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Infrastructure and Sustainable Food Production in Nigeria: An Empirical Study of the FAO Methodology and Keynesian Theory on Government Spending

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ABSTRACT

In a 2016 methodology working document, the Food and Agriculture Organization (FAO) proposed agriculture-specific and agriculture-supportive government expenditures. This study adopted some of the proposed categories of government spending to establish the effects of infrastructure on food security in Nigeria. Time series (1960–2020) on relevant variables were sourced from the WDI database provided by the World Bank, and the Food and Agriculture Organization Statistics (FAOSTAT). Data analysis was based on descriptive statistics and the Dynamic Ordinary Least Squares (DOLS). The included series satisfied the major conditions for applying the DOLS model. Agricultural output (AGO), per capita income (PCI), and per capita food production (PCF) were used as indicators

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of food security. The models' tests conducted have P-values greater than 5 per cent, which shows that the models were fit. The result shows that investment in agriculture (β = 0.0995), transportation (β = 0.1067), health (β = 0.3407), and education (β = −0.3877) significantly influenced agricultural output at the 5 per cent level of significance, while investment in agriculture (β = 0.1079), health (β = 0.2868), and education (β = −0.2671) significantly influenced per capita food expenditure at 1 per cent. This study contributes to the existing body of knowledge as it empirically confirms an improvement to Keynesian theory in that there is a direction in which public spending can impact food security. Emphasis should be on agriculture-related infrastructure or farmers' livelihoods, otherwise, the government's efforts on public spending may not positively impact food security. The study recommends a proper and efficient policy mix for providing agriculture-related infrastructure.

Keywords: FAO Methodology; Infrastructures; Keynesian; SDG; Food Security; Sustainable Food Production

1. Introduction

Food security has been at the forefront of the development agenda for over two decades. Food security is "a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"[1]. This definition has the four pillars of food security –availability, accessibility, utilization, and stability. As knowledge evolves, agency and sustainability are added[2]. Food availability involves food production, effective distribution, and exchange[3]. Food access is determined by income levels and its distribution[4]. Food utilization involves the actual use of food with the required nutrients in the appropriate proportion and safe environment[5]. Food stability involves the availability of food over time[6]. Agency and sustainability emphasize the importance of making informed food choices and promoting environmentally responsible practices to ensure long-term access to nutritious food[7]. Ensuring food security relies on the capacity of agriculture to produce a consistent and sufficient supply of safe, nutritious, and affordable food with a focus on the dietary needs of a growing global population. Consequently, the success of food security initiatives hinges on the sustainable development, modernization, and resilience of agricultural systems worldwide, infrastructural systems inclusive.

The outlook for agriculture in Nigeria is broadly positive but could be further enhanced by consistent policies and strategic investments in infrastructure[3]. Government actions about agriculture and food security are expected to protect her citizens from the vagaries of poverty. Existing evidence has revealed that several interventions implemented to promote agricultural growth have instead become a bane to growth. In many cases, the agricultural infrastructural investment did not achieve its intended goals, sometimes because they were unsustainable, untargeted, or simply ineffective.

In developing countries like Nigeria, the state of infrastructure is critical to determining the effectiveness of food production systems. Despite having significant agricultural potential, Nigeria's food production is often hampered by poor infrastructure, including inadequate road networks, electricity, storage facilities, and irrigation systems[8, 9]. Infrastructure is essential for food production and efficient distribution, preservation, and processing of agricultural products. The lack of access to quality infrastructure leads to high post-harvest losses, limits market access for farmers, and increases the cost of inputs, which contributes to food insecurity[10]. Moreover, poor infrastructure exacerbates the challenges posed by climate change, such as rising temperatures and unpredictable rainfall, by making it harder for farmers to adapt. For instance, without adequate irrigation systems through government investment in agriculture, farmers in regions like Northern Nigeria, which experience frequent droughts, are highly vulnerable to crop failure. Furthermore, infrastructure deficits hinder the ability of smallholder farmers to implement sustainable farming practices, as farmers lack access to modern technology and methods that could boost productivity

Several studies have attempted to establish government spending or public expenditure and food security in developing countries. These can be categorized into four groups: firstly, studies aimed at identifying the types of interventions influencing food security [11–13]. Secondly, studies on monitoring donor investments directed towards food security, analyzing their patterns, and exploring the factors driving them [14, 15]. Thirdly, studies proposing methodologies for quantifying public expenditure on nutrition, food security, or both [16, 17]. Fourthly, studies on government spending with emphasis on nutrition in developing countries, using methodologies informed on an ad-hoc basis [18, 19]. We realized that these existing empirical studies negate consistency and do not adopt an all-encompassing methodology for measuring and classifying government spending (public expenditures) for sustainable food production from the angle of policy analysis. In addressing this, FAO in a 2016 [20] methodology working document proposed agriculture-specific and agriculture-supportive expenditures which aimed at providing direct support to food security (food security-specific expenditures) and expenditures that indirectly support food security (food security supportive). The proposed public expenditures related to food availability include agricultural investment, transportation, and import subsidies, amongst others. Regarding food access, the significance of education, transportation, market infrastructure, and rural infrastructure at large was underscored. The suggested categories for the utilization aspect of food security include health, access to clean water and sanitation, and behaviour change interventions, among others. Factors such as climatic-related variables, transportation expenditure, and natural resource conservation were proposed as relevant proxies for the stability dimension. This present study adopted some of these proposed categories of government spending (investment in agriculture, transportation, education, and health) to model how infrastructure can influence food security in Nigeria. We employed a recent econometric technique to model this relationship. The Dynamic Ordinary Least Squares (DOLS) adopted in this study has some advantages over the common OLS regression model because DOLS fixes issues of serial correlation and heteroskedasticity in time series data, by producing normal t-statistics [21, 22].

