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A Review of Sub-National Population Projections in Nigeria: The Case of Sokoto State 2006-2031

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INTRODUCTION

The main purpose of population projection is to provide estimates of future population size and structure for decision-making. The projections are vital for planning and budgeting by state and non-state stakeholders in the development community, and a well-aimed estimation is essential to making adequate preparation for future demands on resources [1]. Besides, concerns about the localized consequences of human population growth and demographic changes have motivated forecast about the demographic future [2]. Such concerns have necessitated projections to determine both size and structure, especially by sex and age, of future population trends in a geographical region at a particular time [2, 3].

Demographers mainly view population projections as indicative rather than predictive. The methodology of a projection can either be objective or subjective [4] and there are several methods to make population projection [5]. Projections are, in general, based on certain assumptions; hence population projections are the implications of assumptions at future dates as they show a picture of the future population if specific assumptions hold. Nevertheless, they do not predict whether the assumptions will hold [2, 3]. Future events prove the accuracy of a population forecast, as forecast represents an analyst's most realistic prediction of the future population. Projections are conditional as they are the combination of methodological assumptions, available records, and techniques [2].

Agencies such as United Nations Population Division (UNDP), U.S. Census Bureau, International Institute for Applied Systems Analysis (IIASA) and the World Bank make projections for global, regional and national populations, with United Nations projections being the most widely used [6]. Also, various national statistical bodies make projections for their countries [7].

Nigeria's first modern and carefully planned nationwide census was the 1952/1953 enumeration [8, 9] while the most recent population census was conducted in 2006 [10]. Later population figures have been estimated or projected by statistical and population agencies at national and subnational levels. Since its establishment in 1989, the National Population Commission (NPopC) of Nigeria has been tasked with collecting, analyzing and disseminating demographic data in the country. In 2000, the commission received the mandate to "review population policy, coordinate and monitor all population management activities" [11], and has been responsible for making the national population projections and supporting agencies at subnational levels.

Currently, Nigeria is projected as the most populous country in Africa and the 7th largest population in the world [11]. It is projected that Nigeria will be the 3rd largest nation in the world by 2050 [7]. Population estimates at subnational level are based on the 2006 census and annualized population growth rates experienced between the 1991 and 2006 censuses at the respective level. For example, Sokoto State's population was enumerated at 3,702,676 in the 2006 national population census and projections are based on 3% annual growth. On this

basis, the population was estimated to be 4,309,896 in 2011 [12] and 5,313,527 in 2017 [13] by the state ministry of planning.

There are challenges with this method of projection. The projections are based on the fixed age structure obtained from the 2006 census in which 47.5% were under 15 years of age, 49.6% were aged 15-64 and 2.9% were 65 and above [14]. The fixed age structure undermines planning for age-specific groups in the population. Fertility rates have changed substantially from the intercensal experience, and so have mortality and migration trends. Thus, there is need for population projections that incorporate these changes.

METHODS OF POPULATION PROJECTION

Generally, there are three methods for population projection. Each of the three types of methods involves some basic assumption without which its use would not be justifiable. The implicit conditions might be stated as follows:

Mathematical (Trend) Method

The use of a "mathematical" method presupposes that the trend of total population growth is fairly regular and that relevant features of the economic and social setting of the future will be the same as those of the past, or will represent the result of a gradual evolution. Consistent trends of change can reasonably be expected in populations with fairly regular age composition where the social and economic environment exerts a steady or only gradually changing influence.

This is the simplest method of estimating the future size of a population that calculates current population by taking the initial population size and applying it to an assumed rate of increase. The method is "mathematical" because of its emphasis on the formulation of equations as expressing the rates as functions of time, instead of function of particular factors which may influence the trend during any specific time period. These methods are generally referred to as trend extrapolation methods.

"Mathematical" methods are not appropriate for use where the present age structure of the population exhibits marked peculiarities. Moreover, where important and rapid changes in social and economic conditions relevant to population growth can be expected on grounds of current indications or the previous experience of other populations similarly situated, it is not appropriate to use a "mathematical" method that implies the continuation, without modification, of the growth tendencies observed in the past.

Economic Method

The use of an "economic" method is justified where major economic variables, such as the rise or decline of industry, can exert an overriding influence on population change, particularly through migration. Birth rates and death rates are only moderately responsive to economic change, since they depend also on a variety of other factors in the cultural and

social environment, some of which are statistically imponderable. The "economic" method is most pertinent where migration is sufficiently free of legal barriers or other impediments to become a major element in the trend of population. Economic methods include microsimulation and structural modelling.

