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Effect of Climate Change on Total Factor Productivity of Rice in Nigeria

Oyita, G. E.
Department of Agricultural Economics and Agribusiness, Faculty of Agriculture, Dennis Osadebay University, Anwai, Asaba

ABSTRACT
This study examined the effect of climate change variables on rice Total Factor Productivity (TFP) in Nigeria. Data for this study such as the mean annual temperature, mean annual rainfall, mean annual relative humidity, sunshine duration, land area, labour, capital and rice output from 1961 to 2020 were collected from various sources such as Nigeria Meteorological Agency (NIMET), World Bank online statistical depository, United Nations online database, United States Department of Agriculture Economic Research Service (USDA ERS 2022), Food and Agriculture Organisation Corporate Statistical Database (FAOSTAT 2022) and National Rice Development Strategy (NRDS 2020). Data were analysed using descriptive and inferential statistics. Specifically in this study, it was established that although there is a positive trend in rice TFP in Nigeria over the years, the average rice TFP (0.953) is regressive (i.e., less than 1). Rainfall (coefficient = 0.841; p<1%) had a positive significant effect on rice TFP in Nigeria. Based on the findings of this study, it therefore recommends that since rice TFP was regressive, rice farmers should employ the services of agricultural production economists for effective and efficient allocation of resources in order to boost their level of rice productivity.

Keywords: Climate change, Nigeria, Rice, Rainfall, Total Factor Productivity

1.0 Introduction

Climate change, a worldwide environmental problem is negatively affecting sustainable development across the globe (Emaziye, Okoh & Ike, 2013; Gbigbi & Ikechukwuka, 2020). As the research concerning global climate change has moved along in recent years, a number of prior studies have found that climate change is expected to affect agricultural production in various regions (Nelson, Valin, Sands, Havlík, Ahammad, Deryng & Kyle, 2014; Burke & Emerick, 2016; Altieri & Nicholls, 2017; Ding, 2019). This is in no doubt what the Sustainable Development Goals (SDGs) number 2 and 13 of the United Nations are focused on. These SDG goals focus on ending hunger, achieving food security and improving nutrition and promoting sustainable agriculture and taking urgent action to combat climate change and its impacts (SDG, 2022).

A study by Anyaoha, Uba, Onotugoma, Mande, Gracen and Ikenna (2019) has shown that rice (*Oryza sativa*) can be used to offset the major impacts of climate change on agriculture and has become a food security crop due to its increased significance in the country. This is because of its potentials and unique properties as a food crop for urban poor and rural rice-growing populations. Rice is a major cereal in Nigeria in terms of its output and land area. The crop is currently grown in more than 70% of the states in the country (Familusi & Oranu, 2020). About 6 million hectares of land are available for rice production. Only 3.2 million hectares were used for rice production, producing about 3.7 million tons of rice per year (Anyaoha *et al*., 2019). Total demand for rice in 2018 was about 6.4 million tons (United States Department of Agriculture USDA, 2018). Domestic production of rice is only able to cover about 57.8 percent of the national demand for rice.

The main issues with rice production, according to Ajetomobi, Abiodun, and Hassan (2011) and Familusi and Oranu (2020), are drought, flooding, salt stress, and severe temperatures. All of these issues are anticipated to get worse with climate change. Unfavourable growing conditions will be introduced into the cropping calendars as a result of significant changes in rainfall patterns and temperature increases, which will disrupt the growing seasons and perhaps lower crop output. Apart from the climatic variables, rice total factor productivity (TFP) which is the proportion of rice output in relation to input usage in production is a fundamental issue of rice production (Fuglie, 2015). Rice TFP is not only a significant factor affecting rice production growth, but it also plays a crucial role in promoting its steady expansion and sustaining increases in rural incomes (Baldos & Hertel, 2014; Yao & Liu, 2016).

Numerous studies have shown that the most effective way to drive agricultural economic development is to improve its TFP growth in various regions (Awokuse & Xie, 2015; Ding, Dang, Xu, Wang & Xu, 2018), and thus, there is growing concern from academia about studying regional TFP and the corresponding policy issues. Especially with continuous worsening for the problems of global warming, the negative effects from global climate change on TFP have already emerged (Bai, Chen & Huo, 2015; Yin, Li & Fan, 2016). This study aims to achieve a critically balanced assessment of the cyclical effect of climatic factors on rice total factor productivity in Nigeria. The specific objectives are to;

i. describe the trend of TFP of rice in Nigeria from 1961 to 2020; and
ii. examine the effect of climate change variables on TFP of rice in Nigeria.

