ESTIMATION OF OLDER-ADULT MORTALITY FROM CENSUS DATA IN NIGERIA USING FIXED-BASE MODEL

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Abstract

This paper presents the estimates of older-adult (persons aged 60 years and above) mortality from census data in Nigeria using the fixed-base model, an application based on the variable-r method. From the 1991 and 2006 censuses in Nigeria, it was observed that the probability of dying between ages 60 and 65 [${}_5q_{60}$] is 0.068 (or 68 per 1000 persons) among males and 0.033 (or 33 per 1000 persons) among females. While the probability of dying between ages 60 and 70 [${}_{10}q_{60}$] is 0.221 (or 221 per 1000 persons) among males and 0.256 (or 256 per 1000 persons) among females. Furthermore, the probability of dying between ages 60 and 75 [${}_{15}q_{60}$] is 0.324 (or 324 per 1000 persons) among males and 0.389 (or 389 per 1000 persons) among females. The results appear more like the pattern of mortality rates in developed countries than in developing (sub-Saharan) countries, probably due to the lack of completeness of female census data. Even at that, the results from the model are consistent with the estimates from other known sources. It is expected that the results will help in tracking the progress of Sustainable Development Goals (SDGs) in Nigeria, among others.

Key words: *Older-adult mortality, census, fixed-base model, probability of dying, Nigeria.*

INTRODUCTION

Mortality is one of the components of population change that is often used to assess the level of socio-economic development of a nation (Okoro et al., 2020). For computational reasons, mortality may be classified broadly into under-five mortality, adult mortality, and older-adult mortality, respectively. There is a wealth of knowledge on child mortality (the probability of dying before the age of 5) in sub-Saharan Africa, as well as manageable information on adult mortality (the probability of dying between the exact ages of 15 and

60). However, only little is known of the estimates of mortality between the exact ages of 60 and 75 or above (denoted as "older-adult mortality" hereafter).

There has been a visible gain in life expectancy (one of the common indices) for assessing mortality worldwide since 2000, although the improvement is not the same among countries. Between 2000 and 2015, sub-Saharan African countries have shown some improvement, with an expectation of life growing by 9.4 years to 60 years (World Health Organization [WHO], 2015). This growth may be due to progress in under-five mortality, headway in malaria management, and improving access to HIV treatment drugs. This global improvement in expectation of life continued up to 2019 when it reached 73.3 years before the COVID-19 pandemic from 66.8 years in 2000. In the African region, the increase is only slight, not much was added. The expectations of life only grew by 6.8 years (to 66.8 years in 2019) from 60 years in 2015. In addition, the expectation of life globally at 60 years of age also increased to 21.1 in 2019 from 18.8 in 2000 (World Health Statistics, 2021).

According to United Nations World Population Prospects (2019), the population of people aged 65 or above (for the first time in history) in 2018 was greater than that of under-five children worldwide. Also, the population of people aged 80 years or above is likely to increase to 426 million in 2050 from 143 million in 2019. Furthermore, deaths among people aged 60 years and above between 2005 and 2010 were estimated to be 55% (representing 153 million deaths out of the entire 277 million deaths). Even at that, only one-fourth or less of these deaths occurred in sub-Saharan Africa (Li and Gerland, 2013). Again, deaths among people aged 60 and up accounted for 60% of all deaths worldwide between 2010 and 2015 (United Nations Population Division [UNPD], 2017). The number of deaths at old age is the highest and, strangely, the least dependable when compared to the numbers of deaths at child and adult ages. This is due to the fact that, for the majority of developing nations, the numbers of fatalities from old age are not approximated using observed data. They are based on correlations between death rates for young and old people found primarily in developed nations (Li et al., 2018).

The need to estimate older-adult mortality in Nigeria cannot be overemphasized given the little known of the estimates of mortality between the exact ages of 60 and 75 or above. But all direct estimation of older-adult mortality and other demographic parameters in

Nigeria is difficult due to unreliable or incomplete civil registration systems (Nwogu and Okoro, 2017; Okoro, 2019; Okoro and Nwogu, 2019). The derivation of older-age mortality from death count and exposure survey data is not generally acceptable due to sample size challenges or lack of inclusion of questions that can generate the needed data in surveys.

