

**ESTIMATING THE COMPLETENESS OF CENSUS ENUMERATION: A CASE
STUDY OF KENYA POPULATION AND HOUSING CENSUSES 1989 AND 1999**

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DECLARATION

I declare that this research project is my original work and that to the best of my knowledge it contains no materials previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at the University of Nairobi or any other educational institution

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ABSTRACT

This study explores trends in completeness of census data in Kenya for 2 successive inter-censal periods of 1979-89 and 1989-99. The objective of the study was to estimate the completeness of Kenya's 1999 and 1989 censuses relative to the respective previous censuses and; to make appropriate adjustments for coverage. The study utilized secondary data from the KNBS population and housing censuses of 1999 and 1989. The main method of analysis involved the Brass Growth Balance model to estimate completeness of the 1999 census relative to the 1989 census; and completeness of 1989 census relative to the 1979 census by age and sex. The African Standard model life table was used to estimate mortality.

The results indicate that an overall decline in the level of completeness of census enumeration from 1969-79 period up to 1989-99 inter-censal period. A common observation in both inter-censal periods is that ages 5-9, 10-14 and 50+ for both males and females have shown a deviation from the line of best fit, indicating possible higher age misreporting and heaping amongst these age groups. Female enumeration indicated lower levels than males in the three inter-censal periods. These substantial sex differences in the degree of completeness could be caused by similar sex differences in literacy rates, education, or other factors. For example, women may be more likely to have their information reported by a proxy (such as the head of the household) than men. Completeness of estimates of death on the other hand indicated an improvement over time. However, large variations in the completeness of death estimates have a relatively large effect on the estimated expectation of life at age 0 years. For example, a 78.7 per cent lower completeness of death registration amongst females in 1989-99 decreases the estimated e_5 from 65.4 to 54.74 years, a drop of over 10 years. Adjustment of the inter-censal age distributions for the Kenya population yields an adjusted exponential population growth rate over the 1989-99 inter-censal period of 3.66% compared to the reported 3.09%; while the adjusted exponential growth rate for the 1979-89 inter-censal period yields 4.2% compared to the reported 3.4%.

The trends of adjusted mortality and age-sex distribution observed in this study follow similar patterns as those seen in Kenya census analytical reports by the KNBS. Comparison with other data quality measures such as UN Age-sex Accuracy Index, Myers Index and Whipple's Index reflect resemblance in the trends of data quality as those obtained in the application of Hill's

method for all the sexes. This comparison serves the purpose of checking and validating the results obtained in this study and the resemblance shows a high level of accuracy of the findings.

The assumption of none or negligible migration in this method is untenable in Kenya today, given high net migration experienced over the years. Thus, further studies in this area ought to consider adjusting the technique for migration as proposed by Hill and Queiroz (2004).

The diminishing level of data quality (less completeness) over time as seen in the findings of this study implies that estimates of population growth rate could be inaccurate. This introduces a need to consider possible explanations for the inaccuracies in the age-sex structure of the Kenya population in addition to the summary of levels of completeness. Demographers and census experts ought to consider re-examining data quality and institute specific measures to improve on the same, particularly at age groups 5-9, 10-14 and 50+, based on the results of this study. Such measures would ensure quality data for use in policy making and development planning.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Censuses of population are taken by governments to determine the number of inhabitants in their country and various characteristics of the population. Censuses have taken place for several years with the oldest being the Chinese first census conducted in 2 A.D. recording a population of 59.6 million, considered to be quite accurate (CSO, 2011). Since then several countries have conducted recurrent population censuses with varying levels of accuracy.

In Kenya, seven successful censuses have been conducted; two pre and five post-independence censuses. The first census was conducted in 1948 which recorded 5.4 million people, although a full report was not published. The 2nd census was conducted in 1962 and recorded 8.6 million people. Over the years, successful censuses have been held consistently every 10 years until the most recent of 2009 which recorded 38.6 million people. This consistency is attributed to government commitment and funding (KNBS, 2014). Censuses have been a key element in planning, administration and allocation of resources and this has led to an increased push for accuracy of the data.

Despite the successes, population censuses are subject to omissions and other coverage errors. Inaccurate censuses due to under-coverage; and misreporting of age are among the problems often encountered by researchers wishing to use these data-sets (UNFPA, 1983, 2002). Age misstatement has been realized in the tendency to understate the number of persons aged 0-9 in Kenya's censuses mainly due to under-reporting of births. Similarly, persons absent on the night of the census are usually left out of the total count, affecting the completeness of the census.

In order to ensure accuracy of the censuses, the Kenya National Bureau of Statistics conducts Post-Enumeration Surveys (PES) whose main objective is to evaluate the coverage and error rates for the Kenya Population and Housing censuses. The results of the PES are used to adjust the census figures. Females have shown the larger net undercounts than males over time in all the censuses from 1969 to 1999. This is mainly due to the tendency of female respondents to use a proxy to respond to census questions. The probability of errors is therefore quite high. Further,

persons aged 55 and over are also likely to use proxies as respondents hence a higher probability of errors. Data quality seems to have declined over time, with the latest census 2009 raising political heat amongst leaders in Northern Kenya. The results of the census in Mandera, Wajir and Garissa districts showed very large discrepancies, with the rate of population increase higher than the population dynamics of the region would support. To date, there is a court case to determine whether the results can be published or not, owing to these inconsistencies. In addition to these, given the manual nature of the census data processing, the results take long (usually one year) before release. This means that policy makers or anyone wishing to use the data set have to use information already one year old, raising issues of timeliness of data. In the developed world, censuses are not a necessity given fast and robust vital registration systems which gather real time data. The scenario is different in developing countries where censuses are conducted every 10 years and reported 1 year later.

The PES method uses sample enumeration areas to estimate total counts hence is subject to sampling biases. Another challenge associated with PES is low match rate and memory recall due to lateness since PES is conducted 3 to 6 months after main census (Obudho, 2009). This study used other methods, specifically Hill's growth balance method to estimate completeness and adjust population age distributions and growth rates of the Kenya 1989 and 1999 censuses. Completeness is measured relative to a previous census. It provides a comparison between a previous census and a current census.

1.2 Problem statement

The world over, data yielded by censuses have recorded various levels of completeness. In some developed nations, civil registration has been strengthened through robust systems that make census exercises unnecessary. Such data is usually almost 100% complete, for instance Sweden has one of the best known comprehensive and complete civil records than any other country (SCB, 2009). The US census data had a net over-count of 0.01% in 2010 while that of Germany, strengthened by civil records was 100% complete (Williams, 2012). In Africa where civil registration is about 40% complete (IIVRS, 1988), censuses are key in understanding various demographic phenomena. Data generated from these censuses are incomplete due to several reasons some of which are biases arising from under-reporting in certain ages, double-counting

of persons, missing persons on the night of the census and time location errors among others (UNFPA, 1983, 2002).

In Kenya, census completeness varies every census year. Age misstatement has been realized in the tendency to understate the number of persons aged 0-9 in censuses mainly due to under-reporting of births. For example, the United Nations estimates of 1983 and the census of 1979 gave lower mean parities for women over 40 years of age compared to the Fertility Survey (1978) and the Contraceptive Prevalence Survey (1984), which were close to them in time (Jolly, 1993). These differences suggest that there was underreporting of births at the census (1979) and the UN estimates (1983), consequentially affecting enumeration of ages 0-9. It seems likely that there was at least as much underreporting at the earlier censuses and evidence has also shown such disparities in the 1989 and 1999 censuses (KNBS, 2002).