The null hypothesis of this study is stated as follows;

$H_{01:}$ There is no significant effect of climate change on TFP of rice in Nigeria.

2.0 Methodology

Study Area

The Federal Republic of Nigeria is the study area. Nigeria is a country in West Africa. From a geological perspective, it occupies an area of 923,768 square kilometers between latitudes of 40 and 14'N and longitudes of 20 and 140'E. Nigeria is bordered to the north by the Niger Republic, to the west by the Benin Republic, to the east by Chad and Cameroon, and to the south by the Gulf of Guinea (Atlantic Ocean). Organizationally, the country is split into 36 States, with Abuja serving as the Federal Capital territory. As of the end of 2020, there were 206,139,587 people living there (datacatalog.worldbank.org). The country is endowed with an abundance of land, resources, and labour.

Data Collection

Data for this study such as the mean annual temperature, mean annual rainfall, mean annual relative humidity and sunshine duration from 1961 to 2020 were collected from the Nigeria Meteorological Agency (NIMET), World Bank online statistical depository and the United Nations online database. Rice input and output data from 1961 to 2020 were collected from the United States Department of Agriculture Economic Research Service (USDA ERS, 2022), Food and Agriculture Organisation Corporate Statistical Database (FAOSTAT, 2022) and National Rice Development Strategy (NRDS, 2020).

Data Analysis

Data were analysed using descriptive and inferential statistics. The TFP index of rice was generated using the Malmquist Data Envelopment Analysis (DEA) software version 2.0. Test for stationarity, causality, cointegration, serial correlation, heteroscedasticity, normality and stability were carried out using the E-views software version 10.

Description of Variables

The variables used in this study are briefly described in Table 1.

Table 1: Description of variables

Variable name	Description	Unit	*Apriori* expectation
Dependent variables			
TFP	Total Factor Productivity of rice		
Output	Total annual rice output	Metric tonnes	
Independent variables			
Land	Total area of land for rice production	Hectares	+
Labour	Number of persons involved in rice production	Persons	+
Capital	Amount of total capital stock for fertilizer, chemicals, machineries etc.	Nigerian naira ($1USD = ₦460)	+
ARain	Annual rainfall	Millimeters (mm)	+
ATemp	Annual temperature	Degree Celsius (°C)	+
ARHumi	Annual relative humidity	Percentage (%)	+
ASSD	Annual sunshine duration	Hours	+

Source: Author's computation (2023)

Empirical Models

Rice Total Factor Productivity (Malmquist Productivity Index): The Malmquist Productivity Index for rice TFP in this study was generated using the Data Envelopment Analysis (DEA) software 2.0. Land, Labour and Capital were used as the input variables while rice production in metric tonnes was used as the output variable.

Enlightened by research on consumption index by Swedish economist Malmquist, Caves, Christensen and Diewert (1982) constructed Malmquist productivity index (Malmquist index, in short), but without further study on how to measure the distance function. The index was widely used since Fare *et al*. (2016) merged Data Envelopment Analysis (DEA) with nonparametric linear programming. As was already noted, the Malmquist index divides TFP into Technical Change (TC) and Technical Efficiency Change (EC) based on the constant return to scale (CRS) assumption. It also accounts for technological inefficiency. EC can be further subdivided into pure technical efficiency change (PE) and scale efficiency change (SE) if returns to scale are variable. Assuming that there are k decision-making units (DMU), where k = 1, 2, . . ., K, the input and output vectors of each period are $x^{k,t} = (x_1^{k,t}, x_2^{k,t}, \dots, x_N^{k,t}) \in R_+^N$ and
$y^{k,t} = (y_1^{k,t}, y_2^{k,t}, \dots, y_N^{k,t}) \in R_+^M$ respectively, where t = 1, 2, . . ., T. Therefore, the input-oriented Malmquist index can be expressed as (1) under the CRS assumption.

