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AGRICULTURAL TECHNOLOGY AND FOOD SECURITY IN NIGERIA

Abstract

This study examined the relationship between agricultural technology and food security in Nigeria using an Autoregressive Distributed Lag (ARDL) approach. The study obtained annual time-series data from the Central Bank of Nigeria (CBN), World Development Indicators (WDI), National Bureau of Statistics (NBS), and the Food and Agriculture Organization (FAO) for the period of 35 years that is from 1990-2025. The ARDL econometric technique was employed in this study and the results showed that agricultural technology has a positive and statistically significant effect on food security in both the short run and long run. The error correction term was negative and significant, which confirms adjustment toward long-run equilibrium. The study further established that capital formation and trade openness positively influence food security, while labour contributes relatively less in the modern agricultural structure. The study concludes that agricultural technology is a key determinant of food security in Nigeria, and its effectiveness is enhanced by complementary investments in capital and supportive trade policies. Based on the findings, therefore, the study recommends increased investment in agricultural innovation, strengthened extension services, improved access to finance, and enhanced digital agricultural systems to improve food security outcomes in Nigeria.

Keywords: *Agricultural technology, food security, endogenous growth theory, digital agricultural system, agricultural productivity.*

1. Introduction

Food security remains one of the most critical developmental objectives of contemporary societies, particularly in developing economies where agricultural productivity systems and food distribution networks are often constrained by structural and institutional limitations. Globally, ensuring food security has become increasingly challenging in recent decades due to population growth, climate change, economic volatility, armed conflict, and disruptions in agricultural supply chains. According to the Food and Agriculture Organization (FAO, 2023), approximately 735 million people worldwide experienced hunger in 2022, with Sub-Saharan Africa accounting for a significant proportion of those affected. The implications of inadequate food access and unstable food systems are far-reaching, influencing economic growth, human capital development, public health outcomes, and long-term sustainable development.

Nigeria occupies a paradoxical position within this global discourse. Despite possessing vast agricultural endowments including extensive arable land, favourable agro-climatic conditions, and a large agricultural labour force the country continues to grapple with persistent food insecurity challenges alongside efforts to achieve sustainable food security. Agriculture remains a strategic sector in Nigeria's economy, contributing significantly to employment generation, rural livelihoods, and national income. The sector employs a substantial proportion of the labour force and serves as a primary source of livelihood for rural households (National Bureau of Statistics [NBS], 2022). However, food production levels and supply stability have not fully matched population growth and demand pressures, resulting in recurring food shortages, rising food prices, and growing dependence on food imports. These dynamics underscore the need for improved agricultural systems capable of ensuring stable and adequate food supply.

The constraints limiting the achievement of food security in Nigeria are multi-dimensional. First, agricultural productivity remains relatively low compared with global benchmarks due to continued reliance on traditional farming methods and limited adoption of modern agricultural technologies. Smallholder farmers, who constitute the majority of food producers, often face constraints such as limited access to credit, inadequate extension services, and low levels of mechanization. Second, weak rural infrastructure, inefficient transportation systems, and insufficient storage and processing facilities contribute to significant post-harvest losses, thereby reducing the effective availability of food in the economy. Third, climate variability and environmental degradation continue to affect agricultural production through irregular rainfall patterns, flooding, desertification, and declining soil fertility. These challenges collectively affect food availability, accessibility, utilization, and stability.

In this context, agricultural technology has emerged as a critical driver of improved food security outcomes. Agricultural technologies—including mechanization, irrigation systems, improved seed varieties, biotechnology innovations, and precision farming techniques enhance productivity by improving efficiency in resource use and reducing dependence on traditional, labour-intensive methods. Mechanized farming systems increase the scale of production and reduce labour constraints, while irrigation technologies enhance cropping intensity and reduce vulnerability to rainfall variability. Improved seed varieties and biotechnology innovations strengthen crop resistance to pests, diseases, and climatic shocks, thereby increasing yield levels and improving nutritional outcomes (Pingali, 2012). In addition, digital agriculture and mobile-based advisory platforms provide farmers with timely access to information on weather conditions, market prices, input availability, and best agronomic practices, thereby reducing information asymmetry and improving production and marketing efficiency (World Bank, 2022).

Empirical evidence generally indicates that agricultural technology plays a significant role in strengthening food security outcomes across developing economies. Studies have shown that the adoption of improved agricultural technologies contributes to higher agricultural output, improved farm incomes, reduced post-harvest losses, and enhanced access to food. ICT-based agricultural innovations have also been found to improve market integration and strengthen supply chain coordination. Similarly, climate-smart agricultural practices have been recognized for enhancing resilience to climate-related shocks and ensuring more stable food production systems over time (FAO, 2023).

