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Adjustment of reported populations in Nigeria censuses using mathematical methods

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Abstract

This paper examines the adjustment of reported populations in Nigerian censuses. The ultimate objective is to provide reliable base populations which may be used to provide improved estimates of demographic parameters. Mathematical methods were applied to obtain adjusted data from the reported populations by sex and age in single years and five-year age groups in the 1963, 1991, and 2006 Nigerian censuses. Thereafter, the adjusted data were subjected to re-evaluation and used to obtain estimates of demographic parameters. Re-evaluation of the adjusted data shows improved quality of the adjusted data as well as of the estimates of some demographic parameters. It is therefore recommended that the adjusted data be used for estimating demographic parameters and population projection among others.

Keywords: Adjustment of age and sex data, accuracy index, age misreporting, digit preference, age exaggeration, base population.

Résumé

Ce document examine l'ajustement de la population rapportée dans des recensements nigérians. L'objectif final est de fournir les bases populations dignes de confiance qui peuvent être employées pour donner des évaluations améliorées des paramètres démographiques. Des méthodes mathématiques ont été appliquées pour obtenir les données ajusté des populations rapportées par sexe et par âge dans les seules anneés et de la tranche de cinq ans dans les recensements nigérians de 1963, 1991 et 2006. Ensuite, les données ajustées ont été soumises à la réévaluation et utilisées pour obtenir des évaluations des paramètres démographiques. Les résultats de la réévaluation des données ajustées prouvent que les qualités des données aussi bien que des évaluations ajustées de quelques paramètres démographiques se sont améliorées. Il est recommandé alors, que les données ajustées soient employées pour l'évaluation des paramètres et de la projection de population démographiques parmi d'autres.

Mots-clés : Ajustement des données de l'âge et du sexe, index d'exactitude, rapports erronées des âges, préférence de chiffre, exagération de l'âge, la base population.

Introduction

Since it was discovered that demographic data from most developing countries are defective, adjustment of demographic data and, hence, development of indirect techniques have become integral parts of demographic data analysis there. The two main sources of demographic data from developing countries are population censuses and sample surveys. Age and sex are two of the few items on the bases of which data are collected, tabulated, analyzed, and adjusted in all demographic enquiries (Ramachandran 1989); however, they have been shown to be reported with errors in censuses and sample surveys. Age misreporting—(i) digit preference, (ii)

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age shifting across critical age boundaries, and (iii) age exaggeration—is the most commonly found error in demographic data from developing countries. It has often been attributed to illiteracy, poor record-keeping, and sometimes deliberate misstatement of age (Ramachandran 1989). Error detection in age data reported in single years may be achieved using graphical and algebraic methods. Details of these can be found in Kpedekpo (1982), Ramachandran (1989), Shryock and Siegel (1976), and UN (1956, 1983).

The quality of age and sex data in Nigeria has been widely discussed by many researchers, including Ekanem (1972), Nwogu (2006, 2011) and Ohaegbulem (2015). In his work, Ekanem (1972) observed that the end digits 0, 2, 5, and 8 were highly preferred. Using graphical and algebraic methods, Nwogu (2006) showed that the quality of age and sex data in the 1963 and 1991 Nigerian censuses, as well as the 1981/82 NFS, 1990, 1999, and 2003 NDHS for Nigeria, is quite low. Preferences for the end digits 0 and 5, and avoidance of the end digits 1, 3, 7, and 9, were pronounced in all the surveys. So also was the problem of "Age Shifting." When compared with the scale for estimating data reliability, Nwogu (2006) demonstrated the least value of the UN joint score (45.9) for Nigeria in all the surveys between 1963 and 2003, indicating that all the datasets are at best deficient but may be useable with adjustment.

Nwogu (2011) also showed that the UN joint scores (38.52 for the 2006 census and 34.72 for the 2008 Nigeria Demographic and Health Survey) indicate the two datasets are also defective but are usable with adjustments. Ohaegbulem (2015) assessed the quality of the age-sex data from the 1991 and 2006 Nigeria population censuses, using some conventional techniques of evaluating demographic data quality. His results show that there are obvious preference for ages with end-digits 0 and 5, while other end-digits were avoided in the two censuses, this bias being more pronounced for females than males. The joint scores from the distribution of population by sex and five-year age groups computed to be 54.83 for the 1991 census and 38.52 for the 2006 census. These show that the quality of age and sex data is poor and unreliable, but the data are usable if proper adjustments are made.

Age and sex data from censuses are known to provide base populations for the estimation of demographic parameters (like fertility, mortality, and migration) and socio-economic characteristics (like nuptiality, education, and employment) that are required for planning, implementation, and monitoring of development plans. Therefore, the quality of these estimates depends on the quality of the base populations. With the present status of the base populations in Nigeria, how reliable are estimates obtained from there? By how much can these estimates be improved by adjusting the base population data? These and other related questions are what this study intends to address.

The ultimate objective of this study is to obtain adjusted populations of the 1963, 1991, and 2006 Nigerian censuses by age and sex that may be used to improve estimates of the demographic parameters in Nigeria. The specific objectives are: (i) to apply indirect techniques to adjust the Census data; (ii) to assess the adjusted age-sex data for adequacy of the adjustment; and (iii) to compute estimates of demographic parameters with the adjusted populations. Recommendations will be made based on the results.

Methodology

The data for this study are secondary, derived from the 1963, 1991, and 2006 Nigerian censuses. The data were collected from the UN dataset website (data.un.org/data) and the National Population Commission (NPC 2009).

The methods of analysis used are the mathematical methods for adjusting population distribution by sex and age, in single years and by five-year age groups. Section 2.1 presents methods for adjusting the population by age in single years, while section 2.2 contains methods for adjusting the population by five-year age groups.

Adjustment of population by age in single years

The mathematical methods commonly used to adjust population data by sex and age in single years are those based on cumulative populations. These methods are known to be suitable for populations in which

the major problems are mainly those of age heaping resulting from digit preference and avoidance (especially among those aged 10 years and above). In this study, cumulative populations with end-digits 3 and 8 are used because they are located near the mid-points of the most preferred digits, 0 and 5 (UN 1983). The cumulation is designed to reduce the problem of age heaping.

Thus, given the cumulative populations under the end-digits 3 and/or 8, any of the methods of interpolation of point data (Lagrange Multiplier, Karup-King, Sprague, Beers ordinary and modified, etc.) can be used to determine the adjusted populations by age in single years. However, UN (1983) gives the following equations:

$$N(a+12) = -0.048N(a) + 0.864N(a+10) + 0.216N(a+20) - 0.032N(a+30) \quad (1)$$

$$N(a+17) = -0.0455N(a) + 0.3315N(a+10) + 0.7735N(a+20) - 0.0595N(a+30), \quad (2)$$

where a = 3, 8, 13, 18, 23, 28,… for determining populations under 15, 20, 25, 30,… from cumulated populations under the end-digits 3 and 8. To determine the adjusted populations under 10 years from digit 3 series and under 15 years from digit 8 series, UN (1983) gave the equations:

$$N(a+7) = 0.1495N(a) + 1.0465N(a+10) - 0.2415N(a+20) + 0.0455N(a+30) \quad (3)$$

for a = 3 and 8. UN (1983) also gave the equation

$$N_8(10) = 0.672N(8) + 0.504N(18) - 0.224N(28) + 0.048N(38) \quad (4)$$

to determine the population under 10 years for the digit-8 series, while $N_8(5)$ is obtained from the adjusted populations under ages 10, 20, and 30 using the equation

$$N_8(5) = 0.9375N(10) - 0.3125N(28) + 0.0625N(30) \quad (5)$$

To reduce the biases caused by age-heaping, UN (1983) suggests the use of the average

$$\hat{N}(x) = \frac{1}{2}\left(\hat{N}_3(x) + \hat{N}_8(x)\right) \quad (6)$$

as the adjusted population, where $\hat{N}_3(x)$ and $\hat{N}_8(x)$ are, respectively, the adjusted populations from the digits 3 and 8 series.

