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A STUDY ON THE RELATIONSHIP BETWEEN RURAL AND URBAN POPULATION GROWTH AND FOOD AVAILABILITY IN NIGERIA

Oga Ode[1*], Davies Abiodun Obaromi[2], and Thomas Agu Ogar[3].

[1,2]Department of Biostatistics, Federal University of Health Sciences, Otukpo, Nigeria.

[3]Department of Computer Science, College of Health Technology, Calabar, Nigeria.

[*]Corresponding Author's Email: oga.ode@fuhso.edu.ng, ogaode1@gmail.com

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ABSTRACT: *This study investigates the relationship between rural and urban population growth and domestic food availability in Nigeria using annual data from 1961 to 2022. Food availability is proxied by the food production index (FPI), while demographic variables are described by rural population growth (RPG) and urban population growth (UPG). Both short- and long-run dynamics are examined by employing unit root tests, Johansen's cointegration, and the vector error correction model (VECM). Results show that FPI, RPG, and UPG are integrated of order one and cointegrated, confirming a long-run equilibrium. Cointegration estimates reveal that both RPG and UPG undermine food production, indicating that demographic expansion places an irrepressible pressure on domestic food availability. The VECM demonstrates a rapid speed of adjustment, while impulse-response analysis shows RPG and UPG shocks have negative but transitory effects on food availability, with the impact fading with time. These findings underscore the significance of productivity-enhancing agricultural investments, improved distribution systems, and income growth in mitigating population-induced pressure on food availability.*

KEYWORDS: Autocorrelation, cointegration, food production index, impulse-response function, rural population growth, urban population growth, vector error correction model.

JEL Classification: C01, C10, C19

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INTRODUCTION

Access to adequate food is a fundamental prerequisite for human survival, health, and economic well-being. Consequently, maintaining a reliable and sustainable food supply has become a major policy concern at both national and international levels. Food availability, a fundamental dimension of food security, plays a critical role in promoting economic development and improving living standards. Against this backdrop, considerable research has examined the relationship between population growth and food availability, given the growing concern that rapid demographic expansion may exert increasing pressure on domestic food production systems. In the case of Nigeria, it has become particularly worrisome, judging from the massive food imports that have been resorted to over the last decade. Is there adequate evidence to support the findings of certain research studies that the population of Nigeria (both rural and urban) is growing at a rate that outpaces cultivable land and expected production output, or are there other underlying reasons as to why the country has been struggling to produce enough food to cater to the ever-growing populace? Tavershima *et al*. (2022) and Aiyedogbon *et al*. (2022) reported, in their respective studies, that the population of Nigeria has grown beyond the available agricultural output. Ogban *et al*. (2021), however, believes that urban growth directly impacts the availability of agricultural land in urban areas, and this has inescapably hurt food production and other agricultural activities. In another perspective, Soma *et al*. (2023) considers it impossible to feed an ever-increasing urban population based on domestic production alone. Peterside (2024) noted that food availability dynamics in Nigeria are shaped by a complex web of interrelated factors, including soaring inflation, climate change, and insecurity. Farmers' limited access to reasonable capital has also been suggested as a plausible reason for Nigeria's worsening food crisis. There may, perhaps, be other underlying reasons beyond the ones stated above that are responsible for the underwhelming performance of Nigeria in terms of food production and food self-sufficiency.

Nigeria is a country with vast land that supports agricultural cultivation and that produces high yields when put to good use. Although Nigeria's Food Production Index (FPI) has increased over time, its growth has been insufficient relative to rapid rural and urban population expansion, thereby exerting pressure on per capita food availability. Remarkably, the country had, at some time in the not-too-distant past, been self-sufficient in food production, enough for both local consumption and for exporting to other countries. Why has there been a reversal in this trend over time? What can be done to return the country to its days of abundance with respect to food production and availability? These, and perhaps a few more, are questions this study will attempt to answer. Establishing a link between rural and urban population growth rates and food availability (represented by the Food Production Index) is key to providing answers to the salient questions raised above. Food Production Index (FPI) encompasses food crops that contain nutrients and are considered edible (World Bank, 2024). Coffee and tea, for instance, are not classified as part of this definition because they contain no nutritive value. One would expect that food production capacity in Nigeria is scaled up or adjusted regularly to be at par with the steady increase of its population, but this is not the case, as an aggregation of factors has caused agricultural activities to be less attractive to Nigerians. Consequently, this study is an attempt to analyze the effect of population growth on food production and recommend workable solutions to this debilitating problem.

