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Research article

Effect of Rice Input Variables and Climate Change Factors on Total Factor Productivity of Rice in Nigeria

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Abstract

This study evaluated the effect of rice production input variables and climate change variables on rice total factor productivity (TFP) in Nigeria. The research utilizes various data sets obtained from reputable organizations to analyze the period from 1961 to 2020. Descriptive and inferential statistics were employed to analyze the data. The study findings indicate an upward trajectory in rice TFP in Nigeria over the examined period. Regression analysis reveals that labor and capital have a significant positive effect on rice TFP, indicating that increased labor and capital investments can enhance productivity. Rainfall and sunlight duration also show a significant positive relationship with rice TFP, emphasizing their crucial role in rice farming. The study highlights the importance of addressing labor scarcity and promoting access to capital for farmers. Moreover, it emphasizes the quest for optimal rainfall and sunlight conditions throughout the rice cultivation process. The model's diagnostic tests confirm its reliability, and the findings demonstrate the statistical significance of the independent variables in explaining rice TFP. Overall, this research gives insightful information on the factors influencing rice TFP in Nigeria. It offers recommendations for stakeholders and decision-makers to enhance productivity by addressing labor scarcity, promoting capital access, and optimizing climatic conditions for rice cultivation.

Keywords: rice TFP; climate change; Nigeria; rainfall; sunshine duration

1. Introduction

Climate change is among the most pressing challenges facing the world today. It has substantial effects on various aspects of human life, such as food security, health, and economic development (Onyeneke, 2021). One of the sectors that is most vulnerable to climate change is agriculture, especially in underdeveloped nations where the vast majority of people depends on farming for their livelihoods (Barange et al., 2018). Rice is among the most important staple crops in Nigeria, providing a significant portion of the country's food supply and serving as a source of income for many farmers. However, the productivity of rice cultivation in Nigeria is influenced by various factors, including input variables and climate change (Oyita & Otuisi, 2023).

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Changes in temperature, rainfall patterns, and extreme weather events can have both direct and indirect impacts on rice yield (Oyita et al., 2023). Rising temperatures and changing precipitation patterns can result in heat stress, water scarcity, flooding, and increased incidences of pests and diseases, all of which can negatively affect rice production (Oguntunde et al., 2018). Additionally, climate change can disrupt the timing of critical crop management practices, such as planting and harvesting, further impacting rice productivity.

While the individual effects of input variables and climate change on rice productivity have been studied in various contexts, there is a need to understand their combined effects on total factor productivity (TFP) in the Nigerian rice sector. TFP measures the overall efficiency on how inputs are converted into outputs, considering all factors of production. Input variables, such as seeds, fertilizers, and water management practices, play a crucial part in establishing the productivity of rice crops (Fuglie, 2015). Access to high-quality seeds, appropriate fertilization, and efficient water management techniques can enhance crop yield and overall productivity. As opposed to that, inadequate or suboptimal use of these input variables can result in reduced productivity and economic losses for farmers (Oyita et al., 2023). Assessing the combined impact of input variables and climate change factors on TFP can provide valuable insights into the overall productivity of rice cultivation in Nigeria and help identify strategies to enhance efficiency and resilience in the face of changing conditions.

Several studies have looked into the effect of input variables and climate change factors on crop productivity globally. For instance, a study by Lobell et al. (2011) found that temperature increase negatively affects rice yields in many regions, including Africa. Another study by Shafiq et al. (2021) examined the effect of irrigation on rice productivity and reported that appropriate water management significantly improves crop yield. Also, another study by Oyita et al. (2023) on the impact of climate change factors and rice production input variables in Nigeria found that rice output is adversely affected by atmospheric relative humidity.

In the context of Nigeria, several studies have also examined the factors influencing rice productivity, but few have specifically focused on the overall result of input variables and climate change factors on TFP. One notable study by Okon et al. (2021) analyzed the impact of climate change on Nigerian agriculture but did not specifically address rice productivity. Another study by Okoh et al. (2022) investigated the effect of input variables on rice yield in Nigeria but did not consider climate change factors. Furthermore, a study by Oyita and Otuisi (2023) examined the effect of rice TFP on rice output in Nigeria but did not incorporate the causal effect of climate change on rice TFP in their study.

Therefore, there is a research gap regarding the comprehensive analysis of the overall effects of rice input variables and climate change factors on the TFP of rice in Nigeria. Addressing this gap is essential for formulating effective agricultural policies and strategies to enhance rice productivity and ensure food security in the face of changing climatic conditions. Thus, the general objective of this study is to assess the effect of rice production input variables and climate change variables on rice TFP in Nigeria.

2. Materials and Methods

2.1 Study area

The focus of this study centers on the Federal Republic of Nigeria, a significant rice producer in Africa and one of the leading importers of rice globally. For small-scale farmers in Nigeria, the ability to sell 80% of their entire crop while utilizing only 20% for personal consumption is not only vital for generating income but also ensuring food security. Rice emerges as the cash crop that generates the highest income for Nigerian farmers (Oladimeji & Abdulsalam, 2013). Geographically, Nigeria is situated between latitudes 40 and 14'N and longitudes 20 and 140'E, encompassing a land area of 923,768 square kilometers. It shares boundaries with the Niger Republic to the North, Benin Republic to the West, and Chad and Cameroon to the East. To the South lies the Gulf of Guinea, which opens to the Atlantic Ocean. The country is organized into 36 states, with Abuja serving as the Federal Capital Territory. As of 2020, Nigeria has a population of 206,139,587 inhabitants (datacatalog.worldbank.org). Nigeria possesses abundant resources in terms of land, capital, and labor, providing favorable conditions for farming activities and economic development.