Adjustment of population by five-year age groups

The age groups identified by UN (1956) are: "not stated," "under 10" age groups (0–4 and 5–9 years), 10–69 years, and 70 years and above. These groups contain different types of errors associated with them, and therefore require different methods of adjustment.

"Not stated" age group

UN (1956) recommended that the "not stated" age group should be assigned to the group to which it belongs if the identity can be traced or redistributed to other age groups by pro-rating. The pro-rating can be done before or after adjustment of the other age groups.

"Under 10" age groups (0–4 and 5–9 years)

Since the problem with the 0–4 and 5–9 age groups is that of under-reporting, arising from omission of children, especially infants, UN (1983) suggests that the reported population may be adjusted by comparing the birth rate that is consistent with the reported population with the expected birth rate. The birth rate consistent with the reported populations aged 0–4 and 5–9 can be derived by reverse-survival, using a suitably selected life table that pertains to the study population. Thus, given the reported populations of both sexes aged 0–4 ($_5P_0$) and 5–9 ($_5P_5$), the total reported population P, the rate of population growth (r) and the life table populations

aged 0–4 (${}_5L_0$) and 5–9 (${}_5L_5$) years, UN (1983) gives the expression for birth rate consistent with the reported population aged 0–4 years as

$$b_1 = \frac{C(5)}{{}_5L_0} e^{2.5r} \ , \ (l_o = 1) \tag{7}$$

and aged 5–9 years as

$$\mathrm{b}_2 = \frac{{}_5\hat{\mathrm{C}}_5}{{}_5\mathrm{L}_5} \mathrm{e}^{7.5\mathrm{r}}, \ (l_o = 1) \tag{8}$$

where $C(5)=P_{0-4}/p$ is the proportion of the total reported as under 5 years, ${}_5\hat{C}_5={}_5P_5/P$ is the proportion of total population reported as aged 5–9 years, ${}_5L_0$ is the life table population aged 0–4 years, and ${}_5L_5$ is the life table population aged 5–9 years (UN 1983).

Coale (1981) also gives an expression for birth rate, consistent with the population of both sexes under fifteen years (${}_{15}P_0$), as

$$\mathrm{b}_\mathrm{R} = \frac{\mathrm{C}(15)}{{}_{15}\mathrm{L}_0} \mathrm{e}^{7.5\mathrm{r}}, \ (l_o = 1) \tag{10}$$

where $C(15)={}_{15}P_0/P$ is the proportion of population of both sexes reported as under 15 years, ${}_{15}L_0$ is the life table population aged 0–14 years, and l_5 is derived from the Brass (1975) method.

Under the assumptions that (i) birth rate and mortality levels have remained constant in the 15 years preceding the survey; and (ii) the population aged 0–14 years is more correctly reported, then the population reported as aged 0–4 and 5–9 years may be adjusted using the ratios $\mathrm{b_R}/\mathrm{b_1}$ and $\mathrm{b_R}/\mathrm{b_2}$, respectively.

Age range 10–69

For population reported by five-year age groups in the range 10–69 years, the mathematical methods used for adjustment include (a) the United Nations five-point or three-point formula, (b) the Newton's halving formula, and (c) the Carrier- Farrag Ratio method (ECA 1988).

UN Five-Point Method

This method is based on the assumptions that: (i) net gains and losses e of alternate quinary age groups are constant e; and (ii) these deficiencies are independent of age groups. Under these assumptions, the interpolation procedure is to fit a second degree polynomial to the reported populations of five consecutive age groups to obtain the adjusted population for the middle age group. Thus, if W_0, W_1, W_2, W_3 and W_4 denote the reported populations of five consecutive age groups, and U_0, U_1, U_2, U_3 and U_4 denote the corresponding true but unknown populations respectively, then according to assumption (i)

$$U_i = W_i + (-1)^i e, \ i = 0, 1, 2 \ldots 4 \tag{11}$$

If U_i forms a smooth polynomial of order 2, then

$$\nabla^4 U_i = U_4 - 4U_3 + 6U_2 - 4U_1 + U_0 = 0 \tag{12}$$

If we substitute (11) into (12), then we obtain the expression for e as

$$e = -1/16 \ [W_0 - 4W_1 + 6W_2 - 4W_3 + W_4] \tag{13}$$

Hence,

$$U_1 = W_1 - e = 1/16 \ [W_0 + 12W_1 + 6W_2 - 4W_3 + W_4] \tag{14}$$

$$U_2 = W_2 + e = 1/16 \ [-W_0 + 4W_1 + 10W_2 + 4W_3 - W_4] \tag{15}$$

$$U_3 = W_3 - e = 1/16\,[W_0 - 4W_1 + 6W_2 + 12W_3 + W_4] \tag{16}$$

and

$$U_4 = W_4 + e = 1/16\,[W_0 - 4W_1 + 6W_2 - 4W_3 - 15W_4] \tag{17}$$

Newton's halving formula method

The Newton's halving formula method is used to split population by ten-year group into two five-year age groups. The underlying assumption is that by grouping a population into ten-year age groups, some of the undulations in the five-year groups, and other errors, could be reduced. Let U_0, U_1, U_2, U_3, U_4, and U_5 denote the true but unknown populations in six consecutive five-year age groups, and let W_0, W_1, W_2, W_3, W_4, and W_5 denote the corresponding reported populations. The reported populations in three consecutive ten-year age groups are denoted by $V_0 = W_0 + W_1$, $V_1 = W_2 + W_3$, and $V_2 = W_4 + W_5$. Using the method of divided difference, ECA(1988) finds the smoothed value ($\hat{U}_2$) of W_2 as

$$\hat{U}_2 = 1/16\,V_0 + 8/16V_1 - 1/16V_2 = 0.0625V_0 + 0.5V_1 - 0.0625V_2 \tag{18}$$

Carrier-Farrag ratio method

Under the assumption that the ratios of populations of two consecutive five-year age groups are constant, Carrier-Farrag (Shryock and Siegel 1980) developed a ratio method for splitting a ten-year group into two five-year age groups. As in the Newton's halving formula, if W_0, W_1,…, W_5 denote the reported populations in six consecutive five-year age groups, and U_0, U_1,…, U_5 are the corresponding true but unknown populations, then under this assumption

$$\frac{U_0}{U_1} = \frac{U_1}{U_2} = \frac{U_2}{U_3} = \frac{U_3}{U_4} = \frac{U_4}{U_5} = K \tag{19}$$