Cohort Component Method

The cohort component method is superior to "mathematical" methods in that it involves a separate analysis of the changes affecting each component of the population. It is most convenient to project the population by time-intervals equal to the age-intervals into which it has been divided. Thus, if the population is subdivided by five-year groups of ages, the projection can most easily be made for five-year intervals of time: at the end of a five-year period, all surviving members of one age group will have moved into the next subsequent age group. Component projections of a population with respect to characteristics other than sex and age do not require any departure in basic method. It follows that a component method is generally preferable to others except where there are important obstacles to its application (inaccuracy or lack of detailed statistics, smallness of the population), or where an economic or other factor in the environment assumes an overriding importance, with its influence exerted primarily through migration. If one or more of these reasons prejudice the use of a "component" projection, then a "mathematical" or "'economic" method is to be preferred, depending on the conditions of the particular case.

The methods developed by the United Nations staff have as their main objective to facilitate the making of "component" projections for as many countries as possible, including those where the available statistics are defective in several respects. In the latter instances, the procedures include the use of certain general schemes by which the missing figures can be approximated. Since the projections themselves are in the nature of estimates, they are still justified where a part of their statistical basis is likewise estimated. The latter estimates should, of course, be realistic. The method also satisfies all the criteria's for choosing suitable projection method.[15].

TABLE 1: COMPARISON OF PROJECTION METHODS

No	Method	Meaning	Strength	Weakness
1	Trend extrapolation methods [16]	It is based on the continuation of observable historical trends	It is used for making quick estimates for illustration and comparison purposes	It is usually not useful for policy-related purposes. It is not recommended for making official population projections
2	Cohort-Component Method (CCM)[17]	It is based on grouping the initial population into cohorts defined by age and sex.	It provides information on potential growth, decline of a locale by age and sex.	It is based on the assumption of fixed survival, birth rates and estimates of net migration throughout the projection period.
3	Structural modeling [18]	Structural models base population projections on the underlying socio-economic development and other determinants	They are well suited for analyses of policy changes on demographic variables.	The lack of data on one or more parameters in the model
4	Microsimulation [19]	This technique simulates life events for each individual.	It performs well even with large numbers	Data requirements can be prohibitive.

CRITERIA FOR CHOOSING A PROJECTION METHOD

Users face a number of choices in selecting demographic inputs for their analyses. The considerations involved in such choices are varied and depend on the nature of each application. An all-encompassing theme of the general discussion of scenarios and probabilistic projections is that uncertainty in demographic projections is substantial. It is therefore advisable to avoid using a single population projection for any analysis. Either a range of alternative scenarios, or a probabilistic projection, should be employed to imitate the inherent demographic uncertainty. If it is decided that scenarios will be used, the choice of which population scenarios or set of scenarios to use should take into account the assumptions on which they were based and their sources of uncertainty.

The criteria for choosing a projection method include the following:

i. Desired outputs: Length of time horizon (short, medium or long term) and amount of subject detail (total population, broad age groups, five-year age groups, single years of age and subgroups.
ii. Input data: Data availability, Data quality, missing data (Plausible assumptions)
iii. Projection tools[20]

POPULATION PROJECTION PRACTICE BY NIGERIAN STATISTICAL AGENCIES

Effective planning has been a major challenge for the Government of Nigeria at national and subnational levels [21, 22] and population data and projections are fundamental to these challenges. The Government of Nigeria through the NPopC adopted the trend extrapolation method in making population projections. As noted above, this practice determines only the total population without segregating the population into demographic and epidemiological groups. At subnational levels, each State Bureau of Statistics (SBS) develops state population projections using a mathematical formula that grows the 2006 total population at a fixed or varying rate. Common projection methods include exponential growth formula $P_t = P_o e^{rt}$, geometric progression $P_t = P_0(1+r)^t$ and log-linearized formula $P_t = P_0(1+rt)$ where P_t is the total population at time t, P_o is the initial population, r is the annual growth rate, t is duration from time o and e is Euler's number. The use of only mathematical growth formulas for projection do not provide opportunities for comprehensive data for planning purposes. It only estimates the population size (the total number of people in the state) at the end of the time interval based on assumed growth rate of the aggregate population.