This study finds justification in Nigeria's unique agricultural context and the role of infrastructure in sustaining food systems. Nigeria, with an increasing population of over 210 million people, heavily relies on agriculture, which contributes significantly to its GDP and employment. However, insufficient infrastructure, including roads, storage facilities, education, health and energy access, irrigation systems, and market networks, hinders agricultural productivity and sustainability. Poor road networks cause delays and increase costs in transporting food from rural farms to urban markets. Additionally, without proper storage facilities through investment in agriculture, post-harvest losses are substantial, with some estimates suggesting that over 40% of agricultural produce is lost before reaching consumers [23–25]. In terms of policy, Nigeria has implemented several policies, such as the Agricultural Transformation Agenda (ATA), the Agricultural Promotion Policy (APP) and the current National Agricultural Technology and Innovation Policy (NATIP), aiming to modernize its agricultural sector. However, these initiatives can only succeed if supported by corresponding and targeted improvements in infrastructure. Without addressing the infrastructural gaps, Nigeria's goal of boosting agricultural commercialization and reducing rural poverty remains difficult to achieve. Consequently, the purpose of this study is to understand the nexus of infrastructures and sustainable food production in Nigeria.

1.1. The Keynesian Theory on Government Spending

This theory was adopted in explaining the nexus of infrastructure and food security. Keynesian economics, a macroeconomic paradigm by John Maynard Keynes in the 1930s to address the challenges of the Great Depression, focuses on the overall spending within an economy and its impacts on output, employment, and inflation. Keynes recommended increasing government expenditures and decreasing taxes to boost demand, to influence the global economy during the depression [26]. According to the theory, public expenditure is an external factor wielded as a policy tool to influence economic growth, specifically in this case, food security. Keynes posited that an infusion of government spending results in heightened business activity and additional spending, creating a multiplier effect on sustainable food production.

The theory underscores the role of government in regulating the economy. In contrast to classical theorists who attributed unemployment or low growth to government involvement, the Keynesian school of thought advocated for government intervention to foster economic stability [27, 28]. Keynes argued that as income increases, the propensity to consume decreases, while the propensity to save increases, creating an economic disequilibrium in terms of consumption. In line with this theory, to ensure sustainable food production and, consequently, food security, an increase in public or government expenditure is deemed necessary.

The Keynesian theory asserts that overall spending constitutes the primary factor influencing the total output (food security) within a country. Building on Keynesian principles, the resulting aggregate expenditure model breaks down a nation's food security into three components: investment in agriculture, government spending, and net exports, as represented by Equation (1).

$$FS = IA + G + (X - M) \tag{1}$$

Where: FS $\rightarrow$ national food security, IA $\rightarrow$ investment in agriculture, G $\rightarrow$ government

Spending (public expenditure), X $\rightarrow$ value of exports and M $\rightarrow$ value of Imports.

This theory emphasizes that public investment, especially in infrastructure, can stimulate economic growth by increasing aggregate demand. In the context of agriculture, investments in infrastructure like transportation, healthcare, and education can positively affect agricultural output and food security through various mechanisms including transportation, education, and health, among others. Transportation infrastructure, such as roads and railways, enhances the movement of goods and services, allowing farmers to access markets more efficiently and at a lower cost. This reduces post-harvest losses, ensures timely delivery of agricultural inputs, and facilitates food distribution, thereby boosting agricultural output. For example, improved rural road networks have been linked to increased agricultural productivity and income growth in many developing countries, including Nigeria [29–34].

Education infrastructure is expected to increase farmers' knowledge of modern farming techniques and innovations, such as climate-smart agriculture, and improve agricultural productivity [35]. Educated farmers make better decisions and manage their farms more efficiently. In Nigeria, there is a strong link between farmers' educational levels and agricultural productivity, with more educated farmers showing higher adoption rates of new technologies and a better understanding of market dynamics [36].

On the other hand, health infrastructure ensures a healthier workforce, reducing labour shortages during critical farming periods. In Nigeria, diseases like malaria and poor access to health facilities significantly reduce farm productivity [37–39]. Improved health infrastructure can alleviate these burdens and allow farmers to work more consistently and efficiently. Studies show a strong correlation between health infrastructure and agricultural productivity. For example, in many rural areas of Africa, poor health services led to high absenteeism in farm labour due to sickness, affecting food production and household food security [40, 41].

