**Nigerian Population Growth Modelling and Forecasting using Univariate Time series model**

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**Abstract**

Proper planning based on the population growth presently and in the future is essential for the advancement of human development and the improvement of quality of life in a country. In Nigeria and around the world, rapid population growth is a significant problem. To achieve the protuberance needed for planning and decision-making, the study is used to model and forecast Nigerian population growth. A univariate time series model (Autoregressive Integrated moving average, ARIMA) was employed in which model identification was attained using the Autocorrelation function (ACF) and Partial Autocorrelation function (PACF) plots, the coefficients of the model were estimated using Ordinary Least Squares (OLS) method, optimal model was selected using Akaike information criteria (AIC) and Schwarz information criteria (SIC), adequacy and suitability of the model was attained using the Ljung-Box Statistic (LBS), ACF, PACF of the residua, coefficient of determination and adjusted coefficient of determination while forecast performance was determined using Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Chance Error (MAPE).

From the results, the descriptive analysis of the Nigerian population dataset from 1950 to 2050 has a mean of 99,611,692 with a standard deviation of 53,188,740 and a range from 37,189,369 in 1950 to 218,541,212 in 2022. The time plot demonstrated that the series is not stationary and stationarity (d = 2) was attained using the Augmented Dickey-Fuller test. The tentative ARIMA models were identified using ACF and PACF plots. ARIMA(3,2,1) model was selected for having the least AIC and SIC values after model estimation with the OLS method. The LBS, ACF and PACF plots, and are used to indicate ARIMA(3,2,1) as the optimal model. The ARIMA(3,2,1) model forecast, upper and lower bound values signified that the Nigerian population will have a continuous increase every year and the 28-year forecast values indicated Nigerian population may be between 339,237,774 and 418,347,670. The forecast evaluation metrics (RMSE, MAE, and MAPE) which are relatively low signified that the ARIMA(3,2,1) model has a strong predictive accuracy.

In conclusion, the Nigerian population growth forecast indicated an increase of more than 5 million every year and the Nigerian government must develop agreeable plans and recommendations to address the difficulties that will result from this explosive growth which is expected to hit above 418 million by 2050.

**Key words:**

**Introduction**

Population growth is still a major concern worldwide and has elevated to the level of a public health concern, especially in nations within the African continent (Harvard International Review\, 2023). The population of the globe was estimated to be close to 6.1 billion at the start of the twenty-first century (Chamie, 2007). According to UN estimates, there will be more than 9.2 billion humans by 2050 and up to a maximum of 11 billion by 2200 where more than 90% live in developing nations across the globe (Stuart *et al,* 2013). Nigeria is an example with the highest population in Africa and the most populace black nation in the world (West Africa Gateway, 2012). Nigeria's population is growing exponentially and is estimated to hit above 350 million by 2050 (The Economist, 2020).

Nigeria, with its roughly over 200 million inhabitants, is the eighth most populous country in the world and one of the top ten most populous countries worldwide (Nigeria Multidimensional Poverty Index, 2022). Where the exponential growth can be attributed to the high crude birth rate at 37.12 per 1000 population with annual population growth of 2.38 per cent (The Global Economy, 2023). It is noteworthy that a multitude of variables, including lack of education, beliefs, myths, and traditions, among others, impact the fertility prevalence in Nigeria. Extended families, especially the polygamous family system are encouraged by various faiths. The practice of getting married young is very common and has greatly accelerated the country's population increase (Nyoni, 2019).

One important issue which unnecessarily strains advancement and prosperity is the quick increase in population. Since population growth has an impact on social and welfare services, this is a threat to human welfare rather than a numerical one. (Sinding, 2009; United Nations, 2022). The decline of facilities aridity, changing climate, extermination of creatures, lack of a place to live, delays in traffic, pollution, and loss of forests are all negatively impacted by rose population growth (Dominic *et al.,* 2016). An analytical and critical examination of Nigeria's population growth has resulted in challenges for economic, social, and political actors. It also affects public education, health and welfare, and the standard of living environment for individuals (Aliyu and Amadu, 2017; Adejumo, 2020).

