Cross Current International Journal of Economics, Management and Media Studies
Abbreviated Key Title: Cross Current Int J Econ Manag Media Stud
ISSN: 2663-2462 (Print) & Open Access
DOI: 10.36344/ccijemms.2020.v02i09.001

OPEN ACCESS

Volume-2 | Issue-9|November, 2020 |

Research Article

A Time-Series Analysis of the Impact of Population Growth and Climate Change on Food Security in Nigeria

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| **Received:** 06.10.2020 | **Accepted:** 20.10.2020 | **Published:** 07.11.2020 |

Abstract: Food production in Nigeria has not kept pace with rapid population growth resulting in declining levels of national food self-sufficiency. Consequently, Nigeria faces severe food security challenges. This paper, therefore, analyzed the effects of population growth and climate change on food security in Nigeria. Specifically, the study examined the effects of population growth, mean annual rainfall, mean annual temperature, and rate of urbanization on food security (proxied by food production index) in Nigeria; Annual time-series on the above variables from 1984 to 2018 were used. The data were obtained from secondary sources. The study applied Augmented Dickey-Fuller (ADF) unit root test, Johansen cointegration test and Error Correction Mechanism (ECM) on the data. The results of data estimation indicated that population growth has a negative impact on food security while climate change (in terms of rainfall and temperature) has significant adverse effects on food security in Nigeria. The paper recommends among other things, a set of climate change adaptation and mitigation measures to improve the food security situation in the country.
Keywords: Climate Change, Food Security, Population Growth, Rainfall, Temperature.

INTRODUCTION

Before independence in 1960, and up to the first post-colonial decade, Nigeria was mainly an agrarian economy. Thus, the country was self-sufficient in terms of meeting up the domestic food demand. The country was also able to produce cash crops like cotton, rubber, cocoa, groundnut, palm produce, etc for exports [1].

With the discovery of crude oil in 1956, and consequently, the oil boom of the mid-1970s, the once vibrant agricultural sector was neglected. This shift from agriculture to the oil-based economy aggravated the woes of the sector and with it, the food crisis began in Nigeria. Thus, the agricultural sector was no longer able to produce enough food to feed the country's rising population; To augment the domestic food production, the country resorted to food importation with huge foreign exchange spent yearly. Thus, Nigeria has fallen from a net exporter of food to a net importer of food [1, 2].

It is crystal clear that Nigeria faces severe food security challenges today. Food production has not been able to keep pace with population growth. This has resulted in declining levels of national food self-sufficiently [3]. Experts have argued that significant food and nutrition problems exist in Nigeria [4, 5]. Some estimates put the number of hungry people in Nigeria at over 83 million of the country's population. Some analysts have also suggested that 52% of the population lives below the poverty line, and therefore lacks access to food and basic nutrition [6].

Over the years, different governments in Nigeria have introduced several programmes to help tackle the food crisis in the country [1, 7]. Despite these efforts to address the problem of hunger in the country, no serious steps have been taken to consolidate on the little successes achieved so far [8]. Thus, the food crisis in the country keeps deteriorating.

Nigeria has a huge potential to attain food security given her abundant natural and human resources. Despite this, the country is not able to feed its citizens due to several problems militating against the productivity of the agricultural sector [1]. Prominent among these are the problems of rapid population growth and climate change. Rapid population growth remains one of the major challenges to foods security in the country. Although agricultural productivity has risen, it has been outpaced by population growth. In fact, according to the United Nations, there will be 440 million Nigerians by 2050 [19]. This implies that there will be more mouths to feed in the country. Thus, if food production is not increased at a faster rate than the population growth rate, there is bound to be a severe food crisis in the coming years. Similarly, climate

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change leads to intense drought in dry areas and severe flooding in wetter regions. The implications of this include a reduction in the land available for purposeful food production, high cost of land acquisition, destruction of crops and consequently, a decline in food production [6].

It is against this backdrop that this study is designed. This study, therefore, examines the impact of population growth and climate change on food security in Nigeria. In specific terms, the study investigates the impact of population growth rate, mean annual rainfall, mean annual temperature, and urbanization rate on food security (proxied by food production index) in Nigeria. Urbanization rate was introduced as a control variable. The rest of the paper is organized into four sections as follows; section two covers literature review; section three focuses on methodology; section four deals with data analysis and discussion of results while section five is concerned with conclusions and policy recommendations.