2.2 Data collection

The study utilized various data sets encompassing key parameters such as mean annual temperature, mean annual rainfall, mean annual relative humidity, and sunshine duration from the period of 1961 to 2020. These data were sourced from reputable organizations including the Nigeria Meteorological Agency (NIMET), the World Bank's online statistical depository, and the United Nations' online database. To obtain comprehensive information regarding rice input and output, data spanning the years 1961 to 2020 were collected from authoritative sources like the United States Department of Agriculture Economic Research Service (USDA ERS, 2022), the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT, 2022), and the National Rice Development Strategy (NRDS, 2020). These sources were relied upon to guarantee accessibility of accurate and reliable data for analysis and interpretation.

2.3 Data analysis

A comprehensive analysis of the data involved the utilization of both descriptive and inferential statistics. The determination of the TFP index for rice was accomplished through the employment of the sophisticated Malmquist Data Envelopment Analysis. Various diagnostic tests were conducted to assess different aspects of the data, including stationarity, causality, cointegration, serial correlation, heteroscedasticity, normality, and stability. These tests were performed using the advanced E-views software version 10, ensuring a rigorous evaluation of the dataset.

2.4 Empirical models

2.4.1 Rice TFP (Malmquist productivity index)

The Malmquist TFP index offers a valuable tool for determining how TFP has changed over time by considering alterations in both input and output variables (Caves et al., 1982). As it relates to agricultural economics, this index is frequently utilized to evaluate the effectiveness of diverse farming systems and technologies (Coelli et al., 1998). In the specific context of rice production, researchers have employed the Malmquist TFP index to examine the influence of various factors on productivity, including technological advancements, farm size, and irrigation (Zhang et al., 2021; Shiferaw et al., 2009). The Malmquist TFP index is mathematically expressed according to the work of Malmquist (1953):

$$TFP_t = \frac{Y_t}{({L_t}^a * {K_t}^b * {A_t}^c)} \quad (1)$$

Where:

TFP_t = Total factor productivity in period t
Y_t = Rice output in period t (metric tons)
L_t = Total labor input in period t (number of person)
K_t = Total capital input in period t in Naira (where $1USD = ₦1,550)
A_t = Total area of land input in period t, (hectares)
a, b and c are the output elasticities of labor, capital and land respectively.

The Malmquist TFP index is calculated using the Data Envelopment Analysis (DEA) software version 2.0. DEA is a powerful non-parametric technique utilized to evaluate the relative impact of decision-making units (DMUs) that transform input variables, such as land, labor, and capital, into output variables, specifically rice yield, within a specific timeframe. The Malmquist index, derived from this analysis, provides valuable insights into productivity changes (Malmquist, 1953; Oyita & Otuisi, 2023).

When the Malmquist index falls below 1, it indicates a decline in productivity, referred to as productivity regress. That implies that the output has decreased relative to the input, highlighting a decrease in efficiency or effectiveness. As opposed to that, a Malmquist index of 1 signifies no alteration in productivity, meaning that the output has remained consistent relative to the input, suggesting a stable level of efficiency. Finally, when the Malmquist index surpasses 1, it signifies an increase in productivity, termed productivity progress. This indicates that the output has increased relative to the input, showcasing improved efficiency or effectiveness (Oyita & Otuisi, 2023).

The application of the Malmquist TFP index, generated through DEA software, provides a comprehensive and robust framework for evaluating productivity changes and locating areas for improvement in rice production. By assessing the relative impact of input variables on rice yield and considering productivity changes over time, stakeholders can make informed decisions and implement targeted strategies to enhance agricultural productivity in a sustainable and efficient manner.

2.4.2 Unit root test

To determine whether or not the series are stationary, the Augmented Dickey-Fuller (ADF) method was utilized. The following is a description of the ADF testing process:

$$\Delta X_t = \beta_0 + \beta_2 X_{t-1} + \beta_i \sum X_{t-1} + \sum_i \quad (2)$$

Where;

X_t = individual explanatory variables at time, t;
β_o = constant
Δ = the difference term.
The unit root test was then undertaken for the null hypothesis, t ≠0.

The computed test statistic was compared to the relevant critical value for the augmented Dickey–Fuller test (ADF_t). If the statistic is greater (in absolute value) than the critical value at the 5% or 1% level of significance, then the null hypothesis of a unit root is not accepted and no unit root is present. Once this was established, the test for cointegration was carried out.

2.4.3 Test for co-integration

Johansen maximum likelihood test was carried out to show if the relationship between the dependent and independent variables is long-term equilibrium, the equation is shown below:

$$TFP_t = \beta_0 + \beta_1 LAND_{t-1} + \beta_2 LABOUR_{t-1} + \beta_3 CAPITAL_{t-1} + \beta_4 ARAINFALL_{t-1} + \beta_5 ATEMP_{t-1} + \beta_6 ARH_{t-1} + \beta_7 ASSD_{t-1} + U_t \quad (3)$$

Where;

TFP_t, = Total factor productivity of rice
$LAND_t$ = Total area of land for rice production (hectares)
$LABOR_t$ = Number of persons involved in rice production
$CAPITAL_t$ = Amount of total capital stock for fertilizer, chemicals, machineries etc. in Naira (where \$1USD = ₦460)
$ARAINFALL_t$ = Average annual rainfall for each year measured (mm)
$ATEMP_t$ = Average annual atmospheric temperature (°C)
ARH_t = Average annual relative humidity measured in percentage (%)
$ASSD_t$ = Average annual sunshine duration (h)
β_0 refer to intercepts; β_1 to β_7 are parameters to be estimated. U_t is random term while t denotes the year.

