INDUSTRIALIZATION AND FOOD SECURITY IN NIGERIA: IS THERE ASYMMETRY?

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Abstract: This research examined how industrialization influenced food security in Nigeria between 1986 and 2022. Drawing data from the Global Footprint Network, World Development Indicators, and the Central Bank of Nigeria, the study employed econometric techniques such as the ADF Test, Wald Test, and the Non-Linear Autoregressive Distributed Lag (NARDL) model to analyze asymmetric effects. The results indicated a long-term asymmetric nexus, where positive changes in industrialization significantly enhanced food security, while negative changes exhibited a relatively weaker positive effect. Short-run analysis shows positive industrial activities negatively impact food security, whereas negative changes have a weak positive effect. The study recommends firms adopt eco-friendly technologies and adhere to environmental regulations. The government should enhance these regulations and provide incentives for sustainable practices. Additionally, farmers are encouraged to adopt advanced agricultural technologies and diversify their income sources to build resilience against adverse industrial impacts on food security.

Introduction

The process of industrialization stands as a pivotal marker and a defining trait within the trajectory of a nation's economic advancement (Tamuno & Edoumiekumo, 2012). As societies transition towards industrialization, they undergo a profound restructuring of their economic frameworks, marked by a significant surge in the manufacturing and production sectors (Acemoglu & Robinson, 2012). This transformation often heralds a shift away from agrarian-based economies towards more diversified and technologically-driven landscapes (Clark, 2007). Industrialization fundamentally alters the employment structure, fostering the rise of wage labor and urbanization (Clark, 2007), and stimulates technological innovation, which in turn drives productivity gains and economic growth (Mokyr, 2016). The degree of industrialization within a nation profoundly impacts its capacity to produce vital goods and services, alleviate poverty, foster self-sufficiency, enhance living standards, ensure balance of payment stability, economize time and labor, catalyze growth across multiple sectors, cultivate skilled workforce, mitigate social unrest through job creation, augment the earning potential of its populace, and sustain overall economic progress and development (Ogbuabor et al., 2018; Ikonne & Nwogwugwu, 2020). Industrialization not only drives economic growth but also exerts a significant influence on agricultural productivity, wherein advancements in the agricultural sector often stimulate growth in the industrial domain, creating a symbiotic relationship that fuels broader economic development.

Since the 1960s, industrialization has been a core focus of Nigeria's economic policies. However, the late 1960s marked a turning point as the discovery, extraction, and export of oil in commercial volumes created challenges in advancing industrial development. By the early 1980s, the economy experienced stagnation due to inefficiencies associated with a public-sector-dominated structure. In response, the Nigerian government initiated systematic economic liberalization to promote private-sector-led growth. Privatization and commercialization efforts were implemented for some public corporations, while emphasis shifted toward fostering micro, small, and medium-scale enterprises (MSMEs) as drivers of industrialization and economic development. These micro-enterprises align with principles such as free-market dynamics, creativity, innovation, individual and group initiatives, self-reliance, and personal fulfillment (Onyenekenwa, 2005; Chete et al., 2014). According to Isiksal and Odoh (2016), industrial policies became pivotal in accelerating economic growth and development. This strategic direction inspired Nigeria to adopt various policies aimed at advancing industrialization and achieving self-reliance as an industrialized economy.

The symbiotic relationship between Nigeria's industrial and agricultural sectors raises concerns about the impact on food security. While industrial growth theoretically boosts economic prosperity, its actual effects vary. Industrialization may strain resources and prioritize cash crops over staple foods (Nwoko et al., 2020). However, strategic industrial policies can enhance agricultural productivity through infrastructure and value chain improvements (Okafor et al., 2018). In theory, the industrial and agricultural sectors are believed to share a symbiotic relationship, where advancements in one sector can positively affect the other. However, the reality in Nigeria presents a nuanced picture. Rapid industrialization may lead to land use changes, competition for resources, and environmental degradation, negatively impacting agricultural productivity and rural livelihoods. Whether industrial development has improved or decreased food security in Nigeria remains a pressing concern. A review of existing studies showed that there is a notable scarcity of empirical research specifically addressing the impact of industrialization on food security. While there are studies examining related aspects such as agricultural productivity and environmental degradation (e.g Adeoye et al., 2019; Susanti & Maryono, 2020; Liu et al., 2018), comprehensive empirical analyses directly linking industrialization to food security are limited. Moreover, extant literature revealed conflicting results across several themes related to industrialization and food security. While some studies highlight the positive impacts of industrialization on agricultural productivity through technological advancements and improved infrastructure (Spielman et al., 2021; Ajayi & Solomon, 2020), others emphasize the negative consequences such as environmental degradation and labor diversion (Chen et al., 2018; Mupambwa & Dube, 2017). This study therefore seeks to examine the effect of industrialization on food security in Nigeria.

Literature Review

Theoretical Review

Food security, encompassing the availability, access, utilization, and stability of food (Committee on World Food Security, 2015; WHO, 2000), is a complex issue intricately linked to the economic development trajectory of a country. Industrialization, a hallmark of economic growth, presents in theoretical literature, a multifaceted relationship with food security. In other words, while some of the theories argue about the positive response of food security on industrialization, others present the adverse effect of industrial activities on food security.

One of the key theoretical arguments for the positive impact of industrialization on food security is rooted in modernization theory. Modernization theory- developed primarily during the mid-20th century by economist Walt Rostow-was theorized on the grounds that Western industrialized nations are viewed as the epitome of development, serving as a model for other countries. Rostow's modernization theory outlines a linear path of economic development that societies must follow, consisting of five stages. In the traditional society stage, the economy is primarily based on subsistence activities, where producers consume their output and do not engage in trade. Barter serves as the primary means of trade, with goods directly exchanged for other goods. Agriculture dominates as the principal industry, characterized by labor-intensive production with minimal capital investment. Technology remains basic, and resource allocation adheres to traditional practices. In the transitional phase, greater specialization results in surplus production, facilitating trade. A transportation network starts to form to sustain this trade activity. Entrepreneurs emerge as income levels, savings, and investments gradually increase. External trade, primarily focused on primary commodities, becomes more prevalent. A robust central government begins to support private enterprise, creating a foundation for future economic expansion.