However, the 3% annual growth employed by the Sokoto State Bureau of Statistics is quite questionable. Observed fertility rate has increased while mortality has declined moderately due to general improvement in healthcare and other determinants of health. In the Multiple Indicator Cluster Surveys (MICS), Sokoto's total fertility rate (TFR) increased from 5.2 in 2011 to 7.3 in 2016 [23, 24]. At the same time, mortality rate has improved with the rates of infant and under-five mortality decreasing in 2016 as against the 2011 report [23, 24]. Changes in mortality and fertility drive changes in population age structure and these changes are part of the determinants of overall population growth. In addition to insensitivity to fertility and mortality changes over the projection period, current projection methods exclude consideration of socio-economic advances whilst it is proven that population dynamics are strongly related to these events.

These shortcomings impose limitations on suitability of the projections for effective planning. They limit the effectiveness of healthcare interventions, as planning depends largely on demographic data, as well as economic development and poverty reduction initiatives.

Conferring from the figures presented by the Nigerian Bureau of Statistics, population projection is derived from the above-mentioned formulas with constant growth rates per

annum for states and national growth. The growth rate was derived between the difference in the census 1991 and 2006 and it is shown in the table below.

TABLE 2: PROJECTED POPULATION OF SOKOTO STATE BY TREND EXTRAPOLATION

	2006	2010	2011	2012	2013	2014	2015	2016	2017	2018
Growth rate	3.0%									
Linearized	3702676	4146997	4258077	4369158	4480238	4591318	4702399	4813479	4924559	5035639
Compounding	3702676	4167394	4292416	4421189	4553824	4690439	4831152	4976087	5125370	5279131
Exponential	3702676	4174756	4301896	4432908	4567910	4707024	4850374	4998090	5150304	5307154

Source: Author's computations; Growth rate and 2006 numbers are from National Bureau of Statistics.
Notably, Sokoto State Bureau of Statistics currently uses the exponential method.

DEMOGRAPHIC CHANGES SINCE 2006

According to estimates derived from the household health care survey (HHS) in Sokoto state, there are variations in the percentage distribution across different age groups as population indicators vary concerning fertility and mortality for a closed population. Hence, an appropriate scientific method should be applied to calculate an apt estimate for projections that will form the basis of planning and intervention in several areas of economy and development. The table below shows the variation in percentage distribution across different age group.

Household surveys conducted in the state show that there have been changes in the age structure of the population since 2006. Data from available surveys are summarized in the table below.

TABLE 3: VARIATION IN PERCENTAGE DISTRIBUTION ACROSS DIFFERENT AGE GROUPS

	2018/19 NLSS Survey (%)	2008 Household Survey (%)	2006 Census (%)
Gender			
Male	53.1	54.3	50.3
Female	46.9	45.7	49.7
Age			
0 – 4	20.8*	90.6	20.2
5 – 14	29.0+		27.3
15 – 49	48.1		43.6
50 – 64		9.4	6.0
65 +	2.1		2.9
Total	100.0	100.0	100.0

Sources: Nigeria Living Standard Survey (NLSS) 2018/19, NBS/CBN/NCC Social-Economic Survey on Nigeria 2008 and NPopC Census of 2006. The age distribution of the 2008 Household Survey sample was provided for age groups 0-9, 10-19, 20-29, 30-39 and so on. *Refers to 0-5, +Refers to 6-14

Overall, the population of the state grew younger between the Census of 2006 and the NLSS of 2018/19. The share of children under age 15 increased by 2.3% from 47.5% in 2006 to 49.8% 2019. Correspondingly, the share of working-age adults 15-64 reduced by 1.5% from 49.6% to 48.1% and the share of the elderly age 65 and above decreased by 0.8% from 2.9% to 2.1%. Also, the sex ratio of the population shifted notably. The male share of population increased from 50.3% in 2006 to 53.1% in 2018. Although the age structure of population by state was not made available from the 1991 population census, the age dependency ratios made available from both censuses show that the age dependency ratio increased from 91.7% (1991) to 101.7% (2006)[1] and further to 107.9 (2018). Given the decrease in the share of elderly aged 65 and above, it can safely be generalized that Sokoto state population grew younger over time.