2.4.4 Effect of rice input variables and climate change variables on TFP of rice in Nigeria

The model is expressed in implicit form as shown in the equation below:

$$TFP_t = f\left(LAND_t, LABOUR_t, CAPITAL_t, ARAINFALL_t, ATEMP_t, ARH_t, ASSD_t, U_t\right) \quad (4)$$

The functional form is expressed in the explicit form as:

$$TFP_t = \beta_0 + \beta_1 LAND_t + \beta_2 LABOUR_t + \beta_3 CAPITAL_t + \beta_4 ARAINFALL_t + \beta_5 ATEMP_t + \beta_6 ARHUMI_t + \beta_7 ASSD_t + U_t \quad (5)$$

Description of variables in equations (4) and (5) are the same as equation (3).

3. Results and Discussion

3.1 Descriptive statistics

Table 1 presents the descriptive statistics of the variables examined in this study. The findings indicate that the average TFP of rice, represented by a mean value of 0.953, was regressive since it is less than 1. Additionally, the mean value of rice output was 2,655,720 tons. The average values for rainfall, temperature, relative humidity, and sunshine duration were 1,151.293 mm, 27.053°C, 57.598%, and 6.208 h, respectively. Furthermore, the mean values for the labor force, land area used for rice cultivation, and capital stock were 15,960 persons, 1,331,275 hectares, and ₦4.5 billion, respectively.

Examining the kurtosis values, which indicate the peakness or flatness of the distribution, it was observed that rice TFP and rice output had kurtosis values of 8.947 and 3.245, respectively. The climate change variables, including rainfall, temperature, relative humidity, and sunshine duration, had kurtosis values of 2.299, 3.419, 3.028, and 3.243, respectively. These results suggest that only relative humidity exhibited a mesokurtic distribution, indicating a normal distribution with a kurtosis of 3. Whereas all other variables in the study displayed leptokurtic distributions, indicating positive kurtosis and a more peaked curve with higher values.

To assess the normality of the distributions, the Jarque-Bera test statistics were employed, measuring the deviation of skewness and kurtosis from the normal distribution. The analysis revealed that rice TFP (Jarque-Bera 141.691; P-value <5%) and rice output (Jarque-Bera 9.329; P-value <5%) had abnormal distributions. In contrast, temperature (Jarque-Bera 1.450; P-value >5%), rainfall (Jarque-Bera 2.150; P-value >5%), relative humidity (Jarque-Bera 0.883; P-value >5%), sunshine duration (Jarque-Bera 1.691; P-value >5%), land (Jarque-Bera 5.270; P-value >5%), labor (Jarque-Bera 5.492; P-value >5%), and capital (Jarque-Bera 2.926; P-value >5%) followed normal distributions.

3.2 Unit root test

The econometric approach employed in this study involves an initial assessment of the time series properties of the variables through the application of the Augmented Dickey-Fuller (ADF) unit root test. The results of the unit root test, as depicted in Table 2, indicate that all the variables under investigation exhibited orders of integration of 1, thereby necessitating the application of first differences for further analysis.

3.3 Trend of TFP of rice in Nigeria from 1961 to 2020

The graphical representation presented in Figure 1 illustrates the temporal pattern of TFP for rice cultivation in Nigeria, spanning the years 1961 to 2020. Notably, the results demonstrate a discernible upward trajectory in the TFP of rice within Nigeria during the period under examination. This positive slope in TFP is further substantiated by the regression equation put forth in the analysis.

$$RTFP = -3.286 + 0.002 * t + e_i \quad (6)$$

Where;

RTFP = Rice total factor productivity
t = time (year)
e_i = error term

Table 1. Descriptive statistics

Statistics	Rice TFP	Rice Output	Mean Annual Temperature	Mean Annual Relative Humidity	Mean Annual Rainfall	Sunshine Duration	Land Area	Labor	Capital
Mean	0.953	2655720	27.053	57.598	1151.293	6.208	1331275	15960.13	4.50E+09
Median	0.969	2626000	27.070	57.365	1157.905	6.100	1579420	14616.24	4.47E+09
Max	1.054	8435000	27.860	61.770	1335.280	8.800	3088496	21778.00	8.22E+09
Min	0.702	133000.0	26.270	53.950	872.040	4.500	149000	12269.04	1.76E+09
Std. Dev.	0.063	2314847	0.394	1.509	89.070	0.933	980208.6	2724.134	1.83E+09
Skewness	-2.308	0.958072	-0.149	0.297	-0.414	0.393	0.230	0.469	0.334
Kurtosis	8.947	3.244602	2.299	3.028	3.419	3.243	1.623	1.851	2.149
Jarque-Bera	141.690	9.329	1.450	0.883	2.150	1.691	5.270	5.492	2.926
Prob.	0.000	0.009	0.484	0.643	0.341	0.429	0.071	0.064	0.232
Sum	57.176	1.59E+08	1623.170	3455.890	69077.58	372.500	79876470	957607.6	2.70E+11
Sum Sq. Dev.	0.236	3.16E+14	9.157	134.285	468073.6	51.385	5.67E+13	4.38E+08	1.98E+20
Obs.	60	60	60	60	60	60	60	60	60