Industrialization accelerates in the take-off stage, with workers starting to move from agriculture to manufacturing. Economic growth is concentrated in specific regions and industries. Investment levels surpass 10% of GNP, and people begin saving more. New political and social institutions develop to facilitate industrialization. This growth becomes self-reinforcing, as investments drive higher incomes, which, in turn, generate more savings to fund further investments. During the drive-to-maturity stage, the economy expands into new sectors, spurred by technological advancements that create diverse investment opportunities. The production of a wide range of goods and services reduces dependence on imports. Urbanization accelerates, and technology becomes integral across various industries. Ultimately, in the stage of high mass consumption, the economy shifts its focus to mass consumption, characterized by elevated economic activity. Technology is extensively utilized, although its rate of expansion slows. The service sector emerges as the dominant force, with urbanization reaching its peak. Multinational corporations thrive, and a large portion of the population achieves income levels that surpass basic needs for food, shelter, and clothing. There is also a growing emphasis on social welfare.

As a link to the current study, the modernization theory suggests that industrialization leads to economic growth, which translates to increased agricultural productivity through mechanization, fertilizers, and improved techniques. This can lead to greater food surpluses and improved food security (Kline, 2020; Robertson, 2021). However, while the theory provides a structured framework for understanding development, it has been critiqued for its linear progression model and Eurocentric assumptions (Smith & Taylor, 2019; Johnson, 2020; Chen & Patel, 2021; Ahmed, 2022).

The key theoretical arguments for understanding the challenges and limitations of industrialization on food security is evident in the dependency theory. This theory posits that the economic development of developing countries is often constrained by their dependence on developed nations (Dos Santos, 1970; Frank, 1967). Dependency theory argues that industrialization in developing countries often does not lead to the expected benefits of increased productivity and economic growth, rather developing countries are often integrated into the global economy as suppliers of raw materials and low-value goods, while developed countries dominate the production and export of high-value manufactured goods and services. According to Frank, (1967), this unequal relationship leads to a situation where developing countries become heavily reliant on developed nations for capital, technology, and market access. In the agricultural sector, the effect of this inequality is manifested in the heavy reliance of developing countries on developed nations for essential goods, including food. Consequently, their ability to achieve self-sufficiency in food production is compromised, leading to persistent food insecurity (Clapp, 2015; McMichael, 2013). However, while this theory critiques the often exploitative nature of industrialization under global capitalism, it also suggests the potential for developing countries to leverage industrial growth to invest in their own agricultural sectors and achieve food security (Amin, 1976; Kay, 2011).

The Urbanization Theory provide insights on the ripple effect of industrialization on agricultural output in developing economies. It underscores the substantial migration of populations from rural areas to urban centers that often accompanies industrialization. According to this theory, the shift of people from rural to urban areas can lead to a labor shortage in agriculture, reducing the sector's capacity to produce enough food to meet the population's demands (Tacoli, 2003). With fewer individuals available for tasks like farming, planting, and harvesting, agricultural productivity may decline. This challenge is further intensified as urban areas typically provide more attractive and varied employment opportunities than rural farming, making it increasingly difficult to retain agricultural labor.

The environmental downsides of industrialization and its extended effect on agricultural sector can be theoretically elucidated by the Ecological Modernization Theory. The Ecological Modernization Theory, propounded in the early 1980s by Joseph Huber and Martin Jänicke emphasize the growing concerns about environmental consequences of industrialization, such as pollution, resource depletion, and ecological degradation. Industrialization, while driving economic growth and technological advancement, often brings about significant environmental challenges. Industrial processes typically involve the extraction and processing of raw materials, manufacturing of goods, and the disposal of waste products. Each of these stages can contribute to pollution in various forms. For instance, improper disposal of industrial waste, including hazardous chemicals and heavy metals, can lead to soil contamination. This affects soil fertility, harms plant life, and can enter the food chain, impacting human health (Alloway, 2013; McLaughlin et al., 2000).

The ecological impacts of industrialization extend beyond pollution and include broader forms of ecological degradation. Industrialization contributes significantly to greenhouse gas emissions, primarily through the burning of fossil fuels. These emissions lead to global warming, climate change, and associated ecological consequences, such as shifting weather patterns, sea level rise, and increased frequency of extreme weather events (Stern, 2007). In the agricultural sector, these environmental changes have profound effects on food security. Climate change can alter growing seasons, reduce crop yields, and increase the prevalence of pests and diseases, all of which threaten food production. For instance, shifting weather patterns can lead to unpredictable rainfall, causing droughts or floods that devastate crops. The theory further emphasize the potential for industries to innovate and adopt cleaner technologies that reduce environmental impact while maintaining economic competitiveness. This involves a transition to more sustainable production processes, the efficient use of resources, and the integration of environmental considerations into business strategies and government policies. As climate change continues to progress, it is essential to adopt sustainable agricultural practices and develop resilient food systems to mitigate these impacts and ensure a stable food supply for the growing global population.