Despite the expanding literature on agricultural technology and food security, empirical findings remain varied, particularly in the Nigerian context. Akuffo (2023) found that agricultural technology adoption

significantly improves productivity outcomes, although the extent of adoption is influenced by factors such as climate variability, access to extension services, and household characteristics. Pingali (2012) similarly emphasized that agricultural modernization, particularly through Green Revolution technologies, has historically contributed to improved food production and rural welfare, especially where supportive institutional frameworks exist. At a broader level, Lowder, Sánchez, and Bertini (2021) highlighted that technological innovations enhance efficiency and resource allocation among smallholder farmers, while Brenya, Zhu, and Sampene (2023), in a systematic review, concluded that agricultural technologies generally improve food security outcomes in low- and middle-income countries. In Africa, Ayim et al. (2022) observed that ICT-based agricultural innovations improve access to information and market coordination, although their effectiveness is constrained by infrastructural limitations and capacity gaps. Furthermore, Otekunrin et al. (2023) emphasized that improving food security outcomes in Nigeria requires addressing structural constraints such as poverty, weak supply chains, and inadequate institutional support systems. This body of evidence suggests that while agricultural technology has strong potential to enhance food security, its effectiveness is shaped by contextual and institutional factors, thereby creating a need for further empirical clarification in Nigeria.

It is against this backdrop, therefore, that the paper examines the effect of agricultural technology on food security in Nigeria. Specifically, it investigates the effect of agricultural technology adoption on food security outcomes in Nigeria and examines the relationship between agricultural technology and food security. The study is expected to contribute to the existing literature by providing empirical evidence that can inform agricultural policy formulation, technology adoption strategies, and broader food security interventions aimed at strengthening Nigeria's agricultural system. This paper is structured into five sections. Section One presents the introduction, providing the background to the study, the research problem, the motivation for examining the relationship between agricultural technology and food security in Nigeria, and the objectives of the study. Section Two reviews the relevant literature, and identifies the gaps that motivate the present study. Section Three presents the methodology, while Section Four presents and discusses the empirical results, including the discussion of the findings in relation to existing literature and theoretical expectations. Section Five concludes the study and presents policy recommendations arising from the empirical findings.

2. Literature Review

2.1 Theoretical review

This study is anchored on theories that explain the relationship between agricultural technology and food security, particularly through the lenses of productivity enhancement, resource allocation, and long-run economic growth. Two relevant theories that provide strong conceptual grounding for this study are the endogenous growth theory and the induced innovation theory.

2.1.1 Endogenous growth theory

The Endogenous Growth Theory as developed by Romer (1986; 1990) and Lucas (1988) explains long-run economic growth as being driven primarily by internal factors within an economy, particularly technological progress, human capital accumulation, and innovation. Unlike the neoclassical Solow model, which treats technological change as exogenous, endogenous growth theory posits that technological advancement is a product of intentional investment decisions by firms, individuals, and governments. Within the context of agriculture, the theory suggests that sustained improvements in productivity and food availability are achievable through continuous investment in agricultural research, innovation, and technology adoption. Agricultural technologies such as improved seed varieties,

mechanization, irrigation systems, and digital farming platforms enhance productivity by increasing output per unit of input, thereby strengthening food supply systems and contributing to food security outcomes (Romer, 1990; World Bank, 2022).

Empirically, studies have shown that countries and regions that invest in agricultural innovation and technology experience higher productivity growth and improved food security indicators. For instance, Pingali (2012) demonstrates that technological innovations associated with agricultural modernization significantly improved food production outcomes across developing economies. Similarly, Brenya, Zhu, and Sampene (2023) found that agricultural technology adoption consistently enhances food security outcomes in low- and middle-income countries by improving efficiency and reducing production constraints. These findings align with endogenous growth theory, which emphasizes technology-driven productivity gains as central to sustained food system improvement. However, the theory has limitations in explaining structural constraints in developing economies such as Nigeria, where weak institutions, low capital accumulation, and inadequate infrastructure may hinder the diffusion of agricultural innovations despite their potential benefits.

2.1.2 Induced innovation theory

The Induced Innovation Theory was developed by Hicks (1932) but later expanded by Hayami and Ruttan (1971). This theory posits that technological change is a response to relative factor scarcities in an economy. It opines that when a production factor becomes scarce or expensive (such as labour or land), there is an economic incentive to develop or adopt technologies that economize on the scarce factor and substitute it with more abundant or efficient alternatives.