Over the past decade, there has been immense emphasis all over the globe on the implications of increasing population on food production and sustainability. The population of Africa, and Nigeria in particular, is growing at an alarming rate, and this poses dire implications for food

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availability and economic growth (Iwu, 2020). An increase in population has constituted a grave challenge to all concerned stakeholders in the country with respect to food sufficiency and availability. The study administered 1,260 questionnaires to six farm settlements across south-western Nigeria, the focus of which was to analyze the government's approach to overpopulation and food insecurity in the country. The study concluded that the rate of population growth was significantly higher than the rate of food production in South-Western Nigeria. Rapid population growth without a well-developed agricultural sector results in food shortages and soaring food price inflation (Onime, 2019). This study showed, sadly, that an increase in population growth was observed to worsen food security and economic growth. A key factor identified in the study as being responsible for the growing population and worsening food crises in Nigeria was the explosion in the number of refugees and those seeking asylum in the country. In a rather surprising discovery, Aiyedogbon *et al*. (2022) stated that the agricultural output growth of 3.5% between 2011 and 2020, against the backdrop of the population growth rate at 2.6%, was responsible for the food shortage, hunger, and malnutrition being experienced in Nigeria. This study aimed to assess the extent population growth impacts food security in Nigeria with data spanning 1986 – 2020. Two models were employed: the first model analyzed agricultural output as a function of population growth rate, and the impact of population growth and agricultural productivity on economic growth was examined by the second model. The study employed the Cochrane-Orcutt iterative method on the ordinary least squares (OLS). From the findings of this study, population growth had a significant impact on agricultural output, while agricultural output and population growth in Nigeria had a significant and positive relationship with economic growth.

According to a study by De Vos *et al*. (2024), future global urban-area expansion is envisioned to cause substantial food production losses (-2.5% by 2100 for rice), a reduction in biodiversity, and elevated annual land use change (LUCs) emissions; this significantly compromises human livelihoods and the natural environment. The findings of the study indicated that there is a marked difference in rice consumption between urban and rural households in several African regions, with urban households consuming one and a half times more rice than rural households. A plausible explanation for this imbalance is perhaps the incessant rural-urban migration. Jimoh and Otokiti (2022) asserted that urban expansion, which is caused by poorly planned physical development, continues to threaten sustainable food production. This study, which examined the impact of poorly controlled physical development on urban food production in Ibadan, employed the longitudinal survey research design, where both primary and secondary data were sourced. Geographical and remote sensing methods of analysis were used. The findings from this research revealed that Ibadan's total urban area increased from 70.36 *ha* in 1986 to 411.89 *ha* in 2019. Accompanying this expansion was the loss of agricultural land, water bodies, and agricultural land conversion.

Evans (2023) revealed wistfully that there was once a time in Nigeria when food was in surplus and could even be exported to other nations without having any adverse effect on local supply and consumption. During the period referenced in the study, the gradual growth of the country's population did not negatively impact food production. However, for a country once renowned for massive food exports due to excess food production, it has become ironic that Nigeria now faces acute food shortages and depends on food importation to meet its ever-increasing domestic food demand and consumption. Food availability in several nations is now determined more by income than local production, thereby aggravating the dynamics of food production and sufficiency. The United Kingdom, for instance, which is not threatened by food

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insecurity, has been dependent on food imports to satisfy local demand and consumption for more than a century. Soma *et al*. (2023) buttressed the findings of Evans (2023) by showing, in their study, that it is not possible to feed an ever-increasing urban population by relying solely on domestic production. Nigeria's sporadic and rapid population growth over the years has been cited as the major hindrance to food availability. So far, the population explosion in Nigeria has not helped in attaining sufficiency and sustainability in food production but has instead escalated the volume of food imports to keep pace with local food demand and consumption. In a study entitled 'The Time Series Analysis of the Impact of Population Growth and Climate Change on Food Security in Nigeria,' Korgbeelo and Deekor (2020) admitted that food production in Nigeria had not kept pace with rapid population growth, and this has resulted in a decline in the levels of national food self-sufficiency. The paper examined the effect of population growth, mean annual rainfall, mean annual temperature, and rate of urbanization on food security (proxied by the food production index) in Nigeria using annual time series data from 1984 to 2018. Time series methodologies such as the Augmented Dickey-Fuller (ADF) unit root test, Johansen cointegration test, and error correction model (ECM) were applied to the time series data. The study findings showed that population growth had a negative impact on food security, while climate change had a significant negative effect on food security in Nigeria. Similarly, Okijie (2024) showed that rural population growth negatively and significantly impacted food production in Nigeria. Rural-urban migration was attributed to this trend. As such, the study suggested that agriculture should be made more attractive to the rural populace to halt this declining trend. Urban expansion is caused by population increase, which is caused by factors linked to rural-urban migration and natural increase (Ogban, 2021). These factors have a negative effect on farmlands and thus lead to a decrease in food production. Miladinov (2023) investigated the changes in the rural and urban population growth rate and GDP per capita relative to the prevalence of undernourishment as a percentage of the population in low-income countries, lower-middle-income countries, and upper-middle-income countries. The regression models obtained showed that rural and urban population growth had a strong link with the prevalence of malnutrition in the countries highlighted. Fully Modified Ordinary Least Squares results further revealed that the changes in the currency of undernourishment were mostly related to long-term changes in the rural and urban population growth.