A back-projection to 1969 of the population aged 10 and over in 1979 suggested that there had been an under-count of children under 10 (Bore, 2009). The 1979 census gave a total population (all ages) which fell short of the projected figure by about 5%. The 1989 census showed a larger discrepancy between the projected and enumerated populations with an under-count of 7.1% (Bore, 2009). KNBS acknowledges that of all censuses in Kenya before 1999, that of 1969 achieved the highest level of completeness. Christopher (2010) has stated that one of the causes of incomplete census coverage in Kenya has been that the questions posed and the responses elicited are highly variable. Hence, quite often the subsequent published tabulations do not allow for the monitoring of long-term trends. Further, rates of growth and other essential demographic parameters calculated using incomplete census data could lead to poor planning and targeting on the part of central government and development planners.

Incompleteness of census in Kenya is estimated and adjusted using Post Enumeration Surveys (PES). This involves sampling of enumeration areas, re-counting and comparing with recorded figures and generalizing for the whole population (Obudho, 2009). The net under-count is also calculated by measuring the difference between projected and enumerated populations. The PES method suffers from uncertainties arising from sampling errors whereas the comparison between projected and enumerated populations still suffers from actual incompleteness of enumerated

census (Obudho, 2009). This has led to variances in the actual level of completeness. Questions therefore arise on what the actual level of completeness is for the Kenyan census data.

These challenges necessitate the assessment of completeness of coverage of the census data and to make adjustment for the omissions observed. There is need to know the actual level of completeness using other available techniques and to understand the trends in completeness of censuses over the years so that improvements can be made as we seek to enhance the quality of demographic data. This study sought to answer the following research questions:

- i. What are the levels and trends of completeness of Kenya 1999 and 1989 census data relative to the respective previous censuses?
- ii. How do the adjusted age-sex distribution and growth rates compare with the recorded rates for the two censuses?

1.3 Objectives of the study

The general objective of the study was to establish the levels and trends of completeness of the Kenya census data sets, specifically the 1999 and 1989 censuses. The specific objectives were:

- i. To estimate the completeness of Kenya's 1999 and 1989 censuses relative to the respective previous censuses using age-sex and death distributions and;
- ii. To make appropriate adjustments for coverage, and thus estimate age specific distributions

1.4 Justification of the study

The need for a reliable, valid and complete data set capturing key population dynamics of Kenya justifies this study. The study will increase the understanding of trends in completeness of Kenya's census data and will therefore contributed to improving data quality and the drive to ensure that estimates of Kenya's growth rate adequately represent actual statistics. Demographers can be able to use the findings of this study to improve data quality in censuses through planning and putting appropriate measures to ensure complete coverage.

Policy makers can use the findings of this study to improve vital registration and census systems. At development planning level, the achievement of Kenya's development blue-print, the Vision

2030 relies heavily on the provision of accurate, valid and reliable age-sex data for sector-specific development, informed by among other things, demographic patterns and dynamics. This underscores the need to acquire complete and accurate age-specific census information and true estimates of population growth.

1.5 Scope and limitations of the study

The study used census data for 1999 and 1989 which covers the whole country of Kenya. Census is an enumeration covering the whole country, hence age sex distributions for the whole country will be analyzed and adjusted using the methods described in section 3.3 of Chapter 3.

The basic assumption of the study is that Kenya's population is "closed" or "relatively closed", that is, not affected by emigration and immigration. Yet, the assumption is untenable given large-scale immigration of population from neighboring countries and emigration of laborers and students to the developed world (Queiroz, 2004). The problem is that no proper records of emigration are kept and immigration data are not well analyzed to provide volumes and patterns of the two movements. Attempts to capture more accurate and complete data are on-going and since 1999, the body charged with conducting census in Kenya, KNBS has used scanning technology to capture migration, mortality and fertility data. This reduces data transmission errors and improves timeliness of such data. However, data on emigration is still elusive, not only in Kenya but in Anglophone Africa (Christopher, 2010).

In order to estimate completeness, data on deaths is essential in the analysis process, yet data on mortality is incomplete in Kenya. To address this challenge, Brass (1979) proposed a technique to simultaneously estimate mortality and completeness of census. This technique uses Model Life Tables to estimate deaths where data is unavailable or limited and is discussed further in Chapter 3 below. This study therefore used Model Life Tables (African Standard) to estimate deaths by age. However, such estimates do not represent actual figures from civil registration records, but can be used to depict a general picture of mortality in Kenya.

Completeness of census data varies every year depending on the extent of coverage errors. Estimation of the extent of completeness was the general objective of this study and has been addressed in Chapter 4 which focuses on analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter examines various literature on completeness of census. It summarizes the empirical findings of various studies on completeness that have used Brass's technique and discusses the analytical framework for this study.

2.2 Data quality methods

Various methods have been discussed and applied to different data sets with varying and in some cases similar results. Some techniques used in data quality checks and correction include Whipple's index for detecting age misreporting in digits ending with 0 and 5. It yields one index indicating whether the whole census data set is accurate, fairly accurate, inaccurate or very inaccurate and can be applied to females and/or males. Similarly, the Myers index measures age heaping in digits ending with 0 through 9. The UN age-sex accuracy index detects misreporting and yields a single index indicating the accuracy of a specific data set. These indices only yield a single value but do not provide age-specific indices or factors for correction (Ayad.et.al, 1994). This limits the techniques especially where there is need for age-specific indicators and correction factors.

Other techniques include the use of backward forward projections to estimate completeness of death registration and relative census coverage. This is based on a stable population theory (Preston, 1980) which assumes that a population has constant growth rate and closure to migration. In conventional developing country population dynamics, this is untenable given large migration and varying growth rate. The application of this technique by Palloni-Kominski is discussed in the applications in section 2.4 below. One of the popular methods used in estimating and adjusting for incompleteness of census and mortality coverage is the Brass (1975) growth balance method. Hill (1987) later generalized this method for non-stable populations as discussed in the succeeding sections.

2.3 Evolution of the Growth Balance Method

It is not necessary to reject entirely the results of an incomplete census because it is defective. On the contrary, by careful examination of the completeness of enumeration, an improved population estimate can be constructed for the whole country. Demographers have proposed

alternative techniques which combine incomplete registrations and population estimates by age and sex to determine the adjustment factor for acceptable measures of mortality, fertility and overall census estimates, including the life table. Brass (1975) proposed the growth balance method to simultaneously estimate the degree of coverage of two census enumerations and under-registration of adult deaths in populations where assumptions of demographic stability could be reasonably maintained (Dorrington, 2013) . The method assumed that the population was closed to migration; it was demographically stable (growth rate was constant at any age 'a'); the completeness of death recording was constant at any age 'a' after early childhood; and that the completeness of census coverage was also constant at all ages 'a'. Hill (1987) generalized the Brass Growth Balance method to non-stable populations closed to migration. Hill's method does not depend on the assumption of stability and is based upon inter-censal comparisons of successive cohorts with an accounting for registered inter-censal cohort deaths.

