An Empirical Investigation of the Relationship between Agricultural Inputs and Agricultural Output in Nigeria

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Abstract
This study examines the relationship between agricultural inputs and agricultural output in Nigeria from 1990 to 2022, utilizing time series data sourced from the World Development Indicators and the CBN Statistical Bulletin. The specific objectives were to analyze the impact of agricultural expenditure, fertilizer consumption, and arable land proxies for agricultural inputs on crop production proxy for agricultural output in Nigeria. The data analysis techniques employed include descriptive statistics, unit root tests, bounds cointegration, the autoregressive distributed lag (ARDL) estimation method, and residual diagnostics tests. The ADF unit root tests reveal a mix of I(1) and I(0) series, indicating that the variables differ in their levels of integration. Evidence of cointegration was established, suggesting a long-term equilibrium relationship among the variables. The ARDL results indicate that agricultural expenditure has a significant positive effect on crop production in Nigeria, revealing that a unit increase in agricultural expenditure increases crop production; access to arable land has a positive significant effect on crop production, indicating that an increase in access to arable land increases crop production in Nigeria. Furthermore, the results show that fertilizers consumption has a positive and statistically significant effect on crop production in Nigeria. This suggests that a unit increase in fertilizers consumption increases crop production in Nigeria. Owing to the findings, this study concludes that agricultural expenditure, access to arable land and fertilizer consumption enhances crop production of the Nigerian economy. Thus, it is recommended among others that Policymakers, should implement sustained and targeted agricultural expenditure programs focused on infrastructure, research, and farmer access to arable land to ensure long-term productivity growth.

Key words: *Agricultural Expenditure, Arable Land, Fertilizers consumption, Crop Production,*

1. INTRODUCTION

Agricultural productivity is indeed a pivotal component of economic development in Nigeria, a nation where agriculture plays a significant role in both employment and food security. According to recent data from the World Bank (2022), agriculture contributes approximately 24% to Nigeria's GDP and employs about 70% of the workforce. This underscores the sector's critical importance to the country's economic well-being and social stability. The efficiency of agricultural production in Nigeria is influenced by a multitude of inputs, including agricultural expenditure, fertilizer consumption, and arable land. Each of these factors plays a crucial role in determining the overall output and productivity of the agricultural sector. Agricultural expenditure, which encompasses investments in infrastructure, technology, and research and development, is essential for modernizing farming practices and enhancing crop yields. Increased expenditure can lead to the adoption of advanced farming techniques, improved irrigation systems, and better access to markets, all of which contribute to higher agricultural productivity.

Fertilizer consumption is another critical input that significantly impacts crop production. The judicious use of fertilizers can enhance soil fertility, promote plant growth, and increase crop yields. However, it is important to strike a balance between the use of chemical and organic fertilizers to ensure sustainable agricultural practices that do not degrade the environment. Understanding the optimal levels and types of fertilizer use can help farmers maximize their output while minimizing environmental impacts. Arable land is a fundamental resource for agricultural production. The availability and quality of arable land directly influence the potential for crop cultivation and yield. Effective land management practices, including soil conservation, crop rotation, and sustainable farming methods, can help maintain and even improve the productivity of arable land over time. Additionally, policies that address land tenure issues and promote equitable access to land can further enhance agricultural productivity and support the livelihoods of smallholder farmers.

Despite substantial investments in agricultural development, Nigeria continues to grapple with persistent challenges in optimizing crop production. While agricultural expenditure has grown, its impact on productivity remains limited, often due to inefficient allocation and implementation of resources (Ojo et al., 2022). Fertilizer consumption, a critical factor for soil fertility and crop yield, has also been inconsistent, with issues stemming from distribution inefficiencies, subsidy mismanagement, and farmers' limited access to quality inputs (Ibrahim et al., 2022). Furthermore, the management of arable land is a growing concern. With Nigeria's rapidly increasing population, pressure on land resources has led to widespread land degradation and underutilization, exacerbating food insecurity and impeding agricultural productivity (Adeboye et al., 2022). It is against this background that this study raised the following questions: what is the impact of agricultural expenditure on agricultural output in Nigeria? how does fertilizer consumption affect agricultural output in Nigeria? In what ways does access to arable land influence agricultural output in Nigeria? The study therefore investigates the relationship between agricultural inputs and agricultural output in Nigeria over the period 1990 to 2022