As long as the population of the world does not exceed the earth's carrying capacity at any given point in time, there will be enough supply of food to go around for everybody. What this means is that a growing population should not be seen as a disadvantage, as long as it does not overshoot the carrying capacity of the environment in terms of the supply of food and other important resources, as most of the literature that has been reviewed in this section seems to be suggesting. In the case of Nigeria, it may appear that, based on the current lingering food crisis being experienced by the populace, the population is increasing at a rate that overwhelms the capacity of individuals that the available land can support. However, based on the assertion by Evans (2023) that food production in Nigeria was not hampered by the gradual population increase in the past, this study believes that factors other than population growth might be responsible for dwindling food availability in the country. While food insecurity is a multidimensional concept, this study is confined to the availability aspect due to data limitations. FPI is therefore interpreted strictly as an indicator of domestic food availability rather than overall food security. This study contributes to the literature by jointly modeling rural and urban population growth as distinct but interrelated demographic pressures on domestic food production in a unified long-run cointegration framework. Unlike existing

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studies that rely on aggregate population measures, this paper decomposes population growth and examines both long-run equilibrium effects and short-run adjustment dynamics using more than six decades of Nigerian data. Additionally, a critical and novel research question, "Is food production growing fast enough to absorb sustained demographic expansion?" is investigated. This would help to establish if positive output growth can coexist with negative demographic pressure effects.

MATERIALS AND METHODS

Data

This study used time series data on the Food Production Index (FPI), Rural Population Growth (RPG) index, and Urban Population Growth (UPG) index, all spanning 62 years from 1961 to 2022. The data were extracted from the World Development Index (WDI), a publication of the World Bank (last updated in 2023).

Model Specification

As noted by Gujarati (2004), most econometric models link an observable dependent variable, y, to observable explanatory variables $x_1, x_2, \ldots, x_m$; an unobservable variable u (the error term if the model is a linear regression); and parameters $\beta_1, \ldots, \beta_k$, via some function f. In other words,

$$y = f(x_1, x_2, u) \tag{1}$$

Building on equation (1), the model specification for this research is stated as follows:

$$FPI = f(RPG, UPG) \tag{2}$$

Equation (2) can be definitively expressed as:

$$FPI_t = \alpha + \beta_1 RPG_t + \beta_2 UPG_t + u_t \;; \quad t = 1, 2, \ldots, n \tag{3}$$

where;

FPI = food production index; RPG = rural population growth; UPG = urban population growth; α = constant term; β_1, β_2 = coefficients of estimation, and u_t = error term.

Equation (2) presents a conceptual framework that connects FPI, RPG, and UPG, while equation (3) specifies the econometric regression in detail by incorporating an error term, u_t. This regression forms the empirical basis for extending the analysis to the VAR system in equations (4–6) and ultimately to the VECM in equations (7–9).

Estimation Procedure

Vector error correction model (VECM)

The VECM is chosen ahead of alternative models because it produces more efficient estimators of the cointegrating vectors. Equation (3) establishes the baseline regression, while equations (4 – 6) specify the multivariate VAR system.

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$$FPI_t = \sigma + \sum_{i=1}^{k} \beta_1 FPI_{t-1} + \sum_{j=1}^{k} \phi_1 RPG_{t-1} + \sum_{m=1}^{k} \varphi_1 UPG_{t-1} + u_{1t} \tag{4}$$

$$RPG_t = \alpha + \sum_{i=1}^{k} \beta_2 FPI_{t-1} + \sum_{j=1}^{k} \phi_2 RPG_{t-1} + \sum_{m=1}^{k} \varphi_2 UPG_{t-1} + u_{2t} \tag{5}$$

$$UPG_t = \tau + \sum_{i=1}^{k} \beta_3 FPI_{t-1} + \sum_{j=1}^{k} \phi_3 RPG_{t-1} + \sum_{m=1}^{k} \varphi_3 UPG_{t-1} + u_{3t} \tag{6}$$

FPI depends on its own lagged values and the lagged values of the other variables. The same applies to *RPG* and *UPG*, making all variables endogenous.

The differencing operator (Δ) is introduced in formulating the VECM, and this reduces the lag length, *k*, by one, as illustrated in equations (7 – 9). Nonetheless, it is essential to carry out unit root and cointegration tests not only to validate the assumptions of the VAR model but also to justify the transition to the VECM procedure, since stationarity of the series is required in both cases.