$$M_i^k(x^{k,t+1}, y^{k,t+1}, x^{k,t}, y^{k,t})$$
$$= \frac{D_i^{k,t+1}(x^{k,t+1}, y^{k,t+1})}{D_i^{k,t}(x^{k,t}, y^{k,t})} X \left[\frac{D_i^{k,t}(x^{k,t+1}, y^{k,t+1})}{D_i^{k,t+1}(x^{k,t+1}, y^{k,t+1})} X \frac{D_i^{k,t}(x^{k,t}, y^{k,t})}{D_i^{k,t+1}(x^{k,t}, y^{k,t})}\right]^{\frac{1}{2}}$$
$$= EC_i^k XTC_i^k = PE_i^k XSE_i^k XTC_i^k \quad \dots (1)$$

$\frac{D_i^{k,t}(x^{k,t+1}, y^{k,t+1})}{D_i^{k,t+1}(x^{k,t+1}, y^{k,t+1})}$ in (1) measures the EC of DMU k from period t to t + 1, indicating the impact of EC on TFP for a corresponding period, and EC can be further divided into PE and SE. The section in the square bracket measures TC of DMU k from period t to t + 1, which indicates the impact of advancement of production technology frontiers on TFP for a corresponding period.

Rice production in Nigeria as an independent DMU and create the optimal frontier of rice production in the country for periods under the same technical conditions. It is followed by a comparison of the relationship between the coordinates of rice production point of each DMU and the position of the optimal frontier.

The technical efficiency of a DMU is at the highest level if the rice production point of the DMU is just on the frontier, and if the point is within the frontier, then the DMU is characterized by technical inefficiency. Meanwhile, with the time factor taken into consideration as mentioned earlier, the rice production point of a DMU can be compared with the mapping point of the optimal frontier and thus decompose rice TFP into TC and EC. Therefore, if TC = 1 for a DMU, this means there is no technical change or innovation for the DMU from t to t + 1, whereas TC > 1 (or TC < 1) indicates technical progress (or setback). Similarly, EC > 1 (EC < 1) implies there is technical efficiency gain (loss) for the DMU from t to t + 1. Likewise, M= 1 indicates that rice TFP in the DMU from t to t + 1 stays unchanged; M> 1 (M< 1) denotes an increase (decline) of rice TFP.

Unit root test

Augmented Dickey-Fuller (ADF) was used to ascertain whether or not the series are stationary. The testing procedure for the ADF is stated as follows:

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

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 value test statistic was compared with the pertinent critical value for the ADF_t. If the statistics is greater (in absolute value) than the critical value at 5% or 1% level of significance, then the null hypothesis of μ≠0 would not be accepted and no unit root is present. Once this is established, the test for co-integration was carried out.

Test for co-integration

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

$$\Delta TFP_t = \beta_0 + \beta_1 ARAINFALL_{t-1} + \beta_2 ATEMP_{t-1} + \beta_3 ARH_{t-1} + \beta_4 ASSD_{t-1} + U_t \dots \dots (3)$$

Where;
TFP_t, = Total Factor Productivity of rice
$ARAINFALL_t$ = Average annual rainfall for each year measured in millimeters (mm).
$ATEMP_t$ = Average annual atmospheric temperature (°C)
ARH_t = Average annual relative humidity measured in percentage (%)
$ASSD_t$ = Average annual sunshine duration (hours)
β_0 refer to intercepts; β_1 to β_n are parameters to be estimated U_t is random term while t denotes the year.

Effect of climate change variables on TFP of rice in Nigeria
The model is expressed in implicit form as shown in equation below:

$$TFP_t = f(ARAINFALL_t, ATEMP_t, ARH_t, ASSD_t, U) \dots \dots (4)$$

The functional form is expressed in the explicit form as:

$$TFP_t = \beta_0 + \beta_1 ARAINFALL_t + \beta_2 ATEMP_t + \beta_3 ARHUMI_t + \beta_4 ASSD_t + U_t \dots \dots (5)$$

Where;
TFP_t, = Total Factor Productivity of rice
$ARAINFALL_t$ = Average annual rainfall for each year measured in millimetres (mm).
$ATEMP_t$ = Average annual atmospheric temperature (°C)
ARH_t = Average annual relative humidity measured in percentage (%)
$ASSD_t$ = Average annual sunshine duration (hours)
β_0 refer to intercepts; β_1 to β_n are parameters to be estimated U_t is random term while t denotes the year.