From the fore going, the theoretical literature on the relationship between industrialization and food security offers a nuanced perspective, highlighting both its positive and negative impacts. The Environmental Kuznets Curve (EKC) hypothesis bridges these views, proposing that industrialization may initially harm food security due to environmental degradation but can eventually enhance it through technological progress and sustainable practices. The EKC hypothesis describes an inverted U-shaped relationship between environmental degradation and economic development. In the early stages of industrialization, environmental degradation—manifested in pollution, deforestation, and resource depletion—tends to rise, negatively affecting food security by damaging agricultural land and water supplies. However, once a certain level of economic development is reached, further industrialization fosters improvements such as technological innovation, stricter environmental regulations, and sustainable practices that mitigate degradation. In the context of the present study, this theory underscores the interconnectedness of industrial development with food, energy, and water resources. During the initial phases of industrialization, the emphasis on rapid economic growth often exacerbates environmental harm, including pollution, deforestation, and water contamination, which adversely impact agricultural productivity and food security. Over time, however, economic progress enables investments in cleaner technologies, efficient resource management, and sustainable practices. These advancements gradually offset the negative effects of early industrialization, resulting in improved agricultural productivity and enhanced food security.

Empirical Review

Empirical studies are home with conflicting findings on the relationship between industrial activities and agricultural productivity. On one hand, studies have shown that industrialization can lead to increased agricultural productivity through the introduction of advanced technologies, improved infrastructure, and enhanced access to inputs and markets (Spielman et al., 2021; Ajayi & Solomon, 2020; Kassie et al., 2018; Mottaleb et al., 2016; Nkonya et al., 2016; Awotide et al., 2016). On the other hand, evidences from scholarly works have indicated that industrial activities pose significant challenges to agriculture by causing environmental degradation, reducing the availability of arable land, and diverting labour away from the agricultural sector (Nkonya et al., 2016; Chen et al., 2018; Mupambwa & Dube, 2017; Odjugo, 2018; Adeloye et al., 2021). The adoption of technological innovations in agriculture has garnered significant attention among development economists. This is due to the fact that the majority of the population in less developed countries depends on agricultural production for their livelihoods, and new technology presents opportunities to enhance both production and productivity. Existing empirical studies have demonstrated that agriculture advances technologically when farmers adopt new innovations (Abdoulaye et al., 2019; Michler et al., 2020; Ndiritu et al., 2021; Ogunniyi et al., 2022). Technological advancements in agriculture often come from innovations such as improved seeds, modern irrigation techniques, precision farming tools, and advanced machinery. When farmers adopt these innovations, they can increase crop yields, reduce costs, and improve the efficiency of resource use. While technological innovations in agriculture have the potential to enhance productivity and sustainability, several empirical studies highlight significant challenges such as socio-economic disparities, limited access to resources, unintended environmental consequences, and increased risks and uncertainties for farmers (Barrett, Carter, & Timmer, 2019; Asfaw et al., 2019; Pretty et al., 2018; Antle & Capalbo, 2020).

Industrialization often leads to a shift in employment from agriculture to industrial sectors, which can have mixed effects on household incomes and purchasing power. Empirical literature has documented that while employment in industrial sectors typically offers higher wages with more stable income and purchasing power compared to agriculture (Herrendorf et al., 2019; Diao, et al., 2018; Gollin et al., 2016) the transition can also result in increased income inequality with the benefits not evenly distributed, often favoring those with better access to education and skills training, and economic displacement for those unable to find industrial jobs (Gollin, Lagakos, & Waugh, 2014; Kunal et al., 2018; Sinha, 2019; Timmer, 2015; Christiaensen & Todo, 2014). Another strand of empirical literature has demonstrated the importance of nonagricultural employment for rural households in sub-Saharan Africa. Studies have shown that rural households engaged in nonagricultural activities often achieve higher and more stable incomes compared to those solely dependent on agriculture (Haggblade, Hazell, & Reardon, 2010; Davis et al., 2017; Nagler & Naudé, 2017; Yeboah & Jayne, 2018). This additional income can enhance household resilience to shocks such as crop failures and market fluctuations, improve food security, and enable investments in education and health.

The impact of industrialization on the food supply chain is multifaceted, offering significant benefits while also presenting substantial challenges. Empirical literature reveals that industrialization has significantly improved efficiency and productivity in the food supply chain through mechanization and advanced logistics with modern storage facilities reduceing post-harvest losses (Reardon, Timmer, & Minten, 2012; Affognon et al., 2015). Conversely, recent empirical studies highlight that highly industrialized and centralized food supply chains can be particularly vulnerable to disruptions from natural disasters, economic shocks, or pandemics (Manning & Soon, 2016; Suryaningtyas et al., 2019; Doherty et al., 2019; Akinwumi et al., 2021; Okechukwu & Ezirim, 2018; Alabi & Chukwu, 2022).

The detrimental effect of industrialization on food security has also been documented in empirical literature. Industrialization often leads to environmental degradation, which can negatively impact agricultural productivity and, consequently, food security. Empirical studies have shown that industrial activities such as mining, deforestation, and pollution can lead to soil erosion, water contamination, and loss of biodiversity, all of which harm agricultural land (Ezeaku et al., 2020; Chand et al., 2017; Pérez-Soto et al., 2019; Sibanda et al., 2021; Iwuoha et al., 2020; Ogundari et al., 2022). Furthermore, there is empirical evidence that the expansion of industrial zones and urbanization can result in the loss of arable land and labourers (Adeoye et al., 2019; Susanti & Maryono, 2020; Liu et al., 2018; Chand & Srivastava, 2020). These studies concluded that as industrial areas expand, agricultural lands are often converted for non-agricultural uses, reducing the amount of land available for food production and the number of labourers to cultivate the available land.