Trussel and Menken (1979) examined the assumptions underlying Brass's technique and evaluated its performance under ideal conditions in which the assumptions were fully satisfied. Two death rates, based on census survival and registered deaths during the inter-censal period to persons aged 'a' and older at the time of the first census were hypothesized to have a linear relationship. They showed that the estimators proposed by Brass yield a non-linear relationship even in ideal circumstances when all assumptions are adequately met. The non-linearity arises from the definition of the denominator used to calculate the two death rates. Martin (1980) also attempted to adjust (for non-linearity) the Brass estimate of death registration completeness, c . However, Bah (1995) points out that estimation of these factors involves circularity (indirectness/complexity) because the estimate of the mortality condition is the aim of the Brass method in the first place.

Preston and Coale's (1980) death distribution method estimates the completeness of death reporting relative to the population estimate at one point in time. Preston and Coale observe that the number of people alive at any point in time must equal the number of those from that cohort who die from that point in time forward. For a stable population with constant growth rate and closed to migration, the number of deaths for persons aged x , t years into the future, will equal the number of deaths aged x currently multiplied by e^{rt} (Dorrington, 2013). It is then possible to estimate current population using only current deaths by age and the stable growth rate r . Where

there is under-reporting of current deaths, but can be assumed to be under-reported to the same extent, c , at every age, then the estimate of future deaths will be under-estimated to the same extent. It is then possible to estimate the completeness of death reporting by dividing the sum of estimates of future deaths derived from number of deaths at any date by the population at the same date. Mortality rates are then estimated by dividing the number of deaths reported in each adult age group by c and then dividing these numbers by an estimate of population exposed to risk.

Bennet and Horiuchi (1981) have built on the Preston and Coale method that assumes stability. They relax the assumption of stability in their Synthetic Extinct Generations Method which can be used for irregular inter-censal periods. It assumes that the observed number of persons in each 5-year interval is approximately equal to the corresponding number in a stable population inferred from the numbers at ages x and $x+5$ and the observed age-specific growth rates.

Bhat (2002) reformulated the Growth Balance Equation to include migration and to use orthogonal regression instead of the least squares method to fit the linear estimate of the adjustment factor, C . Having obtained values for K and C , the number of registered deaths is adjusted. Different methods for fitting the straight line (least squares, orthogonal regression, group mean method etc.) are available. Bhat advocates for the orthogonal regression approach and restricts the inclusion of the 0-4 age group as well as the 70-74 age groups. This may be due to the fact that the causal relationship between Y and X inherent in the least square method is not applicable here. X could depend on Y or Y could depend on X . The orthogonal regression allows for this (ABS, 2004).

2.4 Applications of the Growth Balance Technique

Demographers have applied various versions of the Brass growth balance technique to data from more developed and less developed nations. The most popular applications are the simple Brass growth balance equation and the generalized version by Hill (1987).

The Bennet and Horiuchi (1981) method was applied to the Mauritius census data with results showing a high degree of completeness of death registration in Mauritius (Bah, 1995). However, some results of the age-specific completeness yielded unrealistic figures, higher than one (1). Bah attributes this anomaly to out-migration. He argues that where there is high out-migration,

yet the population is assumed to be closed, as in the case of Mauritius, the expected number of deaths may form a high proportion of reported deaths or may even exceed them. High out-migration in Mauritius makes the population an open one, rather than a closed one.

Brass's growth balance equation and the generalized version by Hill (1987) were both applied to Japanese female census data to estimate completeness of census and death registration (UN, 2000). In the simple growth balance method by Brass (1975), the results suggest that the registration of deaths was 98.7 per cent complete and that deaths needed to be adjusted upwards by 1.3 per cent (UN, 2000). Brass's method was tested by applying it to synthetic data ("perfect" data reporting conditions) because it is designed for use where under-reporting is much higher than the level found for Japan females. The synthetic data represent approximately the same level of mortality as that of Japan. The application of the method to the synthetic data results in an adjustment factor (C) of 1.0004, thus suggesting that the Brass's growth balance method performs well under conditions where the reporting of deaths is close to complete as is the case for Japan. Although the simple growth balance method suggested that the reporting of deaths for Japan was fairly complete, the Hill's general growth balance method was applied to the same data to assess whether the results were biased by differential completeness of the Japanese censuses.

In the generalized model by Hill (1987), the observed data points fell closely along the fitted line. The residual plot showed that the last two points were outliers, with values relatively far below the fitted line. The intercept and slope of the fitted line were $a = 0.00007$ and slope $b = 1.0070$. The value of K_1 (1960) was found to be 1.000 and K_2 (1970) was found to be 0.9993. The figures show that the 1970 census achieved a slightly less complete enumeration (99.93%) than the 1960 census. To adjust the 1970 census counts to the same level of completeness as the 1960 counts, based on these results, the 1970 counts were divided by 0.9993, i.e., increased by about 0.07 per cent. The results further showed that the inter-censal deaths were under-registered by 0.7%. The general growth balance method therefore estimates a very slight relative under-enumeration in the 1970 census, but mortality is so low that even this slight under-enumeration creates the appearance of many more inter-censal deaths and a much higher level of under-registration than is really the case (UN, 2000).

The same technique used in the Japanese female census data above was applied to female census data in Zimbabwe, comparing Brass's and Hill's simple growth balance and general growth balance techniques respectively. Death registration data in Zimbabwe was only available for 1982, 1986 and 1990-1992, therefore necessitating the estimation of these deaths using Model Life Tables to obtain an estimate of the deaths that would have been registered over the entire inter-censal period (UN, 2000). The simple growth balance method yields an overall completeness of death registration for the inter-censal period of 35.9 per cent. The fitted line shows that the ratio for age $x=5$ is a clear outlier. The remaining points mostly fall in the range of 0.3 to 0.4. However, the variation can be accepted as the range of possible error in estimated completeness. The results of the application of the general growth balance method to data for females enumerated in the Zimbabwe census for 1982-1992 yield the intercept and slope of the fitted line as $a = 0.00268$ and $b = 2.229$, respectively. K_1 and K_2 yield values of 1 and 0.9735 respectively indicating that the 1992 census achieved an enumeration which was 2.65% less than the 1982 census. The estimated completeness of death registration was thus 44.3 per cent, as compared with 35.9 per cent from the simple growth balance method.

The application of the growth balance technique to both Zimbabwe and Japan data show consistent results (UN, 2000). The generalized version shows higher death registration compared to the Brass simpler version.

Magadi (1990) estimates the completeness of Kenya's 1979 census relative to the 1969 census using Hill's (1987) Generalized Growth Balance Equation and compares the results with Palloni Kominski backward and forward projections method. She attempts to identify the nature and extent of age misreporting errors in Kenyan data and make appropriate adjustments, and thus attempt to estimate Kenya's age distribution. Magadi finds that using Hill's method yields 97.11% and 98.79% census completeness for females and males respectively, while death registration completeness is 18.25% for females and 26.18% for males. The Palloni-Kominski method on the other hand yields different results with female and male census completeness at 100.57% and 103.58% respectively and 14.5% and 19.39% for female and male death registration completeness respectively. Further, age heaping patterns were similar in both methods with preference for 0, 5, 8 and 9 figures. The two methods yield different results, although inter-censal completeness lays around 95% to 105%. Magadi recommends analysis and

further work on completeness underscoring the need to explore trends in completeness of the Kenyan censuses.