Furthermore, if we define $V_1 = U_0 + U_1$, $V_2 = U_2 + U_3$, and $V_3 = U_4 + U_5$, then it is easily seen that $V_1 = (1+K)U_1$, $V_2 = (1+K)U_2$, and $V_3 = (1+K)U_5$. Hence,

$$\frac{V_1}{V_3} = \frac{U_1}{U_5} = \frac{U_1}{U_2} \times \frac{U_2}{U_3} \times \frac{U_3}{U_4} \times \frac{U_4}{U_5} = K = \sqrt[4]{\frac{V_1}{V_3}} \tag{20}$$

Thus, an estimate of K derived by substituting W_i for U_i can be obtained as

$$\hat{K} = \sqrt[4]{\frac{\hat{V}_1}{\hat{V}_3}} \tag{21}$$

where $\hat{V}_1 = W_2 + W_3$ and $\hat{V}_3 = W_4 + W_5$. Once the estimate of K has been determined, the smoothed populations ($\hat{U}_2$ and $\hat{U}_3$) in the middle age groups can be estimated as

$$\hat{U}_2 = \frac{V_2}{1+\hat{K}} \tag{22}$$

$$\hat{U}_3 = \hat{V}_2 - \hat{U}_2 \tag{23}$$

Results and discussion

Here, the methods outlined in the previous section are applied to the census data in Nigeria. The first section below consider adjustment of population data by sex and age in single years, while the section following is on adjustment of data by sex and age in five-year age groups.

Adjustment of population by sex and age in single years

The adjusted populations under end digits 0 and 5 obtained for age range 10–64 using Equations (1) through (6) are shown in Table 1. Thereafter, the adjusted populations by age in single years, obtained from the adjusted cumulative populations using the Karup-King method as shown in Appendix A and Figures 1 through 3.

Table 1. Adjusted populations under end digits 0 and 5 from the cumulated populations under end digits 3 and 8

Age	1963		1991		2006	
	Male	Female	Male	Female	Male	Female
10	8,922,094	8,442,114	14,864,530	13,852,782	21,876,089	20,133,989
15	12,356,694	11,735,188	20,634,981	19,549,698	30,701,128	28,406,567
20	15,454,453	15,127,989	25,187,322	24,692,956	38,294,087	36,282,813
25	18,318,243	18,464,490	28,918,685	29,298,114	44,813,346	43,639,159
30	20,903,528	21,404,740	32,155,603	33,228,166	50,341,417	50,106,050
35	22,935,786	23,487,768	34,925,719	36,200,244	54,889,590	55,126,820
40	24,406,978	24,792,698	37,178,939	38,323,846	58,647,766	58,825,111
45	25,466,923	25,628,612	38,980,065	39,884,213	61,808,964	61,602,091
50	26,221,904	26,193,898	40,415,901	41,064,010	64,405,873	63,702,196
55	26,752,869	26,583,129	41,527,831	41,955,508	66,402,537	65,239,781
60	27,144,950	26,869,365	42,374,411	42,649,648	67,857,451	66,350,245
65	27,443,598	27,086,459	43,030,282	43,207,249	68,914,905	67,172,303

From Figures 1 through 3 and Appendix A, it appears that the age heaping on digits 0 and 5 in the reported populations has been smoothed out.