2. LITERATURE REVIEW

Theoretical Literature

The Neoclassical Production Function

The Neoclassical Production Function, particularly the Cobb-Douglas model, provides a foundational framework for analyzing agricultural output in relation to inputs such as land, labor, and capital. Developed by economists Charles Cobb and Paul Douglas in 1928, this model posits that agricultural output (Y) can be understood as a function of several critical inputs: labor (L), capital (K), and total factor productivity (A). The general form of the Cobb-Douglas production function is expressed as: $Y = A \cdot L^{\alpha} \cdot K^{\beta}$

In this equation, A represents total factor productivity, a measure of the efficiency with which inputs are converted into output. The parameters α\alphaα and β\betaβ denote the output elasticities of labor and capital, respectively. These elasticities reflect the proportional change in output resulting from a proportional change in labor and capital, capturing the relative importance of each input in the production process (Cobb and Douglas, 1928).

In the context of agriculture, the Cobb-Douglas production function can be adapted to include specific inputs relevant to this sector, such as agricultural expenditure and arable land. For instance, agricultural expenditure, which includes investments in machinery, infrastructure, and research, can be integrated into the capital component of the production function. Similarly, arable land, an essential factor in agricultural production, can be considered an extension of the capital input. This adaptation allows the model to reflect how variations in expenditure and land availability impact crop production.

By incorporating these variables, the Cobb-Douglas production function provides a nuanced understanding of how different inputs contribute to agricultural output. For example, increases in fertilizer usage or improvements in farming technology (both captured under capital) can lead to higher productivity, while efficient use of land and labor can enhance overall output. This model thus offers valuable insights into the dynamics of agricultural production and the role of various inputs in driving productivity (Cobb and Douglas, 1928).

The Agricultural Productivity Theory

The Agricultural Productivity Theory, as discussed by Hayami and Ruttan (1985), provides a comprehensive framework for understanding how investments in agricultural research and development (R&D) and technological advancements can significantly enhance productivity in the agricultural sector. This theory underscores the pivotal role of strategic investments in driving agricultural growth and efficiency. At the heart of the Agricultural Productivity Theory is the notion that increased expenditure on agriculture, particularly in R&D and inputs such as fertilizers, can lead to substantial gains in agricultural productivity. This theory posits that investments in R&D are crucial for the development of new technologies, improved farming practices, and innovative agricultural inputs. These advancements not only increase crop yields but also enhance the overall efficiency of agricultural production processes.

Hayami and Ruttan (1985) emphasize that technological progress is not a spontaneous occurrence but rather a result of deliberate and sustained investment in research and development. For instance, the development of high-yielding seed varieties, advanced irrigation systems, and precision farming techniques are outcomes of extensive R&D efforts. These technological innovations enable farmers to produce more with the same or fewer resources, thereby increasing agricultural productivity.

Moreover, the theory highlights the importance of inputs like fertilizers in boosting agricultural output. Investments in fertilizers and other agricultural inputs are essential for maintaining soil fertility and optimizing plant growth. The efficient use of these inputs, guided by technological advancements, can significantly enhance crop yields and overall agricultural productivity. The Agricultural Productivity Theory also underscores the role of public and private sector investments in driving agricultural growth. Governments and private entities can foster productivity gains by funding R&D initiatives, providing subsidies for agricultural inputs, and implementing policies that encourage the adoption of new technologies. These investments not only benefit individual farmers but also contribute to the broader economic development of rural communities and nations. In summary, the Agricultural Productivity Theory, as articulated by Hayami and Ruttan (1985), offers a compelling argument for the importance of investments in R&D and technological advancements in enhancing agricultural productivity.

Empirical Review

Alene et al. (2021) in their study impact of agricultural research on productivity and poverty in sub-Saharan Africa. found that increased government spending on agricultural research and infrastructure positively affects agricultural productivity. The researchers observed that higher investment in agricultural R&D and infrastructure led to substantial gains in crop yields, particularly in developing countries.