$$\Delta FPI_t = \sigma + \sum_{i=1}^{k-1} \beta_1 \Delta FPI_{t-1} + \sum_{j=1}^{k-1} \phi_1 \Delta RPG_{t-1} + \sum_{m=1}^{k-1} \varphi_1 \Delta UPG_{t-1} + \lambda_1 ECT_{t-1} + u_{1t} \tag{7}$$

$$\Delta RPG_t = \alpha + \sum_{i=1}^{k-1} \beta_2 \Delta FPI_{t-1} + \sum_{j=1}^{k-1} \phi_2 \Delta RPG_{t-1} + \sum_{m=1}^{k-1} \varphi_2 \Delta UPG_{t-1} + \lambda_2 ECT_{t-1} + u_{2t} \tag{8}$$

$$\Delta UPG_t = \tau + \sum_{i=1}^{k-1} \beta_3 \Delta FPI_{t-1} + \sum_{j=1}^{k-1} \phi_3 \Delta RPG_{t-1} + \sum_{m=1}^{k-1} \varphi_3 \Delta UPG_{t-1} + \lambda_3 ECT_{t-1} + u_{3t} \tag{9}$$

where: k = lag length; σ,α,τ = constant terms; λ_i = adjustment coefficient; $\beta_i, \phi_j, \varphi_m$ = short run coefficients; ECT_{t-1} = error correction term, and u_{it} = errors.

The error correction term captures the long-run dynamics of the model and accounts for past deviations from the long-run equilibrium.

Johansen's cointegration test

The central contribution of the concepts of unit root and cointegration lies in compelling researchers to verify the stationarity or otherwise of regression residuals, thereby avoiding misleading inferences. As noted by Granger (1986), cointegration may be regarded as a diagnostic pre-test designed to prevent "spurious regression" outcomes. Specifically, cointegration refers to a situation in which two or more time series exhibit a joint long-run equilibrium path. A time series is thus said to be integrated of order j, denoted *I(j)*, if it must be differenced j times to achieve stationarity. For example, a series, y_t, is integrated of order one, $I(1)$, if its first difference, Δy_t, is stationary.

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To assess whether multiple time series are cointegrated, Johansen's test is employed. The Johansen test is available in two forms: the *Trace* statistic and the *Maximum eigenvalue* statistic, both of which share the null hypothesis:

H_0: there are r cointegrating vectors

However, the alternative hypotheses differ for both tests. For the *trace* test, the alternative hypothesis is:

H_a: number of cointegrating relationships is $> r$

while for the maximum eigenvalue test, the alternative hypothesis is:

H_a: there are r+1 cointegrating vectors

where r denotes the number of cointegrating relationships.

An important consideration in the implementation of the Johansen test involves the selection of the appropriate lag length for the underlying unrestricted VAR. This study employed both the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC), which jointly indicated an optimal lag length of 2. Consistent with established practice, the Johansen test was therefore estimated with a lag interval of 1 to 2, reflecting the reduction of one lag when transitioning from the unrestricted VAR to the VECM specification. This choice strikes a balance between mitigating residual autocorrelation and avoiding over-parameterization, particularly given the modest sample size.

For robustness, both the *trace* and *maximum eigenvalue* statistics were reported, acknowledging that they may lead to different conclusions due to differences in statistical power. A deterministic trend component was also incorporated in the cointegrating relation, and the resulting estimates remained stable, thereby reinforcing the validity of the identified long-run equilibrium among the variables. Statistical inference was conducted at the 1% and 5% significance levels.

Dickey-Fuller (DF) unit root test

The groundbreaking contribution to unit root testing in time series analysis was made by Dickey and Fuller (1979). A unit root characterizes whether a time series is stationary or non-stationary. A unit root is said to exist when ρ = 1 in the autoregressive process:

$$y_t = \rho y_{t-1} + \beta X_e + \varepsilon_t \tag{10}$$

where y_t denotes the value of the series at time t, X_e is an exogenous variable, and ε_t random error term. The presence of a unit root implies non-stationarity. The standard Dickey-Fuller test is based on the following regression specification:

$$y_t = \alpha + \beta t + \rho y_{t-1} + \phi \Delta y_{t-1} + \varepsilon_t \tag{11}$$

Where y_{t-1} is the first lag of the series, and Δy_{t-1} denotes its first difference. When ρ = 1, the series contains a unit root. To improve robustness, the test is extended to the augmented Dickey-Fuller (ADF) form:

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$$y_t = \alpha + \beta t + \rho y_{t-1} + \phi_1 \Delta y_{t-1} + \phi_2 \Delta y_{t-2} + ... + \phi_p \Delta y_{t-p} + \varepsilon_t \quad (12)$$

Equation (12) incorporates higher-order autoregressive terms to account for serial correlation in the residuals. The optimal lag length p is selected using the AIC to minimize residual autocorrelation. The ADF test statistic is expressed as:

$$\hat{t} = \frac{\rho}{s.e.(\rho)} \quad (13)$$

The hypotheses for the DF and ADF tests are:

H_0: y_t contains a unit root; against

H_1: y_t is stationary

Phillips-Perron unit root test

The Phillips-Perron unit root test, originally proposed by Phillips and Perron (1988), provides a refinement of the conventional unit root testing framework by correcting for serial correlation and heteroskedasticity through a non-parametric adjustment of the test statistic. It modifies the conventional t-statistic for the estimate of ρ as follows:

$$z_\rho = t_\rho - \frac{(\overset{2}{\sigma}_u - s^2)}{2s^2} \frac{T.SE(\rho)}{s} \quad (14)$$

where: t_ρ is the conventional t-statistic for ρ; $\hat{\sigma}_u^2$ denotes a consistent estimate of the long-run variance of u_t; s^2 is the variance of regression residuals; T sample size; and SE(ρ) is the standard error of ρ. This adjustment ensures robustness of the test against both serial correlation and heteroskedasticity in the error term. The hypotheses of the PP test are specified as:

H_0: $\rho = 0$ (series contains a unit root)

H_1: $\rho < 0$ (series is stationary)

The null hypothesis of a unit root is rejected if z_ρ falls below the critical value at the 1% or 5% significance level.

Jarque-Bera normality test

The Jarque-Bera (JB) test is a goodness-of-fit procedure used to assess whether the skewness and kurtosis of sample data are consistent with those of a normal distribution. The test statistic is given as:

$$JB = \frac{n-k+1}{6}(S^2 + \frac{1}{4}(C-3)^2) \quad (15)$$

where n denotes the sample size, S represents the sample skewness, C is the sample kurtosis, and k number of regressors.

The hypotheses for the test are formulated as:

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H_0: errors are normally distributed

H_a: errors are not normally distributed

The null hypothesis is rejected when the *p*-value associated with the test statistic is less than the 5% significance level.

Portmanteau autocorrelation test

The Portmanteau test, also referred to as the Ljung-Box *Q* test, is employed to detect the presence of autocorrelation in the residuals of a fitted time series model. The hypotheses of the Portmanteau test are specified as follows:

H_0: the autocorrelations up to lag *h* are all 0

H_a: one or more lags have autocorrelations that differ from 0.

The test statistic is expressed as:

$$Q_h = n(n+2)\sum_{k=1}^{h}\frac{\rho_k^2}{n-k} \tag{16}$$

where *n* is the sample size, $\hat{\rho}_k$ is the sample autocorrelation at lag *k*, and *h* the number of lags being tested. Under the null hypothesis, Q follows a $\chi^2_{(h)}$. For a given significance level, α, the rejection criterion is Q > $\chi^2_{1-\alpha,h}$, where $\chi^2_{1-\alpha,h}$ denotes the quantile of the chi-squared distribution with *h* degrees of freedom.

It is important to note that the Portmanteau test is typically applied to the residuals of a fitted ARIMA model, rather than to the raw time series.

White test for heteroskedasticity

One of the key assumptions of the classical linear regression model is that the error terms exhibit constant variance and are mutually independent. This requires that $V(\varepsilon) = \sigma^2$ and $Cov(\varepsilon_i,\varepsilon_j) = 0$. A violation of this assumption implies the presence of heteroskedasticity in the residuals. The hypotheses for testing heteroskedasticity are:

H_0: residual variances are homoscedastic

H_a: residual variances are heteroskedastic

The null hypothesis is rejected if the *p*-value of the test statistic is less than the 5% significance level.

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RESULTS AND DISCUSSION

Results

Y-axis: FPI; X-axis: time (years)

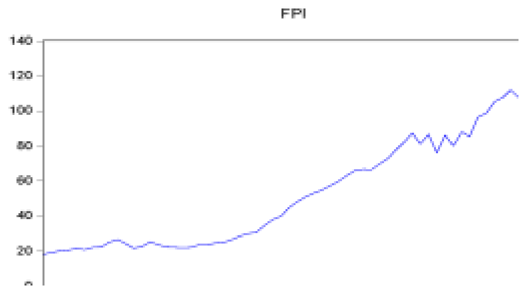

Figure 1a: Graph of FPI at level

Y-axis: RPG (% annual); X-axis: time (years)

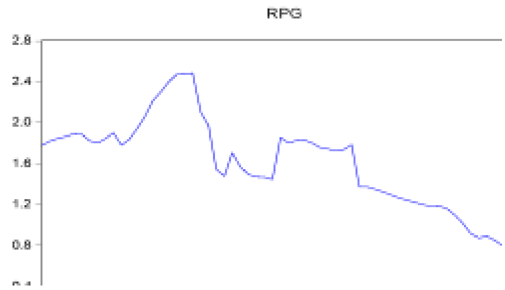

Figure 1b: Graph of RPG at level

Y-axis: UPG (% annual); X-axis: time (years)

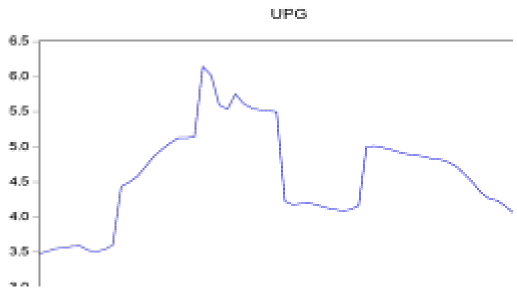

Figure 1c: Graph of UPG at level

Y-axis: FPI; X-axis: time (years)