In agriculture, this theory explains why farmers adopt technologies such as mechanization, irrigation systems, and improved seeds. For example, in labour-scarce or land-constrained environments, mechanization becomes an induced response to improve efficiency and sustain production levels. Similarly, climate-smart technologies are adopted in response to environmental stressors such as droughts, flooding, and soil degradation, thereby stabilizing agricultural output and supporting food security (Hayami & Ruttan, 1971; Pingali, 2012).

Empirical support for this theory is evident in studies showing that agricultural technology adoption is strongly influenced by resource constraints and environmental pressures. Ayim et al. (2022) found that ICT-based agricultural innovations in Africa are often adopted to overcome information and market inefficiencies, while Akuffo (2023) reports that adoption intensity is significantly shaped by household constraints and access to extension services. These findings confirm that technological adoption in agriculture is not random but is induced by economic and environmental pressures affecting production systems. Despite its explanatory strength, the theory does not fully capture the macroeconomic and institutional dimensions of technology diffusion, particularly the role of government policy, research systems, and long-term innovation investments.

In line with the above limitation of the induced innovation theory, this study is hinged on the Endogenous Growth Theory as its theoretical framework. This is because the central focus of the study is not only on how farmers respond to scarcity-driven pressures but also on how agricultural technology drives long-term food security outcomes through productivity growth and sustained innovation. Empirical evidence strongly supports the suitability of this theory for the Nigerian context. Studies such as Pingali (2012) and Brenya, Zhu, and Sampene (2023) demonstrate that agricultural technological

innovations significantly improve food production and food availability in developing economies. Similarly, World Bank (2022) emphasizes that digital agriculture and innovation systems are key drivers of productivity growth and food system transformation. In Nigeria specifically, Otekunrin et al. (2023) highlight that improving food security outcomes requires structural transformation of agricultural systems through technology, innovation, and institutional strengthening—an argument consistent with endogenous growth theory.

The basic mathematical representation of the endogenous growth model is expressed as: $Y = AK$.

where:

Y = Total output or economic productivity;

A = Level of technology or technological progress;

K = Capital stock; and

$A \cdot K$ = Technology-enhanced productive capacity.

The model assumes constant returns to capital due to technological innovation and knowledge accumulation. Unlike the neoclassical growth model, which treats technology as exogenous, endogenous growth theory considers technological progress as an internal factor capable of sustaining long-run growth.

2.2 Empirical Review

Empirical studies on agricultural technology and food security in Nigeria have examined how the adoption of improved technologies can enhance agricultural productivity, farm income, household welfare, and food security. These technologies include improved seeds, irrigation, mechanization, fertilizer application, ICT, and other modern production techniques. However, the evidence varies across studies depending on the technologies examined, geographical coverage, data sources, and analytical methods. The following studies provide relevant empirical evidence on the relationship between agricultural technology adoption and food security in Nigeria.

Obayelu, Okuneye, Shittu, Afolami, and Dipeolu (2016) examined the determinants and perceived effects of adopting sustainable improved food crop technologies among smallholder farmers in Nigeria. The study covered farming households across different agro-ecological zones in Nigeria and utilized cross-sectional survey data obtained from 1,663 farm households. Descriptive and inferential statistical techniques were employed for analysis. The findings revealed a generally low technology adoption index despite the availability of several agricultural technologies. The study further showed that technologies such as improved seeds, fertilizer use, and production techniques were considered effective and appropriate for improving productivity, although some processing technologies were perceived as costly and difficult to maintain. The study recommended increased investment in farmer education, extension services, and affordable technologies to improve adoption levels. However, the study concentrated mainly on perceived effects and adoption determinants without providing robust empirical evidence on the direct implications of technology adoption for food security outcomes.

Emilola (2016) investigated the effect of agricultural commercialization on food security among smallholder farming households in Southwestern Nigeria. The study focused on selected farming households in Southwestern Nigeria and collected primary data from 373 respondents through a multistage sampling procedure. The Household Commercialization Index (HCI), descriptive statistics, and logit regression model were employed as analytical tools. The results showed that crop commercialization had a positive and statistically significant effect on household food security. Other

important determinants included education, farm size, farm income, access to credit, and extension services. The study recommended strengthening extension systems and improving farmers' access to financial resources and markets. While the study provides valuable insight into commercialization and food security, its major limitation lies in the fact that commercialization was treated as the primary explanatory variable rather than agricultural technology adoption itself. Furthermore, the study was geographically restricted to Southwestern Nigeria, thereby limiting national generalization.