Several studies have been carried out on population growth prediction in Nigerian using different approaches and these include the works of Folorunso *et al.,* 2010; Olatayo, T. O. and Adeboye, 2015; Olayiwola, *et al.,* 2015; Aidi, *et al.,* 2016; Nyoni, 2019; Agog *et al.,* 2020; Odimientimi *et al.,* 2021; Lasisi *et al.,* 2021; Ogunjobi *et al.,*  2022; Oladimeji *et al.,* 2022; Orukpe *et al.,* 2023 and many more. These studies yielded good results, but the validity and predictive ability of their approaches were not determined, and the predictive evaluation metrics were not used to confirm the optimality and adequacy of the predictive values. In essence, this study will be used to model and predict Nigerian yearly population growth using the Autoregressive integrated moving average model, the model validation will be achieved using the coefficient of determination while the Adjusted coefficient of determination will be used to determine the model predictive ability. The optimality and adequacy will be attained using the following predictive evaluation metrics (Mean absolute error, Root mean square error and mean absolute percentage error). It is expected that this study will go far to provide better accurate predictive values that will assist policymakers in controlling the population explosion in Nigeria.

**Methodology**

**Data Exploration**

The variation displayed by the Nigerian population series is anticipated to be identified using the time plot and the series will be described and presented using descriptive statistics.

**Augmented Dickey-Fuller (ADF) test**

The stationarity of the series under examination is anticipated to be determined using the Augmented Dickey-Fuller (ADF) test.

This will be accomplished by comparing the corresponding standard errors to the relevant values in the Dickey-Fuller table using three sets of models given as

where equation (1) is a stochastic model, equation (2) has a slope variable and equation (3) combines equations (1) and (2).

**Autoregressive Integrated Moving Average (ARIMA) Model**

The ARIMA model is a type of univariate time series model that consists of an autoregressive component, a moving average part, and a differential order of integration (d). Given is the AR(p) and MA(q) components in equations (4) and (5).

and

In equations (4) and (5), and are the autoregressive and moving average coefficients, is a value taken at period and is a residual term at period . The is independently and identically distributed with . An ARMA process has AR and MA parts, where the present values of the series are termed approximately to its former values and present and, former residual terms.

The ARMA process is defined in equation (6) as

By using backward shift operator on equation (6), this gives

Therefore, equation (7) is an and with and as the difference level.

**Model Identification**

The autocorrelation function (ACF) and partial autocorrelation functions (PACF) are used to determine the order of and in equation (7).

The Autocorrelations function (ACF) is given as

and partial autocorrelation function (PACF) is defined as

and describe the autoregressive parameters, The smallest of the values of Akaike Information criteria (AIC) and Schwartz Bayesian Information criteria obtained after the estimation of the identified model will be chosen as the optimal model.

Akaike Information Criteria (AIC) is defined as

and Schwartz Bayesian Information Criteria (BIC) is expressed as

**Parameter Estimation**

The parameters of the ARIMA model are computed based on the ordinary least squares estimation method. This is achieved using

After the estimation step, the most appropriate model for the series under consideration will be selected using AIC and SBIC.

**Diagnostic Checking**

**Modified Box-Pierce (Ljung-Box) Chi-Square Statistic**

The residual of the estimated model is expected to be checked for stability using the Modified Box-Pierce (Ljung-Box) Chi-Square Statistic denoted as

and is the data points used when the difference is performed.

**Autocorrelation function of Residual**

With time series data, the value of a variable observed in the current period will likely be similar to its value in the previous period, or even the period before that, and so on. Therefore, when fitting a regression model to time series data, it is common to find autocorrelation function (ACF) in the residuals. ACF is defined as

**Coefficient of Determination**

The coefficient of determination is a measurement used to explain how much variability in the dependent variable is jointly explained by the independent variables. This is defined as

where SSE is the sum of the square of error and SST is the sum of squares of total.

**Adjusted Coefficient of Determination**

The ARIMA model predictive ability is going to be ascertained using the Adjusted Coefficient of Determination . This is defined as

where is the value of the coefficient of determination, is the of observations and is the number of estimated coefficients.

**Forecasting**

There are two types of forecasting: within and out sample. The former will be utilized to increase model confidence, and the latter will be utilized to forecast future values.

**Forecast Evaluation Metrics**

The forecast evaluation metrics used for this work are mean absolute error (MAE) denoted in the forms

(16)

root mean square forecast error (RMSE) is described in the form

(17)

and the mean absolute percentage error denoted by

(18)

(Olatayo *et al.,* 2014).

**Results and Discussion**

**Data Exploration**

The descriptive analysis of the Nigerian population obtained from the National Population Commission and National Bureau of Statistics websites between 1950 and 2022 signified that the average yearly population is 99,611,692 with a standard deviation of 53,188,740. The population of Nigeria ranges from 37,189,369 in 1950 to 218,541,212 in 2022. The Nigerian population dataset time plot displayed in Figure 1 demonstrated that the country's population is not stationary. This signified that the dataset exhibited a continuous rise over the years, and this is termed a secular variation.