A meticulous observation from the empirical studies reveals that there is a notable scarcity of empirical research specifically addressing the impact of industrialization on food security. While there are studies examining related aspects such as agricultural productivity and environmental degradation (e.g Adeoye et al., 2019; Susanti & Maryono, 2020; Liu et al., 2018), comprehensive empirical analyses directly linking industrialization to food security are limited. This gap is particularly pronounced in the context of Nigeria, where specific studies on how industrialization affects food security are rare. Existing literature predominantly focuses on broader regions or different countries, leaving a significant research gap in understanding the Nigerian context. Additionally, the thematic review of existing literature reveals conflicting results across several themes related to industrialization and food security. For example, while some studies highlight the positive impacts of industrialization on agricultural productivity through technological advancements and improved infrastructure (Spielman et al., 2021; Ajayi & Solomon, 2020), others emphasize the negative consequences such as environmental degradation and labor diversion (Chen et al., 2018; Mupambwa & Dube, 2017). These contradictory findings suggest a need for more nuanced and context-specific research to reconcile these differences and provide a clearer understanding of the conditions under which industrialization can be beneficial or detrimental to food security.

Methodology

Data and Variables

The study utilized time series data spanning from 1986 to 2022. This period encompasses significant historical events, including the implementation of structural adjustment programs (SAPs) and a notable shift towards industrialization within Nigeria. In addition, the period is long enough, suitable for the intended econometric method of data analysis. The main variables of interest include manufacturing (value added) a proxy for industrialization (INDS) and Food Production Index (FPI) a measure of food security. Other control variables include Gross Domestic Product (GDP), Load Capacity Factor (LCF), and Population growth (POG).

Food Production Index (FPI), a measure of food security measures the relative level of the aggregate volume of agricultural food production for each year in comparison with the base period 2014-2016 (World Bank, 2023). Extant empirical studies widely considered food production index as more comprehensive measure than other indices because it includes all edible crops and accounts for a wide range of agricultural products (Setiawa et al., 2023; Ogundipe et al., 2019). This broad coverage ensures that the index reflects the overall food production landscape rather than focusing on a single crop or a limited set of products. FPI is treated as a dependent variable for this study. Data on FPI is obtained from World Development Indicators (WDI). Manufacturing (value added), a proxy for industrialization (IND) refers to the net output of the manufacturing sector, which includes all industries classified under manufacturing as per the International Standard Industrial Classification. Empirical studies (such as Almed et al., 2022; Opoku & Boachie, 2020; Munir & Ameer, 2020; Opoku & Aluko, 2021) used manufacturing (value added) as a measure of industrialization. While some studies (e.g., Ojeoga & Posu, 2015; Voumik & Sultana, 2022; Nasir, Canh & Lan Le, 2021) have used industry value added (including construction) as a measure of industrialization, it is argued that this metric underestimates the actual impact of the manufacturing sector. Industry value added encompasses additional components such as water, gas, electricity, mining, and construction, which can obscure the contribution of the manufacturing sector (Opoku & Aluko, 2021). Therefore, this study opts for manufacturing (value added) as it is often considered the core of industrialization and usually involves the transformation of raw materials into finished products and is closely associated with technological advancement, productivity improvements, and economic development. Moreover, many industrial policies and development strategies specifically target the manufacturing sector to stimulate economic growth and employment. This choice will help assess the impact of core industrial activities on economic development and their potential implications for food security and environmental consequences. The relationship between industrialization and food security is considered ambiguous in literature. On one hand, industrialization ought to introduce innovations in agriculture, such as mechanization or improved processing techniques, boosting agricultural productivity and hence enhancing food security (Ajayi & Solomon, 2020; Kassie et al., 2018; Mottaleb et al., 2016). Conversely, industrial activities can contribute to environmental pollution and depletion of natural resources, reducing the availability of arable land, and diverting labour away from the agricultural sector, thereby negatively impacting agricultural productivity and food availability (Nkonya et al., 2016; Chen et al., 2018; Mupambwa & Dube, 2017). Data on industrialization was sourced from World Development Indicators of the World Bank. Gross Domestic Product (GDP) is the total monetary value of all goods and services produced within Nigeria in a specific in a year. The a priori expectation of GDP on food security is positive. Generally, higher GDP leads to increased purchasing power among households. With more income, families can afford to buy more and better-quality food, improving overall food security. Data on GDP was sourced from Central Bank of Nigeria's annual publications. In this study, the Load Capacity Factor (LCF) is utilized as a measure of environmental sustainability. Recent empirical studies increasingly give preference to Load Capacity Factor (LCF) over traditional metrics such as greenhouse gas emissions and the ecological footprint (Pata & Isik, 2021; Voumik & Sultana, 2022). These studies suggest that LCF provides a more holistic measure because it considers both the supply and demand aspects of ecological systems, while other metrics often overlook the supply side. While the ecological footprint (EF) incorporates six environmental indicators—cropland, grazing land, built-up land, fishing grounds, CO_2 emissions, and forests—making it a more comprehensive measure of environmental degradation compared to atmospheric emissions (Aladejare & Nyiputen, 2023), it does not account for the productivity of ecological assets, known as biocapacity (Voumik & Sultana, 2022). By combining EF and biocapacity, LCF offers a superior evaluation of environmental degradation, effectively assessing whether countries exceed their sustainability limits. According to the LCF metric, an environment is sustainable when the value is 1 or greater, and unsustainable when it is below 1, with 1 serving as the sustainability threshold. The LCF is calculated as the ratio of biocapacity to the ecological footprint. An increase in LCF, indicating improved environmental sustainability, is expected to positively influence food security, and vice versa.

Population growth, defined as the increase in the number of individuals within a population over a given period, has an ambiguous relationship with food security in the literature. On one hand, rapid population growth may worsen food insecurity by escalating food demand and straining agricultural land and water resources (FAO, 2018; UNFPA, 2015). Data on population growth was obtained from the Central Bank of Nigeria's statistical bulletin.

Model specification

This study is premise on the impact of industrialization on food security in Nigeria. The theoretical model for this study is embedded in the EKC hypothesis. The EKC hypothesis posits that the relationship between environmental degradation and economic development follows an inverted U-shape. In the context of food security, we can adapt this hypothesis to consider how industrialization impacts food security, where industrialization initially degrades food security but improves it at higher levels of development due to better practices and technologies.

