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Detection of Appropriate Model for Nigeria Population Growth Using Root Mean Square Error (RMSE)

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Abstract: Nigeria, a developing nation is experiencing the overwhelming effects of her exponentially ever-increasing population. This paper is aimed at projecting the future population of Nigeria using the exponential and geometric growth models from 1991 and 2006 population censuses of Nigeria. The resultant effects are clearly evident for all stakeholders to see and feel. Researches have been carried out to study, explain and recommend likely solutions to the population growth of Nigeria. The data used in this research paper were extracted from the National Population Commission of Nigeria bulletin which was secondary data. The forecast for Geometric and Exponential models were made using last Nigeria population census 2006 as base population and projection were made from 2012 to 2022 and adopt the Root Mean Square Error (RMSE) to detect which of the methods adopted is better for population projection. RMSE of both geometric and exponential population projections are 1,832,610,950 and 1,930,404,821 respectively. The multiple bar chart was drawn which indicated higher increase in population projection for both geometric and exponential growth models.

Keywords: Population Census, Exponential Model, Geometric Model, Average, Annual Rate, Growth Survey, Sum of Square Error, Projection

1. Introduction

The history of census in Nigeria can be divided into two parts: the pre-independence (colonial) and post-independence census eras. In the pre-independence time, the first organization similar to the modern Nigeria bureau of statistics started in 1866. This census took place every ten years at the beginning of a new decade: 1871, 1881, 1891, and 1901. The Nigeria population census of 1911 was more difficult than the previous ones because five years before the census (in 1906) Lord Lugard united the Lagos colony with Southern Nigeria protectorate into Nigeria. The main counting took place only in the Southern protectorate, and the rest territories were explored partially, so that year population census was inaccurate. The first more or less reliable enumeration was conducted in 1921 under the surveillance of Sir Hugh Clifford as Governor General. The enumeration was divided into two parts: the township census (counted the residents of the towns) and provincial census (in the other territories of Nigeria). The township census was conducted within one day and gave accurate results particularly in comparison with provincial one.

The matter is that provincial census took more time (more than two months) and it was based on tax records of the residents. However, many tax evaders were nor taken into

account, and this part of the census was not entirely accurate. During 1929-1931 the enumeration was completely inaccurate because of the economic depression and numerous tax riots in Aba, Onitsha, and Owerri. The census took place predominantly in Lagos and its outskirts. Ten years later at the beginning of a new decade in 1941, the census did not take place because of the Second World War. The first well planned and more or less modern census in Nigeria took place only in the 1950s, in more than 80 years after the first enumeration of the population! It took about three years for Sir John Macpherson as Governor General to control the enumeration in four parts of the country: in the Lagos colony, in the Northern Region, in the Western and Mid-western Region and the Eastern region. But this census was the beginning of ethnicity of the population in Nigeria. Speaking about politicization and nationalization of the Nigerians – this phenomenon led to the first election in the country in the era of Nigerian post-independence. Tafawa Balewa became the Prime Minister after the elections and in 1962, a new census of the Nigerian population was conducted. But the results were rejected and considered incorrect, so, soon afterward, a new enumeration took place in 1963. This time the results were accepted by the government, but still rejected by the regions. In 1973, a new attempt to count the population took place.

Population growth is the change in the size of population resulting fromthe differences inbirth and death, which are measured both in absolute and relative terms while Population growth rate is the average annual percentage change in population, which is affected by birth and death as well as the balance of the number of people that are coming and leaving a particular country within a specified period of time (Mundi Index. 2012) [7]. One may not be wronged to say that Nigeria is at the verge of been termed over populated as the indicators of overpopulation signals such. These effects of over population are quite severe and seen in Nigeria today. Nigeria is the most populous country in Africa and the tenth in the world. These include the major demographic features as obtained from two major sources, viz.: the 1991 census and the PRB's World Population Data Sheet. With a high fertility rate, evidences show that large population inhibits government's efforts in meeting the basic needs of the people. With a population that already exceeds 170 million people and grows at roughly 3 per cent annually, (World Bank, 2012).

A considerable proportion of the country's resources is, doubtless, consumed instead of being accumulated as capital for development purposes. To that extent, the rate of development lags behind that of population growth, which triggers stagnation in social service delivery. This necessarily impedes whatever progress being achieved in the fight against poverty.