LITERATURE REVIEW

Conceptual Clarifications

Basic Concepts of Population

Population in economic parlance can be seen as the number of people living in a geographical area at a particular time [2]. Gee [10] defines population growth as the increase or change in the size of the population due to natural increases (i.e, the difference between birth rate and death rate). Thus, the growth rate of the population is measured as the natural increase in the population after adjusting for immigration and emigration.

The Concept of Food Security

The United Nations' Food and Agricultural Organization [11] defines food security as "when all people at all times have physical and economic access to sufficient, safe and nutritious food for a healthy and active life". Similarly, the World Food Summit [12] cited in Bajagai [13] defines food security as "when all people at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". Bajagai [13] identifies four dimensions of food security as follows:

i. Food Availability: This addresses the supply side of food security and expects sufficient quantities of quality food from domestic agricultural production or import.
ii. Food Access: This dimension embraces income, expenditure and food buying capacity of households and individuals. In other words, food access addresses whether households or individuals have enough resources to acquire appropriate quantities of quality food.
iii. Food Utilization: This addresses not only how much food people eat but also what and how they eat. It also covers the food preparation, intra-household food distribution, water and sanitation and health care practices.
iv. Food Stability: This dimension addresses the stability of the other three dimensions over time. People cannot, therefore, be considered food secured until there is the stability of availability, accessibility, and proper utilization conditions [13].

The Concept of Climate Change

The United Nations' Framework Convention on Climate Change (UNFCCC)[14] defines climate change as "… the change that can be attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods". Similarly, the Inter-governmental Panel on Climate Change (IPPC) [15] defines climate change as "… a change in the state of the climate that can be identified by changes in the mean and/ or the variability of its properties, and that persists for an extended period typically decades or longer'.

Theoretical Framework

The theoretical basis for this study is the Malthusian population theory. In 1798, the Reverend Thomas Malthus published his population thesis titled, "An Essay on the Principle of Population." Malthus in his theory postulated that population tended to outgrow the means of subsistence. He argued that while population increased in a geometrical progression (e.g 2,4,8,16, 32…) food production increased only in an arithmetical progression (e.g 2,4,6,8,12…). He, therefore, argued that in due course there would be a shortage of food supplies leading to a fall in the standard of living, poverty and misery [16]. The theory was based on the law of diminishing returns which agricultural land is subject to. He argued that output from farmland decreases as more and more of the poor quality lands are cultivated as a result of higher population pressure [17].

Based on the postulates of his theory, Malthus, therefore, proposed both positive (obvious) and preventive checks. The positive checks include an increase in death rates as a result of wars, famines, epidemics, etc. For the preventative checks, he advocated a reduction in birth rates through "moral restraints". By moral restraints, Malthus meant birth control measures such as late marriages and restraint by married couples. As a clergyman, Malthus did not subscribe to artificial birth control measures like the use of contraceptives, abortions, etc. [12, 17].

Malthus based his theory on what was happening in Britain at that time. But as far as Britain was concerned, there was no reduction in population due to death brought about by starvation or other positive checks as predicted by Malthus. This was mainly because food production increased as a result of improvement in farming techniques brought about by the agrarian and industrial revolutions. Also, new lands such as America, New Zealand, Australia and Africa were opened [16]. People could therefore emigrate into these new lands from Europe especially with the improvements in the means of transportation. Because of these and other reasons, Malthus predictions never occurred in Britain [17].

However, Malthus theory has not been totally invalidated. Recently, the world has been experiencing a population explosion [18]. There are fears that unless the rate of population growth is reduced and food production increased, the world will sooner or later, face famine. Besides, many countries in South-East Asia and Africa are experiencing serious population problems. In such countries, the population pressure on available resources is very great. Some of these countries, including Nigeria, are currently having severe food shortages [9].

In Conclusion, therefore, we may say that since the Malthusian population thesis applies to certain parts of the world, especially Africa, Malthus cannot be said to have been totally wrong, although he was very pessimistic.

EMPIRICAL LITERATURE REVIEW

Some of the studies conducted on the relationship between population, growth, climate change, and food security are reviewed in this section.