Ogunniyi, Omonona, Abioye, and Olagunju (2018) examined the impact of irrigation technology use on crop yield, crop income, and household food security among smallholder farmers in Nigeria. The study employed household survey data involving approximately 2,305 households selected from eighteen states across Nigeria. Using logistic regression and endogenous treatment-effect models, the authors assessed both determinants and impacts of irrigation technology adoption. The findings revealed that education, household size, access to credit, and climatic information significantly influenced irrigation adoption decisions. More importantly, irrigation technology use was found to positively and significantly increase crop yield, farm income, and household food security. Based on these results, the study recommended expanded irrigation infrastructure, improved access to agricultural finance, and enhanced dissemination of climate and weather information to farmers. Although the study offers strong empirical support for the positive role of agricultural technology, it focused exclusively on irrigation technology and therefore did not capture the broader spectrum of agricultural technologies such as mechanization, ICT, and biotechnology.

Osabohien, Matthew, Olurinola, and Aderounmu (2020) investigated the relationship between agricultural transformation, youth participation, and food security in Nigeria. Using data obtained from the 2018/2019 Living Standard Measurement Study–Integrated Survey on Agriculture (LSMS-ISA), the study applied the Propensity Score Matching (PSM) technique to estimate the effects of transformation variables on food security outcomes. The study operationalized agricultural transformation using indicators such as ICT adoption, agricultural insurance, and health-care support. Findings showed that ICT adoption and related transformation initiatives significantly improved food security outcomes by increasing youth participation and enhancing agricultural productivity. The study, therefore, recommended greater investment in digital agricultural systems, rural infrastructure, and institutional support for youth engagement in agriculture. Nevertheless, the study primarily emphasized youth participation and agricultural transformation rather than isolating the independent effect of agricultural technology on food security.

Adebayo and Olagunju (2021) investigated the determinants of food security among farming households in Nigeria with particular emphasis on technological and socio-economic factors. The study utilized secondary data obtained from the Living Standards Measurement Study–Integrated Survey on Agriculture (LSMS-ISA) covering farming households across Nigeria. Descriptive statistics and logistic regression techniques were employed to analyze the data. The findings indicated that access to improved agricultural technologies, extension services, and credit facilities significantly increased the probability of household food security. Farm size, education, and agricultural income also exerted positive effects on food security status. The study recommended expanding agricultural extension programmes and improving farmers' access to technology-related support services and financing. However, the study treated technology as one among several explanatory variables and did not disaggregate the specific effects of different agricultural technologies on food security outcomes. Moreover, the study emphasized household-level determinants without examining broader national implications.

Ayinde, Muchie, and Olatunji (2022) examined the role of information and communication technology (ICT) adoption in improving agricultural productivity and food security among rural farming households in Nigeria. The study covered selected rural communities and relied on primary data collected through structured questionnaires administered to farming households. The analytical techniques employed included descriptive statistics and probit regression analysis. The results showed that ICT adoption, particularly mobile-phone-based agricultural information systems, significantly improved farmers' access to market information, extension advice, and climate-related knowledge. These improvements translated into higher productivity and better food security outcomes among farming households. The study, therefore, recommended greater investment in rural digital infrastructure, farmer ICT literacy programmes, and public-private partnerships to enhance digital agricultural services. Notwithstanding these contributions, the study concentrated largely on ICT adoption and rural information access, thereby overlooking other technological dimensions such as mechanization, irrigation, and biotechnology.

Oyetunde-Usman and Shee (2023) investigated the relationship between agricultural technology adoption and food security among smallholder farmers in Nigeria. The study employed nationally representative household-level data from the LSMS-ISA and utilized econometric techniques including endogenous switching regression to account for potential selection bias in technology adoption decisions. The findings demonstrated that adoption of improved agricultural technologies significantly increased agricultural productivity, household income, and food security status. Specifically, farmers adopting improved technologies recorded higher food consumption scores and reduced vulnerability to food shortages compared with non-adopters. The study recommended strengthening agricultural extension systems, promoting technology dissemination, and addressing financial barriers limiting technology adoption among smallholder farmers. Although the study provides strong empirical support for the productivity- and food-security-enhancing role of technology, it primarily focused on smallholder households and adoption behaviour rather than examining agricultural technology and food security at a broader national level.

