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# Econometric Analysis of Rice Yield Determinants

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**ABSTRACT**

*The limited capacity of domestic rice production to match demand raises number of pertinent questions. What socio-economic factors determine the variation in the yield level among smallholder rice farmers? This study attempts to determine the effect of some socio-economic variables namely: farm size, capital, technology, interest rate and government incentives to increase rice yield among farmers. Johansen cointegration, fully modified ordinary least squares error correction model as well as Granger causality test based on Toda-Yamamoto procedure were employed to determine the relationship and effect of the socio-economic variables on rice yield and causality among the variables. The findings reveal that the five variables analyzed were integrated of order one and hence co-integrated. The results show that government incentives, capital, farm size and technology have positive impact on rice yield. The Granger causality test results revealed that rice yield is Granger caused by farm size, capital, technology, interest rate and government incentives. The study concludes with policy recommendations to improve rice productivity yield among smallholder farmers in Nigeria by stakeholders increasing the area of land cultivated and improve farmers' access to capital at low and single digit interest rate.*

## INTRODUCTION

Rice consumption grows faster other grain staple, due to changes in eating habits, population growth, and urbanization (Seck *et al.*, 2013; United Nations Economic Commission for Africa, 2015). Africa rice sector was unable to meet local demand. Consequently, the African continent continues to depend on importation. Nigerian per-capita rice consumption grows annually, it rose from 7.6 kilograms in the 1970s, to 14.9 kilograms in the 1980s, to 22.4 kilograms in 1990s to 26.9 kilograms per annum in 2000s to 31.0 kilograms in 2010-2013 and 31.5 kilograms in 2014 (International Rice Research Institute, 2013; World Bank, 2014).. Importation of rice in Nigeria was forecasted to grow by 12 percent in 2023 (USDA Foreign Agricultural Service, 2022). This situation has been the concern of the government. Rice demand in 2018 was 6.4 million tonnes. Domestic production covered 57.8 percent of annual national demand (Familusi & Oranu, 2019). Nigeria government, therefore, embarked on policy reforms, ranging from restriction, tariff, trade liberalization, Agricultural Transformation Agenda (ATA) and outright ban (Gyimah-Brempong, Johnson & Takeshima, 2016). Gyimah-Brempong et al. (2016) proposed three options for import reduction- trade policies and tariffs; promoting domestic production; and improving technology in post-harvests processing and marketing but penned down improved local production aid by better technical facilities and improved postharvest activities as the way out. Out of about 6 million total hectares available for rice production only half were under cultivation, producing about 3.7 million tons per annum (Familusi & Oranu, 2019). According to previous research, high cost of production because of increase in price of inputs, low efficiency of resource utilization, inadequate capital, land fragmentation, poor technological transfer, high interest rate and inadequate government incentives among other factors were responsible for low productivity of rice. Low productivity prohibits farmers from earning significant returns and hence reduces farm incomes and profit (Oladimeji *et al.,* 2018; Iliyasu & Lawal, 2020).

This study is imperative, as it would identify factors that determine the yield which will be significant for policy formulation that can improve rice productivity among the smallholder farmers. A proper understanding of the determinants and its relationship with a host of farm level factors, will aid policy makers in creating efficiency enhancing policies as well as in judging the efficacy of present and past reforms.

## METHODOLOGY

Data for this work were time series data covering the fiscal year 2000 to 2016. The rice yields each year was log transformed into productivity level. Data on land size, level of technology, capital, interest rate on agricultural loan and government incentives were all obtained as secondary data from ADP, FMARD, CBN and World Bank database.

### Augmented Dickey-Fuller (ADF) Unit Root Test

Unit root test is a statistical test which determines the order of integration of a series. It shows whether a given time series is stationary or not (mean, variance, autocorrelation and so on are all constant over time) (Gujarati, 2003). Let $\{Y_t\}$ be a given time series, the ADF unit root test is used to check whether the given series contains a unit root or whether the given series is stationary or not (Dickey and Fuller, 1979). The ADF test constructs a parametric correction for higher-order correlation by assuming that the series follows an AR (p) process and adding lagged difference terms of the dependent variable to the right-hand side of the test regression:

$$\Delta Y_t = \alpha Y_{t-1} + X_t'\delta + \varphi_1 \Delta Y_{t-1} + \varphi_2 \Delta Y_{t-2} + \dots + \varphi_p \Delta Y_{t-p} + \varepsilon_t \qquad (1)$$

where $X_t$ are optional exogenous regressors which may consist of constant, or a constant and trend, α and δ are parameters to be estimated. $\varepsilon_t$ is assumed to be white noise. The hypotheses are written as:

$H_0$: α = 0 against : α < 0 (2)

and evaluated using the conventional t-ratio for α:

$$H_1 \qquad t_\alpha = \tilde{\alpha} / \{se(\tilde{\alpha})\} \qquad (3)$$

where α̃ is the estimate of α, and se(α̃) the coefficient standard error. An important result obtained by Fuller is that the asymptotic distribution of the t-ratio for α is independent of the number of lagged first differences in the ADF regression.

### Johansen Cointegration Test (JCT)

To investigate the long-term relationship among variables, we employ Johansen Cointegration trace and maximum eigen value tests. The **(JCT)** is only applied on variables which are integrated of the same order. A vector Autoregressive based cointegration test methodology developed by Johansen (1991, 1995) is as follows:

Consider a VAR of order p:

$$y_t = \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \dots + \Phi_p y_{t-p} + Bx_t + \varepsilon_t \qquad (4)$$

where $y_t$ is the k-vector of non-stationary I(1) variables, $x_t$ is the d-vector of deterministic variables and $\varepsilon_t$ is a vector of innovations. We may rewrite this VAR as:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta yt_{t-1} + Bx_t + \varepsilon_t \quad (5)$$

$$\text{where } \Pi = \sum_{i=1}^{p} A_i - I, \quad \Gamma_i = - \sum_{j=i+1}^{p} A_j \quad (6)$$

Granger's representation theorem asserts that if the coefficient matrix $\Pi$ has reduced rank r < k, then there exit *k* x *r* matrices α and β each with rank r such that $\Pi = \alpha\beta'$ and $\beta' y_t$ is I(0).

r is the number of cointegrating relations (the cointegrating rank) and each column of β is the cointegrating vector. Johasen cointegration test computes two statistics: trace statistic and maximum eigenvalue statistic. The trace statistic for null hypothesis of r cointegrating relations is computed as:

$$LR_{tr}(r/k) = -T \sum_{i=r+1}^{k} \log(1 - \lambda_i) \quad (7)$$

The maximum eigenvalue test statistic is computed as:

$$LR_{max}(r/r+1) = -T \log(1 - \lambda_{r+1}) = LR_{tr}(r/k) - LR_{tr}(r+1/k) \quad (8)$$

Where $\lambda_i$ is the i-th largest eigenvalue of the Π matrix is (24), r = 0, 1, 2… k – 1.

**Model Specification for Long-Term Relationship**

To investigate the impact of land size, capital, level of technology, interest on loan and government incentives on rice yield in Nigeria, we employ a multiple cointegrating regression (CR) model using fully modified OLS (FMOLS). The model is specified as follows:

ln RP = f {LS, C, Tech, Int, Gov In} ……………. (9)

The natural log of rice productivity is a function of land size, capital, technology level, interest on loan and government incentives. Our linear model is thus given by:

$$\ln RP_t = \beta_0 + \beta_1 LS_t + \beta_2 C_t + \beta_3 Tech_t + \beta_4 Int_t + \beta_5 Gov\ Int_t + \varepsilon_t \quad (10)$$

Where ln $RP_t$ represents the natural log of rice Productivity level at time t used as proxy for yield level, $LS_t$ represents land size at time t, $C_t$ represents capital at time t, $Tech_t$ represents level of technology at time t, $Int_t$ represents interest rate on loans at time t, Gov $Int_t$ represents government incentives at time t and $\varepsilon_t$ is the error term assumed to be normally and independently distributed with zero mean and constant variance, which captures all other explanatory variables that influence rice productivity but are not captured in the model. $\beta_0$ is the intercept which represents the predictive value of the dependent variable when all the independent variables are kept constant. $\beta_1$, …... $\beta_5$ are the slope coefficients of the independent variables that measure the impacts of the explanatory variables on yield. For the independent variables to have positive impacts on yield, the slope coefficients $\beta_1$, …...$\beta_5$ must be positive and significant.