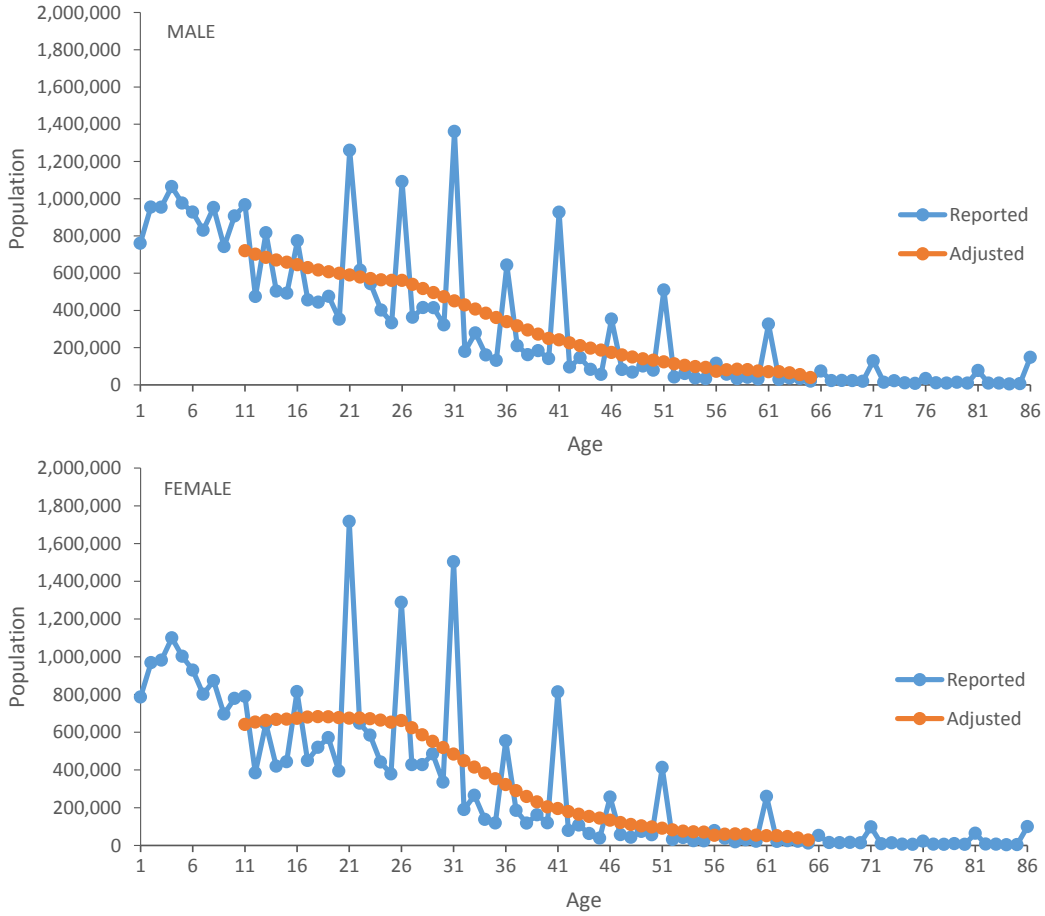

Figure 1. ***Reported and adjusted populations, 1963.***

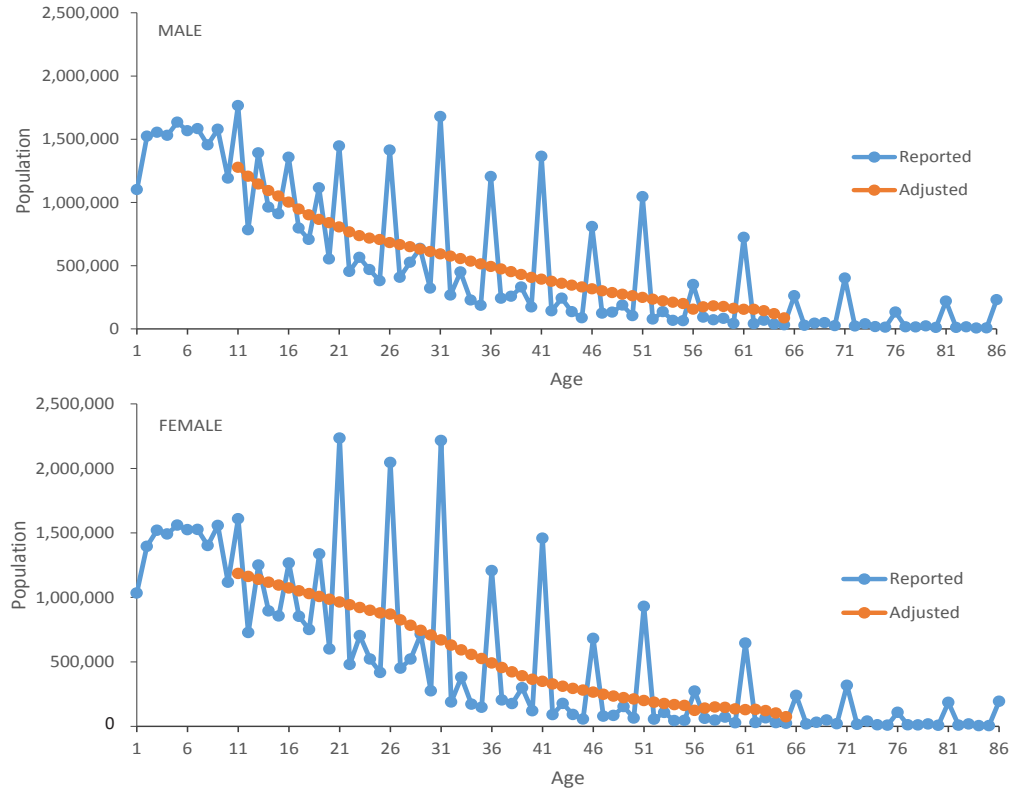

Figure 2. ***Reported and adjusted populations, 1991.***

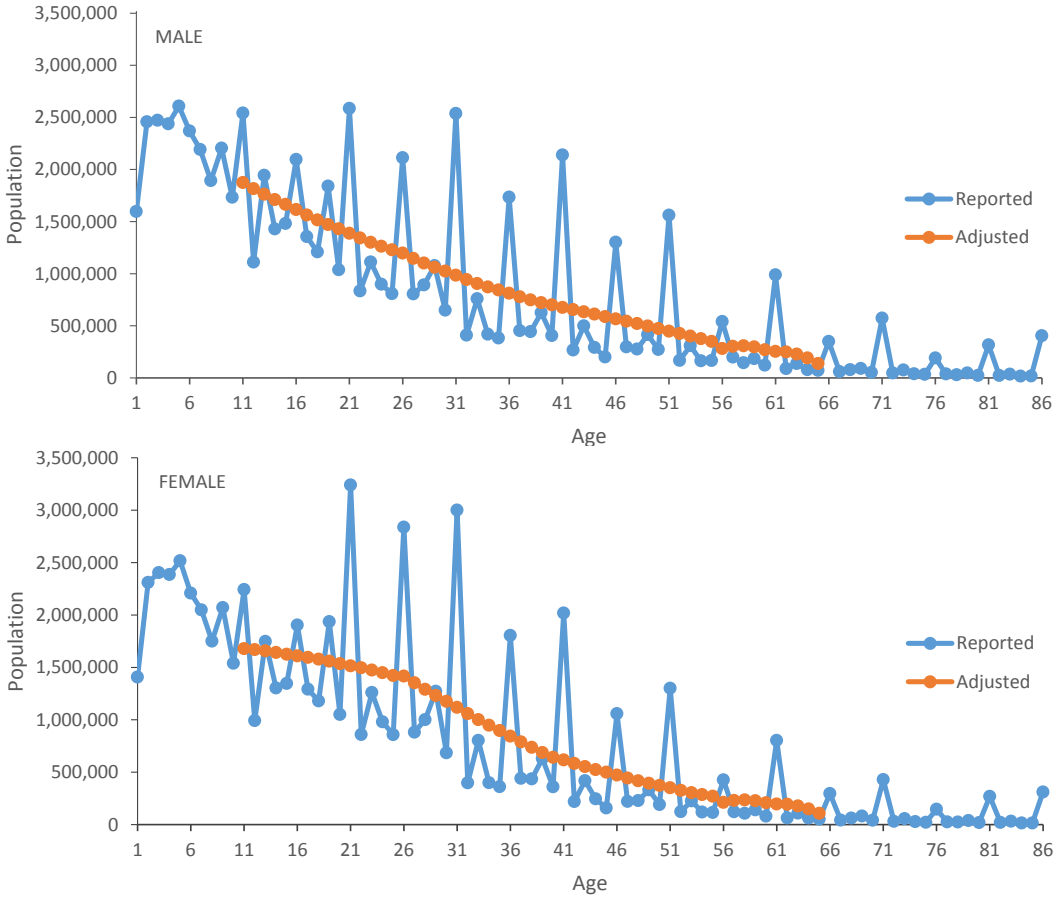

Figure 3. ***Reported and adjusted populations, 2006.***

Adjustment of Population by Sex and five-year age groups

The results of application of the mathematical methods discussed in Equations (7) through (23) in Section 2 are shown in Tables 2 through 5. Firstly, the reverse survival methods in Equations (7) through (10) were used to derive adjusted populations under 10 years shown in Table 2. Nwogu and Nweke (2016) suggested the use of level 15.14 of North model of the Coale- Demeny model life table implied by the 2013 NDHS. According Federal Government of Nigeria (2004), the population growth rate for Nigeria is about 2.9%. Therefore, in this study, a growth rate of 2.9%, level 15 of North model of the Coale- Demeny Model Life Table have been used to obtain the adjusted populations under 10 years. Also, a Sex Ratio at Birth (SRB) of 1.05 was assumed in obtaining the life table function for both sexes combine from the sex-specific function. As Table 2 shows, the adjusted populations indicate that while populations under 5 years appear to be under-reported, populations aged 5–9 years appear to be over-reported in all Censuses.

For populations aged 10–69 years, Tables 3 through 5 contain both reported and adjusted populations by different methods (Carrier Farrag, Newton Halving and United Nations Five point) while the corresponding graphs are shown in Figures 4 through 6.