METHODOLOGY: THE COHORT COMPONENT METHOD

The Cohort Component Method (CCM) presents a more practical method of population projection. CCM makes projection with the summary of components affecting population change. It requires more effort and data and makes more sufficient projections than the mathematical method as it utilizes the fertility rate, mortality rate and migration across various age groups. The method was first proposed in 1895 by English economist Edwin Cannan, re-introduced by Whelpton in 1936, formularized in mathematical terms by Leslie in 1945 and first employed in producing a global population projection by Notestein in 1945.

[1] Annual Abstract of Statistics, 2012 (TABLE 54), National Bureau of Statistics

This modeling was carried out following the pattern of the United Nations (UN) population models and projections [25]. The projection was conducted in 5 stages that focused on the following factors:

a) Data Availability
b) General Analytical Strategy and steps for producing population estimate
c) Addressing challenges arising from data quality issues
d) Fertility Assumptions: Convergence towards a lower fertility rate
e) Mortality Assumptions: Increased life expectancy for the state

This method was used to project Sokoto's age and sex structure, population share of women of childbearing age, population structure and the rate of population change due to fertility and mortality. The age and sex structure of the population is derived for every five-year interval till 2031.

The computation includes the following steps:

a) Survive the base population in time t by age and sex to time $t + n$ in projection period.
b) Multiply each age group population by lifetable survival ratios (open-ended interval requires special handling)
c) Make any adjustments for migration
d) Calculate the total number of births (total, by sex) during $t, t + n$
e) Apply survivorship to these births to determine number that survive to $t + n$
f) Obtain population projection at $t + n$
g) Repeat steps a)-f) for the next projection period [20]

Assumptions were made on fertility and mortality rates based on socio-economic trends and reports from statistical offices. We assumed Sokoto's population to be closed in which case migration has negligible effect in population change.

The 2006 population census is our initial population, and the initial age and sex structure was obtained from the enumeration. All assumptions were made for a period of 5 years. To calculate population structure at the end of the 2006-2011 interval, we segmented the population into 2 groups:

a) Age 5 and above: To derive the segment of population age 5 and above, we calculated the survival ratios from mortality assumptions using the model life table for each of the age groups. These survival ratios were applied to the corresponding size of the age group at the beginning of the projection interval (2006) to determine the number of survivors at the end of the interval (2011), by which time they are 5 years older.
b) Below Age 5: From the total number of births in the interval, we estimated the total and age specific fertility rates and survival rate of births. The number of births were calculated from the fertility rates and the mid-interval numbers of women in different childbearing age groups (15years to 49years). Using the United Nations birth-gender ratio, we calculated proportion of males to females (aged 0-4 years) for the 2006–2011 interval.

This procedure was repeated over subsequent time intervals and projected population structures were obtained for the end of intervals 2011-2016, 2016-2021…...2026-2031.

From the projected population structures, the population indicators and aggregates were calculated for various intervals. The indicators included dependency ratio, proportions by broad age groups, median age, sex ratio and proportion of women in child bearing ages. Population aggregates such as population size, young age population, working age, growth rate etc. were also calculated. Population size is the sum of all persons across various age group both males and females for the interval, young age population is sum of persons' age group 0-14 both males and females for the interval, working age population is the sum of persons in age group 15-64 both males and female for the interval and the number of women of the childbearing ages is the sum of women in age groups 15-49. Other indicators are calculated in same way based on the demographic groups.

ASSUMPTIONS

Assumptions need to be made on the major components of population change – fertility, mortality and migration. Given our modelling of the state as a closed population, we ignore migration. Our fertility assumptions for the first three quinquennials, 2006-2011, 2011-2016 and 2016-2021 are derived from observed Total Fertility Rates (TFR) in Sokoto state as reported in the Nigerian Demographic and Health Surveys (NDHS). We use the TFRs reported in 2008, 2013 and 2018 as they fall in the mid-point of the intervals. For the remaining periods, our projections are based on two scenarios: a flatlined TFR scenario in which TFR remains unchanged from current levels and a declining TFR scenario where a combination of social, economic and population policies to be implemented over the plan horizon to reduce TFR to 6.5 during 2021-2026 and 6.0 during 2026-2031.