In summary, the overall literature indicates gaps in the application of Hill's technique to Kenyan data. The last application was made in the 1979 census data which cannot be used for current decision making or planning; thus highlighting the need to apply the method to more recent data. Further, results indicate consistencies in the application of this method to other developing countries such as Mauritius and Zimbabwe thus emphasizes the desire for further research on the Kenya context.

2.5 Analytical framework

Hill (1987) reformulated the Brass equation to cater for non-stable populations. Hill generalizes Brass's equation for non-stable populations when two or more census enumerations are available. He calculates the growth rate of each segment from the census counts, and the assumption of stability is no longer needed. The relationship of the entry rate minus the growth rate to the death rate estimates:

- i. An intercept that captures change in census coverage between two censuses and;
- ii. A slope that estimates the coverage of death recording relative to coverage of the two censuses.

Hill's method has three assumptions:

- a. That the population is closed to migration
- b. The coverage of population and deaths by age is invariant
- c. There is accurate recording of age for both population and deaths

Hill has shown that in any population closed to migration, the following equation holds for an inter-censal period:

$$\frac{N(a)}{N(a+)} - r(a+) = \frac{1}{t} \ln \frac{1}{K} + \frac{k^{\frac{1}{2}}}{C} \frac{D(a+)}{N(a+)}$$

Where $N(a)$ and $N(a+)$ are the number of person years lived at exact age a , and at ages a and over, respectively, during an inter-censal period; $r(a+)$ is the cumulative age-specific growth rate; $D(a+)$ is inter-censal deaths for ages a and over; t is length of the inter-censal period; K is completeness of second census enumeration relative to the first; and C is completeness of death

registration during the inter-censal period. Values of K and C are assumed to be invariant with age. $N(a)$ and $N(a+)$ are calculated from census population age-sex counts as:

$$N(a) = t(5P1a - 5 * 5P1a * 5P2a - 5 * 5P2a)^{\frac{1}{4}}$$

And
$$N(a +) = t(P1a + * P2a+)^{\frac{1}{2}}$$

where P1 and P2 refer to the population counts at the first and second census respectively. The cumulative age-specific growth rate is calculated as:

$$r(a +) = \frac{1}{t} \ln \left(\frac{P2a +}{P1a +} \right)$$

The equation indicates that the ratio of inter-censal deaths to the inter-censal population is linearly related to a measure easily calculated from two population censuses (UN, 2013). The intercept of the fitted line allows calculations of the coverage of the second census count relative to that of the first census ($K = e^{It}$ where I is the intercept). The value of K can therefore be considered a multiplicative adjustment factor. When applied to the first census, it produces consistency in coverage relative to the second census. The value of K, along with the value of the slope, provides an estimate of the completeness of death registration. Inter-censal deaths can be provided in either of two ways. As one option, a United Nations, Coale-Demeny or user-designated model life table, considered appropriate to the inter-censal period, is provided and the computer program estimates inter-censal deaths from the life table central death rates and the two population age distributions. In the second option, absolute numbers of deaths by age for the inter-censal period are given as input.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the sources of data and the methods that were used to analyze the data.

3.2 Sources of data

The study utilized secondary data from the KNBS population and housing censuses of 1999 and 1989. A census is a study of every unit, everyone or everything, in a population. It is known as a complete enumeration. The Kenya Population and Housing Census uses a quantitative approach to gathering information, mainly the use of household questionnaires. Enumeration is conducted every 10 years. The census targets every man, woman and child and gathers information on size, composition and spatial distribution of the population; levels of fertility, mortality and migration, rate and pattern of urbanization; levels of education; size and deployment of the labor force; size and distribution of persons with disability and housing conditions and amenities. De facto Census is one that enumerates all persons depending on where they spend or are found on the Census night. De jure Census is one that enumerates all persons according to their usual place of residence. Kenya Censuses are historically de facto and conducted on the midnight of 24th/25th August as the reference point in time. They are also primarily canvassed (data collected and recorded on a questionnaire by a pre-trained census official) as recommended for countries that share the same level of socio-economic development as Kenya. However, the 2009 Census questionnaire allowed de jure enumeration. KNBS recruits and trains Trainer of Trainers (ToTs) who train supervisors and the supervisors train the enumerators who collect the census data.

The 1989 census enumerated 21,418,587 persons representing 10,613,627 males and 10,804,960 females (KNBS, 2010). The 1999 census on the other hand enumerated 28,686,607 persons with 13,827,930 males and 14,234,059 females. The focus of the study was on these populations, distributed by age and sex and the mortality patterns of the populations.

3.3 Methods of data analysis

The method of analysis involved Hill's version of the Brass Growth Balance model to estimate completeness of the 1999 census relative to the 1989 census; and completeness of 1989 census relative to the 1979 census by age and sex. Estimates of mortality were generated using the African Standard model life table. Estimates of census completeness and population growth rate were generated using the UN Mortpak software and comparisons between generated and reported growth rates made. The methods are further described below:

3.3.1 The Simple Brass Growth Balance Technique

Brass (1975) developed a method that would simultaneously estimate the completeness of death registration during an inter-censal period and the completeness of enumeration of one census relative to another (Menken, 1979). The method observes that in a stable population (unchanging age structure and constant growth rate r) closed to migration;

$$r = bx - dx$$

Where; r = growth rate, b = birth rate and d = death rate. For any population aged x and older, the equation can be written as; $r = b(x+) - d(x+)$

Brass has stated that for a stable population, growth rate is constant and so the births and deaths are linearly related. Therefore if $N(x)$ and $N(x+)$ are the number of births at exact age x and the population of age group x and over, respectively; and r is the population growth rate, $D(x+)$ is the deaths for age x and over, then;

$$\frac{N(x)}{N(x+)} = r + \frac{D(x+)}{N(x+)}$$

If in this population, the deaths are under-reported to the same extent at each age x , then;

$$\frac{N(x)}{N(x+)} = r + \frac{1}{c} * \frac{D(x+)}{N(x+)}$$

Where, $\frac{D(x+)}{N(x+)}$ is the recorded (observed) death rate for ages x and older and c is the proportion of reported deaths i.e. the completeness of death recording relative to population recording and is assumed constant by age. One can estimate c from the slope of a line fitted to the $\frac{N(x)}{N(x+)}$ and

$\frac{D(x+)}{N(x+)}$ data points. The slope of the line relating the entry rate (birth rate at age x) and the exit rate (death rate at age x) will estimate the completeness of population recording relative to death recording and provide an adjustment factor for the deaths. This estimation is usually confined to

adult ages as the (extent of) completeness of reporting of child deaths usually differs from that of adult deaths. Mortality rates can be estimated by dividing the numbers of deaths reported in each age group by c and then dividing these numbers by an estimate of the population exposed to risk based on the population used to estimate the birth and death rates (Dorrington, 2013).