Table 2. Reported and Adjusted populations aged 0–4 and 5–9 years

Index	1963			1991			2006		
	Male	Female	Both	Male	Female	Both	Male	Female	Both
Reported									
${}_5P_0$	4,709,918	4,839,245	9,549,163	7,344,454	6,999,435	14,343,889	11,569,218	11,025,749	22,594,967
${}_5P_5$	4,360,920	4,078,378	8,439,298	7,374,314	7,126,144	14,500,458	10,388,611	9,616,769	20,005,380
${}_{15}P_0$	12,325,411	11,600,175	23,925,586	20,531,306	19,461,722	39,993,028	30,462,148	28,274,149	58,736,297
P	28,111,852	27,558,203	55,670,055	44,529,608	44,462,162	88,991,770	71,345,488	69,086,302	140,431,790
${}_5C_0$	0.16754	0.17560	0.1715	0.1649	0.1574	0.1612	0.1622	0.1596	0.1609
${}_5C_5$	0.15513	0.14799	0.1516	0.1656	0.1603	0.1629	0.1456	0.1392	0.1425
${}_{15}C_0$	0.43844	0.42093	0.4298	0.4611	0.4377	0.4494	0.4270	0.4093	0.4183
Life table									
${}_5L_0$	4.38014	4.46164	4.4199	4.38014	4.46164	4.4199	4.38014	4.46164	4.4199
${}_5L_5$	4.12555	4.22376	4.1735	4.12555	4.22376	4.1735	4.12555	4.22376	4.1735
${}_{15}L_0$	12.54391	12.82569	12.6814	12.54391	12.82569	12.6814	12.54391	12.82569	12.6814
b_1			0.0417			0.0392			0.0391
b_2			0.0452			0.0485			0.0424
b_R			0.0421			0.0440			0.0410
b_R/b_1			1.0098			1.1233			1.0475
b_R/b_2			0.9330			0.9079			0.9661
Adjusted									
${}_5\hat{P}_0$	4,755,919	4,886,509	9,642,428	8,249,856	7,862,304	16,112,159	12,118,661	11,549,381	23,668,042
${}_5\hat{P}_5$	4,068,884	3,805,263	7,874,148	6,695,201	6,469,886	13,165,087	10,035,997	9,290,353	19,326,349

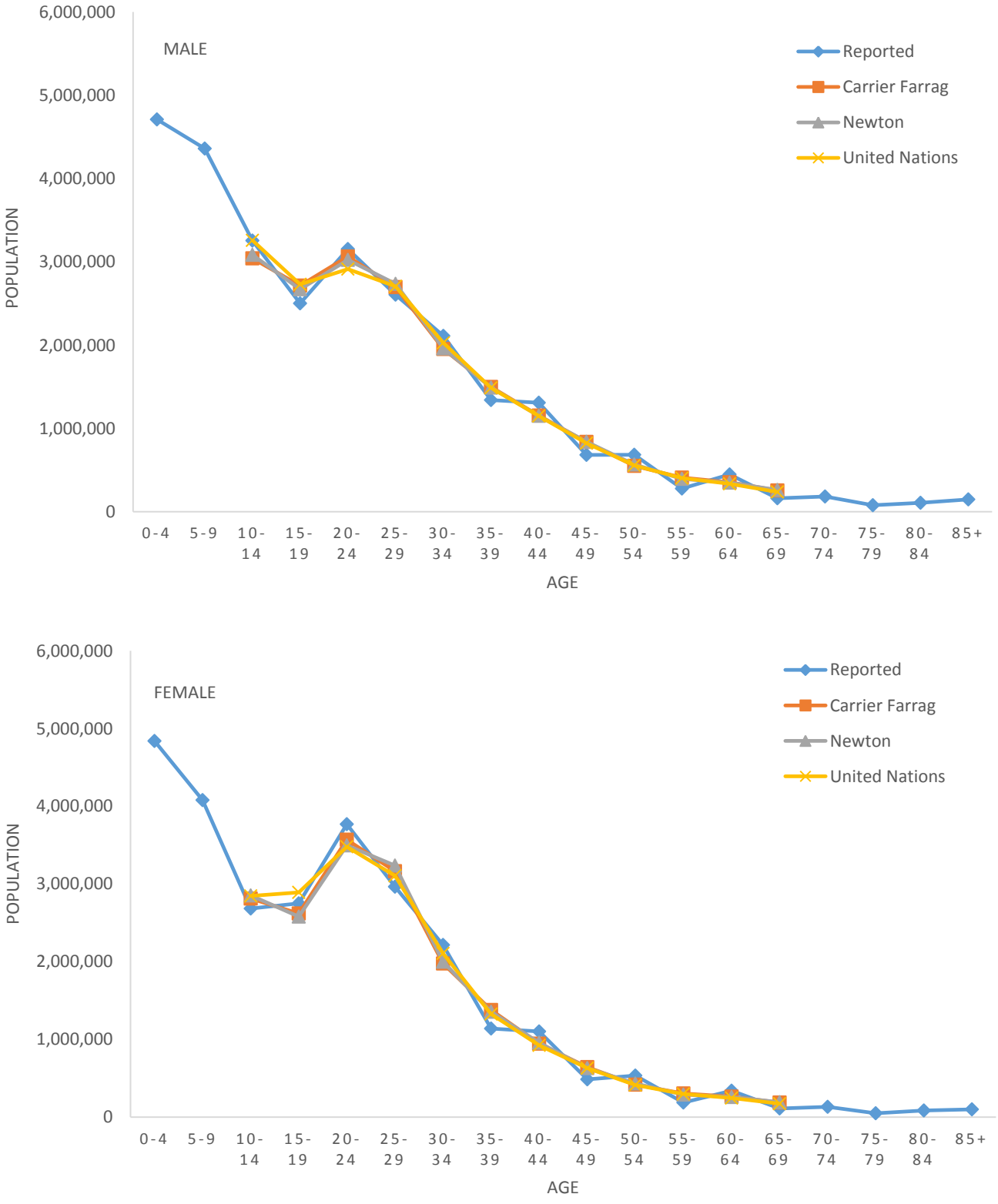

Figure 4. ***Different adjustment procedures for age distributions, Nigeria 1963.***