3.0 Results and Discussions

Descriptive Statistics
The descriptive statistics of the variables in this study is presented in Table 2. The result revealed that the mean value of Rice TFP was 0.953. This result indicates that the average TFP of rice for the period under review was regressive because it is less than 1. The mean value of rice output was 2,655,720 tonnes. The result showed that rainfall, temperature, relative humidity and sunshine duration had mean vales of 1,151.293mm, 27.053°C, 57.598% and 6.208 hours respectively. furthermore, the result of the mean showed that average labour force was 15,960 persons, average area of land used for rice was 1,331,275 hectares and average capital stock was ₦4.5 billion.
The result of the kurtosis of a distribution which measures the peakness (the tallness or flatness) of the series revealed that rice TFP and rice output had kurtosis values of 8.947 and 3.245 respectively. The climate change variable such as rainfall, temperature, relative humidity and sunshine duration had kurtosis values of 2.299, 3.419, 3.028 and 3.243 respectively. This result implies that only relative humidity was mesokurtic and had a normal distribution with kurtosis of 3. Also, all the other variables in the study were leptokurtic which implies that these values had positive kurtosis (peaked-curve or more higher values).
The result of the Jarque-Bera test statistics which measures the difference of the skewness and kurtosis of the series with those from the normal distribution revealed that rice TFP (Jarque-Bera 141.691; P-value <5%) and rice output (Jarque-Bera 9.329; P-value <5%) had abnormal distribution. On the other hand, 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%), labour (Jarque-Bera 5.493; P-value >5%) and capital (Jarque-Bera 2.926; P-value >5%) had normal distributions.

Table 2: Descriptive statistics

Statistics	Rice TFP	Rice Output	Mean annual temperature	Mean annual relative humidity	Mean annual rainfall	Sunshine duration	Land area	Labour	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

Source: Author's computation (2023)

Unit Root Test

The econometric approach is, first, to test for the time series properties of the variables using Augmented Dickey-Fuller (ADF) unit root test. The unit root test result presented in Table 3 shows that all the variables are integrated of orders 1 (first difference).

Table 3: 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)
Labour	1.131	0.997	-6.250	0.000	I(1)
Capital	2.346	1.000	-8.586	0.000	I(1)

Source: Author's computation (2023)

Trend of TFP of Rice in Nigeria from 1961 to 2020

The result in figure 1 shows the trend of rice TFP in Nigeria from 1961 to 2020. The study showed that TFP of rice in Nigeria for the period under review has a positive slope. The regression equation stated as:

RTFP = – 3.286 + 0.002*t + ei…………………………………………………………………….(6)

Where;

RTFP = Rice Total Factor Productivity

t = time (year)

ei = error term

This equation suggests that a percentage change in year will lead to 0.002% change in rice TFP in Nigeria. The result from the study further revealed that rice TFP had a value of 0.718 in the year 1961 before hitting its lowest value of 0.702 in the year 1962. TFP of rice increased to 1.026 in the year 1978 but thereafter experienced a fluctuating trend till it got to its highest peak of 1.054 in the year 2009. This fluctuation continued further till the year 2020. The result of the forecast also suggested an upward trend of rice TFP in Nigeria from 2021 to 2030. This result implies that if the combination of input in rice production and climatic variables are sustained or improved on, this will lead to rice TFP growth in the year 2030. This result is in line with that of Adedeji and Owolabi (2016) who reported that the trend of rice TFP witnessed an overall positive trend over time for the sampled states in Nigeria.