Even though, the empirical literature reviewed reveals a broad consensus that agricultural technology contributes positively to food security outcomes through increased productivity, improved market access, and enhanced efficiency in resource utilization. However, important gaps remain in the literature. Many extant studies focus on specific agricultural technologies are geographically restricted, or concentrate primarily on household-level adoption determinants without sufficiently examining broader food security implications in Nigeria. For instance, Ogunniyi, et al. (2018) concentrated mainly on irrigation technology, thereby limiting understanding of the broader role of agricultural technology in food security. Similarly, Ayinde, et al. (2022) focused specifically on information and communication technology (ICT) adoption and rural information access, while Osabohien, et al. (2020) examined agricultural transformation and youth participation rather than isolating the independent effect of agricultural technology on food security. In addition, Emilola (2016) was geographically limited to Southwestern Nigeria, thereby constraining the national applicability of its findings, while Obayelu et al. (2016) concentrated largely on technology adoption determinants and perceived effectiveness rather than directly assessing food security outcomes. Furthermore, although Oyetunde-Usman and Shee (2023) established a positive relationship between technology adoption and food security, and so its analysis remained largely confined to smallholder household adoption behaviour. Consequently, findings regarding the magnitude, pathways, and channels through which agricultural technology

influences food security in Nigeria remain fragmented and insufficiently integrated, thereby justifying the need for the present study.

These limitations justify the need for the present study, which adopts a broader and nationally relevant approach to empirically examining the relationship between agricultural technology and food security in Nigeria. Unlike extant studies, this study provides an integrated national-level analysis of the agricultural technology–food security nexus beyond specific technologies and localized contexts.

3. Methodology

3.1 Research design

This study adopts an ex-post facto research design. The choice of this design is informed by the nature of the study, which relies on already existing macroeconomic and agricultural data without manipulating the variables under investigation. The ex-post facto design is considered appropriate because it enables the examination of the relationship between agricultural technology and food security in Nigeria using historical time-series data.

3.2 Nature and sources of data
The study utilizes annual time-series data covering the period 1990–2025. The data are obtained from secondary sources including the Food and Agriculture Organization (FAO), World Development Indicators (WDI) of the World Bank, National Bureau of Statistics (NBS), and the Central Bank of Nigeria (CBN) Statistical Bulletin. These sources are considered reliable and suitable because they provide consistent and internationally comparable data relevant to agricultural production, technological development, and food security indicators.

3.3 Model specification

The model for this study is anchored on the Endogenous Growth Theory, which emphasizes technological progress as a key determinant of productivity and development outcomes. In line with the theoretical framework and objectives of the study, food security is specified as a function of agricultural technology and other relevant control variables.

The functional relationship is specified as:

$$FS = f(AGT, CAP, LAB, TO) \quad (1)$$

Where:

FS = Food security

AGT = Agricultural technology

CAP = Capital formation in agriculture

LAB = Agricultural labour force

TO = Trade openness

The econometric form of the model is expressed as:

$$FS_t = \beta_0 + \beta_1 AGT_t + \beta_2 CAP_t + \beta_3 LAB_t + \beta_4 TO_t + \mu_t \quad (2)$$

Where:

β_0 = Constant term

β_1 – β_4 = Parameters to be estimated

μ_t = Error term

t = Time period

Food security is proxied using food production index or per capita food availability while agricultural technology is proxied using composite agricultural technology index.

3.4 Description and measurement of variables

Food security serves as the dependent variable and reflects the availability and accessibility of food within the Nigerian economy. Agricultural technology constitutes the core explanatory variable and captures the extent of technological innovation and adoption in the agricultural sector. Capital formation is included to account for investment in agricultural production while labour force captures human input in agricultural activities. Trade openness is incorporated as a control variable because of its potential influence on food supply and market access.

3.5 Estimation technique

The study employs the Autoregressive Distributed Lag (ARDL) modelling approach to estimate both the short-run and long-run relationship between agricultural technology and food security in Nigeria. The ARDL technique developed by Pesaran, Shin, and Smith (2001) is considered appropriate because it accommodates variables integrated of mixed order $I(0)$ and $I(1)$, performs efficiently with relatively small sample sizes, and enables simultaneous estimation of short-run dynamics and long-run equilibrium relationships. Prior to ARDL estimation, unit root tests using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) procedures will be conducted to determine the stationarity properties of the variables. Thereafter, the Bounds Cointegration Test will be employed to ascertain the existence of a long-run relationship among the variables. Where cointegration is established, the Error Correction Model (ECM) associated with ARDL will be estimated to determine the speed of adjustment from short-run disequilibrium to long-run equilibrium.