Table 2. Unit root test

Variable	Level Difference	Prob	First Diff	Prob	Order of Integration
Rice TFP	-6.234	0.000	-14.011	0.000	I(1)
Rice Output	2.304	0.999	-4.116	0.002	I(1)
Rainfall	-5.639	0.000	-12.76	0.000	I(1)
Temperature	-1.373	0.589	-11.541	0.000	I(1)
Relative Humidity	-7.079	0.000	-14.02	0.000	I(1)
Sunshine Duration	-7.755	0.000	-9.465	0.000	I(1)
Land	0.913	0.995	-10.66	0.000	I(1)
Labor	1.131	0.997	-6.250	0.000	I(1)
Capital	2.346	1.000	-8.586	0.000	I(1)

Equation (6) indicates in this analysis that a percentage change in a given year is associated with a 0.002% change in TFP of rice in Nigeria. Furthermore, the findings of the study illustrate the trajectory of rice TFP in Nigeria over several years. In 1961, the TFP of rice stood at 0.718, but it reached its lowest point in 1962 with a value of 0.702. Subsequently, a rising trend was seen, and by 1978, the TFP had increased to 1.026. However, the TFP exhibited a fluctuating pattern until it reached its peak of 1.054 in 2009. This fluctuation persisted until the year 2020. Notably, the forecasted results indicate a positive trajectory for rice TFP in Nigeria from 2021 to 2030. This forecast implies that if the combination of input variables in rice production and climatic factors are sustained or improved, it would lead to the growth of rice TFP by the year 2030. These findings align with those of Oyita and Otuisi (2023), who observed an overall positive trend in rice TFP over time for the sampled states in Nigeria.

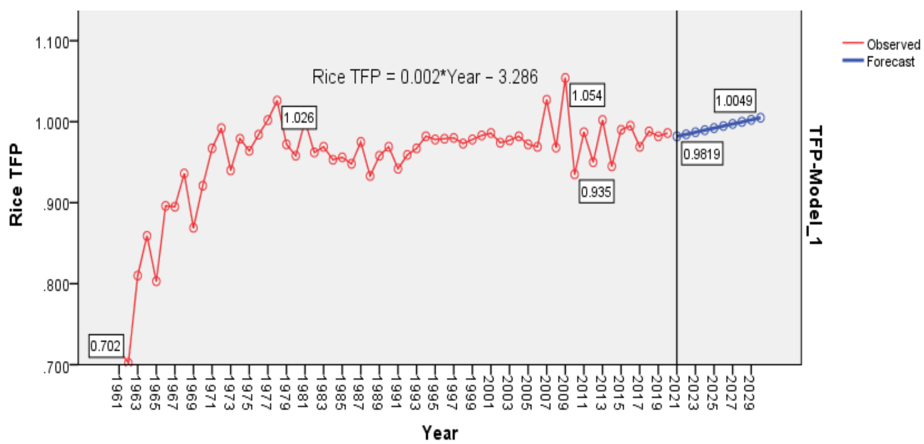

Figure 1. Trend of TFP of rice in Nigeria from 1961 to 2020

3.4 Effect of rice input variables and climate change variables on rice TFP in Nigeria

3.4.1 Lag order selection criteria

Table 3 illustrates the findings of the lag order selection criteria of the variables. Lag 2 was chosen as the lag order for this model. In the case of lag 2, most of the selection criteria were significant at the 5% level of probability.

3.4.2 Cointegration test

Considering the outcomes of the unconstrained trace co-integrating rank test, Table 4 demonstrates that the null hypothesis of no co-integrating equation is rejected and that one co-integrating equation is present at a significance level of 5%. The unconstrained max-eigen co-integrating rank test likewise indicates the existence of one co-integrating equation while rejecting the null hypothesis that there are none at a significance level of 5%. The appearance of a co-integrating equation shows that the independent factors (land, labor, and capital, rainfall, temperature, relative humidity, and sunlight length) and the dependent variable (rice TFP) have a lasting relationship.

Table 3. Lag order selection criteria

VAR Lag Order Selection Criteria
Endogenous variables: DTFP DLAND DLABOR DCAPITAL DRAINFALL DRELATIVE HUMIDITY DTEMPERATURE DSUNSHINE DURATION
Exogenous variables: C
Date: 11/19/22 Time: 16:02
Sample: 1961 2020
Included observations: 56

Lag	LogL	LR	FPE	AIC	SC	HQ
0	401.213	NA	8.11e-12	-14.186	-14.041	-14.130
1	619.690	397.940	5.88e-15	-21.417	-20.694*	-21.137*
2	639.923	33.964*	5.10e-15*	-21.569*	-20.267	-21.064
3	654.753	22.775	5.45e-15	-21.527	-19.646	-20.798
4	671.604	23.471	5.52e-15	-21.558	-19.098	-20.604

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Author's computation (2023)

3.4.3 Pairwise granger causality tests

In Table 5, paired granger causality test findings regarding the effects of rice input factors on rice TFP are shown. This study disproves the null hypothesis that rice TFP is not granger caused by agricultural land (F-stat. 1.045; p-value >5%) and that agricultural land is not granger caused by rice TFP (F-stat. 0.355; p-value >5%). The research presents a case for a bidirectional link, contending that rice TFP granger causes agricultural land granger and agricultural land granger causes rice TFP. The null hypotheses that labor does not granger cause rice TFP (F-stat. 0.788; P-value >5%) and rice TFP does not granger cause labor (F-stat. 0.404; P-value >5%) are both rejected by this study. There is a bidirectional link between labor and rice TFP, with labor granger causing rice TFP and rice TFP granger causing labor.