Fan, Zhang, and Zhang (2000) found that public investment in agriculture, particularly in infrastructure and research, significantly boosts agricultural output. Their study utilized panel data across several countries and demonstrated that increased expenditure leads to higher productivity through improved technology adoption and better resource management.

Thirtle, Lin, and Piesse (2003) provided evidence that agricultural R&D investment yields substantial productivity gains, underscoring the importance of financial inputs in driving technological advancements and efficiency in farming practices.

Jing et al. (2022), in their study employed a panel data analysis across several countries to study biological nitrogen fixation and prospects for ecological intensification in cereal-based cropping systems. The results show that improvements in fertilizer efficiency, coupled with increased application rates, significantly boost agricultural productivity.

Tilman et al. (2002) explored the relationship between fertilizer use and crop production across different regions. The findings revealed that increased fertilizer application directly contributes to higher agricultural output by enhancing soil fertility and crop nutrient availability.

Bumb and Baanante (1996) analyzed fertilizer policies and their impact on crop production in developing countries, showing that targeted fertilizer subsidies can lead to significant improvements in crop yields and overall agricultural productivity.

Fan et al. (2023) explored the effects of arable land expansion on crop production. The researchers found that while increasing the area of arable land can lead to higher output, the benefits are subject to diminishing returns.

Binswanger and Deininger (1997) emphasized that expanding arable land and improving land management practices can lead to increased crop production. Their research highlighted that efficient land use and agricultural practices are essential for maximizing productivity.

Deininger and Olinto (2000) examined land tenure and its impact on agricultural productivity, finding that secure land rights and better land management contribute to higher output by encouraging investment in land improvements.

Pingali (1997) assessed how these inputs interact to influence crop production. The findings indicated that a combination of increased expenditure, effective fertilizer use, and efficient land management practices leads to significant improvements in agricultural productivity. This integrated approach highlights the importance of a holistic strategy in enhancing crop production through various input factors.

3. METHODOLOGY

This study employed ex-*post facto* research design. Time series data for this study were obtained from the CBN Statistical Bulletin and the World Development Indicators from 1990 to 2022.

Model Specification

The theoretical framework of this study is anchored on Neoclassical Production Function given its relevance to this study. The empirical model adopted for this study in built on the model of Fan et al. (2023) with slight modifications. The functional specification of the model is as follows:

$$CRPY = f(AEXP, ARLD, FERT) \quad (3.1)$$

The linear regression equation for this study is specified as follows:

$$CRPY = \beta_o + \beta_1 AEXP + \beta_2 ARLD + \beta_3 FERT + \mu_t \quad (3.2)$$

where:

CRPY = Crop production as a proxy for agricultural output

AEXP = Agricultural expenditure

ARLD = Access to Arable land

FERT = Fertilizer consumption

A priori Expectations In the above model is $\beta 1 - \beta 3 > 0$

Specifically, the ARDL model for this study based on the variables in equations (3.2) is provided below:

$$\Delta CRPY_t = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \Delta CRPY_{t-1} + \sum_{i=1}^{q} \alpha_2 \Delta AEXP_{t-1} + \sum_{i=1}^{q} a_3 \Delta ARLD_{t-1} + \sum_{i=1}^{q} a_4 \Delta FERTL_{t-1} + \lambda_1 CRPY_{t-1} + \lambda_2 AEXP_{t-1} + \lambda_3 ARLD_{t-1} + \lambda_4 FERT_{t-1} + \varepsilon_{1t} \quad (3.3)$$

Where: α_0 = constant parameter to be estimated, α_1 – α_4 = short run parameters, λ_1 - λ_4 = long-run multipliers, , α_1 - α_4 = short-run multipliers p = optimal lag for each of the dependent variables, q = optimal lag of the independent variables, Δ= first difference operator, ε_{1t} = error term