1.2. Some Literature on Infrastructure and Agricultural Production

Studies have examined the factors contributing to agricultural growth in developed and developing countries. Muder et al. [42] examined the impacts of large-scale agricultural investments (LSAIs) on local communities in Central Benin, West Africa, with a focus on a tomato-producing LSAI. Using an expanded "Right to Food" (RtF) framework, the study finds that while LSAIs provide employment opportunities and improve local dietary diversity, they also highlight significant issues like inequalities in compensating former land users and job insecurity for temporary labourers. The study suggests that access to natural resources, market access, and strong local institutions are critical for promoting positive LSAI outcomes. Furthermore, it emphasizes the need for inclusive compensation and improved infrastructure to support local communities.

Morrison et al. [43] focused on the effect of proximity to markets on dairy farming intensity and market participation in Ethiopia and Kenya. The findings reveal that proximity to local service centres leads to increased market participation, higher stocking rates, and better productivity. In Ethiopia, remote farms face challenges due to limited market demand and weak infrastructure. Similarly, an earlier study by Shamdasani [44] estimated the effects of improvements in rural road infrastructure on agricultural production decisions in remote villages in India. The author finds that households in remote villages that gain access to new rural roads diversify their crop portfolio, adopt modern agricultural technologies, and increase hired labour use. The results suggest that rural road infrastructure integrates village labour markets across space, enabling the adoption of labour-intensive production practices. Findings from a study in Haiti by Morre and Koso [45] highlighted the need for inclusive and context-sensitive infrastructural investments that support local food systems rather than perpetuate external control and inequalities.

Eberewore [46] examined the perceptions of rural farmers in Nigeria regarding infrastructure availability and condition. The results indicate that most infrastructure, except for roads, water, community centres, and market structures, is in poor condition and negatively affects farming activities. Additionally, regression analysis identified several factors, such as proximity to urban areas, corruption, community commitment, and financial access, as influencing rural infrastructure development. The study concludes that there is a need to improve the provision of infrastructure to support agricultural productivity in Nigeria.

Sers & Mughal [47] reported that countries allocating substantial portions of their budgets to agriculture experienced improved food security situations. Additionally, investment in agricultural research and development directly influenced Africa's food security, with evidence supporting the temporal effects of public spending. The study underscored the relevance of the Maputo Declaration's commitment to allocate at least 10% of public spending to agriculture.

Alhaji et al. [48] examined the relationship between infrastructural development, agricultural growth, and poverty in Nigeria, using government capital expenditure as a proxy for infrastructure. Employing the Seemingly Unrelated Regression Estimation technique, the study indicated that economic growth, employment, and real wages reduction alleviate poverty. Factors such as investment rate, population growth, and capital expenditure in education positively influenced agricultural sector growth.

Osabohien et al. [49] studied the interplay between food security, institutional frameworks, and technology in Nigeria, utilizing the Auto-Regressive Distributed Lag (ARDL) Approach. Emphasizing the importance of technology, the study highlighted that growth in agricultural science and technology is crucial for enhancing agricultural output and reducing rural poverty, subsequently improving food security. The study also underscored the impact of oil as a major export product contributing to food insecurity in Nigeria.

Chauke et al. [50] conducted a comparative study on the impact of public expenditure on agricultural growth in South Africa and Zimbabwe, employing co-integration tests and the Vector Error Correction Model (VECM). While capital expenditures are positively related to agricultural growth in both countries, the analysis revealed that both governments favoured current expenditures over capital expenditures. The study recommended a reevaluation of priorities to focus more on capital expenditures.

Sunkanmi & Abayomi [51] adopted the Keynesian macroeconomic framework to explore the relationship between government expenditures and poverty levels in Nigeria. The study found a negative relationship between public expenditure on rural education and poverty; consistent with Keynesian theory. The results also indicated that factors like population structure, total savings, and foreign aid tended to increase poverty levels in Nigeria.

Chude & Chude [52] examined the effects of public expenditure in the education sector on agricultural growth in Nigeria, employing the Vector Error Correction Model (VECM). The study revealed a positive relationship between expenditure on education and agricultural GDP growth, aligning with the views of classical economists such as Adam Smith. The conclusion highlighted the influence of both exogenous and endogenous factors on the Nigerian agricultural sector.

Enyim [53] assessed the impact of public expenditure on agriculture and the Agricultural Credit Guarantee Scheme Fund on poverty reduction in Nigeria. Using OLS techniques on time series data, the study found that public spending on agriculture significantly contributed to poverty reduction, emphasizing the need for targeted efforts toward the rural poor. Armas et al. [54] focused on Indonesia, examining the impact of different types of agricultural spending on agricultural growth. The study disaggregated agricultural expenditure into irrigation and subsidies, finding a positive relationship between agricultural GDP and government spending. Omojimite [55] reported that rural infrastructural facilities improve the performance of Nigeria's agricultural sector over time, specifically targeting food self-sufficiency and socio-economic welfare improvement in rural areas.