3.3.2 The Generalized Growth Balance (GGB) Technique by Hill

Hill (1987) adjusted Brass's equation to cater for non-stable populations. For an inter-censal period, Hill states that;

$$\frac{N(x)}{N(x+)} = r(x+) + \frac{1}{t} \ln \frac{1}{K} + \frac{k^{\frac{1}{2}}}{C} \frac{D(x+)}{N(x+)}$$

Where $N(x)$ and $N(x+)$ are the number of person years lived at exact age a , and at ages a and over, respectively, during an inter-censal period; $r(x+)$ is the cumulative age-specific growth rate; $D(x+)$ is inter-censal deaths for ages a and over; t is length of the inter-censal period; K is completeness of second census enumeration relative to the first; and C is completeness of death registration during the inter-censal period. Values of K and C are assumed to be invariant with age. $N(x)$ and $N(x+)$ are calculated from census population age-sex counts as:

$$N(x) = t(5P1x - 5 * 5P1x * 5P2x - 5 * 5P2x)^{\frac{1}{4}}$$

And
$$N(x+) = t(P1x + * P2x+)^{\frac{1}{2}}$$

where P_1 and P_2 refer to the population counts at the first and second census respectively. The cumulative age-specific growth rate is calculated as:

$$r(x+) = \frac{1}{t} \ln \left(\frac{P2x+}{P1x+} \right)$$

3.3.3 Procedure for generation of GGB Tables (Reference to Appendices 1-6)

Columns 1-4: Record the population age distribution of the two censuses and intercensal deaths. Intercensal deaths by age were calculated from conditional probabilities of adult survivorship and the African Standard Model Life Table.

Columns 5-7: Cumulate input age distributions and intercensal deaths from bottom to give numbers of persons aged x and over at the first and second census, and numbers of deaths to persons aged x and over during the intercensal period.

Column 8: Compute the number of person years lived by the population aged x and over using the formula $PYL(x+) = t [P_1(x+)P_2(x+)]^{0.5}$
 $x = 0, 5, 10 \dots$

Column 9: Compute the number of persons reaching exact age x during the intercensal period using the formula $N(x) = t0.2 [P_1(x-5,5)P_2(x,5)]^{0.5}$
 $x = 5, 10\dots$

Column 10: Compute the entry rate $n(x+)$ into the population aged x and over by dividing $N(x)$ by the number of person years lived by the population aged x and over, $PYL(x+)$.

Column 11: Compute the growth rates of the population aged x and over using the formula $r(x+) = [P_2(x+) - P_1(x+)]/PYL(x+)$, $x = 0, 5, 10\dots$; where $P_1(x+)$ and $P_2(x+)$ denote the observed numbers of persons aged x and over at the first and second censuses, respectively.

Column 12: Compute the death rate $d(x+)$ for the population aged x and over by dividing $D(x+)$ by the number of person years lived by the population aged x and over, $PYL(x+)$.

Column 13: Compute $n(x) - r(x+)$ using the values for $n(x)$ and $r(x+)$ in columns 11 and 12, respectively. Columns 13 and 14 give the x and y points, respectively, for fitting a line to estimate the constant a and slope b of the equation $n(x) - r(x+) = a + b.d(x+)$

3.3.4 Fitting the straight line

Fitting the straight line involves the plotting of the $\frac{N(x)}{N(x+)}$ and $\frac{D(x+)}{N(x+)}$ data points. There are two majorly used methods for doing this;

1. The points are divided into 2 equally sized groups, and the mean abscissa and ordinate values are calculated by summing the observations for each group and dividing the sum by the number of observations in each group. Thus, the mean of the first group of death rates $\frac{D(x+)}{N(x+)}$ is denoted by Y_1 and the second by Y_2 (UN, 1983). Once the means of each group have been computed, the slope of the fitted line is calculated as follows:

$$k = (Y_2 - Y_1)/(X_2 - X_1)$$

The value of the growth rate, r is then calculated as:

$$r = Y_1 - kX_1$$

2. Even though the estimate of K obtained above is probably the best possible, a second method is by fitting a robust line as follows:

All the observations are used, but some are "trimmed" at each end of the age range. The weights associated with each observation are listed. The data set is divided into groups of equal size and the weights are symmetrical with respect to the centre. The sum of the weights used and the sum of the weighted observations are calculated (UN, 1983). The weighted totals for the second group are obtained in exactly the same way. Once these totals are computed, the means are obtained by dividing the sum of the weighted observations by the sum of the weights. The X^* and Y^* values are the trimmed means of the grouped observations. From them, the calculation of estimates of K , C and r is straightforward:

$$K^* = (Y_2^* - Y_1^*) / (X_2^* - X_1^*)$$

$$C^* = 1/K^*$$

$$r^* = Y^* - K^*X_1^*$$

The estimates obtained for each of these three parameters by using trimmed means are very similar to those obtained in method one. Indeed, the use of trimmed means reduces the influence of extreme points on the estimated value of K , hence preference for it (UN, 1983).

To obtain adjusted death rates or adjusted age-specific mortality rates, one simply multiplies the observed rates by K or by K^* . Because the trimmed-mean estimate is somewhat more robust, it has been preferred. The procedure for fitting the straight line is described below (Refer to Table 4.5 of Chapter 4):

Columns 1-3: Copy age schedule and x and y points from columns 12 and 13 of Appendix 1.

Column 4: Calculate the intercepts $y-bx$ for each point, where b denotes the slope.

Column 5: For each point, calculate the slope of the line connecting each point and the point at which the fitted line intersects the y axis. This slope is $(y-a)/x$, where 'a' denotes the y intercept. The median of these values will, in general, be very close, though not necessarily identical to the slope of the fitted line. Their variation is an indicator of how closely the points conform to the fitted line (see details on calculation of slope below).

Columns 6-8: Calculate the fitted y value, $a+bx$, for each point (column 6), the residual, $y-(a+bx)$ (column 7) and the residual as a per cent of the observed y value (column 8).

<u>Calculation of Slope</u>			<u>Calculation of Adjustment Factors and Error Indicators</u>			
Group of Points	Median x-point	Median y-point	Formula	Factor	Error	
					Indicator	Percent
			Slope			
Lower 3rd	0.00157	0.01322	(b)=[(k1*k2)^0.5]/c=	4.440	0.231	5.2
Upper 3rd	0.00830	0.04310	Intercept=ln(k1/k2)/t=	0.00587	0.00056	9.5
Slope	4.440		t=	10		
			k1/k2=exp(t*Intercept)=	1.0605	0.0119	1.1
			k1=	1.0000		
			k2=	0.9430		
			k1*k2=	0.9430		
			c=[(k1*k2)^0.5]/Slope=	0.219	0.023	10.4

3.4 Data Required

- i. **Mortality:** Inter-censal deaths can be provided in either of two ways; 1) a United Nations, Coale-Demeny or user-designated model life table, considered appropriate to the inter-censal period, is provided and Mortpak program estimates inter-censal deaths from the life table central death rates and the two population age distributions and 2) absolute numbers of deaths by age for the inter-censal period are given as input. In this case, the study will use estimates of mortality from Model Life Tables, specifically the African Standard Life Table adjusted for HIV/AIDS.
- ii. **Population of first census:** The population by age and sex for the first census. Data will be for age groups 0-4, up through the last open given age group. The study will use census results for 1999.
- iii. **Population of second census:** The population by age and sex for the second census. Data are given for age groups 0-4, up through the last open age group. The study will use census results for 2009.