One escape route is to use census data in the estimation of older-adult mortality in Nigeria, but data from such a source is defective. Therefore, derivation of older-adult mortality in Nigeria can best be achieved through indirect techniques (Okoro and Nwogu, 2020). There are few contemporary approaches available for the estimation of mortality rates among older adults in developing countries. Li and Gerland (2013) proposed a census approach that has the ability to correct the effects of age-misreporting; thereafter, the method is used for estimation of older-adult mortality; and it is a three-in-one model procedure. One of the limitations of this method is that it relies heavily on model life tables at the second stage of the estimation process. It is obvious that most of the data used in simulating life tables is not from developing countries (Nwogu and Okoro, 2021). Ouedraogo (2020) fitted three models (Singular Value Decomposition, Brass model, and Makeham model) to the Burkina Faso censuses, but these procedures require reported deaths for all ages, which is not available in Nigeria. Palloni et al. (2021) proposed an integrated method for estimation of older-adult mortality from information distorted by systematic age-reporting errors. The model in its present state applies to a population whose trends in age-reporting error are similar to those found in Latin American countries (LAC) and requires distributions of death count which is not also accessible in Nigeria.

This present study proposes an application based on the Variable-r Method — denoted as Fixed-base model (FBM) — proposed by Nwogu and Okoro (2021) and used for estimation of adult mortality in developing countries. We used the components of this model to obtain estimate of older-adult mortality in Nigeria. The model adopted a more conservative approach in the estimation of person-years lived ${}_nL_x$. It integrates the components of under-five mortality in deriving the estimates of ${}_nL_x$, thereafter the number of survivors at age x (l_x) is estimated from the estimates of person-years lived ${}_n\hat{L}_x$ using the relationship among life table functions. The aim of this study is to obtain the probability of dying between ages 60 and 75 for males and females from the 1991 and 2006 censuses in Nigeria using the Fixed-base model.

The paper is divided into four sections. The first section is an introduction, the second is about the materials and method, the third is about the results and discussion, and the last section is about the conclusion.

MATERIALS AND METHOD

DATA SOURCES AND LIMITATION

Nigeria is the seventh most densely inhabited country in the world, and first in Africa in terms of population, Nigeria Demographic Health Survey 2013 (National Population Commission [NPC], 2014). The Federal Republic of Nigeria has conducted few censuses but only the age distribution of the last two censuses are used in this present study — the 1991 and 2006 population censuses. The censuses are faced with misreporting errors which common in developing countries hence the application of indirect techniques to the data.

METHOD OF SOLUTION

Given the 5-years distributions of populations of a country at two points in time (0, t), Nwogu and Okoro (2021) obtained an expression for ${}_5L_x$(number of person-years lived between exact ages x and $x+5$ years)

$$ {}_5L_x = {}_5L_{x-5}\frac{{}_5\overline{N}_x}{{}_5\overline{N}_{x-5}}\exp[5({}_5r_{x-5})], \qquad x = 5, 10, 15, \ldots \omega-5 \qquad (1) $$

where

$$ {}_5\overline{N}_x = \frac{[{}_5N_x^{(2)} - {}_5N_x^{(1)}]}{t\ {}_5r_x} \qquad (2) $$

is the mid-point population, and

$$ {}_5r_x = \frac{1}{t}Ln\left(\frac{{}_5N_x^{(2)}}{{}_5N_x^{(1)}}\right) \qquad (3) $$

is the age-specific growth rate. By successive substitution, it was shown that

$$ {}_5L_x = {}_5L_0\left[\frac{{}_5\overline{N}_x}{{}_5\overline{N}_0}\right]\exp[5\sum_{i=x}^{x}{}_5r_i] $$

where

$$_{5}L_{0} = 0.3 + 2l_{1} + 2.7l_{5} \quad (4)$$

is the person- years lived between exact ages 0 and 5 years

The values of estimates in equations (1, 2, 3, and 4), at x = 60, 65, 70, 75, can be used for estimation of older-adult mortality (probability of dying between ages 60 and 75) while the estimates of l_x are derived using the relationship among life table functions according to Preston et al. (2001) as

$$\hat{l}_x = \frac{1}{10}\left[{}_5L_{x-5} + {}_5L_x\right] \qquad x = 60, 65, 70, 75 \quad (5)$$