Ighodaro [56] studied infrastructure and agricultural growth in Nigeria over four decades, employing the Parsimonious Error Correction Model estimation technique. The study reported varying response rates of different infrastructure components to agricultural sector growth, indicating unidirectional causality between telecommunication facilities, labour, and agricultural production. Temel & Maru [57] used a Panel ARDL model to assess the impact of infrastructure and Information and Communication Technology (ICT) on national agricultural research organizations in Georgia. The study identified weaknesses in the linkage between Georgia's well-established broadcasting network and agricultural development, emphasizing the need for improved information flow and management.

Lalli [58] employed descriptive statistics to evaluate the importance of infrastructure on agricultural development in Haryana. The study found that while agricultural infrastructure is necessary, other factors also contribute to development. Disparities in infrastructure distribution were linked to inequalities in agricultural productivity. Limi & Smith [59] concluded that public infrastructure provision could accelerate aggregate agricultural growth. The study suggested that different infrastructures, such as roads and irrigation facilities, could strengthen production efficiency in specific agricultural industries.

Fan & Saurkar [60] analyzed the patterns in government spending across 44 developing countries from 1980 to 2002. Their study evaluated the consequences of shifts in government expenditures on growth and poverty alleviation, giving specific attention to diverse sectors, including agriculture. The findings underscored the influence of research expenditures on enhancing agricultural productivity. Fan & Chan-Kang [61] highlighted the essentiality of high-quality infrastructure for both agricultural growth and poverty reduction in China. Similarly, Fan et al. [62] determined that public investment in rural roads significantly contributed to substantial growth in agricultural productivity in India. Emphasizing the significance of rural infrastructure, Felloni et al. [63] underscored its role in reducing production and transportation costs.

2. Materials and Methods

This study relied on secondary data, utilizing time series data spanning from 1960 to 2020 in Nigeria. Nigeria currently has a population of above 215 million, using the country's population growth rate of 2.58 per cent [64, 65]. The population distribution is uneven, with approximately 63 per cent residing in agricultural rural areas [66]. Positioned between 3° and 14° East Longitudes and 4° and 14° North Latitudes, Nigeria shares borders with the Republics of Benin and Niger to the west, the Republic of Cameroon to the east, Niger and Chad Republics to the north, and the Gulf of Guinea to the south. The climate is predominantly equatorial and semi-equatorial, characterized by high humidity and significant rainfall, divided into wet (April to October) and dry (November to March) seasons.

Approximately 78 per cent of Nigeria's total land area, equivalent to 71.9 million hectares, is arable. However, around 28.2 million hectares of this agricultural land are actively cultivated [64]. Since gaining independence, agriculture has been a major contributor to the Nigerian economy, transforming small to medium and large-scale commercial activities. **Figure 1** illustrates the geopolitical zones of the country.

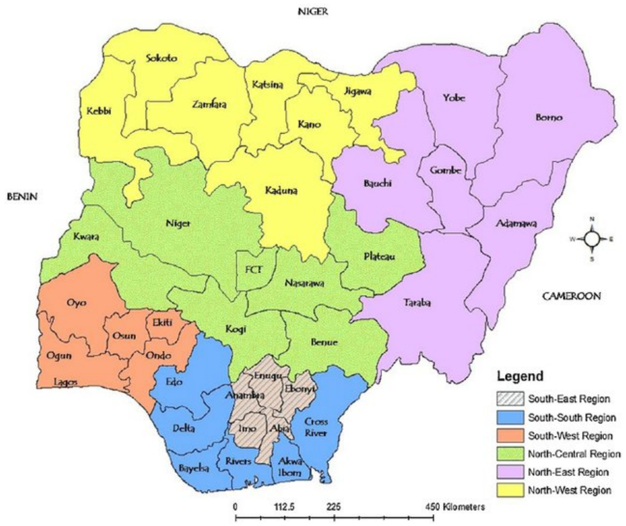

Figure 1. Map of Nigeria showing the geopolitical zones.

Time series data-related variables were obtained from publicly available publications by the World Bank's World Development Indicators (WDI), the Food and Agriculture Organization (FAO), the Central Bank of Nigeria (CBN), and the National Bureau of Statistics (NBS). Dynamic Ordinary Least Square (DOLS) regression model was used to model the proposed relationship.

We tested the null hypothesis of autoregressive unit root using the Augmented Dickey-Fuller (ADF) and the Phillips-Peron (PP) tests. The ADF and PP are shown in Equation (2).

$$Y_t = \alpha_0 + \beta_1 Y_{t-1} + \sum_{i=1}^{k} \lambda_i \Delta Y_{t-1} + e_i \quad (2)$$

Where;

Δ = the first–difference operator

Y = the variable under consideration,

α_0, β_s and λ_1 = parameters to be estimated

e_i = the error term.

As specified in Equations (3)–(5), this study modelled food security as a function of agriculture-related infrastructural facilities as suggested by the FAO.