The study disproves both the null hypotheses that capital does not granger cause rice TFP (F-stat. 0.535; P-value >5%) and that rice TFP does not granger cause capital (F-stat. 0.274; P-value >5%). The findings of this study challenge the null hypotheses regarding the causal relationships between rainfall and rice TFP, as well as rice TFP and rainfall. The results indicate a bidirectional relationship between these variables during the study period. On the other hand, the null hypothesis stating that rice TFP does not granger cause temperature is supported, while the null hypothesis suggesting that temperature does not granger cause rice TFP is rejected. This study reveals a unidirectional causal relationship between temperature and rice TFP within the timeframe examined.

Furthermore, the study refutes the null hypotheses regarding the causal relationships between rice TFP and relative humidity, as well as vice versa. Instead, it establishes a bidirectional relationship, indicating that relative humidity granger causes rice

Table 4. Cointegration test

Date: 02/01/23 Time: 00:58
Sample (adjusted): 1964 2020
Included observations: 57 after adjustments
Trend assumption: Linear deterministic trend
Series: DTFP DLAND DLABOR DCAPITAL DRAINFALL DRELATIVE HUMIDITY DTEMPERATURE DSUNSHINE DURATION
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	p-value
None *	0.846	414.002	159.529	0.000
At most 1 *	0.780	307.335	125.615	0.000
At most 2 *	0.649	221.138	95.753	0.000
At most 3 *	0.607	161.346	69.818	0.000
At most 4 *	0.561	108.089	47.856	0.000
At most 5 *	0.464	61.161	29.797	0.000
At most 6 *	0.237	25.595	15.494	0.001
At most 7 *	0.162	10.139	3.841	0.001

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	p-value
None *	0.846	106.666	52.362	0.000
At most 1 *	0.779	86.197	46.231	0.000
At most 2 *	0.649	59.791	40.077	0.000
At most 3 *	0.607	53.257	33.876	0.000
At most 4 *	0.561	46.927	27.584	0.000
At most 5 *	0.464	35.566	21.131	0.000
At most 6 *	0.237	15.455	14.264	0.032
At most 7 *	0.162	10.139	3.841	0.001

Max-eigenvalue test indicates 8 cointegrating eqn(s) at the 0.05 level
* indicates that the hypothesis was rejected at the 0.05 level.

TFP and vice versa during the time period were considered. Additionally, the research challenges the null hypotheses concerning the causal relationships between sunshine duration and rice TFP, as well as rice TFP and sunshine duration. The study presents evidence supporting a bidirectional linkage between rice TFP and the length of sunshine over the examined time period.

3.4.4 Regression analysis

The effect of rice input variables and climate change variables on rice TFP in Nigeria from the year 1961 to 2020 is presented in Table 6. It is observed that the R^2 value of 0.590 (59%) indicates that rice input variables and climate change variables have a 59% predictive potential in explaining the variation in rice TFP. Furthermore, the adjusted R^2 value of 0.522 demonstrates how the change in 52% of the overall variance in rice TFP can be accounted for by the rice input variables and climate change variables applied in the analysis.

Table 5. Pairwise granger causality tests

Pairwise Granger Causality Tests			
Date: 2/2/23 Time: 16:22			
Sample: 1961 2020			
Lags: 2			
Null Hypothesis:	Obs	F-Statistic	Prob.
DLAND does not Granger Cause DTFP	58	1.045	0.360
DTFP does not Granger Cause DLAND		0.355	0.703
DLABOR does not Granger Cause DTFP	58	0.788	0.460
DTFP does not Granger Cause DLABOR		0.404	0.670
DCAPITAL does not Granger Cause DTFP	58	0.535	0.589
DTFP does not Granger Cause DCAPITAL		0.274	0.761
DRAINFALL does not Granger Cause DTFP	58	0.621	0.650
DTFP does not Granger Cause DRAINFALL		0.944	0.447
DTEMPERATURE does not Granger Cause DTFP	58	2.204	0.083
DTFP does not Granger Cause DTEMPERATURE		3.942	0.041**
DRELATIVE HUMIDITY does not Granger Cause DTFP	58	0.524	0.718
DTFP does not Granger Cause DRELATIVE HUMIDITY		0.960	0.521
DSUNSHINE DURATION does not Granger Cause DTFP	58	1.973	0.114
DTFP does not Granger Cause DSUNSHINE DURATION		0.676	0.612

** significant at 1%

With a coefficient of 0.066 and a significance level of 5%, labor had a statistically significant and favorable impact on rice TFP. Given that most of rice farming families in Nigeria do not employ mechanized farming, this suggests that a 1% rise in labor will have the expected effect on rice TFP of 0.070%. This result supports that of Pinga et al. (2022b) who investigated the labor shortage effects on rice yield and production in the Guma local government area of Benue State. Their findings showed that labor scarcity had an adverse effect on rice production and yield in the research region. The researchers noted that farmers faced difficulties in cultivating both individual and group farms because of scarcity of labor. One farmer shared their experience of losing access to fadama land, where their group farm was located, due to clashes in the year 2018. The same group had harvested 80 bags of rice, each weighing 100 kg, from the land in 2017. Pinga et al. (2022b) argued that labor scarcity has forced farmers to cultivate smaller sizes of rice farms, even if they had larger fields suitable for rice cultivation, to avoid wastage because rice cultivation is labor-intensive.