Equation (5) helps in the adjustment of the $_nL_x$ which is often affect by age-misreporting thereby improving the age-specific estimates of l_x. The aim is to estimate the probability of dying between ages 60 and 75,

$$_{15}q_{60} = 1 - \frac{l_{75}}{l_{60}} \quad (6)$$

The idea of using 60 as the lower limit is merely because it is the retirement age in most developing countries or perceived as the beginning of the old-age population. The main motive for adopting 75 as the upper limit is that some countries' population censuses are tabulated (using 75 and over) as the open class interval (Li and Gerland, 2013). Again, beyond this age, the reporting errors (age exaggeration) may badly affect the estimates of older-adult mortality. In addition, care and caution should be taken because the assumptions that net-migration is negligible and that the completeness of the two census age distributions are similar are still relevant in this paper.

RESULTS AND DISCUSSION

The fixed-base model was applied to the Nigeria male and female census populations for 1991 and 2006. Table 1 shows the estimates of person-years lived between exact ages 60 and 75 years and number of survivors (extracted from appendices A and B respectively). The effect of age heaping on digits ending in zero are clearly observed in Figure 1, which is a classical behaviour of census data from most developing countries. It is obvious that $L_{70} > L_{65}$ which ought not to be so. Using the person-years lived in its present state to obtain older adult mortality without any form of adjustment may have a negative impact on the mortality estimates.

Table 1: Estimates of person-years lived between exact ages 60 and 75 years and number of survivors

Age	L_x		l_x	
	Male	Female	Male	Female
60	4.5306	3.5507	0.7427	0.5589
65	2.3947	1.8515	0.6925	0.5402
70	3.3880	2.3064	0.5783	0.4158
75	1.6339	1.1059	0.5022	0.3412