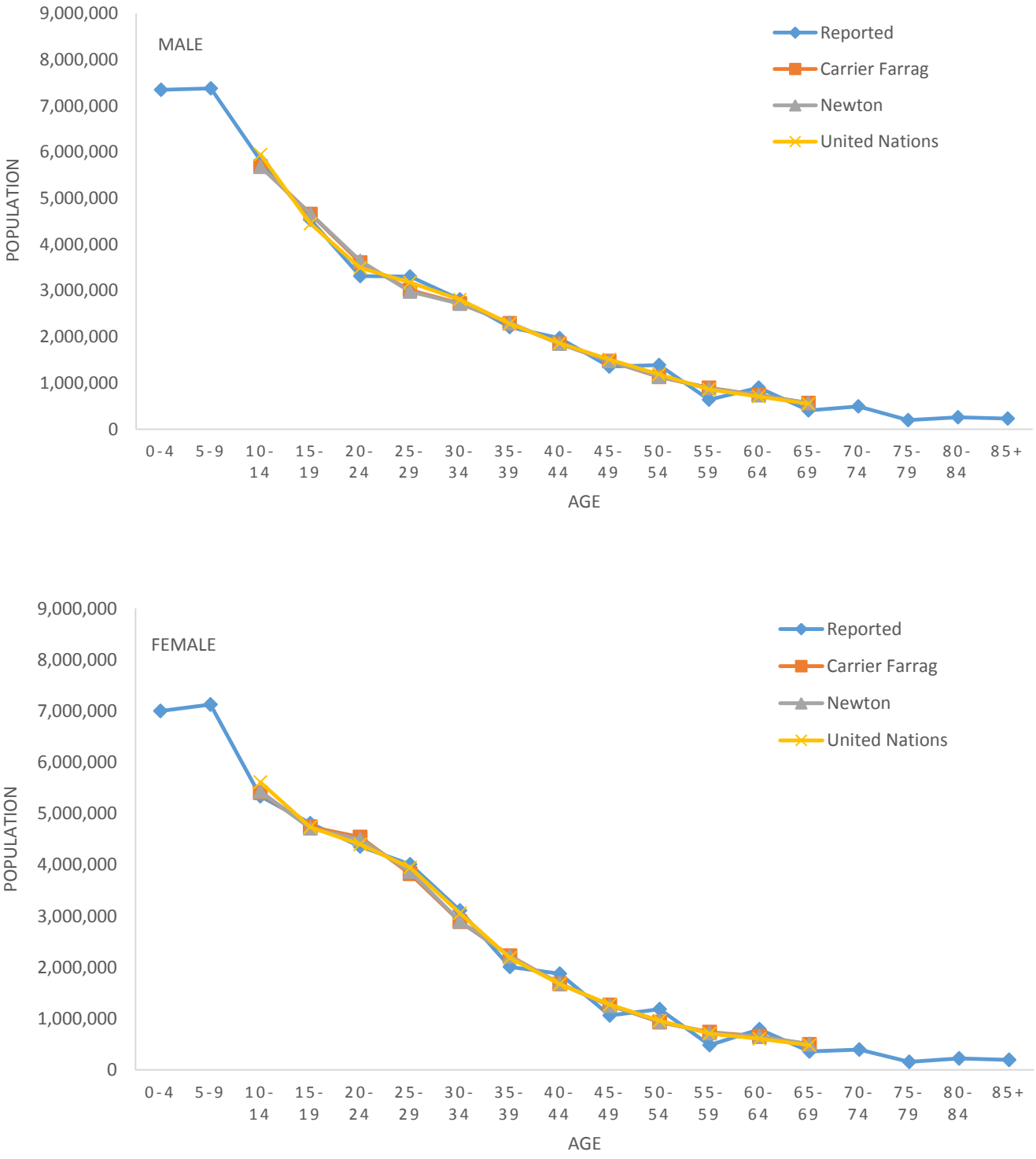

Figure 5. ***Different adjustment procedures for age distributions, Nigeria 1991.***

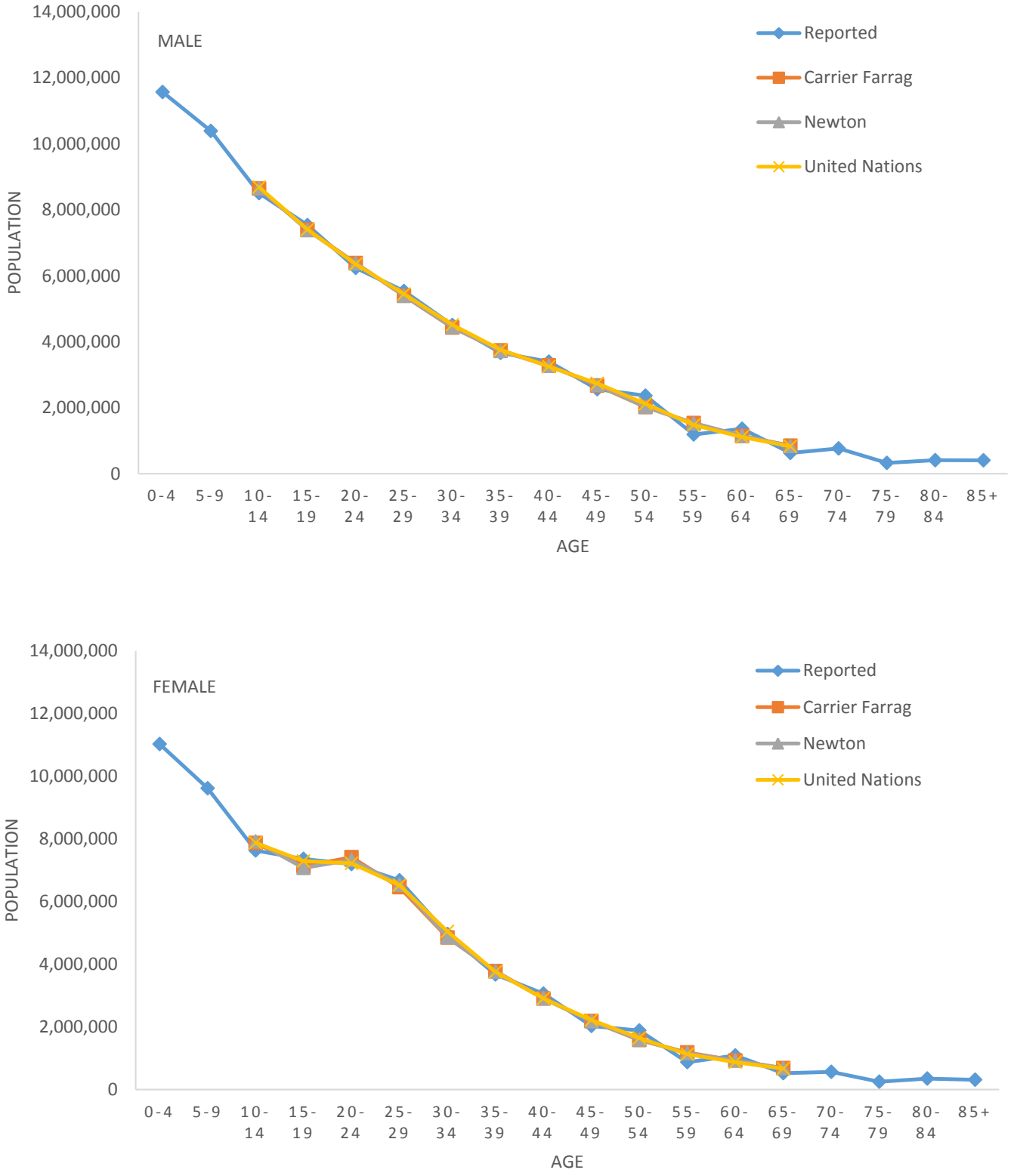

Figure 6. ***Different adjustment procedures for age distributions, Nigeria 2006.***

Tables 3 through 5 show the smoothed populations for the male and female; the smoothed female populations indicate that populations in age groups 15–19, 25–29, 35–39, 45–49, and 65–69 years appear to be under-reported, while the populations in the alternate age groups 10–14, 20–24, 30–34, 40–44, 50–54, and 60–64 years appear to be over-enumerated.