Let FPI represent food security, IND represent industrialization. According to the EKC hypothesis, the relationship between industrialization and food security can be expressed in a simple equation as:

$$FPI = f\,(IND)$$

Including control variables that may influence food security, such as Gross Domestic Product (GDP), Carbon emission (CO2), and Population growth (POG); equation 1.2 can be specified in a functional form as

$$FPIt = f\,(INDt,\ GDPt,\ CO2t,\ POGt)$$

Assuming the asymmetric effect of industrialization on food security, equation 1.2 can be written as

$$FPIt = f\,(IND\_POSt,\ IND\_NEGt,\ GDPt,\ LCFt,\ POGt)$$

The stochastic form of equation 1.3 can be specified as

$$FPIt = \beta0 + \beta1IND\_POSt + \beta2IND\_NEGt + \beta3GDPt + \beta4LCFt + \beta5POGt + \epsilon t$$

In order to be able to capture the non-linear property and heteroscedasticity of the variables, the above equation will be logged. Thus, taking a partial log of the variables, equation 1.4 becomes

$$FPIt = \beta0 + \beta1\ LnIND\_POSt + \beta2LnIND\_NEGt + \beta3LnGDPt + \beta4LCFt + \beta5POGt + \epsilon t$$

Following dynamic linear time series model in an autoregressive form such as:

$$Y_t = \alpha Y_{t-1} + \beta X_t + \in_t$$

Applying the above typical linear time series model to equation (1.5) to assess the asymmetric impact of industrialization on food security in Nigeria, the model is re-stated as:

$$FPIt = \beta 0 + \alpha FPI_{t-1} + \beta 1\ LnIND\_POSt + \beta 2 LnIND\_NEGt + \beta 3 LnGDPt + \beta 4 LCFt + \beta 5 POGt + \epsilon t$$

where: β0 is the intercept, α captures the effect of lag value of food security, β1 captures the positive effect of industrialization on food security, β2captures the negative effect of industrialization on food security, allowing for the inverted U-shape relationship, β3 captures the effect of GDP on food security, β4 captures the effect of load capacity factor, β5 captures the effect of population growth on food security; ϵt is the Stochastic error term at time t, Ln is Natural Logarithmic sign.

Method of Data Analysis

The data for this study underwent econometric analysis techniques. A unit root test was conducted to examine the stationarity properties of the dataset, which informed the selection of the appropriate estimation technique. The Pairwise Granger Causality Test was employed to determine the presence and direction of causality. This study utilized the Non-Linear Autoregressive Distributed Lag Model (NARDL) to estimate the coefficients of the explanatory variables. The NARDL model is preferred because it allows for the incorporation of asymmetric effects of positive and negative changes in the explanatory variables on the dependent variable, unlike the Linear Autoregressive Distributed Lag Model (ARDL), which assumes a constant impact of explanatory variables. The NARDL method also provides graphs of cumulative dynamic multipliers to trace adjustment patterns following positive and negative shocks to the explanatory variables and allows for asymmetry switching between the short-run and long-run (Meo, 2018; Ijirshar et al., 2021). Typically, a linear relationship exists when two quantities are proportional. However, if changes in industrialization do not cause changes in food security at a constant rate, the relationship is non-linear, which is central to this study. This assumption is based on the idea that most relationships in economics are nonlinear, meaning a change in an explanatory variable may not always result in the same change in the dependent variable. The NARDL framework is suitable for this research because it can be applied regardless of whether the regressors are stationary at level or first difference (I(0) or I(1)), and it allows for the detection of hidden cointegration while gauging short-run and long-run asymmetries. The long-run specification of the ARDL model is given as:

$$FPI_t = \beta_0 + \sum_{t=1}^{p} \beta_i\, FPI_{t-1} + \sum_{i=0}^{q1} \beta_i\, lnIND\_POS_{t-i} + \sum_{j=0}^{q2} \beta_j lnIND\_NEG_{t-j} + \sum_{l=0}^{q3} \beta_l lnGDP_{t-l} + \sum_{m=0}^{q4} \beta_m \mathrm{LCF}_{t-m} + \sum_{n=0}^{q5} \beta_m \mathrm{POG}_{t-n} + \mu_t$$

The short-run Error Correction Model (ECM) is specified as:

$$FPI_t = \beta_0 + \sum_{t=1}^{p} \beta_i FPI_{t-1} + \sum_{i=0}^{q1} \beta_i lnIND\_POS_{t-i} + \sum_{j=0}^{q2} \beta_j lnIND\_NEG_{t-j} + \sum_{l=0}^{q3} \beta_l lnGDP_{t-l} + \sum_{m=0}^{q4} \beta_m \text{LCF}_{t-m} + \sum_{n=0}^{q5} \beta_m \text{POG}_{t-n} + \pi ECT_{t-1} + \mu_t$$

The Error Correction Term (ECT) represents the speed of adjustment, denoted by π, which indicates the time it takes for the economy to return to its long-run equilibrium after experiencing shocks.

Result and discussion

Unit Root Test

Time series data is generally considered stationary if its mean and variance are independent of time. If the time series is non-stationary, it implies that its mean and variance are changing over time and hence the presence of unit root. Stationarity is vital in econometrics as most times the series may exhibit unit root problem. If the time series is non-stationary, the regression will produce misleading results. To prevent spurious (misleading) regression results, a stationarity test is conducted. In this analysis, the ADF unit-root test was employed because it accounts for serial correlation. The test was performed with the following hypotheses:

H_0: The variable has a unit root, implying it is non-stationary.

H_1: The variable does not have a unit root, implying it is stationary.

The decision rule is that if the absolute value of the t-statistic exceeds the critical value at a given level of significance, the null hypothesis is rejected. Otherwise, the null hypothesis is not rejected.