**The Error Correction Model**

To determine the short run relationship among the study variables, ECM was applied and specified as:

$$\Delta \ln RP_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta LS_{t-1} + \sum_{i=1}^{p} \beta_{2i} \Delta C_{t-1} + \sum_{i=0}^{p} \beta_{3i} \Delta Tech_{t-1} + \sum_{i=1}^{p} \beta_{4i} \Delta Int_{t-1} + \sum_{i=1}^{p} \beta_{5i} \Delta Gov\ Int_{t-1} + \lambda_6 EC_{t-1} + \varepsilon_{2t} \quad (11)$$

Where is the error correction term, $\boldsymbol{\lambda}$ is the speed of adjustment, it provides the feedback and speed of adjustment which indicated how much of the disequilibrium that is being corrected in the system, Δ is the first difference of the variable. For a stable long-run relationship to exist among the variables, the expected sign of lambda means that the short-run relationship is predictable, otherwise the relationship is unpredictable.

**Granger Causality based on Toda-Yamamoto Procedure**

Toda and Yamamoto procedure uses a Modified Wald (MWALD) test for restrictions on the parameters of the VAR (k) model. The advantage is that it is not necessary to pretest the variables for the integration and cointegration properties and therefore, it avoids the possible pretest biases (Toda and Yamamoto, 1995). The model is specified as follows:

$$Y_t = \alpha_1 + \sum_{i=1}^{k+d} \beta_{1i} Y_{t-i} + \sum_{t-i}^{k+d} \beta_{2i} X_{t-i} + \varepsilon_{yt} \quad (12)$$

$$X_t = \alpha_2 + \sum_{i=1}^{k+d} \gamma_{1i} Y_{t-i} + \sum_{t-i}^{k+d} \gamma_{2i} X_{t-i} + \varepsilon_{xt} \quad (13)$$

Where k is the optimal lag order; d is the maximal order of integration of the series in the system; $\varepsilon_{yt}$ and $\varepsilon_{xt}$ are error terms which are assumed to be white noise. The usual Wald tests are then applied to the first k coefficient matrices using the standard $X^2 -$ statistic. The test checks the following pairs of hypotheses: $X_t$ "Granger causes" $Y_t$ if $\beta_{2i} \neq 0$ in equation (12) against $Y_t$ "Granger causes" $X_t$ if $\gamma_{1i} \neq 0$ in equation (13).

**RESULTS AND DISCUSSIONS**

**Result of ADF Unit Root Test**

To check whether the study variables have the same order of integration, we employ the ADF unit root test both in levels and first differences of the series in the presence of intercept and linear time trend. The ADF unit root test result is presented in Table 1.

**Table 1: ADF Unit Root Test Result**

| | **Ln CRM** | **POV** | **UNP** | **INF** | **INT** | **POP** |
|---|---|---|---|---|---|---|
| Level | -1.9037 | -2.1105 | -2.0815 | -1.1919 | -0.1495 | -1.8634 |
| $1^{st}$ Diff. | -11.6409** | -17.2193** | -35.8017** | -9.4238** | -7.2206** | -21.1028** |
| Remark | I(1) | I(1) | I(1) | I(1) | I(1) | I(1) |

Note: ** denotes significant of the ADF test statistic at 5% level of significance

The ADF unit root test results indicated that all the variables under review: rice productivity, land size, capital, level of technology, interest rate and government incentives are non-stationary in levels, but stationary in first differences (Agboye Komolafe, Alao & Okoruwa 2013): We therefore conclude that all the study variables are integrated of order one, I (1). This means that **(JCT)** can be conducted on the study variables.

**Johansen Cointegration (JCT) Test Results**

Having established that the variables under investigation are integrated of the same order, we are now in a better position to explore their long-term relationships using **(JCT)** procedure. The result of the Trace test is reported in Table 2, while the result of the maximum eigenvalue test is presented in Table 3.

**Table 2: Johansen Cointegration Trace Test Result**

| Hypothesized No. of CE(s) | $H_0$ | $H_1$ | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|---|---|
| None* | $r = 0$ | $r \geq 1$ | 0.822438 | 177.7822 | 95.75366 | 0.0000 |
| At most 1* | $r \leq 1$ | $r \geq 2$ | 0.615089 | 105.1880 | 69.81889 | 0.0000 |
| At most 2* | $r \leq 2$ | $r \geq 3$ | 0.573435 | 65.08875 | 47.85613 | 0.0006 |
| At most 3 | $r \leq 3$ | $r \geq 4$ | 0.422620 | 29.30517 | 29.79707 | 0.0569 |
| At most 4 | $r \leq 4$ | $r \geq 5$ | 0.112867 | 6.236501 | 15.49471 | 0.6676 |
| At most 5 | $r \leq 5$ | $r \geq 6$ | 0.028320 | 1.206589 | 3.841466 | 0.2720 |

Note: Trace test indicated 3 cointegrating equations at the 0.05 level. * denotes rejection of the null hypothesis at the 0.05 level. ** denotes MacKinnon, Haug & Michelis (1999) p-values. This finding is in agreement with (Naidu, Pandaram & Chand, 2017).