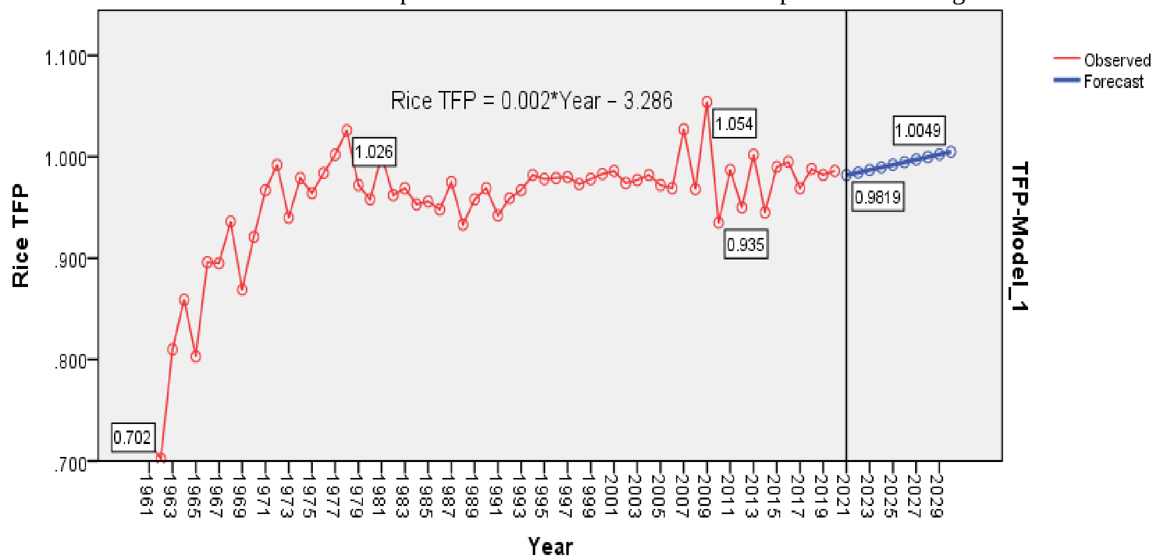

Figure 1: Trend of TFP of Rice in Nigeria from 1961 to 2020

Effect of Climate Change Variables on TFP of Rice in Nigeria

Lag Order Selection Criteria

The result in Table 4 shows the lag order selected by the criterion. The lag order selected for this model was lag 2. This is because most of the lag selection criteria were significant at 5% level of probability at lag 2.

Table 4: Lag Order Selection Criteria

VAR Lag Order Selection Criteria

Endogenous variables: DTFP DRAINFALL DTEMPERATURE DRELATIVE HUMIDITY DSUNSHINE DURATION
Exogenous variables: C
Date: 02/01/23 Time: 00:19
Sample: 1961 2020
Included observations: 56

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-869.806	NA	25487495	31.243	31.424*	31.313
1	-833.406	64.999	17033246	30.836	31.921	31.257
2	-791.163	67.890*	9403552.*	30.220*	32.209	30.991*
3	-769.354	31.155	11145052	30.334	33.227	31.456

* 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)

Cointegration Test

The cointegration test for the effect of rice input variables on rice TFP in Nigeria is presented in Table 5. It was revealed that both unrestricted trace co-integrating rank test and unrestricted max-eigen cointegrating rank test confirmed the presence of co-integrating equation. Hence, there is a long run relationship between the dependent variable (rice TFP) and the independent variables (rainfall, temperature, relative humidity and sunshine duration).

Table 5: Cointegration Test

Date: 02/01/23 Time: 00:20
Sample (adjusted): 1964 2020
Included observations: 57 after adjustments
Trend assumption: Linear deterministic trend
Series: DTFP DRAINFALL DTEMPERATURE DRELATIVE HUMIDITY 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	Prob.**
None *	0.799	304.923	69.819	0.000
At most 1 *	0.747	213.499	47.856	0.000
At most 2 *	0.639	135.232	29.797	0.000
At most 3 *	0.524	77.115	15.495	0.000
At most 4 *	0.457	34.803	3.841	0.000

Trace test indicates 5 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.799	91.424	33.877	0.000
At most 1 *	0.747	78.267	27.584	0.000
At most 2 *	0.639	58.117	21.132	0.000
At most 3 *	0.524	42.311	14.264	0.000
At most 4 *	0.457	34.804	3.841	0.000

* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Source: Author's computation (2023)

Pairwise Granger Causality Tests

The result of the pairwise granger causality tests for effect of climate change variables on TFP of rice in Nigeria is presented in Table 6. This result rejects the null hypotheses that rainfall does not granger cause rice TFP (F-stat. 0.621; p-value >5%) and rice TFP does not granger cause rainfall (F-stat. 0.944; p-value >5%). The study makes a case of bidirectional relationship arguing that rainfall influences rice TFP and rice TFP granger cause rainfall for the period under review. This study rejects the null hypothesis that temperature does not granger cause rice TFP (F-stat. 2.204; p-value >5%) and accepts the null hypothesis that rice TFP does not granger cause temperature (F-stat. 3.941; P-value <5%). The study makes a case of unidirectional relationship arguing that temperature influences rice TFP for the period under review.