3.5 Estimation of mortality using Model Life Tables

Brass proposed the relational 2-parameter logit system in 1971 to estimate mortality (Dorrington, 2013). His model requires conditional probabilities of adult survivorship i.e. l_x/l_y ; an estimate of child survivorship e.g. l_5 and a standard model life table e.g. General or African Standard.

Logits transform the logistic function into a straight line. When a logit is applied to a function that varies between 0 and 1, the extreme values (near 0 and near 1) are "stretched out" while the middle values (near 0.5) are not changed very much. The logit function thus performs like a logarithmic function at the extremes and like a linear function in the middle of the range.

The logit of a value is calculated by: subtracting the value from 1; dividing the difference by the value itself; taking the natural logarithm of the result; and then dividing the result by 2.

The equation becomes:

$$Y = \text{logit } y = \frac{1}{2} \ln\left(\frac{1-y}{y}\right), \text{ where } Y \text{ is the logit of the function } y$$

The Brass Logit system rests on the assumption that two distinct age-patterns of mortality can be related to each other by a linear transformation of the logit of their respective survivorship probabilities. Thus, for any two series of survivorship values, l_x and l_x^s , where the latter is the standard, it is possible to find constants α and β such that

$$\text{logit}(l_x) = \alpha + \beta \text{logit}(l_x^s)$$

Given that $\text{logit}(l_x) = 0.5 \ln \left(\frac{1-l_x}{l_x} \right)$, then

$$0.5 \ln \left(\frac{1-l_x}{l_x} \right) = \alpha + 0.5 \beta \ln \left(\frac{1-l_x^s}{l_x^s} \right)$$

If p is a proportion and $p = 1-l_x$, then $\text{logit}(p) = 0.5 \ln \left(\frac{p}{1-p} \right)$. It can be used only for transforming proportions - hence the use of p rather than x in the equation. A set of l_x values are just proportions if the radix is 1.

This equation reduces to the form $Y_x = a + bY_x^s$; where Y_x is the logit transformation of the life table survivors, l_x and Y_x^s is the corresponding logit of the standard life table. In essence, the logit life table system consists of taking a standard life table and modifying it mathematically until it fits the empirical data.

Of the parameters used in the modification process 'a' determines the overall level of mortality and b determines the steepness with which mortality increases with age i.e. the relationship between child and adult mortality. A high value of b signifies lower child mortality relative to adult mortality and vice-versa.

Where absolute numbers of deaths by age for the inter-censal period are unavailable or unreliable, model life tables are used to estimate the inter-censal deaths. A life table provides the most complete description of mortality in any population. A life table summarizes various aspects of the variation of mortality with age. It is derived by following a birth cohort of persons through life and tabulating the proportion still alive at various ages. An abridged life table assumes that mortality does not vary within each age group. The basic data input needed for its construction are the age-specific death rates calculated from information on deaths by age and

sex (from vital registration) and population by age and sex (from census). However, to generate a life table through indirect techniques requires the use of a model life table. Model life tables perform the dual function of:

- a. Smoothing irregularities and interpolating/extrapolating missing I_x values; and
- b. Linking the estimates of child mortality with those of adult mortality.

A standard life table is usually selected for any application that describes well the balance between infant and child mortality on one hand and child and adult mortality on the other. Hence, where there are reasonable estimates of the mortality pattern for a given country, the best standard life table is selected through comparison of observed patterns to those exemplified by model life tables (Timaeus, 2013). However, in populations where little or no reliable information on mortality by age is available, as in the case of Kenya, demographers can only guess which pattern would be most appropriate.

Brass originally developed an African Standard life table, which he applied to data from the three Kenya censuses (1969, 1979 and 1989). KNBS has however sought to modify the shape of the mortality curve to take account of HIV/AIDS. Deaths from HIV/AIDS tend to be concentrated among younger adults, so that the epidemic introduces a “hump” into the mortality curve (Bore, 2009, p. 38). KNBS developed standard sets of AIDS-related mortality rates, peaking around age 40 for males and age 30 for females, and a third parameter (AIDS) provides a factor for increasing or decreasing these standard rates. They were then combined with the Brass African Standard by cross-multiplying the probabilities of survival. The modified standard was then fitted to the observed values of child and adult mortality: alpha was locked on to the under-5 mortality; beta and AIDS were determined by minimizing the sums of the squared differences between the observed values of adult survival and those of the models. This study however does not use the model life table adjusted for HIV/AIDS given that the pandemic began to be seriously felt (i.e. affect the mortality curve) in the early 90s. To standardize the results for the 1979-89 and 1989-99 inter-censal periods, the Brass original model life table was used in the study.

Data required to construct the life table includes:

- a. Conditional probabilities of adult survivorship i.e. l_x/l_y
- b. An estimate of child survivorship e.g. l_5

- c. A standard model life table e.g. General or African Standard

Procedure for generating the life table is as below:

- Obtain $Y_5 = 0.5 \ln[(1-q_5)/q_5]$ NB: taken as a compliment of p i.e. $q = 1-p$
- Obtain $Y_x^s = 0.5 \ln[l_x^s/(1-l_x^s)]$; where l_x^s is the African Standard
- Start with any value of b and obtain $a = Y_5 - bY_5^s$
- Obtain $Y_x = a + bY_x^s$
- Obtain l_x values since $l_0 = 1$ and $l_x = 1/[1 + e^{-2Y_x}]$; from $Y_x = 0.5 \ln[l_x/(1-l_x)]$ make l_x the subject
- Obtain the fitted adult probabilities of survival:

$$\text{Males: } l_x/l_{35}, \quad 45 < x < 75$$

$$\text{Females: } l_x/l_{25}, \quad 35 < x < 75$$

- Obtain the square s of the differences between the observed and fitted survivorship probabilities i.e. $(O-F)^2$
- Obtain the sum of squares i.e. $\text{SUM } (O-F)^2$
- Vary b until $\text{SUM } (O-F)^2$ is minimal
- Generate the remaining columns of the life table:

$${}_nq_x: \quad {}_1q_0 = 1-l_1, \text{ since } {}_1q_0 = 1- {}_1p_0 = 1-l_1/l_0$$

$${}_nq_x = 1-l_{x+n}/l_x$$

$${}_nL_x \quad L_0 = 0.25l_0 + 0.75l_1$$

$$L_1 = 1.9l_1 + 2.1l_5$$

$${}_5L_0 = 0.25l_0 + 2.65l_1 + 2.1l_5$$

$${}_nL_x = n/2[l_x + l_{x+n}]$$

$$T_x \quad T_x = T_{x+n} + {}_nL_x \quad \text{or} \quad T_x = \sum {}_nL_x$$

$$e_x: \quad e_x = T_x/l_x$$

$${}_nm_x: \quad {}_nm_x = {}_nd_x/{}_nL_x = [l_x - l_{x+n}]/{}_nL_x$$

CHAPTER 4

COMPLETENESS OF ENUMERATION AND MORTALITY ESTIMATES

This chapter presents the results of analysis. It begins by presenting trends in completeness of census enumeration and mortality estimates and later offers a discussion of the findings.