**Augmented Dickey-Fuller test Interpretation**

For the Nigerian population dataset, the Augmented Dickey-Fuller test was utilized to achieve stationary. The results in Table 1 demonstrate that the series is stationary at the second level but non-stationary at the first level. I(2) is used to indicate this at levels of significance of 1, 5, and 10%, respectively. Using the ADF test results in Table 1, the Nigerian population is stationary at d = 2.



**Figure 1: Time plot of the Nigerian population from 1950 to 2022**

**Table 1. Augmented Dickey-Fuller Unit Root Test result**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  | Adj. t-Stat | Prob.\* |
| Augmented Dickey fuller test | | | -5.810369 | 0.0000 |
| Test critical values: | 1% level |  | -4.094550 |  |
|  | 5% level |  | -3.475305 |  |
|  | 10% level |  | -3.165046 |  |

**identification for the ARIMA model**

Using ACF and PACF, estimation models for ARIMA models are found. p = 1,2,3 and q = 1 or p = 3 and q = 1,2 are chosen because the ACF plots in Figures 2 and 3 fade at lag 1 and the PACF limit after lag 3. Preliminary ARIMA models include , , and



**Figure 4.2. Autocorrelation function for the Nigerian population**



**Figure 3. Partial autocorrelation function for Nigeria population**

**Model estimation**

The four suggested ARIMA modes' parameters were estimated using the ordinary least squares approach. The least estimated values of the Akaike and Schwarz information criterion as shown in Table 2 were used to choose the ARIMA((3,2,1)) model as the better model for modelling and forecasting the Nigerian population. The estimated coefficients of the ARIMA((3,2,1)) model are given in Table 3.

**Table 2. The corroboration results of the model for setting orders for the population**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| R-squared | 0.912217 | 0.935237 | 0.911367 | 0.918723 |
| Adjusted R-squared | 0.873679 | 0.905982 | 0.879281 | 0.880358 |
| Akaike Info. Criterion | 25.23594 | 25.19010 | 25.23594 | 29.38254 |
| Schwarz Info. Criterion | 25.39528 | 25.38131 | 25.39528 | 29.57376 |

**Table 3. Coefficient of ARIMA(3,2,1) model for the Nigerian population**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ARIMA(3,2,1) | Coefficient | Std. error | t-statistics | p-value |
| AR(1) | 0.9234 | 0.2260 | 4.0 | 0.000 |
| AR(2) | -0.4193 | 0.1846 | -2.27 | 0.026 |
| AR(3) | 0.4146 | 0.1197 | 3.47 | 0.001 |
| MA(1) | 0.3506 | 0.2439 | 1.44 | 0.155 |

**Model diagnostic check**

The computed Modified Box-Pierce (Ljung-Box) Chi-Square Statistic values shown in Table 4 were used to determine the ARIMA(3,2,1) model's suitability for population forecasting in Nigeria. This was further supported by the error term's ACF and PACF in Figures 4 and 5 where the residuals lacked structure and were significant at =0.05. In essence, ARIMA(3,2,1) is adequate when forecasting the population of Nigeria. The ARIMA(3,2,1) model is therefore, the most suitable and adequate model for modelling and forecasting the Nigerian population. The was further ascertained and validated using the estimated coefficient of determination and adjusted coefficient of determination for all the estimated models. The results are given in Table 2 where the coefficient of determination for the ARIMA(3,2,1) model signified the variation in the dependent variable is explained above 83% by the independent variables and the adjusted coefficient of determination signified that the ARIMA(3,2,1) model has the predictive ability of more than 91%. Based on these, ARIMA(3,2,1) is optimal for the forecast population of Nigeria than all other models estimated.

**Table 4. Modified Box-Pierce (Ljung-Box) Chi-Square Statistic result**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Lag | 12 | 24 | 36 | 48 |
| Chi-square | 9.0 | 12.7 | 26.6 | 28.6 |
| Degree of freedom | 8 | 20 | 32 | 44 |
| P-value | 0.342 | 0.888 | 0.738 | 0.965 |

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**Figure 4. ACF of Residuals for population**



**Figure 5. PACF of Residuals for population**

**Forecasting with ARIMA(3,2,1) model**

In Figure 6, the forecast outcome from ARIMA(3,2,1) model is shown. The forecast, upper and lower limit values for the Nigerian population are also discussed using Table 5. Figure 6 and Table 5 showed that the population forecast for Nigeria using ARIMA(3,2,1) signified a consistent increase on an annual basis. This suggests that the population of Nigeria will continue to increase, and based on the upper and lower bounds, the population of Nigeria may range from 339,2377,74 to 418,347,670 in the next 28 years. Based on the forecast evaluation metrics that is, RMSE, MAE, and MAPE values given in Table 6 signified relatively low values. Therefore, the ARIMA(3,2,1) model has a reasonable degree of predictive accuracy for forecasting the Nigerian population growth.