Model 1

$$AGO_t = f(IVA, TRP, HLT, EDC) \quad (3)$$

Model 2

$$PCI_t = f(IVA, TRP, HLT, EDC) \quad (4)$$

Model 3

$$PCF_t = f(IVA, TRP, HLT, EDC) \quad (5)$$

The explicit form of Equations (3)–(5) is specified in Equations (6)–(8):

$$AGO_t = \beta_0 + \beta_1 LNIVA + \beta_2 TRP + \beta_3 HLT + \beta_4 EDC + \mu_{it} \quad (6)$$

$$PCI_t = \beta_0 + \beta_1 LNIVA + \beta_2 TRP + \beta_3 HLT + \beta_4 EDC + \mu_{it} \quad (7)$$

$$PCF_t = \beta_0 + \beta_1 LNIVA + \beta_2 TRP + \beta_3 HLT + \beta_4 EDC + \mu_{it} \quad (8)$$

Where:

AGO_t = agricultural output

PCI_t = per capita income

PCF_t = per capita food production

IVA = government investment in agriculture

TRP = public spending on transportation

HLT= public spending on health

EDC = public spending on education

Following Stock-Watson, the DOLS model is specified in Equation (9):

$$Y_t = \beta_0 + \beta X + \sum_{i=-q}^{p} d_j \Delta X_{t-j} + \mu_t \quad (9)$$

Where

Y_t = dependent variable

X = independent variables

β = cointegrating vector

p = lag length

q = lead length

It is expected that the higher the expenditure on any of these explanatory variables, the better the food security situation in the country.

Measurement of Variables

The variables used in this study were measured as given in **Table 1**.

Table 1. Measurement of Variables.

Variables	Measurement	Expected Sign
AGO, Agricultural Output	This is one of the dependent variable, which was used as a proxy for food security, as suggested by FAO. It is determined as the mean quantity of all agricultural produce produced by the farmers in Nigeria during the period under study. This variable was measured in Naira equivalence (₦)	Not Applicable
PCF; Per capita food production	This is one of the proxies for food security and it is the quantity of food per head within the study period. The variable was measured in Food output per person	Not Applicable
PCI; Per capita income	This is also one of the explanatory variables and it is the value of gross domestic product (GDP) per head within the study period. The variable was measured as GDP per capita	Not Applicable
POP; Population	This represents the total number of persons in Nigeria within the study period. It is one of the explanatory variables and was measured in 'Million persons	-ve (following Malthusian theory, an increase in population will inversely affect food security)
Government expenditure on transportation	This represents government spending on transportation and transportation facilities within the study period. The variable is one of the agriculture supportive variables given by the FAO in 2016. It was measured in Naira equivalence (₦)	+ve (increase in the amount spent on transportation infrastructure is expected to increase food security).
Government expenditure on heath	This is the amount of public expenditure on health. The variable is one of the agriculture supportive variables given by the FAO in 2016. It was measured in Naira equivalence (₦)	+ve (high public spending on health is expected to increase food security)
Government expenditure on education	This represents the amount spent on education. The variable is one of the agriculture supportive variables given by the FAO in 2016. It was measured in Naira equivalence (₦)	+ve (high public spending on education is expected to increase food security)
Investment in agriculture	This is one of the agriculture specific infrastructural policy variables given by the FAO in 2016. It was measured in Naira equivalence (₦)	+ve (high level of investment in agriculture is expected to increase food security)

3. Results and Discussion

3.1. Effects of Infrastructural Facilities on Food Security in Nigeria

The DOLS parameter estimates of the cointegration regression model applied in analyzing the effects of infrastructure on food security [using agricultural output (AGO), per capita income (PCI), and per capita food production (PCF) as indicators of food security] over the study period are summarized in **Table 2**. As a major condition in applying the Dynamic Ordinary Least Square (DOLS) model, the series should be in their first difference. From the results in **Table 3**, the PP test, variables included in the model attained stationarity after first differencing, hence, they were integrated at order one, I(1). After satisfying the condition for DOLS, the DOLS model was used to examine the effect of infrastructure on food security as presented in **Table 3.**

Table 2. Results of the DOLS model on the effect of infrastructure on food security

Dependent Variables	**AGO**		**PCI**		**PCF**	
Independent Variables	Coeff.	Std. Err.	Coeff.	Std. Error	Coeff.	Std. Error
LNIVA	0.0995 (3.31)***	0.0301	0.5807 (3.83)***	0.1518	0.1079 (3.76)***	0.0287
LNTRP	0.1067 (2.24)**	0.0477	0.2252 (0.90)^{NS}	0.2492	0.0311(0.66)^{NS}	0.0472
LNHLT	0.3407 (4.80)***	0.0710	0.0991 (0.26)^{NS}	0.3755	0.2868 (4.04)***	0.0710
LNEDC	−0.3877 (−4.30)**	0.0902	−0.6140 (−1.30)^{NS}	0.4714	−0.2671 (−2.99)***	0.0892
C	15.9462 (80.06)***	0.1992	4.2617 (4.21)***	1.0131	2.7286 (14.24)***	0.1917
R^2	0.988		0.886		0.985	
R^{-2}	0.982		0.841		0.98	
Jarque – Bera	0.746		0.632		0.632	
Probability	0.6887		0.7288		0.6447	
Kurtosis	2.4		2.7		2.3	

Source: Author's Computation using EViews 11; *** and ** ⟶ figures are significant at 1% and 5% level of significance, respectively. NS = Not Significant. LN = Natural Logarithm. Figures in parentheses are t-values.

Table 3. Outcome of ADF and PP Tests.