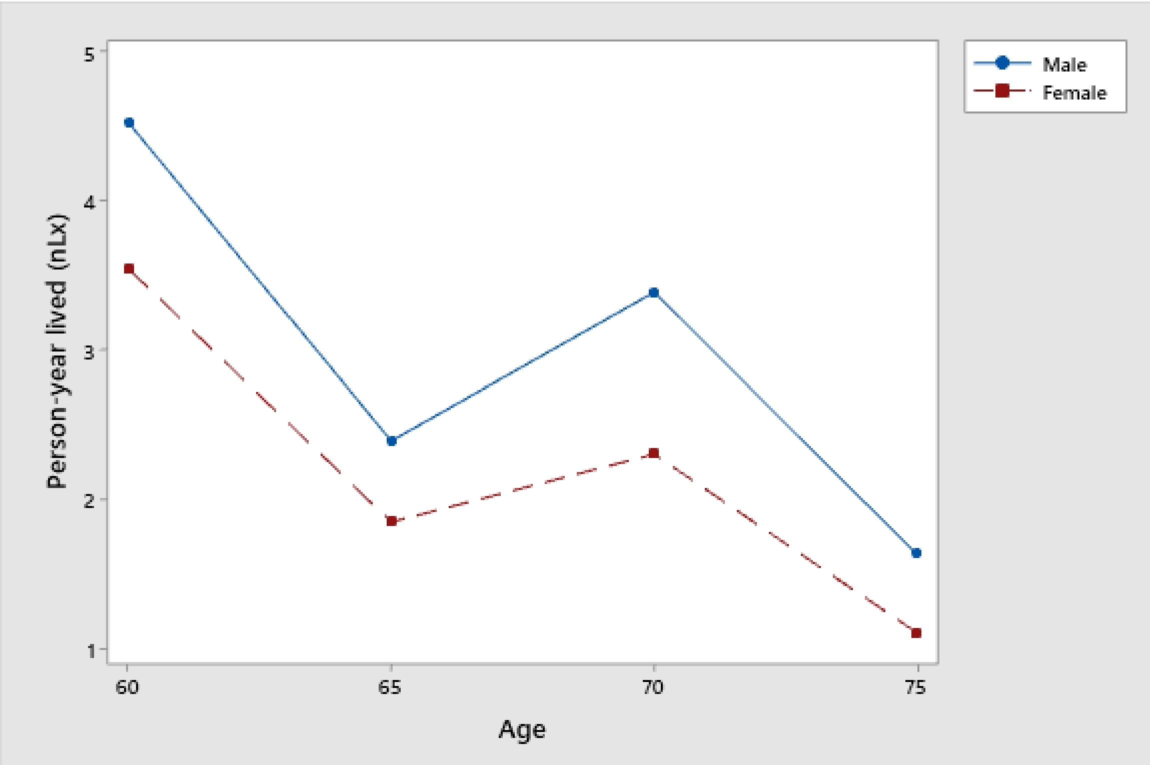

Figure 1: Estimates of person-years lived for older adults in Nigeria, 1991 to 2006.

Equation (5) was used to adjust the estimates of the ${}_nL_x$ which is affected by age-misreporting as clearly shown in Table 1 and Figure 1 respectively, and to also derive the estimates of l_x. Figure 2, shows that the estimates of l_x for the four ages appear to have improved after the adjustment of the ${}_nL_x$. Because the number of survivors at age 65 is greater than the number of survivors at age 70 for both males and females respectively.

The estimates of l_x dropped consistently depicting the traditional pattern of a model life table for both-sexes. Although, it appears there are greater number of male survivors than for females in the age range under consideration.

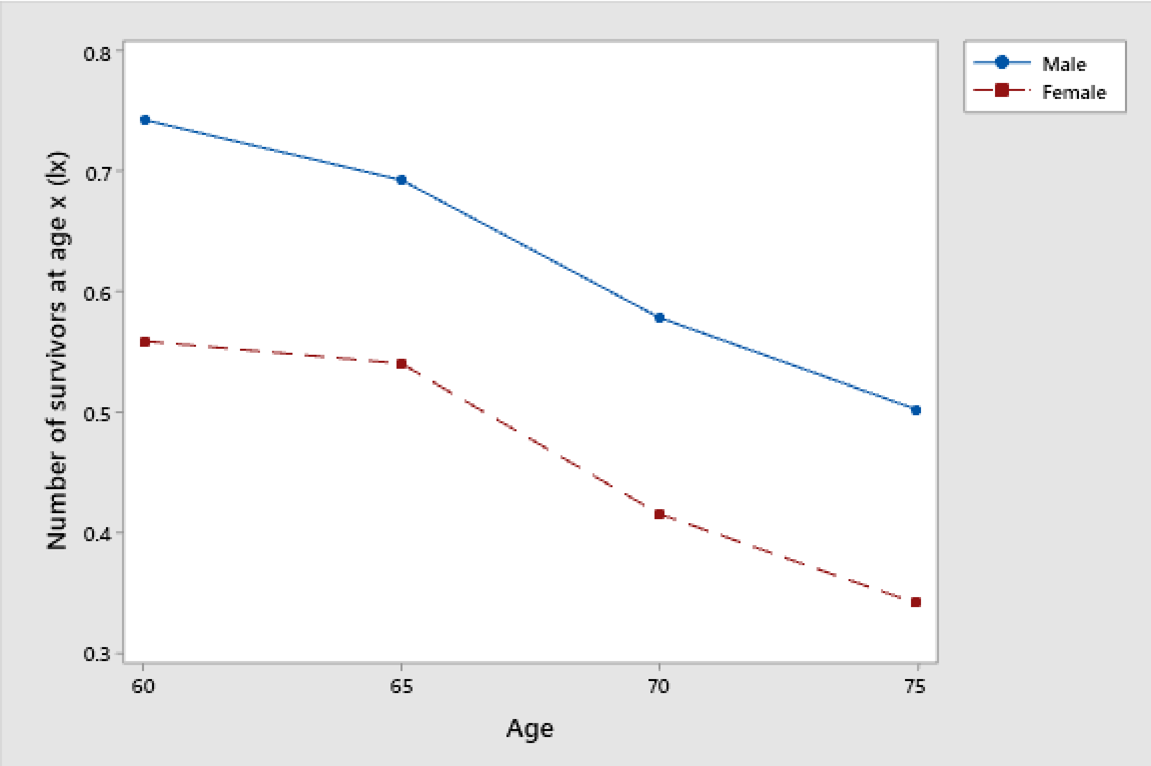

Figure 2: Estimates of number of survivors at age x for older adults in Nigeria, 1991 to 2006.