This research work is aiming at projecting the future population of Nigeria using the arithmetic, exponential and geometric growth models from 1991 and 2006 population censuses of Nigeria.

The objectives of the study are to: project the Nigerian population using the arithmetic, exponential and geometric growth model; determine the best model using the root mean square errors; Forecast the Nigerian population up to 2040 using the best model.

2. Literature Review

Several studies have been conducted in the area of population growth and projections. This is as a result of the growing quest to check the negative impacts of population growths in Nigeria and the world at large. Some of these studies are reviewed. [10] Investigated the time series role of population growth on economic growth in Nigeria and how economic growth is effected through population growth. This study this extends the literature by employing a linear model to analyze economic growth fluctuations vise-visa population growth. The study employed annual secondary observation from 1960 to 2008. The empirical results were based on Augmented Dickey-Fuller (ADF) stationary test combined with Granger Causality and Co-integration tests. Empirical results support that population growth has a significant impact on economic growth. The study also found that there is a sustainable long run equilibrium relationship between economic growth and population growth. There is also the evidence of unidirectional causality between population growth and economic growth. Policy implications of the study are provided. The socio-demographic analysis of the factors that lead to high birth and deathrates in South Western region of Nigeria and itsconsequences on the economy [12].

Their results revealed that the Crude Birth Rate (CBR) of South West was between 0.59 and 0.78 while the Crude Death Rate (CDR) was estimated to be between 0.19 and 0.24 per '000 yearly population. Using Regression analysis, their study demonstrated that both birth and death rates for the given sample period, have exerted much significant influence upon the population of South West as observed in the Coefficient of determination (R^2) of 72.3% arrived at in the Regression analysis. [13] study was carried out to find the trend, fit a model and forecast the population growth rate of Nigeria. The data were based on the population growth rate of Nigeria from 1982 to 2012 and obtained from World Bank Data (data.worldbank.org). They tested both time and autocorrelation plots to assess the Stationary of the data. The use of GIS and Remote Sensing in monitoring the growth and development pattern of Ile-Ife, Osun State, Nigeria over a period of 21 yearswith a view to predicting its direction of growth [2]. In effect, their study sought to identify and explain the rate and extent of changes in the study area between 1986 and 2007; measured the rate of urban growth in the study area between 1986 and 2007; assess the impact of urban growth on land use patterns; and predict the trend of urban growth in the study area. Data for the study were generated from both primary and secondary sources. Remote Sensing Imagery of Landsat TM 1986, Landsat ETM 2002 and ALOS 2007 were used to measure the extent of growth and to show the effects of this growth on other Land use/Land cover types.

Their results showed that that changes occurred in the magnitude and rate of urbanization in the study area between 1986 and 2007. They discussed their result mainly focusing on the trend of urban growth expansion and its effect to the Environment natural resources, farmland and food security

and its contribution to climate change. [1] examined the effect of population on economic development in Nigeria. Thus, Malthusian theory of population is relevant to Nigeria as a developing economy. The study examined the time series properties using the Phillips-Perron (PP) non-parametric unit root test. The analysis showed that real gross domestic product, population growth and per capita income are non-stationary at levels, but the null hypothesis of non-stationary was rejected at first difference for both test models with intercept andtrend. [5] argued on the importance of statistical knowledge of Nigeria's population, in terms of planning and development. In order to have an accurate and trustworthy data of Nigeria citizens, a biometric system for data collection is proposed as well as a centralized database for storing these data [6] employed an artificial neural network for population prediction (ANNPP) that handles incomplete and inconsistent nature of data usually experienced in the use of mathematical and demographic models while carrying out population prediction. According to them, ANNPP uses the three demographic variables of fertility, mortality and migration which are the major dynamics of population change as the input data. The datasets were divided into train, validation and test data. An equation and a projection of Nigeria population was made. They employed the multiple linear regression using SPSS [9].

The equation they obtained was $Y=37184.262+0.825X_1+1.051X_2+1.654X_3$, they used this equation toestimate the symptomatic value and compared with the National Population Commission value, it was discovered that Symptomatic Estimated population for Nigeria is approximately the same with National Population Commission that is, the symptomatic Estimated is 163,736,835 while that of NPC is 163,609,494, theythereforerecommendedthat themodel obtained can be usedto project the Nigerian population.[14] empirically tested the association between population growth and economic development in Nigeria between 1980 and 2003 and found that growth in population outweighs that of output and this has hindered the capacity of successive governments to efficiently provide social services to the people, thereby negatively affecting development.