TABLE 4: FERTILITY ASSUMPTION

Time interval (years)	TFR (Flatlined)	TFR (Declining)
2006-2011	8.7	8.7
2011-2016	7.0	7.0
2016-2021	7.0	7.0
2021-2026	7.0	6.5
2026-2031	7.0	6.0

Data Source: NDHS 2008, 2013 and 2018; Author's assumptions

Our mortality assumptions are summarized by life expectancies over the projection period. The numbers are derived from model life table using assumed levels of child mortality.[2] The

[2] The computations were carried out in MORTPAK software developed by the UN Population Program.

resulting life expectancies increase linearly through the years for both males and females by a total of 2.22 years and 2.44 years respectively over the 25-year period of planning.

TABLE 5: MORTALITY ASSUMPTIONS – EXPECTATION OF LIFE AT BIRTH

Time interval (years)	Male	Female
2006-2011	51.21	54.58
2011-2016	51.76	55.16
2016-2021	52.31	55.75
2021-2026	52.87	56.34
2026-2031	53.43	56.94

Data source: Model Life Table

PROJECTION RESULTS

Using the CCM, we have been able to forecast changes in population structure over time. We decided to show varying changes in population overtime.

TABLE 6: POPULATION PROPORTION ACROSS AGE-GROUPS (%) AT THE END OF INTERVAL – FLATLINED FERTILITY SCENARIO

Population proportion across age-groups (%) at the end of interval

Age Group	2006	2011	2016	2021	2026	2031
0-4	20	21	21	20	19	17
5-14	27	30	30	31	30	29
15-49	44	42	42	43	44	45
50-64	6	5	5	5	5	7
65+	3	3	2	2	2	2
Total	100	100	100	100	100	100

Source: Authors' projections

TABLE 7: POPULATION PROPORTION ACROSS AGE-GROUPS (%) AT THE END OF THE INTERVAL DECLINING FERTILITY SCENARIO

Age Group	2006	2011	2016	2021	2026	2031
0-4	20	21	21	20	18	15
5-14	27	30	30	31	31	29
15-49	44	42	42	43	45	47
50-64	6	5	5	5	5	7
65+	3	3	2	2	2	3
Total	100	100	100	100	100	100

Source: Authors' projections

The underlying total population obtained from the projection is provided below for each of the scenarios – Mathematical projections based on 2006 fixed age structure and constant growth rate, CCM projection based on declining TFR for the final two quinquennials, and CCM projection based on flatlined TFR for the final two quinquennials.

TABLE 8: TOTAL PROJECTED POPULATIONS FROM 2006 TO 2031

Year (End of Interval)	**Mathematical Projection**	**CCM with Declining TFR for 2021-2031**	**CCM with Flatlined TFR for 2021-2031**
2006	3,702,676	3,702,676	3,702,676
2011	4,292,416	4,494,392	4,494,392
2016	4,976,087	5,390,390	5,390,390
2021	5,768,649	6,456,472	6,456,472
2026	6,687,445	7,553,758	7,657,435
2031	7,752,581	9,095,346	9,426,272

Source: NBS and Author's projection

PROJECTED POPULATION PYRAMIDS

The resulting age distributions of the projected population in the scenarios are presented below.