Table 2 and Figure 3 show sex-specific estimated older-adult probabilities of death for Nigeria. It is observed from Figure 3 that the probabilities of dying between ages 60 and 65 are higher among males than females. Furthermore, the probabilities of dying among males were consistently lower than those of their female counterparts for ages 60 to 70 and 60 to 75, respectively.

Table 2: Estimated older-adult probabilities of death for Nigeria

Index	Period	Male	Female
${}_{5}q_{60}$	1991-2006	0.068	0.033
${}_{10}q_{60}$	1991-2006	0.221	0.256
${}_{15}q_{60}$	1991-2006	0.324	0.389

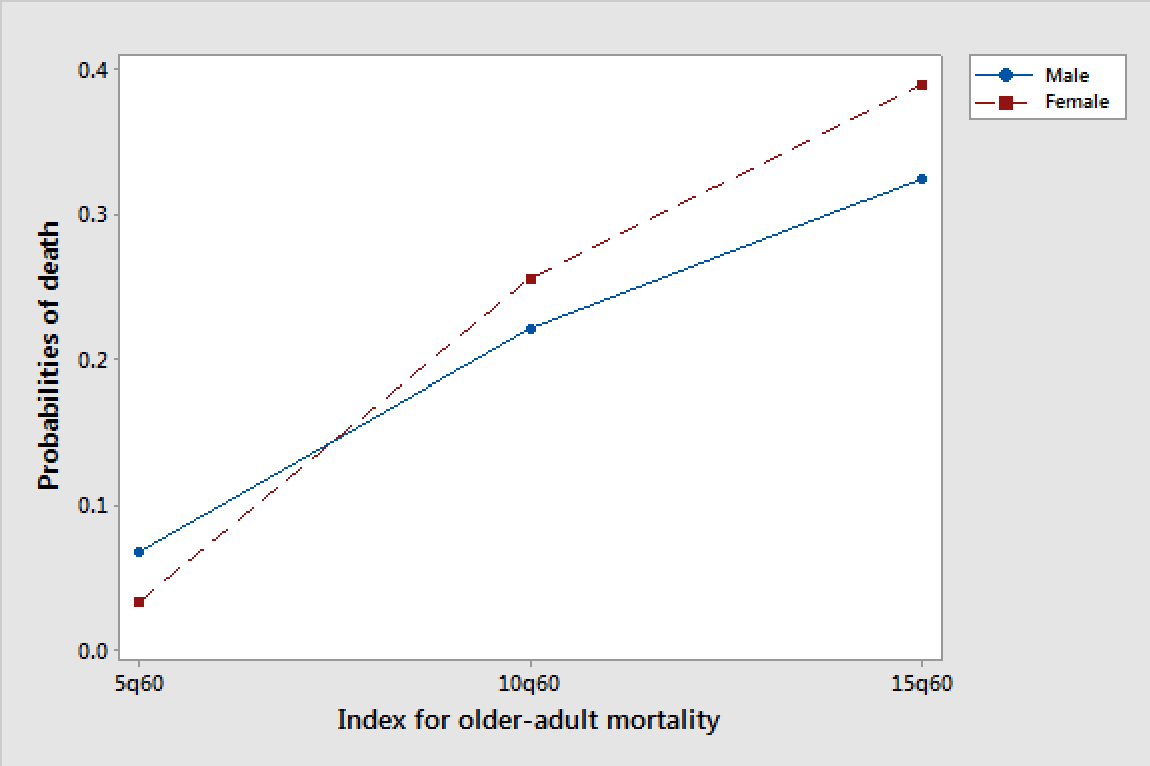

Figure 3: Estimates of the probability of dying for older adults in Nigeria, 1991 to 2006.