Kumar and Sharmar [19] studied the impact of climate change on food security in rural India and found out that climate change has a negative impact on food security in India. Josephson, Ricker-Gilbert and Florax [20] studied the nexus between rural population density and agricultural intensification and productivity in Ethiopia. The study found a significant association between population density and smaller farm sizes and decreased productivity. Zewdie [21] established that climate change has adverse effects on food security in Sub-Sahara Africa. Kundu [22] observed that population growth causes a food crisis in India. Tong *et al*. [23] examined the potential impact of climate change on food, water and health in China and concluded that climate change has potentially harmful effects on food, water and health systems. Masipa [24] found that climate change presents a high risk to food security in South Africa. Mahrous [25] established that temperature has an adverse effect on food security while rainfall and increased cereal crops cultivation have a positive impact on food security in a sample of five countries of the East African Community (EAC) region.

In Nigeria, Babatunde and Ajayi [26] in their study established a strong adverse relationship between population growth and food crop production. From a study sample of 900 respondents across Nigeria. Apata [27] concluded that there would be an increase in hunger-related deaths if grain production does not keep pace with population growth in favourable climatic conditions. Abdulrahaman [11] observed that population growth has no significant effect on food security in Nigeria. On their part, Osuafor and Nnorom [28] found out that environmental degradation occasioned by climate change poses serious threats to food security in Nigeria. Similarly, Ladan [29] found that climate change has a negative impact on food security in Nigeria. Mbah, Ezeano and Saror [30] concluded from their study of 90 rice farmers in Benue State, Nigeria that climate change adversely affects rice production. Idumah *et al*. [31] established from their study that rainfall and temperature have insignificant negative long-run effects on food production in Nigeria for the period 1975-2010. Through a survey of dietary intake of 266 households in Jigawa State, Ahungwa *et al*. [32] found that population growth adversely affects food security in Nigeria. Similarly, Osu [33] found that dependent population growth adversely affects food production in Nigeria. Oladimeji [16] tested the validity of the Malthusian population theory on the trend of population growth and rice production in Nigeria. The study confirmed that the population increased exponentially while rice production increased arithmetically. Finally, Igbokwe-Ibeto [34] observed that climate change leads to food insecurity and human underdevelopment in Nigeria.

From the empirical literature reviewed, apart from Apata [27], most of the studies conducted in Nigeria concentrated either on the impact of population growth or climate change. That is, the studies did not incorporate population growth and climate in a single study. Also, while some of the studies established significant negative effects of population growth and climate on food security in Nigeria, few others found no significant effects of population and climate change on food security. Finally, the majority of studies conducted in Nigeria are case studies of particular states or regions in the country. Therefore, to fill the above gaps, this study captured the effects of both population growth and climate change on food security in Nigeria. Besides, the made use of country-wide or national data to investigate the impact of population growth and climate change on food security in the country.

METHODOLOGY

Model Specification

The mathematical form of the model is specified as:

FPI = (PGR, MAR, MAT, UR)…………………3.1

Where FPI = Food Production Index (a proxy for food security)

PGR = Population Growth Rate

MAR= Mean Annual Rainfall

MAT= Mean Annual Temperature

UR= Urbanization Rate

F= Functional Notation

FPI is the dependent variable while PGR, MAR, MAT and UR are the explanatory variables. Urbanization rate was introduced as a control variable.

The OLS linear regression equation based on the above mathematical relation is expressed as:

$FPI = = \beta_0 + \beta_1\ PGR + \beta_2\ MAR + \beta_3\ MAT + \beta_4 + UR + U$…………………………………………...3.2

Where β_0 is the regression constant, β_1, β_2, β_3 and β_4 are the coefficients of the explanatory variables, while U is the error term. All other terms are as previously defined.

A logarithmic transformation of equation 3.2 above gives the following equation.

$FPI = = \beta_0 + \beta_1\ PGR + \beta_2\ LogMAR + \beta_3\ LogMAT + \beta_4\ UR + U$…………………………………….3.3

Where Log is the natural logarithm of the variables.

A priori Theoretical Expectations

$FPI = = \beta_0 + \beta_1\ PGR + \beta_2\ LogMAR + \beta_3\ LogMAT + \beta_4\ UR + U$ 3.

$(\beta_1 < 0,\ + \beta_2 < 0,\ \beta_3 < 0, \beta_4 < 0)$

Nature and Sources of Data

The study made use of annual time-series data from 1984 to 2019. The data were obtained from secondary sources including the Central Bank of Nigeria Annual Statistical Bulletin, World Bank [36] Development Indicators (various years), the Nigerian Meteorological Agency and the National Bureau of Statistics (various years), etc.