4.1 Results of estimation of mortality

Brass proposed the relational 2-parameter logit system in 1971 to estimate mortality (Dorrington, 2013). His model requires conditional probabilities of adult survivorship i.e. l_x/l_y ; an estimate of child survivorship e.g. l_5 and a standard model life table e.g. General or African Standard. The Brass Logit system rests on the assumption that two distinct age-patterns of mortality can be related to each other by a linear transformation of the logit of their respective survivorship probabilities. The basic data input needed for its construction are the age-specific death rates calculated from information on deaths by age and sex (from vital registration) and population by age and sex (from census). However, to generate a life table through indirect techniques requires the use of a model life table. The procedure used to generate the life tables is described in section 3.5 of chapter 3.

This study used the African Standard Model Life table given its application to contexts characterized by lower infant mortality and higher child mortality (UN, 1983). Findings are calculated using the procedures described in section 3.5 in Chapter 3 and summarized in Tables 4.1 to 4.4 below. Results show that the 1979-89 and 1989-99 inter-censal periods both had male child mortality higher than females in the same age group. Similarly, total male deaths for all age groups are higher than female deaths as expected in the normal mortality curve. This is similar to the trend reported in many national surveys and studies in Kenya and sub-Saharan Africa, which show greater mortality rates among male children (KNBS, 2002). Deaths decline significantly into adulthood compared to childhood but begin to increase gradually at 60+ years. Highest deaths for both sexes were recorded at ages 0-5 and at 60+ years.

Table 4.1: Estimation of 1979-89 male deaths using the African standard Model Life Table

Age	$l(x)$	$q(x)$	$L(x)$	$T(x)$	$e(x)$	$Y_s(x)$	$Y(x)$	$m(x)$	Male
0	1.0000	0.0709	0.9468	57.8791	57.88		0.5294	0.0749	25717
1-4	0.9291	0.0496	3.6196	56.9323	61.28	0.9639	1.2867	0.0127	16860
5-9	0.8830	0.0190	4.3731	53.3126	60.38	0.6125	1.0106	0.0038	5730
10-14	0.8662	0.0075	4.3150	48.9395	56.50	0.5151	0.9341	0.0015	1919
15-19	0.8598	0.0126	4.2716	44.6245	51.90	0.4802	0.9067	0.0025	2586
20-24	0.8489	0.0174	4.2075	40.3529	47.54	0.4246	0.8630	0.0035	2687
25-29	0.8341	0.0236	4.1214	36.1454	43.33	0.3541	0.8076	0.0048	3099
30-34	0.8144	0.0331	4.0048	32.0240	39.32	0.2675	0.7395	0.0067	3326
35-39	0.7875	0.0395	3.8598	28.0192	35.58	0.1598	0.6549	0.0081	3025
40-44	0.7564	0.0437	3.6993	24.1595	31.94	0.0473	0.5665	0.0089	2815
45-49	0.7233	0.0489	3.5282	20.4602	28.29	-0.0622	0.4805	0.0100	2507
50-54	0.6879	0.0571	3.3415	16.9320	24.61	-0.1707	0.3953	0.0118	2462
55-59	0.6487	0.0715	3.1274	13.5905	20.95	-0.2836	0.3066	0.0148	2370
60-64	0.6023	0.0971	2.8654	10.4631	17.37	-0.4096	0.2075	0.0204	2634
65-69	0.5438	0.1416	2.5267	7.5977	13.97	-0.5618	0.0879	0.0305	3256
70-74	0.4668	0.2154	2.0827	5.0710	10.86	-0.7583	-0.0665	0.0483	3606
75-79	0.3662	0.3322	1.5271	2.9884	8.16	-1.0227	-0.2742	0.0797	6149
80+	0.2446	0.4945	0.9206	1.4613	5.97	-1.3914	-0.5639	0.1314	10800

Table 4.2: Estimation of 1979-89 female deaths using the African standard Model Life Table

	$l(x)$	$q(x)$	$L(x)$	$T(x)$	$e(x)$	$Y_s(x)$	$Y(x)$	$m(x)$	Female
0	1.0000	0.0698	0.9476	61.7484	61.75		0.6448	0.0737	25195
1-4	0.9302	0.0410	3.6405	60.8008	65.37	0.9583	1.2946	0.0105	13765
5-9	0.8920	0.0149	4.4268	57.1603	64.08	0.6060	1.0557	0.0030	4461
10-14	0.8787	0.0058	4.3808	52.7335	60.01	0.5093	0.9901	0.0012	1461
15-19	0.8736	0.0104	4.3452	48.3528	55.35	0.4746	0.9666	0.0021	2188
20-24	0.8645	0.0200	4.2793	44.0075	50.91	0.4156	0.9266	0.0040	3432
25-29	0.8472	0.0270	4.1789	39.7283	46.89	0.3122	0.8565	0.0055	3800
30-34	0.8243	0.0298	4.0603	35.5494	43.12	0.1891	0.7730	0.0061	2991
35-39	0.7998	0.0310	3.9370	31.4891	39.37	0.0703	0.6924	0.0063	2463
40-44	0.7750	0.0318	3.8135	27.5521	35.55	-0.0389	0.6184	0.0065	2061
45-49	0.7504	0.0340	3.6881	23.7387	31.64	-0.1394	0.5503	0.0069	1781
50-54	0.7249	0.0389	3.5538	20.0505	27.66	-0.2366	0.4844	0.0079	1715
55-59	0.6966	0.0492	3.3975	16.4967	23.68	-0.3379	0.4157	0.0101	1594
60-64	0.6623	0.0685	3.1983	13.0992	19.78	-0.4541	0.3369	0.0142	1968
65-69	0.6170	0.1022	2.9272	9.9009	16.05	-0.5995	0.2383	0.0215	2156
70-74	0.5539	0.1595	2.5487	6.9737	12.59	-0.7914	0.1082	0.0347	2665
75-79	0.4656	0.2564	2.0294	4.4251	9.50	-1.0528	-0.0690	0.0588	4325
80+	0.3462	0.4063	1.3793	2.3957	6.92	-1.4199	-0.3179	0.1020	9593

Table 4.3: Estimation of 1989-99 male deaths using the African standard Model Life Table

Age	$l(x)$	$q(x)$	$L(x)$	$T(x)$	$e(x)$	$Ys(x)$	$Y(x)$	$m(x)$	Male
0	1.0000	0.0616	0.9538	51.3576	51.36		0.3721	0.0646	31083
1-4	0.9384	0.0612	3.6331	50.4038	53.71	0.9639	1.3618	0.0158	25601
5-9	0.8810	0.0257	4.3485	46.7707	53.09	0.6125	1.0010	0.0052	9734
10-14	0.8584	0.0104	4.2696	42.4222	49.42	0.5151	0.9010	0.0021	3704
15-19	0.8495	0.0179	4.2093	38.1526	44.91	0.4802	0.8652	0.0036	5162
20-24	0.8343	0.0252	4.1188	33.9434	40.69	0.4246	0.8081	0.0051	5656
25-29	0.8133	0.0351	3.9949	29.8246	36.67	0.3541	0.7356	0.0071	6703
30-34	0.7847	0.0506	3.8244	25.8296	32.92	0.2675	0.6467	0.0104	7388
35-39	0.7451	0.0621	3.6095	22.0052	29.54	0.1598	0.5362	0.0128	7415
40-44	0.6988	0.0706	3.3704	18.3957	26.33	0.0473	0.4207	0.0146	6474
45-49	0.6494	0.0804	3.1165	15.0253	23.14	-0.0622	0.3082	0.0168	5875
50-54	0.5972	0.0951	2.8439	11.9088	19.94	-0.1707	0.1968	0.0200	5797
55-59	0.5404	0.1195	2.5404	9.0650	16.78	-0.2836	0.0809	0.0254	5120
60-64	0.4758	0.1614	2.1869	6.5246	13.71	-0.4096	-0.0485	0.0351	6056
65-69	0.3990	0.2300	1.7656	4.3376	10.87	-0.5618	-0.2048	0.0520	6619
70-74	0.3072	0.3331	1.2803	2.5721	8.37	-0.7583	-0.4066	0.0799	8056
75-79	0.2049	0.4738	0.7818	1.2918	6.31	-1.0227	-0.6780	0.1242	9049
80+	0.1078	0.6363	0.3676	0.5101	4.73	-1.3914	-1.0566	0.1866	16565