Also, the study rejects the null hypothesis that relative humidity does not granger cause rice TFP (F-stat. 0.524; P-value >5%) and that rice TFP does not granger cause relative humidity (F-stat. 0.960; P-value >5%). Thus, the study makes a case of bidirectional relationship arguing that relative humidity influences rice TFP and vice-visa for the period under review. This study also rejects the null hypothesis that sunshine duration does not granger cause rice TFP (F-stat. 1.973; P-value >5%) and that rice TFP does not granger cause sunshine duration (F-stat. 0.676; P-value >5%). The study makes a case of bidirectional relationship arguing that sunshine duration influences rice output and vice-visa for the period under review.

Table 6: Pairwise Granger Causality Tests

Pairwise Granger Causality Tests
Date: 02/01/23 Time: 00:20
Sample: 1963 2020
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
DRAINFALL does not Granger Cause DTFP	59	0.621	0.650
DTFP does not Granger Cause DRAINFALL		0.944	0.447
DTEMPERATURE does not Granger Cause DTFP	59	2.204	0.083
DTFP does not Granger Cause DTEMPERATURE		3.942	0.041**
DRELATIVE HUMIDITY does not Granger Cause DTFP	59	0.524	0.718
DTFP does not Granger Cause DRELATIVE HUMIDITY		0.960	0.521
DSUNSHINE DURATION does not Granger Cause DTFP	59	1.973	0.114
DTFP does not Granger Cause DSUNSHINE DURATION		0.676	0.612

** significant at 5%
Source: Author's computation (2023)

Regression Model

The result of the regression analysis for the effect of climate change variables on rice TFP in Nigeria in is presented in Table 7. The result reveals that the R^2 of 0.568 (57%) which shows the extent to which the climate change variables predict rice TFP was 57%. The adjusted R^2 of 0.527 shows that 53% of the variance in the rice TFP was accounted for by climate change variables.

From the result in Table 7 it could be seen that rainfall (coefficient = 0.841; p<1%) had a positive influence on rice TFP and was statistically significant at 1% level of probability. The statistics suggest that a percentage increase in rainfall will increase rice TFP by 0.841%. This means that any increase in rainfall will or can cause an increase in rice TFP in Nigeria. This might be due to the fact that rainfall is a key factor of production in rural areas and on most commercial farms. It provides the much-needed moisture that stimulates the growth of rice plants. Result from the study of Abbas and Mayo (2021) revealed that number of tillers and rice plant diet increase with the positive impact of rainfall at tillering stage. Furthermore, this study supports that of Kunimitsu, Iizumi and Yokozawa (2014) and Rahman, Kang, Nagabhatla and Macnee (2017) who revealed that rainfall had a positive impact on rice TFP. Hossain, Kamil, Masron and Baten (2013) also reported that rainfall has a positive impact on rice production efficiency. Tiamiyu *et al*. (2015) reported that rainfall was positively related to productivity of rice in Nigeria in all vegetation grouping except Sudan savanna but relationship was not statistically significant at 5% level. This result was 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) shows that a negative relationship only exists in poor countries between climate change and TFP growth rates by about 1.1–1.8 percentage points, whereas the impact is indistinguishable from zero in rich countries. Beding, Palobo, Tiro, Lestari and Rumbarar (2021) also reported that rainfall gave a negative effect on rainfed lowland rice TFP. This result suggests that although rainfall had a positive effect on rice TFP, it could at the same time have a negative effect on rice TFP. This implies that there are optimum levels of rainfall requirements for every stage of rice production. These optimum levels can be controlled through the application of artificial irrigation techniques.