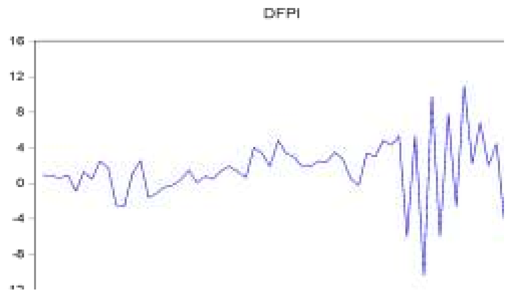

Figure 2a: Graph of FPI at first difference

Y-axis: RPG (% annual); X-axis: time (years)

Figure 2b: Graph of RPG at first difference

Y-axis: UPG (% annual); X-axis: time (years)

Figure 2c: Graph of UPG at first difference

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Figures 1a, 1b, and 1c display graphs of the unit root tests on FPI, RPG, and UPG at level, respectively. From these graphs, we see non-stationary time series for the three variables, as evidenced by their frequently changing means. However, after differencing, as shown in Figures 2a, 2b, and 2c, the graphs appear stationary as their respective means become constant over time.

Table 1: ADF unit root tests at level

Variables	ADF Test Statistic	Critical Value (1%)	Critical Value (5%)	Prob*	Integration Order
FPI	2.112055	–3.548208	–2.912631	0.9999	I(1)
RPG	–0.210782	–0.210782	–2.910019	0.9309	I(1)
UPG	–1.775729	–1.775729	–2.910019	0.3889	I(1)

Table 2: ADF unit root tests at first difference

Variables	ADF Test Statistic	Critical Value (1%)	Critical Value (5%)	Prob*	Integration Order
FPI	–4.191288	–3.548208	–2.912631	0.0015	I(0)
RPG	–6.697294	–3.544063	–2.910860	0.0000	I(0)
UPG	–7.078815	–3.544063	–2.910860	0.0000	I(0)

Table 3: PP unit root tests at level

Variables	ADF Test Statistic	Critical Value (1%)	Critical Value (5%)	Prob*	Integration Order
FPI	3.381540	–3.542097	–2.910019	1.0000	I(1)
RPG	–0.524461	–3.542097	–2.910019	0.8787	I(1)
UPG	–1.843339	–3.542097	–2.910019	0.3565	I(1)

Table 4: PP unit root tests at first difference

Variables	ADF Test Statistic	Critical Value (1%)	Critical Value (5%)	Prob*	Integration Order
FPI	–10.37553	–3.544063	–2.910860	0.0000	I(0)
RPG	–6.760089	–3.544063	–2.910860	0.0000	I(0)
UPG	–7.078815	–3.544063	–2.910860	0.0000	I(0)

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The ADF unit root test results at levels, presented in Table 1, indicate that none of the time series are stationary, as evidenced by p-values exceeding the 0.05 significance threshold. This implies the presence of a unit root in all three series at their levels. Consequently, first differencing was applied, and the results in Table 2 demonstrate that each series attained stationarity, thereby establishing that they are integrated of order one, $I(1)$.

The PP test results, reported in Tables 3 and 4, accentuate these findings by similarly showing that the series are non-stationary at levels but become stationary after first differencing. Given that the PP test is robust to heteroskedasticity and serial correlation, its joint use alongside the ADF test provides more compelling evidence that the variables under consideration are $I(1)$.

Table 5a: Johansen co-integration test (Trace)

Hypothesized number of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.**
None*	0.338257	47.06304	29.79707	0.0002
At most 1*	0.247292	23.11616	15.49471	0.0029
At most 2*	0.108167	6.639650	3.841466	0.0100

Table 5b: Johansen Cointegration test (Maximum Eigenvalue)

Hypothesized number of CE(s)	Eigenvalue	Max-Eigen statistic	0.05 critical value	Prob.**
None*	0.338257	23.94689	21.13162	0.0195
At most 1*	0.247292	16.47651	14.26460	0.0220
At most 2*	0.108167	6.639650	3.841466	0.0100

Table 6: Co-integration result

Cointegrating eq.	Estimate	t-Statistic	Standard error
FPI(−1)	1.000000		
RPG(−1)	6.805423	1.65012	4.12419
UPG(−1)	8.756981	4.26657	2.05247
C	−1.442471		

Tables 5a and 5b report the results of Johansen's cointegration test based on the *trace* and *maximum eigenvalue* statistics, respectively. Both tests identify the presence of at least one cointegrating relationship among the variables. Accordingly, the null hypothesis of "no cointegration" is not rejected, and we conclude that a long-run equilibrium relationship exists among the time series variables. The cointegration results, summarized in Table 6, at the 5% significance level, yield the following long-run cointegrating relationship:

$$FPI + (6.805423*RPG + 8.756981*UPG - 1.442471) = 0 \quad (17)$$

which may be equivalently expressed as:

$$FPI = 1.442471 - 6.805423*RPG - 8.756981*UPG$$

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The estimated coefficients suggest that both rural and urban population growth exert a negative impact on the food production index, implying that population increases are associated with a decline in food production. In other words, a unit increase in each of the values of RPG and UPG will cause FPI to drop by 6.81 and 8.76 units, respectively. Notably, the estimated model provides consistent results, as the coefficient signs align with theoretical expectations.