**Table 3: Johansen Cointegration Maximum Eigenvalue Test Result**

| Hypothesized No. of CE(s) | $H_0$ | $H_1$ | Eigenvalue | $\lambda_{max}$ Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|---|---|
| None* | $r = 0$ | $r = 1$ | 0.822438 | 72.59428 | 40.07757 | 0.0000 |
| At most 1* | $r \leq 1$ | $r = 2$ | 0.615089 | 40.09920 | 33.87687 | 0.0080 |
| At most 2* | $r \leq 2$ | $r = 3$ | 0.573435 | 35.78359 | 27.58434 | 0.0036 |
| At most 3* | $r \leq 3$ | $r = 4$ | 0.422620 | 23.06866 | 21.13162 | 0.0264 |
| At most 4 | $r \leq 4$ | $r = 5$ | 0.112867 | 5.029912 | 14.26460 | 0.7380 |
| At most 5 | $r \leq 5$ | $r = 6$ | 0.028320 | 1.206589 | 3.841466 | 0.2720 |

Note: Max-eigenvalue test indicated 4 cointegrating equations at the 0.05 level. * Denotes rejection of the null hypothesis at the 0.05 level. ** denotes MacKinnon, Haug and Michelis (1999) p-values. This is in line with the work of Joharji. & Martha (2011),

The Johansen cointegration trace test result indicated 3 cointegrating equations at 0.05 significance level while the maximum eigenvalue test result indicated 4 cointegrating equations at 0.05 significance level. These results show that the variables cointegrated. This means the existence of long-term relationship between rice yield, land size, capital, level of technology, interest rate and government incentives and the variables share a common stochastic drift and cannot wander away from each other in the long-run.

**Estimates of Cointegrating Regression (CR) Model**

To investigate the impact of land size, capital, level of technology, interest rate and government incentives on productivity level, CR model was employed using fully modified OLS. The result is presented in Table 4.

**Table 4: FMOLS Estimation of Long-run Coefficients**

**Dependent Variable: lnRP Method: Fully Modified Least Squares (FMOLS)**

| Variable | Coefficient | Std. Error | t-Statistic | P-value |
|---|---|---|---|---|
| RP | 4.509048 | 3.983788 | 1.131850 | 0.2646 |
| LS | 0.151137 | 0.012815 | -3.179628 | 0.0435 |
| C | 0.107047 | 0.023258 | 4.602599 | 0.0000 |
| Tech | 0.012658 | 0.006576 | 1.924943 | 0.0166 |
| Int | -0.041643 | 0.027319 | -1.524311 | 0.1355 |
| Gov Int | 3.058980 | 1.478192 | 2.069406 | 0.0452 |

$R^2$ 0.847922 Adjusted $R^2$ 0.764323 Durbin Watson statistic 2.136846

The result on Table 4 shows that land size capital, level of technology and government incentives positive and significant impacts on Productivity level (these findings agree with Osanyinlusi, and Adenegan, 2016; Anthony, *et, al.*, 2021). Therefore, an increase in these variables will lead to increase in rice productivity. Interest rate has negative and insignificant relationship with Productivity level. The intercept of the regression line is positively related to rice productivity, but not significant. This indicated the level of rice productivity with all independent variables constant.

The coefficient of determination, $R^2$ showed 84.79% of the variability in the model was explained by the explanatory variables while the remaining 15.21% variations were accounted for by the error term and factors not included in the model. That is, there are other variables that have impact on rice productivity which are not included in the model. The Durbin Watson statistic > $R^2$ meaning that our long-run model is non-spurious. This study identified government incentives having higher impact on rice followed by land size, capital and level of technology in the long-run.

**The Error Correction Model**

Using the residuals obtained from CR equation in Table 4, we estimate the (ECM) which adjusts the speed of disequilibrium in the system. The result is presented in Table 5.