The ECM coefficient of -0.325 indicates that ECM(-2) is well specified and the diagnostic statistics are good. The negative sign shows the short run adjustment of the independent variables to the dependent variable. The ECM term also shows a 32% speed of adjustment towards equilibrium. This implies that 32% of disequilibrium caused by exogenous shocks or short run fluctuations in the previous period is corrected in the current year.

The result of the F-statistics as shown in Table 7 further reveals that the F-statistics value of 11.167 was significant at 1% level of probability. This implies that all the independent variables in the model jointly explained the dependent variable and was statistically significant. The Durbin-Watson test for autocorrelation had a value of 2.029 which lies within the range of 1.5 to 2.0. Thus, there was no case of autocorrelation in the model.

Test of hypothesis: Rainfall (coefficient = 0.811; p<1%) was statistically significant in the model. Therefore, the null hypothesis which states that there is no significant effect of climate change variables on TFP of rice in Nigeria is hereby rejected.

Table 7: Regression Model

Dependent Variable: DTFP
Method: Least Squares
Date: 02/01/23 Time: 00:31
Sample (adjusted): 1964 2020
Included observations: 57 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DRAINFALL	0.811***	0.133	6.107	0.000
DTEMPERATURE	16.630	31.995	0.520	0.606
DRELATIVE HUMIDITY	-11.238	6.717	-1.673	0.100
DSUNSHINE DURATION	6.565	7.142	0.919	0.362
ECM(-2)	-0.322**	0.132	-2.436	0.018
C	7.089	9.797	0.724	0.472
R-squared	0.523	Mean dependent var		5.674
Adjusted R-squared	0.476	S.D. dependent var		102.117
S.E. of regression	73.932	Akaike info criterion		11.543
Sum squared resid	278762.400	Schwarz criterion		11.759
Log likelihood	-322.989	Hannan-Quinn criter.		11.627
F-statistic	11.167	Durbin-Watson stat		2.029
Prob(F-statistic)	0.000			

*** and ** significant at 1% and 5% level of probability respectively
Source: Author's computation (2023)

Serial Correlation Test

The result in Table 8 shows the Breusch-Godfrey Serial Correlation LM Test. The result revealed that the F-statistic (1.378; p >5%) and the observed R-squared (0.646; p>5%) were not statistically significant at 5% level of probability. This result therefore implies that there is no serial correlation problem in the model. Therefore, the error terms are not serially correlated and the predictions based on the regression estimates are thus efficient.

Table 8: Serial Correlation Test

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.378	Prob. F(2,51)	0.118
Obs*R-squared	0.646	Prob. Chi-Square(2)	0.313

Source: Author's computation (2023)

Heteroskedasticity Test

The Breusch-Pagan-Godfrey Test for Heteroskedasticity as shown in Table 9 was carried out to check if the error term in the model exhibits constant variance. The result from the study revealed that the F-statistic (2.097; p>5%) and the observed R-squared (9.745; p>5%) were not statistically significant at 5% level of probability. Thus, the violation of the assumption that there is presence of heteroscedasticity in the model. This further suggests that the regression result is valid.

Table 9: Heteroskedasticity Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	2.097	Prob. F(5,53)	0.080
Obs*R-squared	9.745	Prob. Chi-Square(5)	0.083
Scaled explained SS	9.433	Prob. Chi-Square(5)	0.093

Source: Author's computation (2023)

Jarque-Bera Normality Test

The result in figure 2 shows that the Jarque-Bera statistics of 2.986 was not significant at 5% level of probability thus its therefore agreed that the residuals in the equation are normally distributed.