FIGURE 1: POPULATION PYRAMID FOR 2031 BASED ON MATHEMATICAL PROJECTION

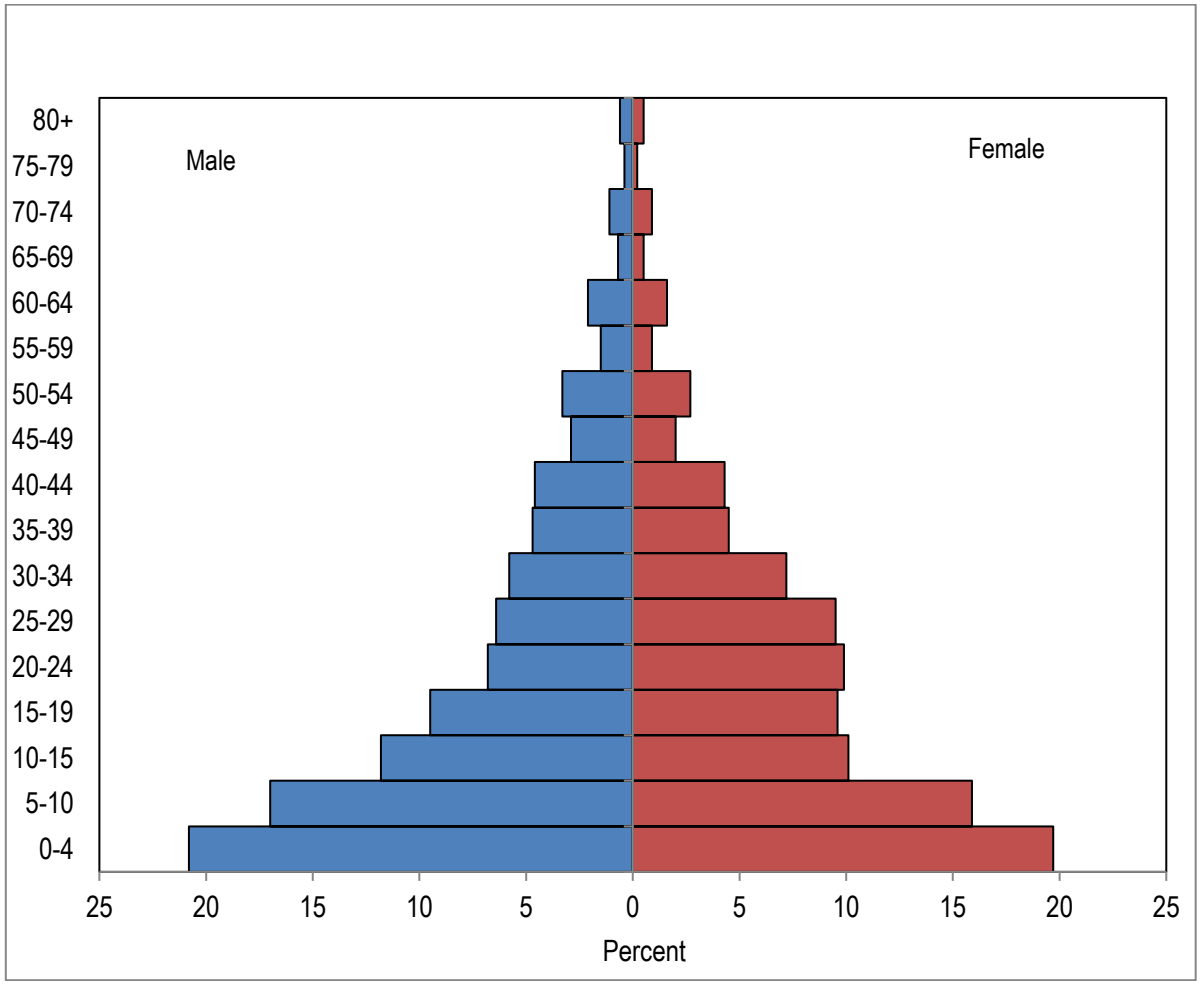