Variables	Augmented Dickey-Fuller Test				Phillips – Perron Test				Decision
	ADF stat	Prob.	Critical value @ 5%	Order	PP Stat	Prob.	Critical value @ 5%	Order	
AGO	−3.372640	0.0160**	−2.912631	Δ I(1)	−10.86421	0.0000***	−2.911739	Δ I(1)	Stationary
PCI	−6.124303	0.0000***	−2.911730	Δ I(1)	−5.985591	0.0000***	−2.911730	Δ I(1)	Stationary
PCF	−3.340581	0.0174**	−2.912631	Δ I(1)	−11.16841	0.0000***	−2.911730	Δ I(1)	Stationary
IVA	−12.49063	0.0000***	−2.912631	Δ I(1)	−8.992016	0.0000***	−2.911730	Δ I(1)	Stationary
TRP	−6.065480	0.000***	−2.911730	Δ I(1)	−5.945056	0.0000***	−2.911730	Δ I(1)	Stationary
HLT	−9.033270	0.0000***	−2.911730	Δ I(1)	−10.32944	0.0000***	−2.911730	Δ I(1)	Stationary
EDC	−13.13693	0.0000***	−2.911730	Δ I(1)	−12.94967	0.0000***	−2.911730	Δ I(1)	Stationary

Source: Author's Computation using EViews 11; Δ = difference operator; *** and ** ⟶ figures are significant at 1% and 5% level of significance, respectively.

The slope coefficient of investment in agriculture (IVA) was positively signed and exerted significant effects on the three food security indicators considered in this study at a 1 per cent level of significance within the period of study. For every one per cent (1%) increase in investment in agriculture, agricultural output is expected to increase by 10 per cent, while per capita income and per capita food production are expected to increase by 58 per cent and 11 per cent, *ceteris paribus*. This result is in line with the *a priori* expectation. Public and private investment in agriculture and rural development is expected to increase food security status and alleviate poverty. This result is in tandem with FAO's reports which established the relevance of the agricultural sector in achieving food security.

Addressing the dimensions of food security requires a significant increase in investment in agriculture across food systems. For Nigeria to be food secure or self-sufficient in food production, there is the need to consciously prioritize the agricultural sector with more investment as the sector makes a significant contribution to enhancing sustainable livelihoods, eradicating poverty, increasing economic growth, and therefore achieving sustainable development. The findings of this study agree with Fakayode et al.[67] who found that investment in agriculture is indispensable to agricultural progress as it supports economic growth, reduces poverty, and makes development environmentally sustainable. The result also corroborates Ojo & Adebayo[68] who found that investment in agricultural biotechnology has the potential to produce higher yields, with a multiplier effect on sustainable food production.

The slope coefficient of transportation (TRP) as shown in **Table 2** was positive in the estimated models within the period under study. However, the variable significantly influenced agricultural output in the country within the period under study at a 5 per cent level of significance. From the result, a one per cent increase in the amount invested in transportation will increase agricultural output by 11 per cent. This is in line with the *a priori* expectation. Government investment in transportation, especially in rural roads, provides an enabling environment for the movement of agricultural produce from the area of production to the available markets for possible consumption or use as raw materials. In Nigeria and other developing nations, smallholder farmers form over 70% of the farming population. This population is, however, threatened due to a shortage of agricultural labour occasioned by rural-urban migration. Public spending on agricultural-related infrastructures in rural areas is expected to transform the agricultural space while guaranteeing sustainable food production. This finding agrees with Fan et al.[69] who reported that increased investment in transportation and other related activities positively influence agriculture and agribusinesses. The finding of this study further agrees with the position of Lacroix[70] that transportation improves food security. An earlier study by Omojimite[55] also found that rural infrastructural facilities improve the performance of the agricultural sector in Nigeria. Government spending on transportation positively impacts the development of the economy with a multiplier effect on improved food security and zero hunger. For example, improved access to road networks in rural areas of Nigeria could lead to a rise in the profits realized by local producers, and therefore their purchasing power, by reducing post-harvest losses and transport costs to competitive input markets and remunerative output markets. This study corroborates the report of Harding and Wantchekon[71] that government spending on infrastructures positively impacted food security (using the number of stunted children below 5 years) in Benin, Ghana, Mali, and Senegal.

Table 2 also shows that government spending on health (HLT) and food security in the country within the period under study are directly related. The direct relationship of health with the food security indicators considered in this study implies that a per cent increase in government spending on health will increase the food security status of Nigeria. Specifically, the result shows that a one per cent increase in government spending on health will lead to an improvement in the value of agricultural output and food production per head by 34 per cent and 29 per cent, respectively, at a 1 per cent level of significance. This result agrees with the *a priori* expectation. Increased public expenditure on health facilities or infrastructures will increase farmers' access to healthcare services. Maintaining good health is essential for living a productive and economically sustainable life. A decline in health can impose significant challenges on farming households, including financial burdens, reduced labour capacity, absenteeism, and in extreme cases, fatalities, or death. The well-being of the household is fundamentally influenced by the health condition of its labour force, as it directly impacts their capacity to engage in work. This finding agrees with Shaibu & Ibrahim [72] when they found that increased government/public expenditure on health-related activities increased the likelihood of utilization and access to healthcare service delivery with a multiplier effect on increased agricultural productivity. Government expenditure on health serves as the mechanism through which public policy influences health outcomes and can directly affect the availability, quality, and productivity of labour in agriculture. This study's findings align with Fan and Lei's [73] report on public health expenditures and the well-being of households. In the context of Tanzania, Allen et al. [74] proposed that changes in the utilization of agricultural inputs impact farm productivity, with the health status of farm households being a determining factor affected by various categories of government health expenditures.