Also, in Pinga et al. (2022a) research, it was found that farmers who cultivated large plots were unable to fulfil labor demands and consequently had lower yields compared to those who cultivated smaller portions and could manage them effectively. Due to this, farmers have observed over time that it is more beneficial to cultivate smaller portions and manage them well than to cultivate more and waste resources while still obtaining poor yields. Many farmers have agreed with this conclusion. However, it is crucial to note that smaller portions may result in lower yields. This is demonstrated by the fact that some farmers who used to harvest 50, 60, and 70 bags of rice, each weighing 100 kg, are now only able to obtain 20 or even less than 10 bags due to the decrease in size of their rice farms, which is concerning as it is motivated by a lack of labor.

In line with the study of Ijirshar et al. (2015), one of the major factors causing labor scarcity among rice farmers is the threat to life resulting from clashes, including those between farmers and herdsmen or communal clashes. These clashes have resulted in the loss of lives and the migration of some young men to safer areas, thereby affecting the supply of labor to farms. Ijirshar et al. (2015) stated that conflicts between farmers and herders have significantly impacted the agricultural production in seven out of the 23 LGAs in Benue State, Nigeria. Some respondents highlighted the fact that due to the frequent clashes and loss of lives, members of farmer groups no longer reside in the same communities, thereby affecting their collective farming activities, which are typically aimed at mutual financial and labor support.

A favorable effect on rice TFP was shown by the capital coefficient, which was 0.013 and statistically significant at a level of probability of 5%. According to this finding, a 1% rise in capital will lead to a 0.013 % rise in rice TFP. As commonly believed, farmers can increase production by accessing capital. With adequate financial resources, farmers can purchase high yielding varieties and invest in modern farming technologies such as mechanized farming and artificial irrigation equipment. This result supports a study conducted by Akinbode (2013) which found that farmers with credit access had higher rice productivity, supporting the economic sustainability of the enterprise. This study also aligns with Kea et al. (2016) research, which showed that the productivity of Cambodian rice production varied based on the level of capital investment in agricultural machinery and technical fertilizer application within provinces.

As seen in Table 6, there is a strong favorable influence of rainfall ($\beta = 0.813$; $p<1\%$) on rice TFP. Statistical evaluation indicated that a rise in annual rainfall by 1% would result in corresponding rise in rice TFP by 0.813%. This finding suggests that a rise in annual rainfall can potentially enhance rice TFP in Nigeria, as it is a crucial element in rice farming, both in rural areas and on commercial farms. The much-needed moisture from rainfall encourages the development of rice plants. This result corroborates with the study of Abbas and Mayo (2021), who stated that number of tillers increased with the positive impact of rainfall at the tillering stage. This research also supports that of Kunimitsu et al. (2014) and Rahman et al. (2017), who revealed that rainfall had a favorable effect on rice TFP. Hossain et al. (2013) also reported that rice production efficiency was positively impacted by rainfall. Also, according to Tiamiyu et al. (2015), rainfall was favorably correlated with rice productivity in Nigeria across all vegetation types with the exception of the Sudan savanna, albeit the correlation was not statistically significant at the 5% level. This result is also in line with that of Molla et al. (2020) who stated that rice productivity was positively and significantly correlated with annual rainfall amount. In contrast, a study by Letta and Tol (2019) showed that a negative relationship only existed in poor countries between rainfall and TFP growth rates by about 1.1–1.8 percentage points, whereas the impact was indistinguishable from zero in rich countries. Beding et al. (2021) also reported that rainfall gave a negative effect on rainfed lowland rice TFP. According to the study's findings, while rainfall positively affected rice output, it also had a potentially negative impact on rice TFP. This demonstrates that there are ideal rainfall amounts required for each stage of rice cultivation, which may be controlled by using artificial irrigation techniques.

A positive and statistically significant influence of sunlight duration on rice TFP was discovered by the study, with a coefficient of 6.873 and a p-value of less than 1%. More specifically, a percentage increase in sunlight hours would lead to an increase in rice TFP of 6.87%. This demonstrates how important sunlight is in the process of producing rice.

This result aligns with that of Danbaba et al. (2019), who highlighted the importance of sunshine not only during the growing and reproductive stages of rice, but also after harvesting. Many rice processors in Nigeria rely on sunshine to dry their harvested grains during processing, as inadequate sunshine can lead to spoilage and ultimately low TFP. This is particularly critical for early maturing rice varieties harvested during the rainy season, as drying is a key postharvest unit operation, as noted in the National Rice Development Strategies (JICA, 2013).

The primary objective of rice drying is to reduce the moisture content to safe levels for storage or milling without causing cracks or stresses on the rice kernel, which may lead to breakage during subsequent milling operations. In Nigeria, the energy for rice drying is mostly provided by direct sunlight, but the efficiency of sun drying depends heavily on weather conditions. Traditional drying methods in Nigeria include drying on bare ground, along highways, or on mats, as there are few mechanical paddy dryers available for farmers, and the cost of operating them is often prohibitively high, despite some development of drying equipment such as rotary dryers (Danbaba et al., 2019).