FIGURE 2: POPULATION PYRAMID FOR 2031 BASED ON DECLINING TFR

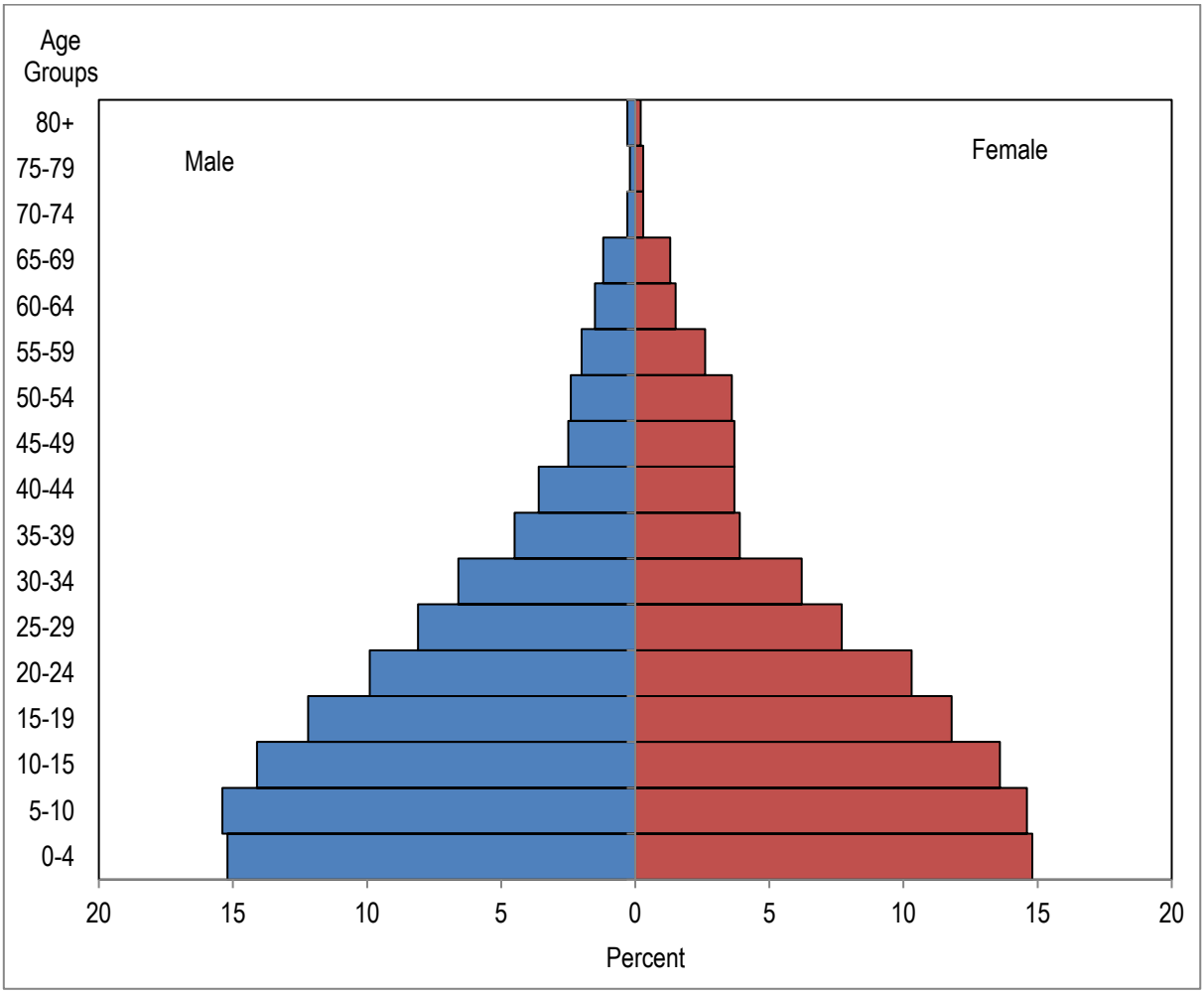
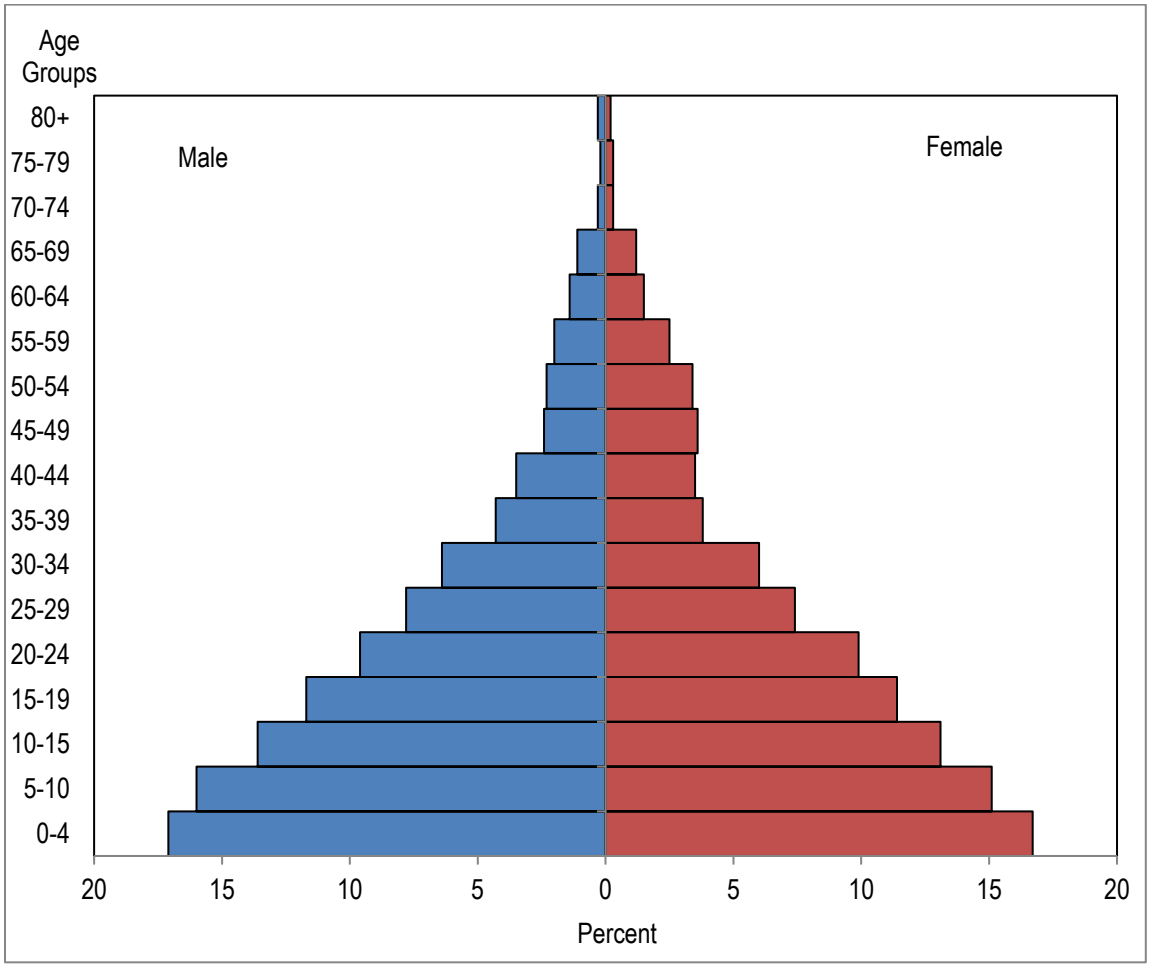