Table 3. Reported and adjusted population, Nigeria, 1963

Age group	Male				Female			
	Reported	Carrier Farrag	Newton	United Nations	Reported	Carrier Farrag	Newton	United Nations
0–4	4,709,918	–	–	–	4,839,245	–	–	–
5–9	4,360,920	–	–	–	4,078,378	–	–	–
10–14	3,254,573	3,041,187	3,084,917	3,258,212	2,682,552	2,811,492	2,852,656	2,845,590
15–19	2,501,434	2,714,820	2,671,090	2,730,042	2,749,750	2,620,810	2,579,647	2,891,409
20–24	3,153,836	3,064,011	3,024,159	2,912,756	3,769,352	3,569,617	3,496,745	3,478,258
25–29	2,606,386	2,696,211	2,736,063	2,705,086	2,964,199	3,163,934	3,236,807	3,105,625
30–34	2,110,969	1,953,421	1,961,191	2,027,115	2,214,629	1,975,993	1,998,055	2,105,309
35–39	1,340,277	1,497,825	1,490,055	1,487,030	1,138,169	1,376,805	1,354,743	1,324,770
40–44	1,308,671	1,153,482	1,151,282	1,149,008	1,101,473	944,187	958,044	922,549
45–49	682,464	837,653	839,853	823,257	485,584	642,870	629,013	629,664
50–54	682,577	550,464	566,296	556,798	534,322	416,600	431,361	411,899
55–59	277,241	409,354	393,522	402,943	186,235	303,957	289,196	297,343
60–64	447,156	353,789	348,232	335,165	338,636	263,403	258,627	244,348
65–69	161,793	255,160	260,717	236,376	111,106	186,339	191,115	172,382
70–74	182,481				131,842			
75–79	77,214				48,624			
80–84	106,428				84,728			
85+	147,514				99,379			

Table 4. Reported and adjusted population, Nigeria, 1991

Age group	Male				Female			
	Reported	Carrier Farrag	Newton	United Nations	Reported	Carrier Farrag	Newton	United Nations
0–4	7,344,454	–	–	–	6,999,435	–	–	–
5–9	7,374,314	–	–	–	7,126,144	–	–	–
10–14	5,812,538	5,685,446	5,676,862	5,942,423	5,336,143	5,403,290	5,431,646	5,608,576
15–19	4,528,721	4,655,813	4,664,397	4,444,720	4,806,977	4,739,830	4,711,474	4,731,896
20–24	3,314,303	3,608,057	3,642,381	3,490,981	4,357,267	4,539,306	4,496,471	4,399,179
25–29	3,304,739	3,010,985	2,976,661	3,175,220	4,006,932	3,824,893	3,867,728	3,944,045
30–34	2,808,629	2,722,915	2,713,547	2,802,952	3,105,298	2,889,253	2,895,849	3,055,016
35–39	2,206,871	2,292,585	2,301,954	2,283,011	2,007,882	2,223,927	2,217,331	2,183,165
40–44	1,971,197	1,850,674	1,849,917	1,860,161	1,874,721	1,672,735	1,683,629	1,671,039
45–49	1,355,101	1,475,624	1,476,381	1,509,061	1,061,332	1,263,318	1,252,424	1,271,970
50–54	1,388,650	1,131,589	1,139,918	1,186,951	1,182,149	928,873	943,464	957,881
55–59	638,555	895,616	887,287	860,835	481,394	734,670	720,079	705,631
60–64	898,711	740,290	736,348	705,416	791,573	653,401	644,053	605,915
65–69	406,540	564,961	568,903	549,686	357,400	495,572	504,920	479,937
70–74	492,186				394,116			
75–79	195,455				156,368			
80–84	258,059				222,627			
85+	230,585				194,404			

Table 5. Reported and adjusted population, Nigeria, 2006

Age group	Male				Female			
	Reported	Carrier Farrag	Newton	United Nations	Reported	Carrier Farrag	Newton	United Nations
0–4	11,569,218	–	–	–	11,025,749	–	–	–
5–9	10,388,611	–	–	–	9,616,769	–	–	–
10–14	8,504,319	8,644,155	8,657,039	8,683,562	7,631,631	7,869,286	7,920,260	7,875,728
15–19	7,536,532	7,396,696	7,383,812	7,400,608	7,362,887	7,125,232	7,074,258	7,290,736
20–24	6,237,549	6,381,548	6,378,162	6,353,122	7,197,530	7,415,243	7,334,846	7,221,296
25–29	5,534,458	5,390,459	5,393,845	5,444,866	6,676,968	6,459,255	6,539,653	6,523,481
30–34	4,505,186	4,429,980	4,446,597	4,512,574	4,962,352	4,854,651	4,865,471	5,047,211
35–39	3,661,133	3,736,339	3,719,723	3,757,378	3,670,622	3,778,323	3,767,503	3,755,801
40–44	3,395,489	3,287,170	3,266,796	3,248,525	3,060,981	2,905,568	2,912,325	2,910,233
45–49	2,561,526	2,669,845	2,690,219	2,737,629	2,029,767	2,185,180	2,178,423	2,220,976
50–54	2,363,937	2,018,684	2,024,689	2,117,865	1,885,282	1,578,260	1,598,446	1,645,609
55–59	1,189,770	1,535,023	1,529,019	1,476,023	876,477	1,183,499	1,163,313	1,131,362
60–64	1,363,219	1,141,497	1,149,596	1,110,943	1,087,067	926,433	926,385	876,071
65–69	628,436	850,158	842,059	830,250	522,612	683,246	683,294	668,995
70–74	765,988				564,609			
75–79	327,416				252,422			
80–84	408,680				351,373			
85+	404,021				311,204			

Assessment of adequacy of the adjustment

One of the ways to assess the adequacy of any adjustment is to re-evaluate the adjusted population. The adjusted data were re-evaluated to see if there is an improvement in the quality of the data.

Re-evaluation of adjusted data

The Myers index was used to re-evaluate the adjusted population by age single years and the results obtained are shown in Table 6. From Table 6, the values of M.I. dropped from values well above 20 to values below 1 in all the survey. Overall, it appears there is a substantial improvement as all the indices are quite low for the three Censuses. The results of the Myers index from the adjusted figures compare favourably well with figures from some developed countries with good quality data such as United States of America and Canada.

Table 6. Measures of digit preference

Method	Reported			Adjusted		
			1963			
MYERS INDEX	Male	Female	Both	Male	Female	Both
$\frac{1}{2}\sum\lvert\%B_i - 10\rvert$	25.74	27.22	26.49	0.32	0.38	0.35
			1991			
MYERS INDEX	Male	Female	Both	Male	Female	Both
$\frac{1}{2}\sum\lvert\%B_i - 10\rvert$	26.79	31.82	29.38	0.27	0.29	0.27
			2006			
MYERS INDEX	Male	Female	Both	Male	Female	Both
$\frac{1}{2}\sum\lvert\%B_i - 10\rvert$	23.13	25.35	24.2	0.13	0.20	0.16

Note: The Myers index was calculated using age range 10–59.

For populations reported by sex and five-year age groups, Table 7 contains the UN accuracy index for the reported and adjusted populations. The Joint Scores of the adjusted census data lie between 20 and < 40 as Table 7 shows. These suggest that the quality of the age and sex data is still poor, and thus they may require more adjustments, although they are better than the reported data. Even so, the results should be interpreted with care and caution, as the evaluation was restricted only to the age range 10–69 years. There are indications that results from the UN method are better than results from other methods.