Table 1: Unit Root Test Result

Source: Extract from Author's computation from E-views 10

Variables	At Levels			At 1st Difference			Level of integration
	t-stat	Crit. Value (5%)	Prob. (0.05)	t-stat.	Crit. Value (5%)	Prob. (0.05)	
FPI	0.272	2.951	0.918	3.208	2.954	0.028	I(1)
LnIND	0.427	2.945	0.893	4.724	2.948	0.000	I(1)
LnGDP	3.603	3.557	0.045	-	-	-	I(0)
LCF	2.123	1.950	0.034	-	-	-	I(0)
POG	1.292	2.954	0.621	2.080	1.951	0.037	I(1)

I(0) indicate that the variable is stationary at levels while I(1) shows that the variable is stationary at first difference. The results from Table 1 show that variables such as LnGDP and LCF are stationary at levels, while FPI, LnIND, and POG are stationary at first difference, indicating a mixed order of integration among the dataset. Consequently, it can be asserted that LnGDP and LCF are I(0), whereas FPI, LnIND, and POG are I(1). This result provides favorable conditions for using the Nonlinear ARDL model to examine the effect of industrialization on food security in Nigeria. Furthermore, considering that most relationships in economics are nonlinear, this study adopts the NARDL method, which accounts for both the short- and long-run asymmetric effects of industrialization on food security.

ARDL Optimal lag selection criteria

Understanding the criteria for selecting the optimal lag is essential for interpreting Autoregressive Distributed Lag (ARDL) models, as it determines the appropriate lag length for the variables. Given that ARDL models include lags of the dependent variables, choosing the optimal lag ensures that the model accurately captures the relevant temporal dynamics and relationships within the data. This selection process is vital for obtaining precise parameter estimates and making reliable inferences. In this study, the Akaike Information Criterion (AIC) is employed to determine the optimal lag order for the series. The results are illustrated graphically in Figure 1 below.

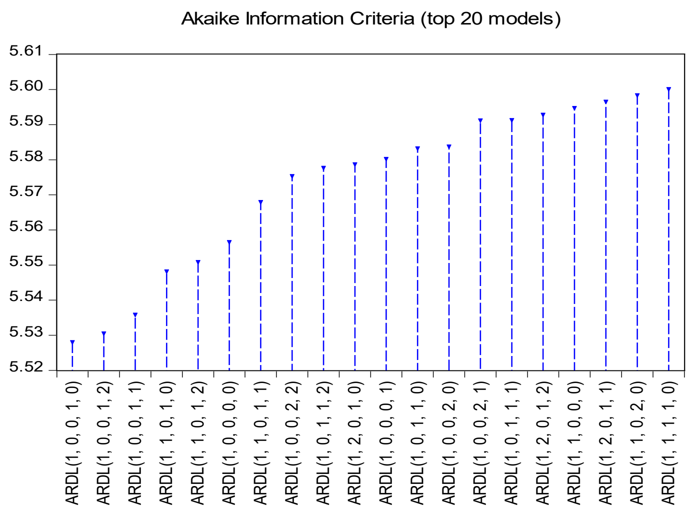

Figure 1: ARDL optimal lag selection result

From the results presented in Figure 1, it can be observed that the maximum lag length is two (2), with the optimal lag length being ARDL (1 1 1 1 0). This is based on the Akaike Information Criterion (AIC), which yielded the lowest value when compared to the other top 20 models. Therefore, the model will be estimated using a lag of two (2) to ensure optimal performance and an accurate representation of the data.

ARDL Long run Bound Test

In econometric analysis, examining long-run relationship between/among variables is crucial for understanding the underlying equilibrium dynamics and the stability of economic relationships over time in order to drive insights into the economic implications and policy relevance of such relationships. The ARDL Bound Test, operating within the Autoregressive Distributed Lag (ARDL) model framework, is well suited for this purpose. Unlike traditional cointegration tests, it accommodates mixed orders of integration and includes lagged variables, enabling analysis of non-stationary and mixed-order integrated time series data. Thus, this study utilized the ARDL Bound Test to evaluate the long-term relationship among the study variables.

As a guideline, if the F-statistic value for the bound test exceeds the upper bound for both actual and finite samples, we conclude that, at the specified level of significance, there exists a long-term relationship between the variables. Otherwise, if the F-statistic value falls below the upper bound, the variables do not cointegrate in the long run. The outcome of the bound test for cointegration is presented in Table 2 below

Table 2: ARDL Bound Test Result

Test Statistic	Value	Signif.	I (0)	I (1)
			Asymptotic: n=1000	
F-statistic	9.274500	10%	2.08	3
k	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

Source: Author's computation from E-views 10

Result in Table 2 indicates that there is long-run relationship among the variables incorporated in the model. This is because; the F-statistic Value of 9.274500 is greater than the Pesaran upper and lower bounds critical values of 2.39 and 3.73 respectively at 5% level of significance. This means that in the long run, there is no tendency that the variables will drift apart, and hence there is cointegration among them.

Test for long-run asymmetry

The study utilized the Wald Test to examine the presence of asymmetry in the long-run relationship between industrialization and food security in Nigeria. The results are presented in Table 3 below.

Table 3: Wald Test for Long-run Asymmetry

Source: Author's computation from E-views 10

Test Statistic	Value	df	Probability
t-statistic	2.681	30	0.011
F-statistic	7.190	(1, 30)	0.011
Chi-square	7.190	1	0.007
Null Hypothesis: C(2) = C(3) = 0			

The test results for the asymmetric impact of industrialization on food security show t-statistic value of 2.681481, an F-statistic value of 7.190342 and a chi-square value of 7.190342, with probability values of 0.0118, 0.0118, and 0.0073, respectively. Since these probability values are less than the 0.05 significant level, there is evidence of long-run asymmetric relationship. Thus, increases in industrial activities and decreases in industrial activities significantly differ in their long-term effects on food security in Nigeria. This implies that food security in Nigeria does not respond equally to positive and negative shocks to industrialization in the long run.