Their contention, therefore, was that curbs on population growth through appropriate policies that would integrate the country's population programmers into the mainstream development efforts are necessary. [15] analyzedthe urban growth of Akure using medium resolution Landsatimageries. Landsat (MSS), Landsat Thematic Mapping (TM) and Landsat Enhanced Thematic Mapper (ETM+) images for 1972, 1986 and 2002 respectively were used in a post-classification comparison analysis to map the spatial dynamic of land cover changes and identify the urbanization process in Akure. The land cover statistical results revealed a rapid growth in the built-up area of Akure from 997.2 hectares in 1972 to about 3852.70 hectares in 2002 due to increase inpopulation of Akure within the said period. Results of the prediction showed that the built-up area of the city has increased in size from 977.2 hectares in 1972 to 5863.66 hectares in 2022 corresponding to 500% at the rate of 13.1% per annum. Implications of growth include loss of open space, pressure on limited infrastructure, overcrowding, traffic congestion and poor standardof living. The authors recommendedregular monitoring of urban area, development of small towns around the city area to avoid overcrowding, training of planners and administrators to acquire more knowledge in the use of GIS and remote sensing to enhance efficiency.

In 1996 Nigeria made the list and was ranked 10th, then only to overtake developed countries like Germany and Russia in 2016 to make the 7th position on the list [16] and according to United Nations projections, Nigeria is estimated to surpass the population of USA in 2050 to be the 3rd most populous country in the world with 733 million inhabitants [16]. But unfortunately, some researchers have failed to address key issues in regression modelling as used in their studies, such as; using Wald's test statistic as a variable selection tool [4], rather than the much consensus purposeful variable selection techniques [8,3] ignoring the existence of multicollinearity among the explanatory variables and also not addressing the issue of missing data. These issues are quite relevant enough to render the findings in most of the reviewed studies inadequate, invalid and misleading to be used as a policy-making tool [4,11]. Research that used the same variables from the same source as this current study, did ignore these potential problems and still went ahead to model Nigeria's population growth rate using ordinary least squares regression models. This would have definitely led to reduced statistical power, misleading results, spurious findings, bias and invalid conclusions [4, 11].

3. Materials and Methods

The study compares two population projection models: geometric model and exponential model. The projections are made from 2006 to 2040. Using the interpolated values, the Sum of square error (SSE) for each interpolated value are then calculated. The population growth rate of 2.8 as given by 2006 population census was used in this study. The mean square errors (MSE) and root mean square errors (RMSE) are also calculated. The RMSE is the square root of the mean/average of the square of all of the error. The use of RMSE is very common and it makes an excellent general purpose error metric for numerical predictions. Compared to the similar Mean Absolute Error, RMSE amplifies and severely penalizeslarge errors.

The population models employed here are given below:

3.1. Geometric Growth Model

Population with $P_t$as the number of individuals at time t, P_0 as the initial number of individuals, ras the population growth rate and tis the number of time intervals or generations. For a population growing at a geometric rate, the population size at any time t can be calculated as:

$$P_t = P_o(1 + r)t$$

3.2. Exponential Growth Model

Given that $P_t$is the number of individuals at time t, P_0 is the initial number of individuals, e is the base of the natural logarithms, ris the per capita rate of increase, and t is the number of time intervals (here in years), for a population growing at an exponential rate, the population size at any time t can be calculated as:

$$P_t = P_o ert$$

The exponential model is appropriate for populations with overlapping generations. This is because it deals with population growth as a continuous process. In this model, r is a constant and P is a variable. Therefore, as population size, P, increases the rate of population increase, dp/dt, gets larger and larger, sincethe constant r is multiplied by a larger and larger population size, P. Consequently, during exponential growth, the rate of population growth increases over time.