Method of Data Analysis

The Autoregressive distributed lag (ARDL) technique was adopted for model estimation. ARDL is a least square method developed by Pesaran, Shin and Smith (2001) that allows us to include the lag values of the dependent and independent variables of a model while carrying out regression analysis. This test is usually adopted because the literature behind it states that if the series are of different order of integration 1(0) and 1(1), ARDL bound test then becomes the appropriate Co-integrating technique for possible long run relationship among the series. This method has three decision options which are existence of cointegrating, no cointegrating and inconclusive relationships, when the calculated F-statistic value is respectively greater than the upper bound *I(1),* below the lower bound *I(0)* and between the lower *I(0)* and the upper *I(1)* bounds. The general model for ARDL Bounds cointegration equation is:

$$Y_t = \Delta_t Y_{t-1} + \ldots \Delta_p Y_{t-p} + \delta R_t + U_t \quad (3.4)$$

Where Y_t = the time series variables under consideration in time t, Y_{t-1} and Y_{t-p} = cointegrating equations estimates, Δ= First difference operator and U_t = stochastic error term.

Sequel to establishing long-run relationship among the variables, the ARDL long-run and the short-run dynamic estimations were carried out to examine the theoretical and significance relationship between the dependent and independent variables of the model.

In addition, post-diagnostic tests such as: the serial correlation **test** to know whether the residuals are serially independent, the heteroscedasticity test to check for homoscedasticity, the Jarque-Bera normality statistic test to ascertain if all variables are jointly normally distributed, and the CUSUM stability test to check whether the estimated model is stable were conducted to validate the robustness of the model's estimated results.

4. RESULTS AND DISCUSSION

Unit Root Test

As a precondition to time series analysis, the unit root test was conducted using the ADF method to ascertain the stationary properties of the series. The results are presented in Table 4.1:

Table 4.1: ADF Unit Root Test Results

Variable	ADF statistics at levels	ADF statistic at 1st difference	5% critical value	Order of integration
FPI	-3.781	-	-2.93	I(0)
GFCF	-3.799	-	-2.93	I(0)
NHAW	-1.536	-7.579	-2.93	I(1)
RGDP	-3.203	-	-2.93	I(0)

Source: Author's Computation from EViews Software (2024).

The results of ADF unit root test in the table (4.1) above shows that arable land is the only variable found to be stationary at level given that its ADF statistic at levels is greater than its corresponding critical values at the 5% significance level. Consequently, the null hypothesis of unit root for this variable is rejected at the 5% level. The implication of this result is that arable land is integrated at level, I(0). On the other hand, after first difference, the results show that other variables became stationary because their ADF statistics are greater than the associated critical value at the 5% significance level. This indicates that they are integrated of order one, I(1). Overall, the results show that the variables are mixed integrated, thus, necessitating the application of the bounds cointegration test method.

ARDL Bounds Cointegration Test

The ARDL bounds cointegration test results are presented in Table 4.2.

Table 4.2: Summary of ARDL Bounds Cointegration Test Results

Series: GDP CMCR CPS MS		
Null Hypothesis: No long-run relationships exist		
Test Statistic	Value	K
F-statistic	3.764	3
	Critical Value Bounds	
Significance	I0 Bound	I1 Bound
10%	2.37	3.2
5%	2.79	3.67
2.5%	3.15	4.08
1%	3.65	4.66

Source: Author's Computation from EViews Software (2024).

Note: K denotes the number of regressors

The results of the bounds cointegration from table 4.2 above shows that the computed F-statistic value of (3.764) is greater than the lower bound value of (2.79) and the upper bound critical value of (3.67) at the 5% significance level. This finding necessitates the rejection of the null hypothesis that no long-run relationships exist among the variables at the 5% significance level. Therefore, it follows from the results that crop production has a long-run relationship with the independent variables used. Based on this finding, this study adopted the ARDL method to estimate the model.

ARDL Model Analysis Results

The ARDL model Short and Long-run results are presented in Table 4.3.