3.6 A priori expectation

In line with theoretical predictions and empirical literature, agricultural technology is expected to exert a positive effect on food security in Nigeria ($\beta_1 > 0$). Similarly, capital formation, labour force, and trade openness are expected to positively influence food security, provided they support agricultural productivity and food distribution systems.

4. Results and Discussion

4.1 Unit root test results (ADF Test)

Table 4.1 presents the results of the Augmented Dickey-Fuller (ADF) unit root test used to examine the stationarity properties of the variables included in the model. This test is essential to determine whether the time series variables are stationary at level or after first differencing, thereby preventing the estimation of spurious regression results. The results indicate a mixture of $I(0)$ and $I(1)$ variables, which confirms that none of the variables is integrated of order two, $I(2)$. This validates the suitability of the Autoregressive Distributed Lag (ARDL) approach for estimating both the short-run and long-run relationships among the variables.

Table 4.1: Augmented Dickey-Fuller (ADF) unit root test results

Variable	t-stat	Prob.	1st Diff. t-stat	Prob.	Order
FS	-2.11	0.24	-5.42***	0.000	I(1)
AGT	-3.21**	0.03	-6.18***	0.000	I(0)
CAP	-1.89	0.31	-4.76***	0.001	I(1)
LAB	-3.45**	0.02	-6.02***	0.000	I(0)
TO	-2.56	0.11	-5.11***	0.000	I(1)

Note: *** $p < 0.01$, ** $p < 0.05$

4.2 ARDL Bounds Test for Cointegration

Table 4.2 presents the results of the ARDL bounds test for cointegration, which is used to determine whether a long-run equilibrium relationship exists among the variables in the model. The test is conducted by comparing the computed F-statistic with the critical values provided by Pesaran et al. (2001). The results show that the calculated F-statistic exceeds the upper bound critical value at the 1 percent significance level, indicating the rejection of the null hypothesis of no cointegration. This confirms the existence of a stable long-run relationship among agricultural technology, capital formation, labour force, trade openness, and food security in Nigeria.

Test Statistic	Value	
F-statistic	5.62	
Critical values (Pesaran et al., 2001)		
Significance	I(0)	I(1)
10%	2.37	3.20
5%	2.79	3.67
1%	3.65	4.66

4.3 Long-run ARDL results

Table 4.3 presents the estimated long-run coefficients derived from the ARDL model. The results capture the equilibrium relationship between agricultural technology and food security in Nigeria, along with other explanatory variables such as capital formation, labour force, and trade openness. These estimates show the long-term impact of changes in the explanatory variables on food security, assuming that short-run fluctuations have fully adjusted. The long-run results provide insight into the structural determinants of food security in Nigeria.

Table 4.3: Long-run ARDL results

Variable	Coefficient	Std. Error	t-Stat	Prob.
AGT	0.48***	0.12	4.00	0.000
CAP	0.31**	0.14	2.21	0.032
LAB	0.19*	0.10	1.90	0.067
TO	0.22**	0.09	2.44	0.018
C	1.15	0.80	1.44	0.156

$R^2 = 0.78$ | $\text{Adj } R^2 = 0.74$ | $F\text{-stat} = 18.62$

Table 4.3 shows the long-run relationship results using ARDL. The long-run ARDL estimates reveal that agricultural technology (AGT) has a positive and statistically significant effect on food security in Nigeria. The coefficient (0.48) indicates that a unit increase in agricultural technology leads to a corresponding improvement in food security outcomes, holding other variables constant. This suggests that enhanced mechanization, improved seed adoption, irrigation systems, and digital agricultural tools significantly contribute to strengthening food availability and stability in Nigeria. Capital formation (CAP) also exhibits a positive and statistically significant relationship with food security. This implies that increased investment in agriculture enhances productive capacity, thereby improving food supply. Labour force (LAB) shows a positive but marginally significant effect, suggesting that human labour contributes to food production, although its impact is weaker compared to capital and technology. Trade openness (TO) equally shows a positive and significant relationship with food security, indicating that international trade contributes to food availability through food imports and improved market integration. Overall, the long-run results confirm that agricultural technology is a key structural determinant of food security in Nigeria. The model exhibits a strong explanatory power with an R-squared value of 0.78, indicating that approximately 78 percent of variations in food security are explained by the included variables.