The long-run effect of Industrialization on food security in Nigeria

Having established that there is long-run equilibrium and asymmetric relationship between industrialization and food security, the asymmetric long-run estimates were computed at the ARDL optimal lag of (1 1 1 1 0) and the results are presented in Tables 4.

Table 4: Long-Run Effect of industrialization on Food Security

Source: Author's computation from E-views 10

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNIND_POS	42.081	17.255	2.438	0.022
LNIND_NEG	13.499	13.509	0.999	0.328
LNGDP	-13.655	16.837	-0.811	0.425
LCF	-189.983	66.762	-2.845	0.009
POG	-39.536	20.139	-1.963	0.061
C	609.771	425.938	1.431	0.165

Table 4 presents the result of the long-term asymmetric impact of industrialization on food security in Nigeria, alongside the results of the linear long-term effects of other control variables on food security. Result from Table 3 reveal that positive changes in industrialization has a positive and significant effect on food security in Nigeria in the long-run by 42% whereas negative changes in industrialization exerts positive but weak influence on food security in the long run by 13%. This result implies that in the long run, increased industrial output or investment have a strong and significant effect on improving food security in Nigeria. This could be rationalized on the grounds that increased Industrialization often leads to job creation in both the industrial sector and related industries. More employment opportunities can enhance household incomes, which allows individuals to afford better and more nutritious food. This result is theoretically plausible and aligns with the empirical findings of Rao & Kumar (2021), Ahmed & Bukhari (2022), Khan & Ullah (2023) who found that industrial growth leads to increased employment and higher incomes, which in turn improve access to nutritious food. Conversely, negative changes (decline) in industrial activities, though not as pronounced as when industrialization increases, results to some level of benefit to food security in Nigeria. The weak or insignificant effect of industrial decline on food security in Nigeria suggests that while industrialization is crucial for enhancing food security, the system has some level of resilience and adaptability that reduces the impact of industrial downturns. For example, households and markets in Nigeria have alternative ways to secure food that are less dependent on industrial activities, reducing the overall impact on food security. The findings are in line with those of Ogunleye & Ayodele (2022) who found that while industrial declines do have an effect, the presence of robust agricultural policies, strategic food reserves, and infrastructure support helps mitigate these impacts. On the effect of other control variables on food security, Table 3 shows that while economic growth and population growth has a negative but weak effect on food security in the long run, load capacity factor (a measure of environmental sustainability) exerts a negative and significant effect on food security. Although contrary to theoretical expectation, this result implies that efforts to improve LCF are focused on long-term environmental sustainability at the expense of short-term agricultural productivity. This trade-off can negatively impact food security in the immediate term, even if it aims to benefit the environment in the long run.

Short-run Effects of Industrialization on Food Security in Nigeria

Estimates of the short-run asymmetric effect of Industrialization of food security are presented in Table 5 below.

Table 5: Short-run Effects of Industrialization on Food Security in Nigeria

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-121.857	21.837	-5.580	0.000
D(LNIND_POS)	-22.711	9.868	-2.301	0.030
D(LNIND_NEG)	10.608	10.399	1.020	0.317
D(LCF)	-31.577	29.789	-1.060	0.299
D(POG)	-7.013	15.681	-0.447	0.658
ECM(-1)*	-0.902	0.158	-5.703	0.000

R-Square = 0.581987, Adjusted R2= 0.509916, DW=2.371369
Source: Author's computation from E-views 10

Table 5 presents the estimates of the short-run asymmetric impact of industrialization on food security in Nigeria. Result in Table 4 shows that positive changes in industrial activities has a negative and significant impact on food security in the short run by 22% while negative changes in changes industrialization exerts a positive but weak impact on food security. This result implies that in the immediate term, increased industrialization may strain food security in Nigeria. This is because in the short run, increased industrial activities can lead to environmental pollution, including air, water, and soil contamination. Pollutants from industrial processes can degrade agricultural land and water sources, negatively impacting crop yields and food quality. On the other hand, when industrial activities decline, there is a positive but weak impact on food security, indicating some level of short-term benefit to food security when industrial activities decrease. The reason is that when industrial activities decline, resources such as labor and capital may be redirected to agriculture, leading to a temporary boost in food production and security. These findings are in line with those of Singh & Sharma (2022), Okoro & Adeoye (2023) who found that a decline in industrial activities shifts labour and capital to agriculture, improving food security.

The short run result in Table 4 also indicates that, in an event of any temporary shock, the variables in the model can adjust back to the long run path at the speed of about 9% yearly. This is because the ECM coefficient is negative (-0.902322) and statistically significant at 5%.The results of the R-Squared (0.581987) and Adjusted R-squared (0.509916) show that over 58% of the variations in food security in the short run are explained by the variation in industrialization and other variables captured in the model. Also, the Durbin -Watson statistic of 2.37, which can be conveniently approximated to 2.00 shows that the model does not suffer any incidence of autocorrelation.

The Dynamic Multipliers

The study calculates the cumulative dynamic multipliers effect on change in food security of a unit change (positive and negative changes) in industrialization. The result of the dynamic multipliers is therefore presented in Figure 2 below.