These findings highlight the critical challenge of balancing population dynamics with agricultural productivity. The negative association between population growth and food production suggests that rapid demographic expansion places pressure on agricultural setups, thereby deepening food scarcity. This calls for integrated strategies that combine population management with targeted investments in the agricultural sector. Policy makers may need to prioritize programs that enhance rural productivity through mechanization, irrigation, and access to modern inputs, while simultaneously addressing urban pressures through improved food distribution systems and reduced post-harvest losses. Furthermore, sustainable improvements in food production cannot be achieved without long-term commitments to both the public and private sectors. Policies that encourage agricultural financing, strengthen land tenure systems, and foster innovation through research and development are likely to yield dividends in mitigating the adverse effects of population growth on food security.

By and large, the long-term cointegration result affirms not only the existence of equilibrium relationships among the variables but also provides a convincing case for policy interventions aimed at productivity-enhancing agricultural investments. This has tremendous implications for food security planning, poverty alleviation, and attainment of broader development goals.

Table 7: Vector error correction model

Error Correction	Estimate	t-Statistic	Standard error
D(FPI)	−1.045185	-4.00638	0.26088
D(RPG)	0.000553	0.04738	0.01168
D(UPG)	−0.031982	−1.16202	0.02752

$R^2 = 0.771255$ Adjusted $R^2 = 0.739231$

Results of the VECM are reported in Table 7. The estimated coefficient of the error correction term is negative (-1.045185), as expected, indicating that deviations from the long-run equilibrium are corrected at an adjustment speed of approximately 104.5%. This suggests that the system converges rapidly back to equilibrium following short-run shocks. Moreover, past values of FPI exert a significant feedback effect on its current levels in Nigeria, reflecting the dynamic nature of food production in the short run and further confirming the robustness of the model. The coefficient of determination, R^2, is 0.77, implying that about 77% of the total variation in FPI is explained by RPG and UPG, thereby affirming the strong explanatory power of the model. The coefficient of RPG is statistically insignificant and does not undermine the stability of the VAR.

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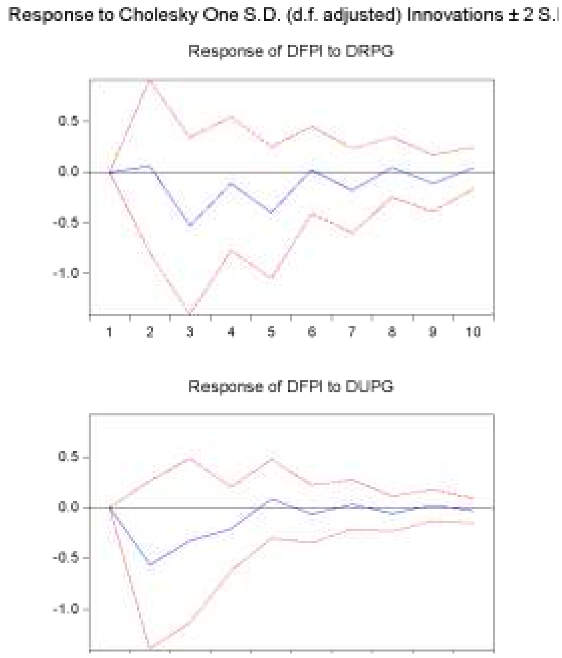

Figure 3: Impulse-Response Function Graph

Figure 3 presents the impulse-response function (IRF) analysis derived from the VECM. The blue lines represent the estimated responses, while the red dotted lines denote ±2 standard error confidence intervals. The IRFs indicate that both RPG and UPG shocks exert adverse but temporary effects on food production growth in Nigeria. The absence of persistent long-run deviations is consistent with the VECM results, which show rapid adjustment toward the long-run equilibrium. These findings suggest that while demographic expansion can strain food production systems in the short run, long-term outcomes depend on the economy's capacity to adjust through improved agricultural productivity and efficient food distribution systems. From a policy perspective, these findings highlight the importance of stabilizing food production to mitigate adverse short-term demographic pressures by investing in agricultural productivity and food supply responsiveness. Strategic interventions can help cushion these short-term disruptions and sustain balanced demographic and economic growth.

