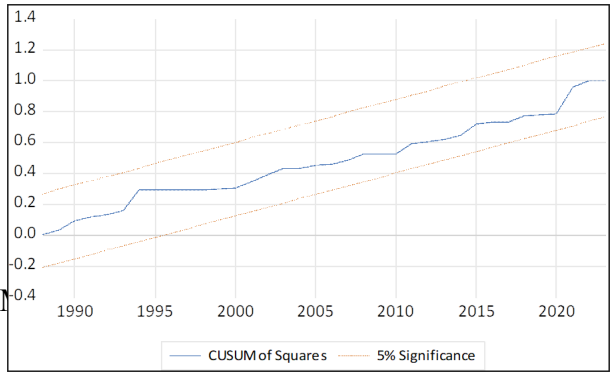
Tests							
Normality		Serial Correlation		Heteroscedasticity		Functional Form	
Jaque-Bera	Prob.	F-stat.	Prob.	F-stat.	Prob.	F-stat.	Prob.
2.361	0.307	21.696	0.647	2.384	0.352	1.029	0.316

Source: Researcher's computation (2025), using E-Views 13.

On the other hand, The Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ) tests were performed. The plots for both CUSUM and CUSUMSQ remain within the critical boundaries.



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5.1 Conclusion

This study examined the effects of climate change and human capital on food stability in Nigeria using annual data from 1971 to 2023 and the ARDL approach. The findings indicate that CO_2 emissions, population growth and food exports negatively and significantly affect food stability, suggesting that environmental degradation, demographic pressure and increased food exports can weaken the consistency and reliability of food availability over time. Conversely, human capital has a positive and significant effect, indicating that improvements in education, skills, health and knowledge can strengthen households' capacity to cope with food-related shocks and enhance the resilience and stability of the food system.

5.2 Recommendations

Based on these findings, the study recommends strengthening climate-change adaptation and mitigation measures, increasing investment in human capital development, promoting sustainable domestic food production, and implementing appropriate policies to manage food exports. The government should also improve agricultural infrastructure, storage facilities, irrigation and access to climate-resilient technologies to reduce disruptions in food supply. An integrated policy approach that combines environmental protection, human capital development, population management and agricultural resilience is essential for achieving sustainable food stability in Nigeria.

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