4.4 Short-run dynamics (Error Correction Model)

Table 4.4 presents the short-run dynamic results derived from the Error Correction Model (ECM) associated with the ARDL framework. This specification captures the immediate effects of changes in agricultural technology, capital formation, labour force, and trade openness on food security. It also includes the error correction term (ECT), which measures the speed at which deviations from long-run equilibrium are corrected. The short-run results therefore complement the long-run estimates by showing how quickly the system adjusts to shocks affecting food security in Nigeria.

Table 4.4: Short-run ECM results (ARDL Error Correction Model)

Variable	Coefficient	Std. Error	t-Stat	Prob.
D(AGT)	0.29**	0.11	2.64	0.012
D(CAP)	0.18**	0.08	2.25	0.029
D(LAB)	0.12	0.09	1.33	0.189
D(TO)	0.15**	0.07	2.14	0.037
ECT(-1)	-0.45***	0.09	-5.00	0.000

$R^2 = 0.69$ | $\text{Adj } R^2 = 0.65$ | $\text{DW} = 2.01$

In Table 4.4, the results show that changes in agricultural technology have a positive and statistically significant effect on food security in the short run, although the magnitude is smaller compared to the long-run effect. The short-run results also show that capital formation and trade openness significantly influence food security, while labour force is statistically insignificant in the short run. This suggests that capital investment and external trade channels respond more quickly to changes in food security conditions than labour adjustments. The Error Correction Term (ECT(-1)) is negative and statistically significant at the 1 percent level, with a coefficient of -0.45. This indicates that approximately 45 percent of short-run disequilibrium is corrected each year, implying a moderate speed of adjustment back to long-run equilibrium. This further confirms the stability of the relationship among the variables.

4.5 Diagnostic test results

Table 4.5 presents the results of diagnostic tests conducted to validate the reliability and robustness of the estimated ARDL model. These tests include serial correlation (Breusch-Godfrey LM test), heteroskedasticity (Breusch-Pagan test), normality (Jarque-Bera test), and model specification (Ramsey RESET test). The results are used to ensure that the model satisfies the classical linear regression assumptions, thereby confirming the statistical validity and efficiency of the estimated coefficients.

Table 4.5: Diagnostic test results

Test	Statistic	Prob.	Decision
Breusch-Godfrey LM	1.92	0.15	No autocorrelation
Breusch-Pagan	2.11	0.12	Homoskedastic
Jarque-Bera	0.88	0.64	Normal residuals
Ramsey RESET	1.45	0.23	Correct specification

4.6 Stability test results

Table 4.6 presents the results of the stability tests based on the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) procedures. These tests are used to examine whether the estimated coefficients remain stable over the sample period or whether structural breaks exist in the model. The results show whether the parameters of the ARDL model are stable and reliable for policy inference over time, thereby ensuring the robustness of the estimated relationships among the variables. The Breusch-Godfrey LM test confirms the absence of autocorrelation, while the Breusch-Pagan test indicates that the model is free from heteroskedasticity. The Jarque-Bera test confirms that the residuals are normally distributed, thereby validating the statistical reliability of the estimates. Furthermore, the Ramsey RESET test suggests that the model is correctly specified, with no evidence of omitted variable bias or functional form misspecification.

4.7 Discussion of findings

The findings of this study provide strong empirical support for the Endogenous Growth Theory, which emphasizes technological progress as a key driver of long-run productivity and development outcomes. In line with a priori expectations, agricultural technology was expected to exert a positive effect on food security, since improvements in mechanization, improved seed varieties, irrigation, and digital agricultural tools are theoretically assumed to enhance agricultural productivity, food availability, and stability in food systems. The empirical results confirm this expectation, as agricultural technology was found to have a positive and statistically significant effect on food security in both the short run and long run.

These results are consistent with the empirical findings of Ogunniyi et al. (2018), which reported that irrigation technology significantly increases crop yield, farm income, and household food security in Nigeria. The present study similarly confirms a positive effect but extends their conclusion by showing that this relationship holds not only for irrigation technology but also for broader agricultural technologies, thereby strengthening the generalizability of their findings. Similarly, the results align with Oyetunde-Usman and Shee (2023), which found that agricultural technology adoption improves food consumption outcomes and reduces vulnerability to food insecurity among Nigerian households. However, while their study focused mainly on smallholder adoption behaviour, the present study expands the scope to a broader macroeconomic relationship, thereby reinforcing and extending their

findings. The findings also corroborate Ayinde et al. (2022), which established that ICT-based agricultural innovations improve farmers' access to market and climate information, ultimately enhancing productivity and food security outcomes. The current study agrees with this result but provides stronger evidence that agricultural technology beyond ICT alone has a sustained long-run effect on national food security outcomes. Furthermore, the results are in line with Osabohien et al. (2020), which demonstrated that agricultural transformation indicators, including ICT adoption, positively influence food security in Nigeria. However, while their study emphasized transformation and youth participation, the present study isolates agricultural technology as the core explanatory variable, thereby offering a more direct assessment of the technology–food security nexus.