Table 4.3: ARDL Short and Long Run Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CRPY(-1))	0.887878	0.216928	4.092961	0.0018
D(CRPY(-2))	1.158030	0.158706	7.296697	0.0000
D(AEXP)	0.122553	0.040418	3.032166	0.0114
D(AEXP(-1))	-0.127731	0.043855	-2.912560	0.0141
D(AEXP(-2))	-0.101313	0.036822	-2.751419	0.0188
D(ARLD)	-1.072454	1.146681	-0.935269	0.3697
D(ARLD(-1))	-2.877942	1.237469	-2.325668	0.0402
D(ARLD(-2))	-2.418113	1.167285	-2.071571	0.0626
D(FERT)	0.822120	0.223814	3.673229	0.0037
D(FERT(-1))	-1.315025	0.292152	-4.501166	0.0009
D(FERT(-2))	-1.133392	0.275916	-4.107750	0.0017
D(FERT(-3))	-0.719395	0.209505	-3.433781	0.0056
CointEq(-1)*	-0.796884	0.157299	-5.066059	0.0004

Long-run results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AEXP	0.375092	0.125553	2.987522	0.0124
ARLD	4.526733	1.345049	3.365479	0.0063
FERT	2.103072	0.413332	5.088098	0.0004
C	-124.4517	52.41839	-2.374198	0.0369

$R^2 = 0.860754$; Adj.$R^2 = 0.749358$.

Source: Author's Computation from EViews Software (2024).

The ARDL (Auto-Regressive Distributed Lag) model above provide insights into both short-run and long-run dynamics concerning crop production (CRPY) in Nigeria, influenced by agricultural expenditure (AEXP), arable land (ARLD), and fertilizer consumption (FERT).

In the short run, the results show significant lagged effects for most variables. Crop production exhibits a strong autoregressive nature, as shown by significant coefficients for its own lags, with a positive coefficient of 1.158 for the second lag and p-value of 0.000, which is less that 0,05 at 5% level of significance ($p < 0.05$), indicating persistence in crop yield effects. Agricultural expenditure shows mixed results: the current period positively impacts crop production with a positive coefficient 0.122, and p-value 0.0114, which is less than 0,05 at 5% level of significance while lagged values show negative effects, with the first and second lags with coefficients (-0127, and -0.101) respectively both significantly reducing crop output with p-values of 0.0141 and 0.0188) respectively, given that they less than 0.05 (5% level of significance). This suggests a short-term volatility in how expenditure translates into productivity, possibly due to delays in the effects of government spending.

Arable land (ARLD) exhibits mostly negative impacts in the short run, with a significant coefficient for the first lag (-2.877) with p-value of 0.0402 less than 0.05 (5% level of significance) and an insignificant negative coefficient -2.418 with p-value of 0.0626 greater than 0.05 (5% level of significance) as well as at the current period which showed a negative coefficient -1.0724 with a p-value 0.3697 greater than 0.05 (5% level of significance). This could reflect issues related to land management or temporary reductions in productivity. Fertilizer consumption plays a crucial role, with a positive significant current impact on crop yield with a coefficient 0.822, and p-value of 0.037 less than 0.05(5% level of significant). However, the lagged effects of fertilizer consumption are negative and significant, suggesting that over time, diminishing returns or possible soil depletion may occur when high fertilizer use is sustained over several periods.

The error correction term (CointEq(-1)) is highly significant and negative, with a coefficient of -0.796, and p-value of 0.0004 less than 0.05(5% level of significance), indicating a strong correction mechanism, with approximately 80% of deviations from the long-run equilibrium being corrected within a year.

R-squared: 0.8608, meaning that 86.08% of the variability in crop production is explained by the independent variables (agricultural expenditure, fertilizer consumption, and arable land) in the model.

Adjusted R-squared: 0.7494, which adjusts for the number of predictors in the model, suggesting a good overall fit after accounting for the degrees of freedom.

Long-Run Dynamics

In the long run, agricultural expenditure (AEXP) positively and significantly affects crop production in Nigeria, with a coefficient 0.375 and P-value of 0.0124 less than 0,05 alpha level. This indicates that over time, increased spending leads to higher productivity, despite short-run volatility.

Furthermore, the results show that Arable land has an even stronger positive long-run impact with a coefficient 4.527 and P-value of 0.0063 less than 0.05 alpha level., suggesting that, despite short-run challenges, the availability of land remains critical for sustainable crop yields in Nigeria.

In addition, the fertilizer consumption also demonstrates a significant long-run positive effect with a coefficient 2.103 and P-value of 0.0004 alpha level, underscoring its importance in maintaining agricultural productivity in the Nigerian economy.