Table 7. Summary of indices measuring the accuracy of data

Index	Reported	Adjusted population		
		Carrier-Farrag	Newton	United Nations
		1963		
Sex ratio score	14.44	6.85	7.53	7.66
Male age ratio score	33.27	7.28	7.76	6.56
Female age ratio score	40.74	11.61	12.09	8.90
Accuracy index	117.33	39.45	42.43	38.43
		1991		
Sex ratio score	12.61	7.18	7.67	7.32
Male age ratio score	21.91	2.69	2.82	3.19
Female age ratio score	27.79	4.79	4.89	4.22
Accuracy index	87.54	29.03	30.72	29.37
		2006		
Sex ratio score	8.96	7.30	7.63	7.29
Male age ratio score	15.15	2.25	2.26	2.28
Female age ratio score	17.71	4.66	4.89	4.16
Accuracy index	59.73	28.82	30.05	28.30

Note: The accuracy index was calculated using age ranges 10–14 through 65–69.

Estimate of fertility measures from the adjusted populations

The Crude Birth Rate and Child-Woman Ratio of the adjusted populations were computed and the results so obtained are shown in Table 8. When the CBR obtained from the adjusted populations were compared with that of the reported populations and from other notable sources such as US Census Bureau, it appears that CBR from reported population seem to be higher across the censuses. The CBR from the adjusted population appears to be consistent with that of US Census Bureau. The Child-Woman Ratio appear to have improved significantly across the Censuses as the reported CWR is less than the adjusted CWR which suggests that the CWR may have been under reported across the censuses.

Table 8. Comparison of fertility measures of the reported and adjusted populations

Year, source	CBR (%)			CWR (‰)	
	Reported	Adjusted	US(CB)	Reported	Adjusted
1963 Census	66.0	42.1	46.03	662.01	674.57
1981/82 NFS	46.0	–	47.0	–	–
1990 NDHS	39.0	46.9	45.0	834.28	751.96
1991 Census	44.6	44.0	44.0	675.95	761.69
1999 NDHS	38.0	43.9	43.0	657.45	663.66
2003 NDHS	41.7	42.8	44.0	717.27	620.78
2006 Census	–	41.0	41.0	646.29	681.62
2008 NDHS	39.0	43.6	41.0	818.18	690.13

Note: NFS = National Fertility Survey, NDHS = Nigeria Demographic and Health Survey, USCB = US Census Bureau, CBR = Crude Birth Rate, and CWR = Child-Woman Ratio.

Summary, recommendations, and conclusion

In summary, this study has discussed the adjustment of age and sex data from the 1963, 1991, and 2006 Nigerian censuses. It was designed in order to obtain base populations for improved estimates of demographic parameters. Mathematical methods were used to obtain adjusted populations from those reported by sex and age in single-year and by five-year age groups. The adjusted populations were subjected to re-evaluation, to assess the adequacy of the adjustment and estimates of fertility measures calculated. Results show that preferences for the end digits 0 and 5 appear to have been smoothed out, and the accuracy index improved substantially for five-year age groups across the censuses.

In view of the above, it is recommended that estimates of demographic parameters be based on the adjusted rather than reported populations. Methods of adjustment other than mathematical ones can also be used to obtain adjusted data, since the results of the re-evaluation indicate that there is still room for improvement.

Nevertheless, data adjustment should not replace the care and caution that are needed in data collection. It would be harmful to create an impression that various methods and models for data adjustment are better than effective and efficient data collection processes.

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APPENDIX A

Table A-1. Adjusted population by sex and age in single years (Karup-King method).

Age	1963		1991		2006	
	Male	Female	Male	Female	Male	Female
10	720,451	640,651	1,276,956	1,184,672	1,873,711	1,678,314
11	701,217	653,377	1,205,992	1,161,654	1,815,558	1,669,380
12	684,451	662,359	1,144,559	1,139,010	1,761,207	1,657,481
13	670,154	667,597	1,092,658	1,116,739	1,710,656	1,642,616
14	658,327	669,089	1,050,287	1,094,842	1,663,907	1,624,786
15	644,853	673,078	1,001,563	1,072,695	1,614,624	1,608,933
16	629,733	679,564	946,484	1,050,300	1,562,807	1,595,057
17	617,083	682,305	900,937	1,028,278	1,514,791	1,578,215
18	606,901	681,301	864,921	1,006,630	1,470,576	1,558,407
19	599,188	676,553	838,436	985,355	1,430,162	1,535,634
20	589,829	674,301	805,597	963,831	1,387,214	1,514,838
21	578,825	674,545	766,403	942,058	1,341,732	1,496,019
22	570,289	671,045	736,741	920,658	1,300,051	1,474,235
23	564,222	663,800	716,611	899,632	1,262,171	1,449,485
24	560,624	652,811	706,011	878,979	1,228,093	1,421,769
25	560,785	661,692	681,522	869,656	1,196,160	1,416,981
26	539,114	622,972	665,655	825,205	1,146,329	1,352,212
27	517,250	586,151	648,586	783,382	1,101,057	1,290,411
28	495,193	551,229	630,315	744,187	1,060,341	1,231,577
29	472,943	518,206	610,841	707,620	1,024,184	1,175,710
30	450,822	483,917	592,169	669,301	984,988	1,117,865
31	428,830	448,362	574,298	629,231	942,754	1,058,042
32	406,644	414,707	555,226	591,788	905,077	1,001,187
33	384,266	382,950	534,950	556,973	871,958	947,298
34	361,695	353,092	513,473	524,786	843,396	896,377
35	339,252	321,968	492,797	490,847	811,797	843,478
36	316,938	289,578	472,923	455,156	777,158	788,601
37	294,431	259,087	451,846	422,093	747,078	736,691
38	271,732	230,495	429,567	391,658	721,554	687,748
39	248,839	203,802	406,086	363,850	700,589	641,773
40	241,567	194,886	392,097	348,424	675,082	616,865
41	224,835	178,765	375,168	328,034	654,524	583,386
42	210,046	164,913	359,232	309,859	633,103	552,651
43	197,200	153,331	344,289	293,898	610,819	524,662
44	186,297	144,019	330,340	280,151	587,672	499,416
45	174,098	133,194	315,728	264,929	565,100	472,341
46	160,604	120,856	300,455	248,230	543,104	443,437
47	149,053	110,787	286,174	233,745	520,245	417,276
48	139,445	102,989	272,887	221,475	496,523	393,861
49	131,780	97,460	260,593	211,419	471,937	373,190
50	122,819	90,417	247,636	199,887	447,928	350,689
51	112,563	81,862	234,018	186,879	424,493	326,359
52	104,250	75,576	221,393	176,085	400,196	304,773
53	97,880	71,561	209,761	167,506	375,035	285,931
54	93,452	69,815	199,122	161,141	349,012	269,834
55	72,757	53,309	154,802	122,803	280,540	211,012
56	80,512	58,829	173,223	140,921	301,601	229,360
57	83,341	60,798	180,480	148,933	306,823	234,900
58	81,246	59,216	176,573	146,840	296,204	227,633
59	74,225	54,083	161,502	134,642	269,746	207,559
60	70,488	51,317	153,873	129,180	253,848	196,022
61	70,034	50,919	153,688	130,456	248,509	193,025
62	64,655	46,970	142,338	121,626	227,331	177,219
63	54,350	39,470	119,825	102,690	190,313	148,606
64	39,121	28,419	86,147	73,649	137,454	107,185