Table 3: Sex-specific estimates of older-adult mortality compared with another source

		Estimates of FBM		**Li and Gerland (2013)**	
Index	Period	Males	Females	Males	Females
${}_{15}q_{60}$	1991-2006	0.324	0.389	0.356	0.479

The aim is to estimate the probability of dying between ages 60 and 75 by applying equation (6). The results obtained as shown in Table 3, indicates that the females' probability of dying between ages 60 and 75 is higher than their male counterparts', according to the fixed-base model estimates. This result is consistent with the estimates by (Li and Gerland, 2013). While the difference between the males and females is 0.065 (65 per 1000 persons) for the fixed-base model, that of Li and Gerland (2013) was 0.123 (123 per 1000 persons). This difference may be due to overestimation by their models or underestimation by the fixed-base model. The estimates of the fixed-base approach appear to be more consistent with the pattern of death records from Nigerian surveys. There are higher death rates for females than for males in NDHS 2008 for ages 15–40, and for ages 15–49 in NDHS 2013, but the difference is not large. In the NDHS 2008, the difference between males and females in the number of deaths was 37 for ages 15–40, while in the 2013 NDHS it was 62 deaths. Our findings also agree with the study by Chukwu and Oladipupo (2012), where they observed, using the Lee-Carter model, that females have a higher mortality rate than males in Nigeria and predicted that the trend will continue for males up to 2019, all things being equal. Furthermore, the higher mortality rates for females than for males are probably due to a difference in the completeness of census data. Traditionally, male populations in developing countries appear more complete than female populations.

CONCLUSION

Estimation of demographic parameters, especially older-adult mortality in Nigeria, is a herculean task. There is grossly insufficient data to make direct estimation of mortality beyond 60 years an easy job. The reliance on indirect techniques to derive older-adult mortality faces many problems — age-heaping, systematic age exaggeration, poor census completeness, strong assumptions in some models, which are difficult to manage. The fixed-base model applied in this study is not an all-cure approach but provides useful results in narrowing the research gap in the estimation of older-adult mortality in Nigeria and sub-Saharan Africa. The application of indirect techniques for the estimation of older-adult mortality, and other demographic parameters ought not to discourage the race to enhance the civil registration networks or systems so that demographic parameters can be deduced directly from death counts without the complex process of indirect techniques.

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Appendix A

Table 2: Fixed-base Model applied to Nigeria, Males: 1991-2006

Age	1991	2006	${}_5\overline{N}_x$	${}_5r_x$	$5({}_5r_x)$	$5\sum_{x=5}^{x-5} {}_5r_x$	$Exp[5\sum_{x=5}^{x-5} {}_5r_x]$	$\frac{{}_5N_X}{{}_5N_5}\exp[5\sum_{x=5}^{x-5} {}_5r_x]$	${}_nL_x$	l_x
0	7,344,454	11,569,218	9,297,405	0.0317	0.1587	-	-	1.0000	4.4097	-
5	7,374,314	10,388,611	8,795,545	0.0239	0.1197	0.1587	1.1720	1.1088	4.8894	0.9299
10	5,812,538	8,504,319	7,073,269	0.0266	0.1330	0.2785	1.3211	1.0051	4.4321	0.9322
15	4,528,721	7,536,532	5,905,513	0.0356	0.1779	0.4114	1.5090	0.9585	4.2266	0.8659
20	3,314,303	6,237,549	4,622,902	0.0442	0.2209	0.5894	1.8028	0.8964	3.9530	0.8180
25	3,304,739	5,534,458	4,324,210	0.0360	0.1801	0.8103	2.2485	1.0458	4.6116	0.8565
30	2,808,629	4,505,186	3,590,348	0.0330	0.1651	0.9904	2.6924	1.0397	4.5848	0.9196
35	2,206,871	3,661,133	2,872,917	0.0354	0.1768	1.1555	3.1756	0.9813	4.3271	0.8912
40	1,971,197	3,395,489	2,619,114	0.0380	0.1900	1.3323	3.7899	1.0676	4.7080	0.9035
45	1,355,101	2,561,526	1,894,728	0.0445	0.2224	1.5223	4.5829	0.9339	4.1185	0.8826
50	1,388,650	2,363,937	1,833,259	0.0372	0.1859	1.7448	5.7246	1.1288	4.9776	0.9096
55	638,555	1,189,770	885,760	0.0435	0.2174	1.9306	6.8938	0.6568	2.8962	0.7874
60	898,711	1,363,219	1,114,884	0.0291	0.1456	2.1480	8.5680	1.0274	4.5306	0.7427
65	406,540	628,436	509,459	0.0304	0.1522	2.2936	9.9105	0.5431	2.3947	0.6925
70	492,186	765,988	619,028	0.0309	0.1545	2.4458	11.5393	0.7683	3.3880	0.5783
75	195,455	327,416	255,787	0.0360	0.1802	2.6003	13.4675	0.3705	1.6339	0.5022
80	258,059	408,680	327,619	0.0321	0.1606	2.7805	16.1273	0.5683	2.5060	0.4140
85+	230,585	404,021	309,239	0.0392	-	-	-	-	-	-