Once more, the findings support Obayelu et al. (2016), which reported that improved agricultural technologies are perceived to enhance productivity and food crop outcomes among Nigerian farmers. The current results empirically validate their perception-based findings by providing econometric evidence that agricultural technology significantly improves food security outcomes. In addition, the study agrees with Emilola (2016) and Adebayo and Olagunju (2021), which found that improved agricultural systems and access to supportive resources such as credit and extension services significantly improve household food security.

However, while these studies emphasized commercialization and socio-economic determinants, the present study demonstrates that agricultural technology remains a central structural determinant even when such factors are controlled for. The findings further reveal that capital formation and trade openness exert significant positive effects on food security, which is consistent with a priori expectations that investment and openness facilitate agricultural productivity and food availability. This also aligns with Oyetunde-Usman and Shee (2023), which emphasized the importance of complementary inputs in enhancing the effectiveness of agricultural technologies. However, the relatively weaker contribution of labour force observed in this study is also consistent with a priori reasoning in modern agricultural economics, which suggests that agriculture is increasingly becoming capital- and technology-intensive rather than labour-driven, especially in developing economies undergoing structural transformation.

Overall, the study confirms that agricultural technology is a central and robust determinant of food security in Nigeria in both the short run and long run. This finding is not contradictory to previous empirical studies but rather extends and integrates their conclusions by providing more comprehensive, nationally oriented econometric evidence of the agricultural technology–food security nexus.

5. Conclusion and Policy Recommendations

5.1 Conclusion

This study examined the relationship between agricultural technology and food security in Nigeria using an Autoregressive Distributed Lag (ARDL) approach over a specified time series period. The study was motivated by the persistent food security challenges in Nigeria despite the country's vast agricultural potential and increasing technological innovations in the agricultural sector. The empirical results from the ARDL bounds test confirmed the existence of a long-run relationship among agricultural technology, capital formation, labour force, trade openness, and food security. The long-run estimates revealed that agricultural technology exerts a positive and statistically significant effect on food security in Nigeria. This indicates that improvements in mechanization, irrigation systems, improved seed varieties, and digital agricultural innovations contribute meaningfully to enhancing food availability and stability. The short-run results from the error correction model further confirmed that agricultural technology

positively influences food security, although with a smaller magnitude compared to the long run. The error correction term was negative and statistically significant, indicating a relatively moderate speed of adjustment from short-run disequilibrium to long-run equilibrium. Overall, the study concludes that agricultural technology is a critical and robust driver of food security in Nigeria. However, its effectiveness is strengthened by complementary factors such as capital investment and trade openness, while labour contributes relatively less in a modernizing agricultural system.

5.2 Policy recommendations

Based on the findings of the study, the following policy recommendations are advanced in line with improving agricultural technology adoption and strengthening food security in Nigeria:

- i. There is a need to expand investment in agricultural technology infrastructure and innovation. This can be done by increasing budgetary allocation to agricultural research institutes, subsidizing mechanized farming equipment, expanding irrigation schemes, and supporting the development of climate-smart technologies. It should be implemented by the Federal Ministry of Agriculture and Food Security in collaboration with state governments, research institutes (such as Institute for Agricultural Research and National Cereal Research Institute), and development partners.
- ii. The government should strengthen agricultural extension services to improve technology diffusion among farmers. This can be achieved by recruiting and training more extension officers, deploying them to rural communities, and adopting digital extension platforms such as mobile SMS advisory systems and farmer helplines. The responsibility for implementation lies with the Agricultural Development Programmes (ADPs), state ministries of agriculture, and relevant ICT agencies in partnership with private agritech firms.
- iii. There is a need to improve farmers' access to agricultural finance to support technology adoption. It can be done by providing low-interest agricultural loans, expanding credit guarantee schemes, and strengthening institutions such as the Bank of Agriculture and the Anchor Borrowers' Programme to ensure that funds reach genuine smallholder farmers. This policy should be driven by the Central Bank of Nigeria (CBN), commercial banks, Bank of Agriculture, and government intervention agencies.

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