Technique of Data Estimation

The ordinary least square (OLS) regression technique was used to estimate the time-series data used for the study. The choice of OLS was based on certain desirable characteristics it possesses [35].

The OLS technique is based on the assumption that the time-series are stationary. However, in real-world situations, many macroeconomic data are non-stationary. Hence, to overcome the phenomenon of non-stationarity and other problems associated with time-series analysis, the data estimation was preceded by a unit root test. Consequently, the Augmented Dickey-Fuller (ADF) unit root test was used to test for stationarity of the time-series. Based on the outcome of the ADF unit root test, the Johansen cointegration test was used to test if the variables have a long-run relationship while the error correction mechanism (ECM) was used to adjust the short-run variability of the time-series to their equilibrium trend.

PRESENTATION AND DISCUSSION OF RESULTS

Stationarity Test Results

The results of the Augmented Dickey-Fuller (ADF) unit root test are presented in table 4.1 below.

Table-41: ADF Stationarity Test Results

Variables	ADF Statistic	Critical Value 1%	Critical value 5%	Prob	Order of integration
FPI	-9.891125	-3.646342	-2.2954021	0.0000	*I*(1)
PGR	-4.013757	-3.646342	-2.954021	0.0298	*I*(1)
LOG (MAR)	-7.764393	-3.646342	-2.954021	0.0000	*I*(1)
LOG (MAT)	-4.055036	-3.646342	-2.954021	0.0034	*I*(1)
UR	-5.023191	-3.646342	-2.954021	0.0003	*I*(1)

Source: Computed from E-view results

The stationarity test results presented in table 4.1 above show that none of the series was stationary at levels. However, they were all stationary after taking their first differences. Hence, all were integrated of order one, ie., I(1).

Johansen Cointegration Test Results

The results of the Johansen cointegration test are presented in table 4.2 below. The Trace statistic and the Maximum Eigen statistic are used in interpreting the results at 0.05 level of significance.

Table-4.2: Johansen Cointegration Results

Hypothesized No. of CE(s)	Trace Statistic	0.05 Critical Value	Prob
None*	104.5485	69.81889	0.0000
At most 1*	54.75563	47.856130	0.0098
At most 2	29.61225	29.79707	0.0525
At most 3	9.699531	15.49471	0.3046
At most 4	2.345616	3.841466	0.1256
Hypothesized No. of CE (s)	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob ****
None*	49.79286	33.87687	0.0003
At most 1	25.14338	27.58434	0.0995
At most 2	19.91272	21.13162	0.0733
At most 3	7.353915	14.26460	0.4482
At most 4	2.345616	3.841466	0.1256

Source: Computed from E-views results

Trace test indicates 2 cointegrating equations at the 0.05 level.
Max-Eigen test indicates 1 cointegrating equation at the 0.05 level
* denotes reject of the hypothesis at the 0.05 level
* Mackinnon-Haug-Michelis [10] p- values

The table above shows that the trace test indicates 2 cointegrating equations while max-eigen test shows 1 cointegrating equation.

This result implies that the Johansen cointegration test indicates the presence of a long-run relationship among the variables of the study.

Error Correction Mechanism (ECM) Result

Table 4.3 below shows the result of Parsimonious error correction model

Table-4.3: Error Correction Mechanism (ECM) Result

Variable	Co-efficient	Std. Error	t-statistic	Prob
C	899.0124	304.9894	2.947684	0.0070
LOG (MAR)	-25.35849	11.67925	-2.171243	0.0391
LOG (MAR(-1))	-9.266780	4.033390	-2.297516	0.0294
LOG (MAT)	-100.8183	46.46601	-2.169721	0.0402
LOG (MAT(-1))	-54.08377	46.20089	-1.170622	0.2532
PGR	-12.15016	48.33224	-0.251388	0.8037
PGR(-1)	-73.56886	47.14888	-1.560352	0.1318
UR	-11.48117	5.139947	-2.233713	0.0351
UR(-1)	-7.121876	5.120257	-1.390922	0.1770
ECM (-1)	-0.096344	0.01242	-9.408593	0.0000
R-squared	0.779076	Mean dependent var		83.97618
Adjusted R-squared	0.751230	S.D dependent var		28.17132
S.E of Regression	4.778360	Akaike info criterion		6.206000
Sum squared resid	547.9854	Schwarz Criterion		6.654930
Log-likelihood	-95.50201	Hannan- Quinn Criter.		6.359098
F-Statistic	124.7799	Durbin-Watson stat		2.175381
Prob (F-Statistic)	0.000000			