Note: ${}_5L_0$ = 4.4097, l_1 = 0.9048, l_5 = 0.8519, (derived from 2013 Nigeria DHS).

Appendix B

Table 3: Fixed-base Model applied to Nigeria, Females: 1991-2006

Age	1991	2006	${}_5\overline{N}_x$	${}_5r_x$	$5({}_5r_x)$	$5\sum_{x=5}^{x-5} {}_5r_x$	$Exp[5\sum_{x=5}^{x-5} {}_5r_x]$	$\frac{{}_5N_X}{{}_5N_5}\exp[5\sum_{x=5}^{x-5} {}_5r_x]$	${}_nL_x$	l_x
0	6,999,435	11,025,749	8,860,650	0.0317	0.1587	-	-	1.0000	4.4097	-
5	7,126,144	9,616,769	8,309,338	0.0209	0.1047	0.1587	1.1720	1.0991	4.8468	0.9257
10	5,336,143	7,631,631	6,415,589	0.0250	0.1250	0.2635	1.3014	0.9423	4.1553	0.9002
15	4,806,977	7,362,887	5,994,389	0.0298	0.1490	0.3885	1.4747	0.9977	4.3995	0.8555
20	4,357,267	7,197,530	5,659,102	0.0351	0.1753	0.5374	1.7116	1.0932	4.8205	0.9220
25	4,006,932	6,676,968	5,228,822	0.0357	0.1784	0.7128	2.0396	1.2036	5.3076	1.0128
30	3,105,298	4,962,352	3,961,545	0.0328	0.1638	0.8912	2.4380	1.0900	4.8066	1.0114
35	2,007,882	3,670,622	2,756,163	0.0422	0.2108	1.0549	2.8718	0.8933	3.9391	0.8746
40	1,874,721	3,060,981	2,419,578	0.0343	0.1713	1.2657	3.5455	0.9682	4.2694	0.8209
45	1,061,332	2,029,767	1,493,585	0.0453	0.2265	1.4370	4.2079	0.7093	3.1278	0.7397
50	1,182,149	1,885,282	1,506,466	0.0326	0.1631	1.6635	5.2777	0.8973	3.9569	0.7085
55	481,394	876,477	659,324	0.0419	0.2093	1.8266	6.2124	0.4623	2.0385	0.5995

60	791,573	1,087,067	931,522	0.0222	0.1108	2.0359	7.6591	0.8052	3.5507	0.5589
65	357,400	522,612	434,787	0.0266	0.1328	2.1467	8.5567	0.4199	1.8515	0.5402
70	394,116	564,609	474,266	0.0251	0.1256	2.2795	9.7715	0.5230	2.3064	0.4158
75	156,368	252,422	200,576	0.0335	0.1673	2.4051	11.0791	0.2508	1.1059	0.3412
80	222,627	351,373	282,121	0.0319	0.1594	2.5724	13.0967	0.4170	1.8388	0.2945
85+	194,404	311,204	248,241	0.0329	-	-	-	-	-	-

Note: ${}_5L_0$ = 4.4097, l_1 = 0.9048, l_5 = 0.8519, (derived from 2013 Nigeria DHS).