This finding also backs up the claim of Kingra (2016), who reported that an increase in average sunshine hours during the vegetative phase, reproductive phase, and the entire growth season of rice resulted in increased rice productivity. Specifically, the relationship between grain yield and sunlight hours was quite strong during the vegetative stage. As the reproductive stage progressed, a positive correlation was also observed, as sunshine hours helped determine grain weight and the percentage of filled grains. Similar findings were reported by Sandhu et al. (2013) in their study at Ludhiana, where they found a highly significant positive correlation ($p=0.05$) between rice productivity and sunshine hours. Sandhu et al. (2012) also reported similar results, where a reduction in sunshine hours till 90 days after transplanting in a low-yielding year (2010) resulted in a decrease in the average number of panicles m^{-2} by 2.69% and a reduced grain weight per panicle by 3.77% after heading. Additionally, Mahajan et al. (2009) found that higher numbers of panicles m^{-2} were produced during the tillering stage when more sunshine hours were received, resulting in higher grain yield.

The lagged error term (ECM(-2)) in Table 6 showed an ECM coefficient of -0.276. The negative sign indicated a short-term adjustment of the independent variables to the dependent variable. Furthermore, the ECM term showed that the model returned to equilibrium 28% of the disequilibrium brought on by external shocks or brief fluctuations from the preceding period.

Additionally, according to the results shown in Table 6, the F-statistics value of 8.782 was significant at a 1% level of probability. Accordingly, it is inferred that every independent variable in the model was statistically significant and taken together they all accounted for the dependent variable. Additionally, the Durbin-Watson test for autocorrelation had a value of 2.026, which fell within the acceptable range of 1.5 to 2.0, indicating that there was no autocorrelation present in the model.

Further work can be done in the near future to help explain various aspects which were outside the scope of this analysis and could, among other factors, relate to an investigation into the effect of technological change on TFP for rice, mainly regarding mechanization and modern irrigation methods. Such a study may complement the existing reliance on human labor with the use of technologies and reduce the challenge of the shortage in labor. Also, a comparison of different regions in Nigeria might consider varying ecological zones to provide more information on how these regional differences affect rice TFP. This would arguably allow for better targeting of interventions toward particular areas as a means of improving overall rice productivity within the country.

Table 6. Regression analysis

Dependent Variable: DTFP				
Method: Least Squares				
Date: 02/03/23 Time: 14:01				
Sample (adjusted): 1963 2020				
Included observations: 58 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLAND	-0.001	0.000	-1.611	0.114
DLABOR	0.066**	0.032	2.067	0.044
DCAPITAL	0.0126**	0.005	2.505	0.012
DRAINFALL	0.813***	0.130	6.232	0.000
DTEMPERATURE	21.67	30.817	0.703	0.485
DRELATIVE HUMIDITY	-8.564	6.403	-1.338	0.187
DSUNSHINE DURATION	6.873***	2.652	2.591	0.009
ECM(-2)	-0.276***	0.100	-2.760	0.007
C	-3.244	10.693	-0.303	0.762
R-squared	0.589	Mean dependent var		5.769
Adjusted R-squared	0.522	S.D. dependent var		101.219
S.E. of regression	69.977	Akaike info criterion		11.476
Sum squared resid	239943.600	Schwarz criterion		11.796
Log likelihood	-323.802	Hannan-Quinn criter.		11.600
F-statistic	8.782	Durbin-Watson stat		2.026
Prob(F-statistic)	0.000			

*** and ** significant at 1% and 5% respectively

3.4.5 Test of hypothesis

Labor (coefficient = 0.066; p<5%), capital (coefficient = 0.013; p<5%), rainfall (coefficient = 0.813; p<1%) and sunshine duration (coefficient = 6.873; p<5%) had statistically significant effect on TFP of rice. As a result, the null hypothesis, which claimed that neither rice input factors nor climate change variables had a discernible effect on the TFP of rice in Nigeria, is therefore rejected.

3.4.6 Serial correlation test

The Breusch-Godfrey Serial Correlation Lagrange Multiplier Test result is presented in Table 7. The outcome showed that the observed R-squared value (2.618; p>5%) and the F-statistic (1.206; p>5%) were not significant at 5% probability level. This finding suggests that there was not an issue with the model's serial correlation. The predictions made using the regression estimates were therefore accurate since the error components were not serially associated.

Table 7. Serial correlation test

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.206	Prob. F(2,51)	0.308
Obs*R-squared	2.618	Prob. Chi-Square(2)	0.270

3.4.7 Heteroskedasticity test

The study conducted a Breusch-Pagan-Godfrey Test for Heteroskedasticity on the error terms in the model, and the results are presented in Table 8 to ensure that it had constant variance. The findings indicated that both the F-statistic (1.824; p >5%) and the observed R-squared (7.020; p>5%) were not significant at a 5% level of probability. Thus, it was established that the model did not show heteroscedasticity.

Table 8. Test of Heteroskedasticity

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	1.824	Prob. F(4,53)	0.138
Obs*R-squared	7.020	Prob. Chi-Square(4)	0.135
Scaled explained SS	8.456	Prob. Chi-Square(4)	0.076

3.4.8 Normality test

Considering the results presented in Figure 2, it can be concluded that the Jarque-Bera statistics value of 1.364 did not reach statistical significance at the 5% level of probability. Therefore, it can be inferred that the residuals within the equation exhibited normal distribution characteristics.