FIGURE 3: POPULATION PYRAMID FOR 2031 BASED ON FLATLINED TFR



DISCUSSION

Public policymakers and planners around the globe use population projections to gauge future demand for food, water, energy, services, and to predict future demographic characteristics. Population projections can allow policymakers craft policies that can be adapted for various projection scenarios. The accuracy of population projections has been attracting more attention, driven by concerns about the possible long-term effects of aging, HIV/AIDS, and other demographic trends.

The National Research Council of the U.S National Academy of Science (NAS) convened a panel of experts in 1998 to examine the assumptions, accuracy, and uncertainty related to the most widely used population projections and to recommend ways to improve these projections. After extensive review, the panel concluded in July 2000 that current world population projections to the year 2050 are based on scientific evidence and provide plausible forecasts of demographic trends for the world. The panel warned, however that projections for specific countries, for certain population groups, or for longer periods in the future are less than global and shorter-range projections.[6]

Users of population projections need to understand the reliability and the limitations of projection series. Awareness of how projections are prepared and the possible sources of uncertainty in the numbers can help policymakers more effectively incorporate projections in their planning process.

Policymakers and program planners can undertake several steps to ensure projections are useful for policy and planning purpose, the steps include:

a. Proper understanding of the causes of uncertainty in population projections and the implications of this uncertainty for plans and policies that span different time horizons and target specific population groups.
b. Contributing to national and international efforts to collect more accurate demographic data which would lead to more accurate assumptions about fertility, mortality, and migration and better projections
c. Cooperate with national and international research efforts to develop more accurate projections by supporting organizations that investigate better projection methodologies, the demographic effect of HIV/AIDS, the effect of policies and programs on fertility trends[6]

Population projections come with some uncertainty and it was discussed extensively in International Statistical review [26], The review concluded that

a. Uncertainty should be ignored and one projection should be published
b. Alternative probability-free scenarios should be defined
c. High, medium and low variants that are supposed to cover a plausible range should be publish
d. Probabilistic projections that give quantitative information about the range of uncertainty should be publish.

Another area where conventional population projections are in need of renewal and expansion of focus is the explicit incorporation of other major covariates in addition to age

and sex. Level of education and rural/urban place of residence are two prime candidates for such explicit inclusion in population projections, because both fertility and mortality tend to vary greatly with level of education and place of residence.

Making this important hidden source of heterogeneity explicit and including it in the form of multistate population projections significantly affects the projected population dynamics. In addition to this purely demographic effect, variables such as place of residence and education are very important in their own right. In the June 2001 issue of Population and Development Review, the first global population projections by level of education was produced. The changing educational composition of the population is very significant at different levels: It matters greatly for individual development and individual life changes. It makes a big difference for a nation's institutional and economic performance. It also matters for the relative weights, productivity, and competitiveness of major world markets. [27]

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