In assessing the best model for the Nigerian population, the RMSE is employed as follows:

$$\text{RMSE} = \sqrt{\left[\frac{1}{n}\right]\sum_{i=1}^{n}[y - \hat{y}]^2}$$

3.3. Analysis of Data

Table 1. *ShowingAge and Sex distribution of 1991 population census in Nigeria.*

Age	Males	Females	Both Sexes
0-4	7,344,454	6,999,435	14,343,889
5-9	7,374,314	7,126,144	14,500,458
10-14	5,812,538	5,336,143	11,148,681
15-19	4,528,811	4,806,977	9,335,788
20-24	3,314,303	4,357,267	7,671,570
25-29	3,304,739	4,006,932	7,311,671
30-34	2,808,629	3,105,298	5,913,927
35-39	2,206,871	2,008,062	4,214,933
40-44	1,971,197	1,874,721	3,845,918
45-49	1,355,101	1,061,602	2,416,703
50-54	1,388,650	1,182,149	2,570,799
55-59	6,383,375	481,394	1,119,769
60-64	898,801	791,573	1,690,374
65-69	406,540	357,400	763,940
70-74	492,186	394,116	886,302
75-79	195,455	156,368	351,823
80-84	258,059	222,627	480,686
85+	230,505	194,404	424,909
TOTAL	44,529,608	44,462,612	88,992,220

Source; National Population Commission (https://www.populalation.gov.ng)

Table 2. *Showing Age and sex distribution of 2006 population census in Nigeria.*

Age	Males	Females	Both Sexes
0-4	11,569,218	11,025,749	22,594,967
5-9	10,388,611	9,616,769	20,005,380
10-14	850,439	7,631,631	16,135,950
15-19	7,536,532	7,362,887	14,899,414
20-24	6,237,549	7,197,530	13,435,079
25-29	5,534,458	6,676,968	12,211,426
30-34	4,505,186	4,962,352	9,467,538
35-39	3,661,133	3,670,622	7,331,755
40-44	3,395,489	3,060,981	6,456,470
45-49	2,561,526	2,029,767	4,591,293
50-54	2,363,937	1,885,282	4,249,219
55-59	1,189,770	876,477	2,066,247
60-64	1,363,219	1,087,067	2,450,286
65-69	628,436	522,612	1,151,048
70-74	765,988	564,609	1,330,597
75-79	327,416	252,422	579,838
80-84	408,680	351,373	760,053
85+	404,021	311,204	715,225
TOTAL	71,345,488	69,086,302	140,431,790

Source; National Population Commission (https://www.populalation.gov.ng)

3.4. Geometric Growth Model Analysis

The Geometric Growth Model is given as:

$$P_t = P_0(1 + r)t$$

To find the Annual growth rate r, we use

$$(1 + r)t = \left[\frac{P_t}{P_0}\right]$$

$$1 + r = \left[\frac{P_t}{P_0}\right]^{\frac{1}{t}}$$

$$r = \left[\frac{P_t}{P_0}\right]^{\frac{1}{t}} - 1$$

$$P_t = P_{2006} = 140{,}431{,}790;\ P_0 = P_{1991} = 88{,}992{,}220;\ t = 2006 - 1991 = 15;$$

$$r = \left[\frac{140{,}431{,}790}{88{,}992{,}220}\right]^{\frac{1}{15}} - 1 = 1.03088 - 1 = 0.03088 \approx 0.03 = 3\%$$

Note: All calculations are done per million population and r = 3% is used throughout.

Taken the projection from 2012, t = 2012 – 2006 = 6.

Exponential Projection Analysis

The exponential projection model is given as;

$$P_t = P_0 e^{rt} for r = 3\% = 0.03,$$

Taken the projection from 2012, as t = 6;

Table 3. *Showing summary of projections from growth models.*

	Observed value (y)	Geometric ($\hat{y}$)	Exponential ($\hat{y}$)
Years	Population (million)	$P_0(1 + r)^t$	P_0e^{rt}
2012	164.75	167.68	168.13
2013	169.28	206.23	207.42
2014	173.94	261.25	263.68
2015	178.72	340.87	345.41
2016	183.64	458.10	466.25
2017	188.69	634.12	648.54
2018	193.88	904.10	929.57
2019	199.21	1,327.70	1,372.96
2020	204.68	2,008.27	2,089.59
2021	210.31	3,128.82	3,276.20
2022	216.10	5,020.84	5,294.58

Table 4. *Showing the Root Mean Square Error (RMSE) using* $\sqrt{\left[\frac{1}{n}\right]\sum_{i=1}^{n}[y_i - \hat{y}]^2}$.