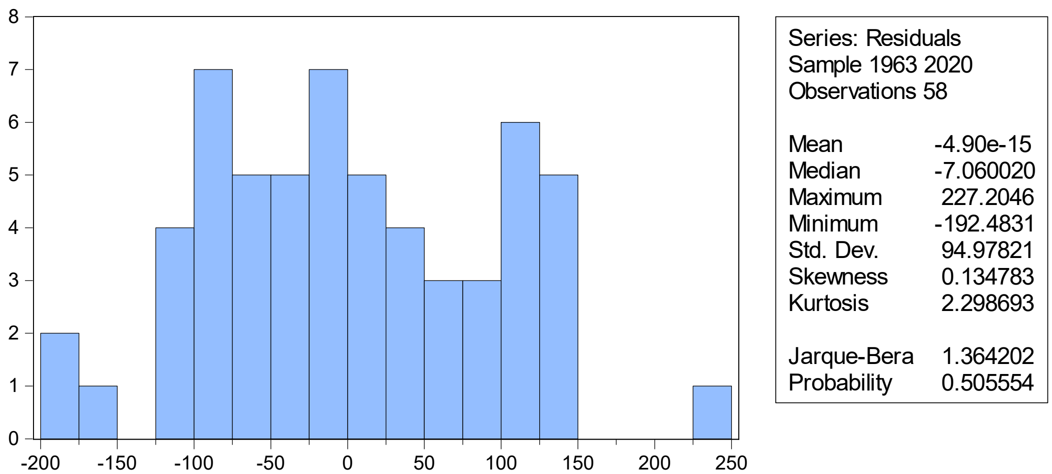

Figure 2. Normality test

3.4.9 Stability test

The appropriateness and stability of the model were assessed through a Cumulative Sum (CUSUM) test, as depicted in Figure 3. In the study, it was found that the CUSUM plot remained within the 5% critical bounds, indicating no structural instability in the model's parameters. Consequently, all the coefficients in the model were deemed stable.

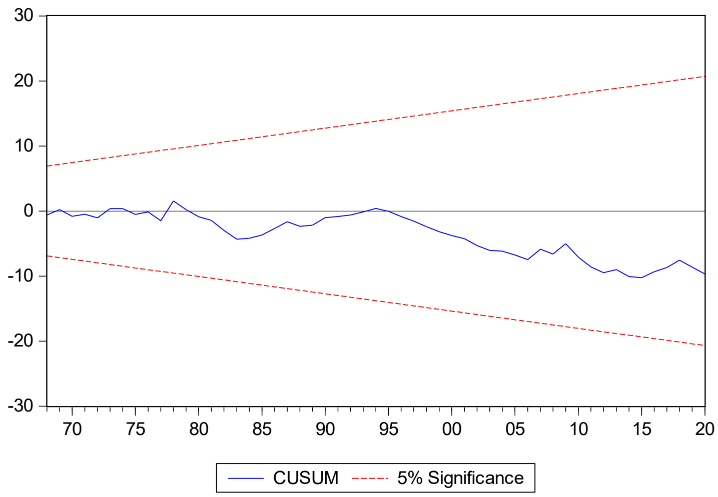

Figure 3. Stability test

4. Conclusions

The results of this research have shown a number of significant findings. The descriptive statistics highlighted the average values and trends across the research period, giving important insights into the variables under investigation. An overall favorable trajectory was found in the assessment of the TFP trend for rice farming in Nigeria, suggesting possible future increases in rice TFP. Significant findings were obtained from the regression analysis, which further examined the effects of several variables on rice TFP. The positive impacts of labor and capital on rice TFP were discovered, highlighting the need for a sufficient labor supply and availability of financial resources. The amount of rain and sunshine duration were also shown to be significant variables that positively affected rice TFP. On the basis of the study's findings, the following recommendations are made:

i. Given the significant positive impact of labor on rice TFP, efforts should be made to address labor scarcity issues in rice farming. Measures such as providing training and education to farmers, promoting mechanized farming techniques, and implementing policies to attract and retain labor in rural areas can help alleviate this challenge.

ii. Recognizing the favorable effect of capital on rice TFP, policymakers should prioritize facilitating access to financial resources for rice farmers. This can be achieved through the provision of affordable credit facilities, agricultural loans, and other financial support mechanisms. Encouraging partnerships between financial institutions and rice farmers' associations can also contribute to improving capital access.

iii. Considering the significant positive impact of rainfall on rice TFP, strategies for efficient water management should be adopted. This includes promoting irrigation techniques such as artificial irrigation systems to ensure a consistent water supply for rice cultivation. Additionally, implementing measures to capture and store rainwater can help mitigate the negative effects of water scarcity during dry periods.

iv. Based on the favorable influence of sunlight duration on rice TFP, efforts should be made to maximize its utilization. Promoting post-harvest technologies that optimize rice drying processes, such as the use of mechanical paddy dryers, can reduce reliance on direct sunlight for drying and enhance efficiency. Moreover, exploring innovative approaches for solar-powered drying systems can be beneficial in areas where access to electricity is limited.

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6. Conflicts of Interest

The authors declare no conflict of interest.

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