**Table 5: Parameter Estimates of Error Correction Model**

**Dependent Variable: ΔlnRP Method: OLS**

| Variable | Coefficient | Std. Error | t-Statistic | Prob |
|---|---|---|---|---|
| C | 0.055905 | 0.094555 | 0.591246 | 0.5581 |
| ΔlnRP(-1) | -0.431239 | 0.159346 | -2.706302 | 0.0103 |
| ΔLS(-1) | -0.007725 | 0.719252 | -1.401287 | 0.0406 |
| ΔC(-1) | 0.046184 | 0.042196 | 1.094506 | 0.0210 |
| ΔTech(-1) | -0.005242 | 0.005850 | -0.896146 | 0.3761 |
| ΔInt(-1) | -0.002902 | 0.035199 | -0.082432 | 0.9348 |
| ΔGov(-1) | 0.162977 | 1.326633 | 3.122850 | 0.0029 |
| EC(-1) | 0.932032 | 0.012660 | 0.736330 | 0.0003 |

$R^2$ 0.7629; Adjusted $R^2$ 0.7195; Durbin Watson 2.1835

F-statistic 11.834030 Prob. (F-statistic) 0.000578

From the estimates of ECM in Table 5 the slope coefficients of ΔlnRP(-1), ΔLS(-1), ΔC(-1), ΔTech(-1), ΔInt(-1) and ΔGov Int(-1) are the short-run equilibrium coefficients whereas the slope coefficient of EC(-1) is the long-run equilibrium coefficient known as the error correction coefficient. Econometric theory expects the coefficient of EC(-1) to be negative and significant. The short-run equilibrium coefficients tell us the rates at which the previous period's disequilibrium in the system is being corrected. In our ECM model the system corrects its previous period's disequilibrium at the speed of 43.12% between rice productivity level and rice productivity level lag one year, 0.77% between rice productivity and land size lag one year, 4.62% between rice productivity and capital lag one year, 0.52% between rice productivity and level of technology lag one year and 0.29% between rice productivity and interest rate lag one year and 16.30% between rice productivity level and government incentive lag one year. The small percentage values show how slow the previous period's disequilibria between rice productivity level and other explanatory variables in the model are being corrected. The slope coefficients of ΔlnRP(-1), ΔLS(-1), ΔC(-1) and ΔGov Int(-1) are statistically significant at lag one year indicating that the effect of rice productivity on land size, capital and government incentives is not just temporary but long lasting whereas the slope coefficients of ΔTech(-1) and ΔInt(-1) are not significant at lag one year indicating that the effect of rice productivity in level of technology and interest rate is temporal and not long lasting.

The one lag period ECM is represented by EC(-1). This guides the independent variables in the system to restore back to equilibrium when it is negative and statistically significant. In our case this coefficient is negative and statistically significant at 5% level indicating that the system corrects its previous period's disequilibrium at a speed of 93.20% yearly. This means that the ECM model has identified a reasonable speed of adjustment by 93.20% for correcting disequilibrium annually for attaining long term equilibrium steady state position.

**4.5 Granger Causality Test Result based on Toda-Yamamoto Approach**

To conduct Granger causality test based on Toda-Yamamoto procedure, we estimate two equations in VAR model, the various information criteria suggest that we should specify a maximum lag length of 3 for each variable in the model as indicated in Table 6.

**Table 6: VAR Lag Order Selection Criteria**

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | -472.9501 | NA | 1831.711 | 24.52143 | 26.25910 | 25.15836 |
| 1 | -388.0506 | 117.2423 | 198.6531 | 22.19288 | 25.41999 | 23.37574 |
| 2 | -316.0380 | 78.87088* | 48.15599* | 20.47800 | 25.19453* | 22.20680* |
| 3 | -273.1681 | 34.70424 | 67.33079 | 20.15086* | 26.35682 | 22.42559 |

Note: * lag order selected by the criterion

Since the estimated VAR must satisfy the stability condition before, modified Wald test, serial correlation LM test of residuals of the estimated VAR model was conducted and presented in Table7.