Years	Geometric ('000,000)	Exponential ('000,000)
2012	8.5849	11.4244
2013	1,365.3025	1,454.6596
2014	7,623.0361	8,053.2676
2015	26,292.6225	27,785.5561
2016	75,32228.2916	79,8868.4121
2017	198,407.8849	211,462.0225
2018	504,412.4484	541,239.7761
2019	1,273,489.68	1,377,689.063
2020	3,252,936.888	3,552,885.708
2021	8,517,700.62	9,399,681.492
2022	23,085,526.47	25,790,959.11
SSE	36,943,091.83	40,991,090.49
MSE	3,358,462.894	3,726,462.772
RMSE	1,832.61095	1,930.404821

Explanations of the table above: SSE = $[y - \hat{y}]^2$ that is;

SSE_{2012} = $(164.75 - 167.68)^2$ = 8.5849 million…… Geometric Model.

SSE_{2012} = $(164.75 - 168.13)^2$ = 11.4244 million …. Exponential Model etc.

$$MSE = \left[\frac{1}{n}\right]\sum_{i=1}^{n}[y - \hat{y}]^2 \text{ and } RMSE = \sqrt{\left[\frac{1}{n}\right]\sum_{i=1}^{n}[y - \hat{y}]^2}$$

while n = 11 (i.e. numbers of projected years in the study).

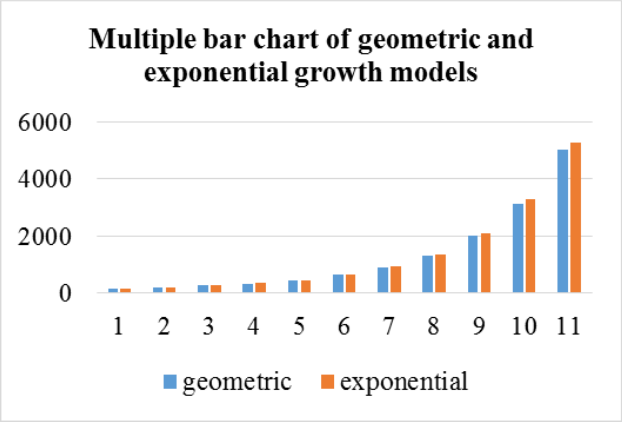

Figure 1. *Indicated higher increase in population projection for both geometric and exponential growth models.*

4. Conclusion

The results of population projection models were presented in table 4 of the previous chapter which indicated the forecast for Geometric and Exponential models using last Nigeria population census 2006 as base population and projection were made from 2012 to 2025. From the same table 4 we can however deduced that the geometric and exponential growth models predicted values gave a closest results, although both models showed higher forecasted values compare to the observed value population given per million people. Meanwhile the extrapolation in the projected values of both geometric and exponential projections indicated high increase of Nigeria population and this may lead to over crowd/overpopulation which has adverse effect on Nigeria Economy.

(i). SSE of geometric and exponential population projections.

(ii). MSE of both geometric and exponential population projections.

(iii). RMSE of both geometric and exponential population projections of 1,832,610,950 and 1,930,404,821 respectively.

Model the population of Nigeria using geometric and exponential models and obtained nearer values as reported earlier started from 2012 to 2022 taken 2006 population as base year.

Obtained the Root Mean Square Error (RMSE) of the projections made on geometric and exponential growth models to determine which of the two models employed is more efficient in forecasting the Nigeria population, meanwhile geometric population growth model gave the lesser RMSE value compare to exponential as presented earlier. Hence, geometric model is more efficient in use than exponential model.

Ascertain that the Nigeria population has been projected for eleven years started with 2012 and ended with 2022 as presented under findings.

5. Recommendation

For the purpose of this research work the following recommendations will be made;

a) The population regulatory agency should advice Nigerians to give birth to a reasonable number of children to disallow overpopulation.

b) There should be a programme organize by Federal Government Agency to enlighten people on how to be self-reliance (entrepreneurship).

c) The government should provide free education to Nigerians to reduce illiteracy among the populace.

d) The government should lay emphasis on urban and rural renewal to disallow congested population at a particular geographical /settlement area.

e) The Federal Health Officer should educate people on the importance of family planning to reduce overpopulation.

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