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**Figure 6: Forecast of Nigerian population from 1950 to 2050**

**Table 5. Forecast of Nigerian population from 2023 to 2050**

|  |  |  |  |
| --- | --- | --- | --- |
| Year(s) | Forecast values | Lower limit | Upper limit |
| 2023 | 223751713 | 223633578 | 223869848 |
| 2024 | 229020900 | 228694809 | 229346991 |
| 2025 | 234342022 | 233742824 | 234941219 |
| 2026 | 239715767 | 238768240 | 240663295 |
| 2027 | 245140661 | 243749914 | 246531408 |
| 2028 | 250612251 | 248679318 | 252545184 |
| 2029 | 256127331 | 253556170 | 258698492 |
| 2030 | 261684196 | 258377073 | 2649913192 |
| 2031 | 267280769 | 263136163 | 271425375 |
| 2032 | 272914519 | 267829470 | 277999568 |
| 2033 | 278583272 | 272454756 | 284711787 |
| 2034 | 284285221 | 277009693 | 291560748 |
| 2035 | 290018559 | 281491799 | 298545320 |
| 2036 | 295781476 | 285899112 | 305663839 |
| 2037 | 301572306 | 290230171 | 312914441 |
| 2038 | 307389523 | 294483686 | 320295359 |
| 2039 | 313231664 | 298658509 | 327804819 |
| 2040 | 319097329 | 302753724 | 335440935 |
| 2041 | 324985205 | 306768631 | 343201780 |
| 2042 | 330894061 | 310702678 | 351085443 |
| 2043 | 336822728 | 314555442 | 359090014 |
| 2044 | 342770101 | 318326632 | 367213571 |
| 2045 | 348735139 | 322016081 | 375454197 |
| 2046 | 354716858 | 325623720 | 38389995 |
| 2047 | 360714329 | 329149569 | 392279088 |
| 2048 | 366726674 | 332593732 | 400859616 |
| 2049 | 372753066 | 335956387 | 409549745 |
| 2050 | 378792722 | 339237774 | 418347670 |

**Table 6. Forecast Evaluation Metrics for ARIMA Model**

|  |  |
| --- | --- |
| Forecast Evaluation Metrics |  |
| MAE | 4.480962 |
| RMSE | 5.882820 |
| MAPE | 32.69064 |

**Conclusion**

The Autoregressive Integrated Moving Average model is utilized in this study to model and forecast the historical annual time series dataset for the Nigerian population from 1950 to 2050. A time series model for the historical Nigerian population was built using the study. According to the descriptive analysis result, the annual population of Nigeria had a mean of 99,611,692 with a standard deviation of 53,188,740. The population of Nigeria ranges from 37,189,369 in 1950 to 218,541,212 in 2022. The Nigerian population's time plot demonstrated the presence of secular variation, and this signified the series is not stationary. The Augmented Dickey-Fuller test was used to attain stationarity at the second difference (d = 2). The tentative ARIMA models were identified using autocorrelation and partial autocorrelation function plots of the Nigerian population. The ARIMA(3,2,1) model was selected for having the lowest values of Akaike and Schwarz information criteria after model estimation with the ordinary least squares method.

The Modified Box-Pierce (Ljung-Box) Chi-Square Statistic, autocorrelation, and partial autocorrelation of the residual were used to ensure the suitability of the ARIMA(3,2,1) model for forecasting the Nigerian yearly population series. Also, ARIMA(3,2,1) was validated using the coefficient of determination and adjusted coefficient of determination where the former signified above 83% of the variation in the dependent variable is explained by independent variables and the latter indicated the model has above 91% predictive ability. The ARIMA(3,2,1) model forecast, upper and lower bound values signified that the Nigerian population will have a continuous increase every year. The 28-year forecast values indicated a population range between 339,237,774 and 418,347,670. The forecast evaluation metrics RMSE, MAE, and MAPE) which are relatively low signifying that the ARIMA(3,2,1) model has a strong predictive accuracy.

In conclusion, the Nigerian population growth forecast indicated an increase of more than 5 million every year and the Nigerian government must develop agreeable plans and recommendations to address the difficulties that will result from this explosive growth which is expected to hit above 418 million by 2050.

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