Table 4.4: Post-Estimation Test Results

Test Type	Null Hypothesis	Test Statistic	Probability value	Decision
Breusch-Godfrey Serial Correlation LM Test	H_0: Serial independence	1.500	0.030	Accept H_0
Breusch-Godfrey-Pagan heteroskedasticity test	H_0: Homoscedasticity	14.190	0.999	Accept H_0
Normality test	H_0: Normal distribution of residuals	0.572	0.751	Accept H_0

Source: Author's Computation from EViews Software (2024).

The post estimation test results in Table 4.6 provided evidence that all the variables (Agricultural expenditure, Arable land, fertilizer consumption and crop production) in the model conform to the basic assumptions of ordinary least squares estimation. Specifically, it showed that the residuals are serially independent, that there is no heteroscedasticity, and that the variables are normally distributed. These tests were conducted to validate the robustness of the model's estimated results.

Discussion of Findings

This study examines how agricultural inputs affected output in the Nigerian economy. The agricultural input was measured by the agricultural expenditure, access to arable land, and fertilizers consumption. On the other hand, agricultural output was measured by the crop output.

The long-run results of the ARDL model reveal that agricultural expenditure (AEXP) significantly influences crop production in Nigeria. This aligns with previous research that underscores the importance of government expenditure on agricultural development. For instance, Akpan (2012) finds that increased government spending on agriculture leads to substantial improvements in agricultural output in the long run. Similarly, Udoh and Ogbuagu (2013) highlight that sustained public investment in the agricultural sector can significantly boost productivity, particularly in sub-Saharan African countries, where agriculture forms a critical part of the economy. The positive long-run impact of AEXP in the current analysis supports these findings, suggesting that, despite short-run volatility, increased agricultural expenditure enhances crop productivity over time.

Moreover, the results show that arable land (ARLD) has an even stronger positive long-run effect on crop production. This finding resonates with the work of Nwosu, Oguoma, Ben-Chendo, and Henri-Ukoha (2012), who argue that land availability and management are pivotal to sustaining agricultural yields, especially in developing countries. The positive relationship between ARLD and crop production suggests that land expansion or more efficient use of existing arable land could contribute significantly to increasing agricultural output. This aligns with the broader literature on land use and agricultural productivity, which often emphasizes the importance of land in scaling up food production, particularly in countries with high agricultural potential but underutilized land resources (Oluwatayo, Sekumade, and Adesoji, 2008).

Fertilizer consumption (FERT) also plays a critical role in the long-run productivity of the agricultural sector. The significant positive coefficient for FERT is consistent with the findings of studies such as those by Yusuf, Abdu, and Bashir (2015), who report that fertilizer usage is directly linked to higher crop yields in Nigeria. Fertilizer provides essential nutrients that improve soil fertility, thereby enhancing plant growth and productivity. The current findings underscore the necessity of maintaining adequate fertilizer application to sustain long-run agricultural productivity in Nigeria, a view supported by Adetunji (2011), who finds that the intensification of fertilizer use correlates with increases in crop yield across various regions in sub-Saharan Africa.

These results highlight the need for policy measures that promote sustained investments in agricultural expenditure, arable land management, and the efficient use of fertilizers to enhance Nigeria's long-term agricultural productivity.

5. CONCLUSION AND RECOMMENDATIONS

Concluding Remarks

This study explores the connection between agricultural input and the agricultural output in Nigeria economy, specifically examining the roles of agricultural expenditure, access to arable land, and fertilizers consumption on crop production in Nigeria. The findings indicate that both agricultural expenditure, access to arable land, and fertilizers consumption have positive effects on crop production. Based on these results, the study concludes that agricultural expenditure, access to arable land, and fertilizers consumption are essential for crop production in the Nigerian economy.

Policy Recommendations

The recommendations proffered for this study based on the findings are as follows:

i Policymakers should implement sustained and targeted agricultural expenditure programs focused on infrastructure, research, and farmer access to credit to ensure long-term productivity growth.

ii Government should promote land reforms that improve access to arable land and encourage sustainable land use practices, maximizing crop production efficiency.

iii Government provides subsidies and reduce import barriers on fertilizers, while promoting best practices in fertilizer application to optimize yields and preserve soil health.

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