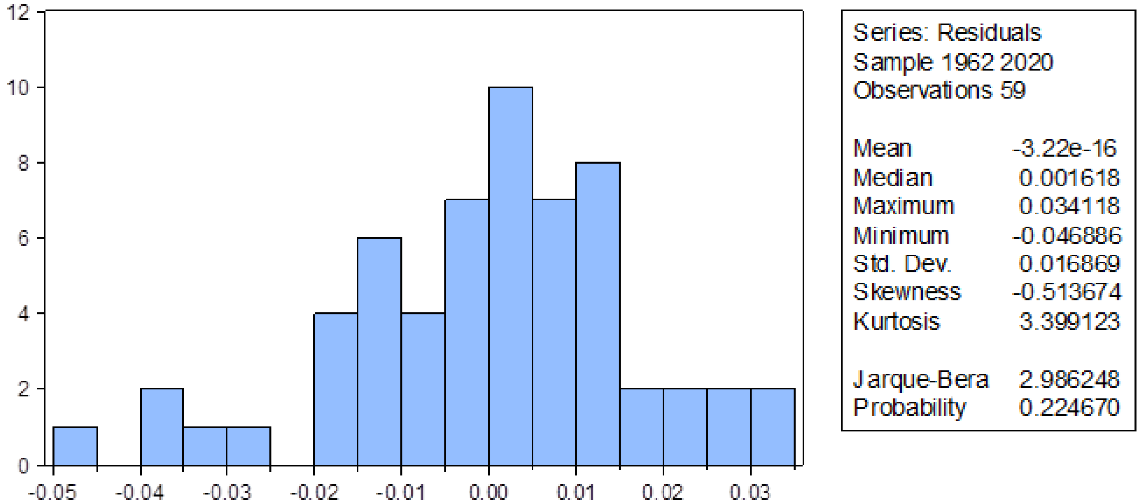

Figure 2 Jarque-Bera Normality Test for the Effect of Climate Change Variables on TFP of Rice in Nigeria

CUSUM stability test

The result in figure 3 shows the Cumulative Sum (CUSUM) test which was performed to determine the appropriateness and stability of the model. The result from the study revealed that the plot of the CUSUM stayed within the 5% critical bounds which implies that the parameters of the model do not suffer from any structural instability. Thus, all the coefficients in the model are stable.

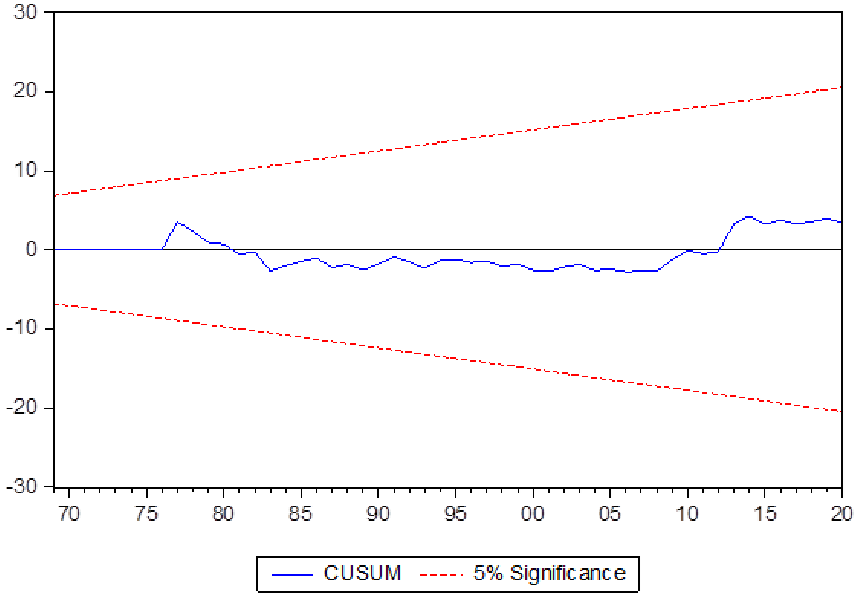

Figure 3 CUSUM stability test for the Effect of Climate Change Variables on TFP of Rice in Nigeria

4.0 Conclusion and Recommendations

This study critically examined the effects of climate change variables on rice TFP in Nigeria. Specifically in this study, it was established that although there is a positive trend in rice TFP in Nigeria over the years, the average rice TFP is regressive (i.e., less than 1). Rainfall had a significant positive effect on rice TFP but other literatures indicated a negative effect. This in others words suggests that there are optimal water requirement levels for rice productivity which could be controlled through artificial irrigation. The study therefore recommends that since TFP of rice was regressive, rice farmers should employ the services of agricultural production economists for effective allocation of resources in order to boost their level of rice productivity. Also, there is need for rice farmers to adopt artificial irrigation in order to mitigate the effect of climate change for optimum rice productivity.

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