**Table7: Estimated VAR Residual Serial Correlation LM Test and Autoregressive Roots Table**

| VAR Residual Serial Correlation LM Test | | | AR Roots | |
|---|---|---|---|---|
| **Lags** | **LM-Stat.** | **P-value** | **Roots** | **Modulus** |
| 1 | 66.73862 | 0.1404 | 0.742023 - 0.230246i | 0.776924 |
| 4 | 55.22347 | 0.2127 | 0.742023 + 0.230246i | 0.776924 |
| 7 | 34.29336 | 0.5499 | 0.686078 - 0.325127i | 0.759217 |
| 10 | 54.68855 | 0.2137 | 0.686078 + 0.325127i | 0.759217 |
| 11 | 27.72170 | 0.8370 | 0.555219 | 0.555219 |
| 12 | 25.63619 | 0.9002 | 0.151355 | 0.151355 |

The null hypothesis of no serial correlation at lag order 12 is accepted since the p-values are not statistically significant at 5% level of significance and since no root lies outside the unit circle, our estimated VAR model has satisfied the stability condition. Therefore, the VAR can use to conduct Granger causality test based on Toda-Yamamoto procedure. The result of Granger causality test is presented in Table 8.

**Table 8: Granger Causality Test Result based on Toda-Yamamoto Procedure**

| Variable | | | Modified | Wald Test | | |
|---|---|---|---|---|---|---|
| | RP | LS | C | Tech | INT | GOV |
| RP | …….. | 13.2865 | 17.2272 | 14.4544 | 11.4221 | 7.23291 |
| | | [0.0034]* | [0.0002]* | [0.0007]* | [0.0033]* | [0.0269]* |
| LS | 2.78854 | ………. | 11.2441 | 0.30690 | 1.40035 | 11.2007 |
| | [0.2480] | | [0.0042]* | [0.8577] | [0.4965] | [0.0045]* |
| C | 1.36668 | 3.02901 | ………. | 0.28321 | 1.39069 | 13.2596 |
| | [0.5049] | [0.2199] | | [0.8684] | [0.4989] | [0.0036]* |
| Tech | 1.57927 | 5.51481 | 1.17180 | ………. | 39.4203 | 5.43419 |
| | [0.1137] | [0.0635] | [0.5566] | | [0.0000]* | [0.0661] |
| INT | 1.45664 | 0.22088 | 4.04459 | 13.9766 | ……… | 1.85335 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | [0.4827] | [0.8954] | [0.1324] | [0.0009]* | | [0.3959] |
| GOV | 0.41479 | 7.31576 | 3.91351 | 3.50067 | 0.85276 | |
| | [0.8127] | [0.0231]* | [0.1413] | [0.1737] | [0.6529] | |

The Granger causality test result shows that land size, capital, technology level, interest rate and government incentives were all Granger causes of rice productivity. The result also shows bidirectional causality between government incentives and land size. The result also reveals that land size in Nigeria is Granger caused by capital, while capital is Granger caused by level of government incentives to the rice farmers. A bilateral causality also exists between technology level and interest rate.

## CONCLUSION

This study has attempted to investigate the determinants of rice productivity by analyzing the impact of some variables: land size, capital, level of technology, interest rate and government incentives on rice productivity in Nigeria. The study used annual time series data from 2006-2016. The unit root and stationary properties of the time series data are examined using Augmented Dickey-Fuller unit root test. Johansen cointegration was employed to examine the long-term relationship among study variables, CR equation using FMOLS was applied to investigate the impact of study variables on rice productivity. ECM was employed to determine the speed of adjustment for correcting disequilibrium in the system while Granger causality test based on Toda-Yamamoto procedure was used to find the direction of causality among study variables. The unit root test result shows that all variables are integrated of order one, I(1). The (JCT) indicated the existence of long-term relationship among study variables. The study finds government incentives, capital, land size and level of technology as having the highest impact. The ECM has identified a sizable speed of adjustment by 93.20% for disequilibrium correction annually for attaining long-run equilibrium steady state position. Although the speed of adjustment between rice productivity and the independent variables are found to be very slow. Government incentives, land size and capital are found to have permanent effect on rice productivity in Nigeria, while level of technology and interest rate are found to have temporal effect on rice productivity. The Granger causality test results revealed that rice productivity is Granger caused by government incentives, land size, capital, level of technology and interest rate in Nigeria. The result also shows bidirectional causality between government incentives and land size. The result also reveals that land size in Nigeria is Granger caused by capital while capital is Granger caused by level of government incentives. A bilateral causality also exists between level of technology and interest rate. The implication of the Granger causality test result is that when rice farmers have access to land suitable for rice production, rice productivity is increased.

Based on the findings of this study, the following recommendations are suggested to help improve rice productivity in Nigeria. Government incentives and stakeholder's interventions should be in the provision of land, capital, improved technology and reduction of interest.

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