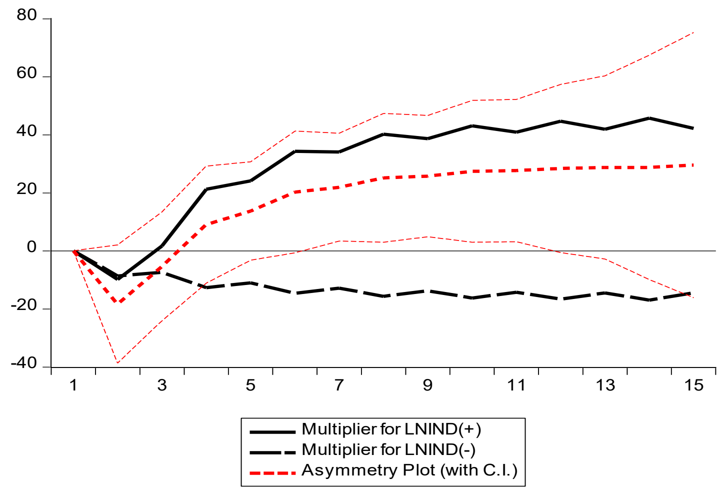

Figure 2: Result of the Dynamic Multipliers

Figure 2 shows the multipliers for positive and negative changes in the industrialization on food security over time. Figure 2 shows that positive changes in industrialization (indicated by continuous black line) starts below zero but shortly became positive and increases over time, indicating that positive changes in industrialization have a positive and increasing impact on food security. On the other hand, negative changes in industrialization (indicated by the dotted black line) starts below zero and decreases further, it indicating that negative changes in industrialization have a negative and increasing (in magnitude) impact on food security.

The graph shows that positive changes in industrialization has a progressively increasing positive impact on food security, while negative changes in LNIND have a progressively increasing negative impact. Initially, Positive and negative multipliers are statistically similar (no significant asymmetry). However, significant asymmetry emerges as the effects of negative changes diverge from those of positive changes, indicated by the non-overlapping confidence intervals. The clear divergence between the positive and negative multipliers indicates significant asymmetry in the relationship.

NARDL Diagnostic Test

A diagnostic examination is necessary to determine the validity of the model. Essentially, this diagnostic process is conducted to ascertain whether the developed model exhibits any issues related to goodness of fit. The criteria for residual diagnostic checks in this study encompass various tests, such as the Ramsey test for correct model specification, the LM test for serial correlation, a heteroskedasticity test, as well as CUSUM and CUSUM squared tests to assess the significance of the relationship. The results of the diagnostic tests are presented in Table 6 below

Table 6: Diagnostic Test Results

Test	F-statistic	Probability
Ramsey RESET Test	4.530346	0.0774
Breusch-Godfrey heteroskedasticity	1.524711	0.1957
LM Serial Correlation,	0.564447	0.4627

Source: Extract from Authors' computations in E-views 10

According to the data presented in Table 6, the test statistic for serial correlation, along with its corresponding probability value, shows insufficient evidence to reject the null hypothesis, indicating the absence of serial correlation. Similarly, the test statistic for heteroskedasticity does not provide enough evidence to reject the null hypothesis, suggesting that heteroskedasticity is not present. The Ramsey RESET Test, which checks for general misspecifications in the regression model, indicates that the model is correctly specified, as the p-value exceeds the 0.05 significance level. Furthermore, the CUSUM and CUSUM of squares tests were conducted to assess the stability of the model. The results are shown in Figures 3 and 4, respectively.

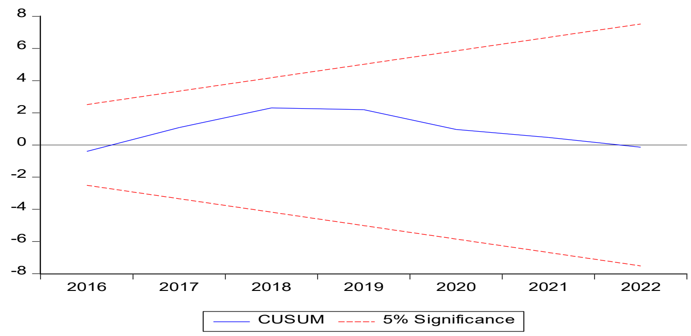

Figure 3: CUSUM Test Result
Source: Extract from Eviews10

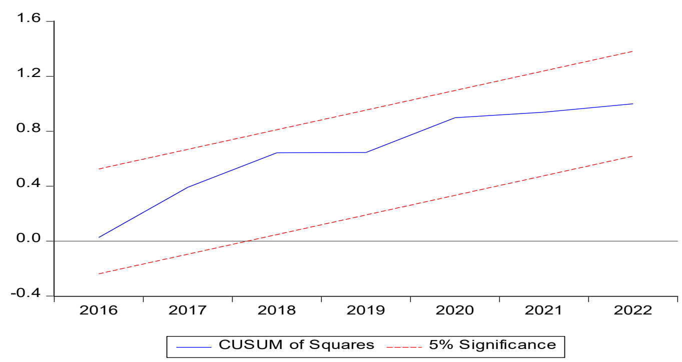

Figure 4: CUSUM of Squares Test Result
Source: Extract from Eviews10

The results of the CUSUM and CUSUM of squares tests, presented in Figures 2 and 3, clearly show that the model is stable, as the cumulative sum of the residuals remains within the 5% confidence intervals (represented by the red dotted lines). This suggests that the findings of this study are reliable and can be used to inform the policymaking process.

Conclusion and Recommendations

The study concludes that industrialization has a long-run asymmetric impact on food security in Nigeria. Specifically, positive changes in industrialization significantly and positively affect food security, while negative changes have a positive but weaker influence in the long run. Conversely, in the short run, positive changes in industrial activities negatively and significantly impact food security, whereas negative changes exert a positive but weak effect. This suggests that while industrialization can enhance food security over the long term, short-term industrial activities might pose challenges to achieving immediate food security goals. Based on the findings presented in this study, the following recommendations are made: Firms should implement eco-friendly technologies and comply with environmental regulations to minimize negative impacts on food security. Government on the other hand should strengthen and enforce environmental regulations, and provide incentives for firms adopting sustainable practices. More so, farmers should adopt advanced agricultural technologies and diversify income sources to enhance resilience on the adverse effect of industrial activities on food security. Additionally, government should develop and maintain infrastructure to support efficient and reliable food supply chains, and offer financial support to smallholder farmers

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