The slope coefficient of education (EDC) as shown in **Table 2** was negative, and significant across the food security indicators. The negative relationship reported in this study implies that an increase in public expenditure on education will decrease food security. Pointedly, a one per cent increase in education will lead to a 39 per cent and 27 per cent reduction in agricultural output and per capita food production, respectively. This is not in line with the *a priori* expectation. Expectedly, a per cent increase in government spending on education should increase the adoption of agricultural innovation with its expected direct effect on output and per capita food production. Education was also expected to increase per capita income as it facilitates access to employment opportunities. The inverse relationship between education and food security observed in this study could be associated with the nature of investment or public spending on education. The result could also be associated with the reported significant number of uneducated persons, especially smallholder rural farmers who may not necessarily have access to quality educational infrastructures. The finding of this study on education agrees with Mutisya et al. [75] who found a direct relationship between educational attainment and food insecurity in adulthood in Nairobi; each additional year of parents' school enrolment produced a significant decline in household food insecurity.

The results of all post-model tests (see **Figures A1–A3**) indicated P-values greater than the 5 per cent probability level, signifying the absence of serial correlation, heteroscedasticity, and a confirmation of normally distributed data. These tests were crucial for establishing the reliability of the model. The result further shows that all the included variables significantly influenced agricultural output at the 5 per cent level of measurement. However, one and three out of the four included infrastructural variables significantly influenced per capita income and per capita food expenditure, respectively.

3.2. Policy Implications

Our findings portray relevant policy implications to ensure sustainable food production in developing nations like Nigeria. We highlight the significance of allocating public funds towards agricultural infrastructure. Policymakers should give utmost importance to allocating resources towards the development of agricultural infrastructure, such as rural roads and transportation networks, to establish a conducive environment for the movement of agricultural goods. Furthermore, the positive influence of government spending on healthcare on food security implies that policymakers should persist and even enhance investment in health-related infrastructure. This entails enhancing the availability of healthcare services for farmers, which can have a beneficial effect on their efficiency and contribute to food security.

While the study found an inverse relationship between public spending on education and food security, we highlight the need for a nuanced approach. Policymakers should assess the nature and effectiveness of education spending, ensuring that it aligns with agricultural innovation and empowers farmers. Education programs should be tailored to enhance the skills and knowledge relevant to agriculture. Additionally, the strong positive relationship between investment in agriculture and food security underscores the imperativeness of increasing investment (public and private) in the agricultural sector. This investment should cover elements such as the use of technology, the development of infrastructure, and the provision of assistance to smallholder farmers.

Considering the established relationship between government expenditure on infrastructures and food security, policymakers should engage in collaborative endeavours with the private or business sector. Public-private partnerships can enhance the progress and upkeep of agricultural infrastructure, guaranteeing long-term viability and optimal utilisation of resources. This study also suggests the need for a well-designed and effective combination of policies to support the establishment of agricultural infrastructure. Policymakers should meticulously formulate policies that specifically address issues such as transportation, health, and education, to optimize their influence on food security. Furthermore, there is a need to develop systems to consistently monitor and assess the effects of government expenditures on agricultural infrastructure. Periodic evaluations will assist policymakers in making well-informed choices, adapting plans, and guaranteeing that resources are efficiently employed to attain sustainable food production and security.

4. Conclusions

After satisfying the major condition in applying the adopted model, the DOLS parameter estimates of the cointegration regression model were applied in analyzing the effects of infrastructure on food security. All the post-model tests conducted have a P-value greater than 5 per cent, confirming the model's reliability. It can be concluded that investment in agriculture and government spending on health guarantees sustainable food production vis-à-vis food security. Expenditure on transportation significantly influenced agricultural output, while the education variable negatively influenced food security. Consequently, there is an improvement to Keynesian theory in that there is a direction to which public spending can impact food security. If it is not directed to agriculture-related infrastructures or farmers' livelihoods, it may not have a direct impact on food security. Since higher investment in agriculture will guarantee sustainable food production, the government at all tiers should be intentional in prioritizing the agricultural sector. Therefore, the government must increase investment in agricultural infrastructure to enhance food production. Furthermore, collaboration with the private sector is essential in providing infrastructure related to agriculture. To ensure sustainability, there should be public orientation and reorientation on the gains of preserving and maintaining both government and privately provided infrastructures.