Source: E-view's Result

From the ECM result presented in Table 4.3 above, all the variables were correctly signed. Mean annual rainfall (MAR) has a negative and significant relationship with food security (proxied by food production index, FPI). Similarly, mean annual rainfall lagged by one period (MAR (-1)) has a significant negative impact on food security. In the same manner, mean annual temperature (MAT) has a significant negative relationship with food security. However, mean annual temperature lagged by one period (MAT (-1)) has a negative but insignificant relationship with food security. The implication is that climate change has a significant adverse effect on food security (particularly food production) in Nigeria.

Population growth (PGR) has a negative but insignificant relationship with food security. Similarly, population growth lagged by one period (PGR(-1)) is negatively but insignificantly related to food security. On its part, the rate of urbanization (UR) has a negative significant effect on food security while its one-period lag is negatively but insignificantly related to food security.

The coefficient of multiple determination (R^2) is 0.779076. This shows that about 77 per cent of the total variations in the dependent variable (FPI) was accounted for by the joint action of all the explanatory variables.

The adjusted R^2 is 0.751230 indicating that the reduction in the degree of freedom as a result of the inclusion of additional explanatory variable may not significantly alter the goodness of fit of the regression plane.

The F-Statistic is 124.7799 with prob (F-Statistic) of 0.000000. This implies that the model is statistically significant at 0.05 level of significance. The Durbin-Watson statistic is 2.175381. This revealed that our model was not affected by the problem of the autocorrelation of the error term.

Finally, the ECM variable shows a negative sign. Hence, it is correctly signed. An ECM (-1) coefficient of -0.096344 shows a speed of adjustment of about 9 per cent to long-run equilibrium from short-run disequilibrium.

CONCLUSIONS AND POLICY RECOMMENDATIONS

Conclusions

Based on the results of the data estimation, the following conclusions were drawn

i. Population growth has a weak negative effect on food security in Nigeria,
ii. Climate change (in terms of rainfall and temperature) has a significant adverse consequence on food security in Nigeria,
iii. Urban expansion (i.e rate of urbanization) has a significant adverse effect on food security in Nigeria.

Policy Recommendations

From the findings of the study and the conclusions above, we recommend the following policy actions. First, there is a need to review and update the 2004 national population policy to accommodate current demographic challenges in the country. Also, to curtail the negative effect of population on food security, the government should carry out a comprehensive public enlightenment campaign. Such a campaign will help to educate Nigerians on the need to have a smaller number of children through modern family planning techniques.

Secondly, to reduce the adverse effect of climate change on food security, there is the need to adopt some climate change adaptation and mitigation measures. The adaptation measures include;

(i) Introduction of modern irrigation schemes to address the problem of unpredictable rainfall and uncertainty in the cropping pattern. This will help to boost crop production in the affected areas.

(ii) Change planting dates and farm operations in some agro-ecological zones.

(iii) Development and introduction of drought-resistant seed varieties.

(iv) Making short-cycle seeds available in agro-ecological zones that are susceptible to adverse climatic conditions like flooding. This will help to increase future resilience to hazardous climatic effects. Fast-growing and fast-maturing crop varieties allow for harvesting before the peak of the flood season or for a quick harvest following replanting after flooding.

The following climate change mitigation measures are also recommended

i. Promotion of agricultural land management system such as the promotion of agroforestry systems, rehabilitation of degraded crop and pasture land, conservation tillage, etc

ii. Promoting good soil use practices and technologies

iii. Promoting efficient fertilizer application and enhancing management of agricultural wastes.

iv. Stop indiscriminate burning of bushes and deforestation.

Finally, because the majority of Nigerian farmers are poor, it will be difficult for them to adapt to climate change without government assistance. The government can therefore facilitate adaptation through measures such as crop and livestock insurance, safety nets, research and distribution of flood and drought-tolerant crop varieties. Also, the government should provide timely climate information (early warning signals) and technical advice to farmers

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