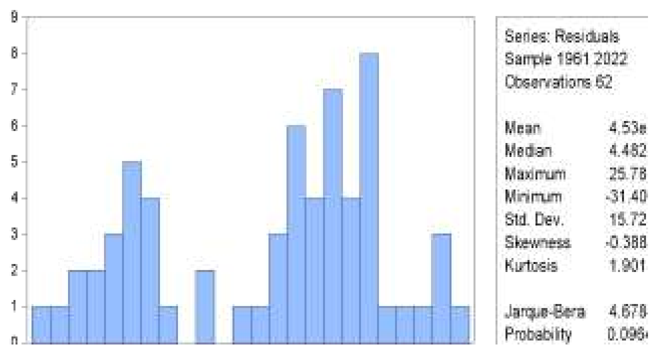

Figure 4: Jarque-Bera normality test

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Figure 4 displays the result of the Jarque-Bera normality test for the time series. According to the test criterion, the null hypothesis of normal distribution is rejected when the probability value falls below the 0.05 significance level; otherwise, the null hypothesis is not rejected. In this case, the reported probability value is 0.096, which exceeds the 0.05 threshold. As such, the null hypothesis is not rejected, which leads to the conclusion that the residuals follow a normal distribution.

Table 8: VEC Residual heteroskedasticity tests (levels and squares)

Joint test:

Chi-Square	Degrees of freedom	Probability
87.37910	84	0.3788

The residual heteroskedasticity test, reported in Table 8, was employed to assess whether the variables exhibit constant variance. The test yielded a probability value of 0.3788, which is greater than the 0.05 significance level. Consequently, sufficient evidence does not exist to reject the null hypothesis, and the conclusion is therefore that the residuals are homoscedastic. This outcome is desirable, as it supports the validity of the model's estimation results.

Table 9: VEC Residual Portmanteau tests for autocorrelations

Lags	Q-Stat	Prob.*	Adj. Q-Stat	Prob.*	d.f.
D(FPI)	0.931472	---	0.947814	---	---
D(RPG)	2.425057	---	2.494741	---	---
D(UPG)	10.14222	0.8107	10.63284	0.7782	15

As shown in the results of the Portmanteau autocorrelation test in table 9, which assesses the presence of serial correlation among the variables, the reported probability value of 0.7782 exceeds the 0.05 significance level. The null hypothesis is therefore not rejected, leading to the conclusion that no evidence of autocorrelation exists among the time series variables.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study investigated the relationship between rural and urban population growth and food availability in Nigeria using time series data spanning 1961–2022 and employing econometric methods, including unit root testing, Johansen's cointegration tests, and VECM. The results established that FPI, RPG, and UPG series are stationary after first differencing and are cointegrated, confirming the existence of a long-run equilibrium relationship among the variables. The negative coefficients associated with RPG and UPG in the cointegrating equation provide strong evidence that both rural and urban population growth exert an adverse effect on food production. The VECM further demonstrated a high speed of adjustment to equilibrium, indicating that deviations from the long-run path are quickly corrected. Impulse-

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response analysis revealed that RPG and UPG shocks generate short-run pressure on food production, but these effects dissipate with time.

The results highlight important policy implications. Rather than focusing on population control as a primary response, policy efforts should prioritize investments in agriculture capable of enhancing productivity. Strengthening food distribution systems, reducing post-harvest losses, and improving rural infrastructure can further take the edge off pressure on domestic food supply and availability. Additionally, income growth and trade boosts remain essential complements, enabling households to access food even when domestic production faces constraints.

In a nutshell, this study contributes to the literature by providing long-run and short-run evidence on how rural and urban population dynamics interact with food production capacity in Nigeria by employing a rigorous time series methodology over an extended historical period. Also, policy-relevant insights for managing demographic pressures and sustaining domestic food supply in a rapidly growing economy are proffered.

Recommendations

Addressing food shortages in Nigeria requires a comprehensive, multifaceted approach that integrates security, governance, and agricultural productivity. Firstly, the government should declare a state of emergency on food production, recognizing food availability as a matter of national survival. Ensuring the safety of farmers and farming communities must be prioritized. Thus, this study recommends that the government strengthen security in farming communities to create a safe environment for agricultural production and encourage farmers to cultivate available arable land. Secondly, agricultural policy supervision should be carried out meticulously, with transparent monitoring and effective follow-up mechanisms to reduce policy failures and corruption leakages. Investments should focus on mechanization, irrigation, modern farm inputs, research, and development to enhance productivity and resilience. Given the negative impact of rapid rural and urban population growth on food production, population management strategies, including family planning campaigns and rural development programs, should be integrated into agricultural planning.

Lastly, targeted interventions should be employed to improve food distribution systems, reduce post-harvest losses, and boost private sector involvement in agricultural financing and innovation. Aligning these measures with long-term development strategies will not only assuage the short-run disruptions of food production shocks but also ensure that food is available for the average Nigerian all year round.

Conflict of Interest Statement

The authors declare no competing interests relating to this article.

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