Author Contributions

Conceptualization, U.M.S. and J.C.U.; literature, S.A, O.D.K. and F.O.O.; methodology, U.M.S.; software, U.M.S. and F.P.O.; validation, J.C.U. and M.K.I.; formal analysis, U.M.S., F.P.O., and M.K.I.; data curation, U.M.S. and F.P.O.; results interpretation, U.M.S., F.P.O., and S.A.; writing—original draft preparation, U.M.S., F.P.O.; writing—review and editing, U.M.S., F.P.O., S.A., O.D.K., F.O.O.; visualization, U.M.S., F.P.O., S.A., O.D.K., F.O.O., J.C.U. and A.M.; supervision, J.C.U., M.K.I. and A.M.-B. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

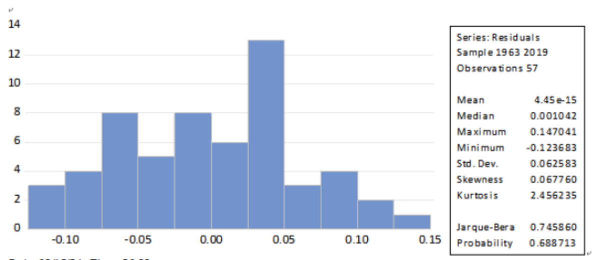
The data used in this study are available on request.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix A

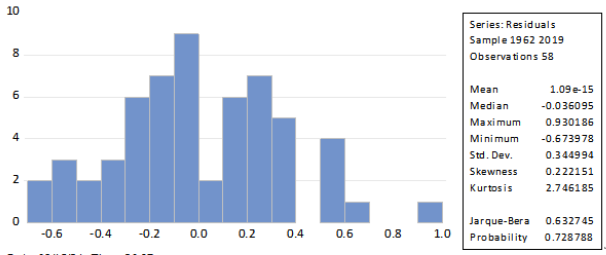
Post Model Test – DOLS



Date: 06/15/21 Time: 20:33
Sample (adjusted): 1962 2019
Included observations: 58 after adjustments

	AC	PAC	Q-Stat	Prob*
1	0.017	0.017	0.0173	0.895
2	0.203	0.203	2.5842	0.275
5	-0.025	-0.087	8.2320	0.144
6	0.059	0.038	8.4615	0.206
7	0.028	0.022	8.5144	0.289
8	0.020	-0.016	8.5406	0.383
9	-0.089	-0.075	9.0912	0.429
10	-0.104	-0.064	9.8695	0.452
11	-0.102	-0.068	10.626	0.475
12	0.012	0.012	10.637	0.560
13	-0.039	-0.100	10.754	0.631
14	-0.097	-0.117	11.485	0.648
15	-0.077	-0.017	11.963	0.682
16	-0.033	-0.067	12.055	0.740
17	0.080	0.072	12.590	0.763
18	0.018	-0.060	12.619	0.814
19	-0.053	-0.087	12.870	0.845
20	-0.035	0.027	12.979	0.878
21	0.029	-0.006	13.055	0.907
22	-0.037	-0.104	13.185	0.928
23	-0.068	-0.068	13.636	0.937
24	-0.006	-0.014	13.640	0.954

Figure A1. AGO_Model 1.



Date: 06/15/21 Time: 20:37
Sample (adjusted): 1962 2019
Included observations: 58 after adjustments

	AC	PAC	Q-Stat	Prob*
6	-0.050	-0.112	10.539	0.104
7	-0.071	-0.062	10.886	0.144
8	-0.124	-0.085	11.964	0.153
9	-0.145	-0.094	13.464	0.143
10	-0.079	-0.039	13.916	0.177
11	-0.167	-0.199	15.980	0.142
12	0.049	0.140	16.161	0.184
13	0.164	0.093	18.248	0.148
14	0.109	-0.064	19.185	0.158
15	-0.133	-0.258	20.609	0.150

Figure A2. PCI_Model 2.

Date: 06/15/21 Time: 20:43
Sample (adjusted): 1962 2019
Included observations: 58 after adjustments

	AC	PAC	Q-Stat	Prob*
1	0.022	0.022	0.0305	0.861
2	0.190	0.190	2.2762	0.320
3	0.117	0.114	3.1436	0.370
4	-0.162	-0.210	4.8333	0.305
5	-0.019	-0.065	4.8572	0.434
6	-0.087	-0.025	5.3660	0.498
7	-0.012	0.056	5.3762	0.614
8	-0.048	-0.051	5.5363	0.699
9	-0.039	-0.053	5.6462	0.775
10	-0.067	-0.082	5.9711	0.818
11	-0.036	-0.003	6.0683	0.869
12	-0.057	-0.036	6.3162	0.899
13	-0.013	-0.001	6.3303	0.933
14	-0.006	-0.017	6.3328	0.957
15	-0.037	-0.044	6.4433	0.971
16	-0.002	-0.028	6.4437	0.983
17	0.009	0.022	6.4511	0.990
18	0.073	0.085	6.9196	0.991
19	-0.059	-0.093	7.2267	0.993
20	-0.056	-0.130	7.5106	0.995
21	-0.028	-0.027	7.5824	0.997
22	-0.033	0.059	7.6875	0.998
23	-0.050	-0.042	7.9373	0.998
24	-0.066	-0.122	8.3851	0.999

Figure A3. PCF_Model 3.

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