Table 4.4: Estimation of 1989-99 female deaths using the African standard Model Life Table

Age	$l(x)$	$q(x)$	$L(x)$	$T(x)$	$e(x)$	$Ys(x)$	$Y(x)$	$m(x)$	Female
0	1.0000	0.0640	0.9520	54.7356	54.74		0.4953	0.0672	31660
1-4	0.9360	0.0523	3.6411	53.7836	57.46	0.9583	1.3412	0.0135	21459
5-9	0.8870	0.0206	4.3893	50.1425	56.53	0.6060	1.0302	0.0042	7677
10-14	0.8687	0.0082	4.3258	45.7532	52.67	0.5093	0.9449	0.0017	2879
15-19	0.8616	0.0150	4.2757	41.4274	48.08	0.4746	0.9143	0.0030	4408
20-24	0.8487	0.0294	4.1810	37.1517	43.78	0.4156	0.8622	0.0060	7518
25-29	0.8237	0.0410	4.0341	32.9707	40.03	0.3122	0.7709	0.0084	8426
30-34	0.7899	0.0468	3.8573	28.9366	36.63	0.1891	0.6622	0.0096	6803
35-39	0.7530	0.0499	3.6711	25.0793	33.31	0.0703	0.5573	0.0102	6045
40-44	0.7154	0.0523	3.4836	21.4082	29.92	-0.0389	0.4610	0.0108	4737
45-49	0.6780	0.0568	3.2936	17.9247	26.44	-0.1394	0.3723	0.0117	4168
50-54	0.6395	0.0660	3.0918	14.6311	22.88	-0.2366	0.2865	0.0136	3962
55-59	0.5973	0.0840	2.8609	11.5393	19.32	-0.3379	0.1970	0.0175	3662
60-64	0.5471	0.1170	2.5754	8.6784	15.86	-0.4541	0.0944	0.0249	4754
65-69	0.4831	0.1725	2.2071	6.1030	12.63	-0.5995	-0.0339	0.0378	5235
70-74	0.3998	0.2604	1.7386	3.8960	9.75	-0.7914	-0.2032	0.0599	6787
75-79	0.2957	0.3911	1.1893	2.1574	7.30	-1.0528	-0.4340	0.0972	6908
80+	0.1800	0.5582	0.6489	0.9681	5.38	-1.4199	-0.7580	0.1549	16656
95	0.0028	1.0000	0.0070	0.0070	2.50	-3.8869	-2.9357	0.4000	

4.2 Estimation of completeness of census enumeration and mortality for Kenya 1979-89 inter-censal period

Hill's method was applied to estimate completeness of census enumeration and mortality estimates for the 1979-1989 inter-censal period. Appendices 1, 2 and 3 show the results of applying the general growth balance method to data for various sexes for the inter-censal period with the procedures described in section 3.3.3 of Chapter 3. It should be noted that the estimates of death used in this study are those obtained for hypothetical cohorts of life tables hence do not represent recorded deaths from civil registration systems. The calculations follow the formulas discussed in section 3.3.1 and 3.3.2 of the same Chapter. Application of the GGB method to the Kenya 1979-89 inter-censal population involves calculation of plotting points x and y , fitting a straight line of these points and calculation of the slope k . This slope, k , of the line relating the entry rate (birth rate at age x) and the exit rate (death rate at age x) estimates the completeness of population recording relative to death recording and provides an adjustment factor, c , for the deaths.

4.2.1 Completeness of male enumeration and mortality 1979-89

The last two columns of appendix 1 display the results of calculation of the x and y points which are used to estimate values of K and C . Figure 4.1 shows the scatter plot and the fitted line of the (x,y) points $d(x+)$ and $n(x)-r(x+)$. The observed data points fall closely along the fitted line, hence it's straight forward to draw the line. The results indicate a value of 93.12% as completeness (K_2) of male enumeration in the 1989 census in comparison to the 1979 census. This implies that male enumeration in the 1989 census was 6.9% less complete than that of 1979. Further results in Table 4.5 (last column) indicate that the undercount was mostly concentrated around ages 5-9 and 15-19. This is probably due to age heaping in digits ending in 0, 5 and 9. Completeness of death estimates (C) on the other hand was 21% meaning that deaths were under-estimated by 79 per cent in 1989 compared to 1979.

4.2.2 Completeness of female enumeration and mortality 1979-89

The results of applying the GGB method to female data for 1979-89 inter censal period are shown in Appendix 2 while Figure 4.2 shows the scatter plot and the fitted line of the (x,y) points $d(x+)$ and $n(x)-r(x+)$. The estimate of completeness of enumeration (K_2) was 91.15%. This

implies that female enumeration in the 1989 census was 8.85% less complete compared to that of 1979. Deviations from the line of best fit (last column of Table 4.6) are concentrated among ages 5-15 indicating larger undercounts in these ages perhaps due to age mis-reporting. Female death estimates on the other hand were 75.1% less complete in 1989 compared to 1979.

4.2.3 Completeness of enumeration and mortality of combined sexes 1979-89

Detailed results are shown in Appendix 3. Figure 4.3 further displays the fitted line with values of $d(x+)$ and $n(x)-r(x+)$. Results indicate that total enumeration for both sexes was 91.88% complete (K_2) in 1989. This means that total census enumeration (both sexes) in 1989 was 8.12% less complete compared to the 1979 enumeration. Table 4.7 (last column) and Figure 4.3 indicate that undercounts were concentrated around ages 5-9 and 50-54 possibly due to age misreporting and age heaping. Estimates of death for both sexes in 1989 are 77.3% less complete compared to those of 1979.

In summary, for all the sexes in the 1979-89 inter-censal period, completeness of enumeration varies across ages and across sexes. However, a common observation in this period is the possible higher age heaping and misreporting at age group 5-9 and at the beginning of old age (50-54) but particularly for males. Further possible explanations are discussed in section 5.9 of Chapter 5. Incompleteness of death estimates is quite high, mainly because life table estimates of death are simply a hypothetical cohort but which are the closest estimate of deaths by age. It is based on available data and given that mortality data is quite scanty in Kenya, such mortality estimates have shown large incompleteness. Further, such estimates do not represent actual figures from civil registration records, but can be used to depict a general picture of mortality in Kenya.

Table 4.5: Kenya males 1979-89; fitting a straight line to the data points

Age	x-point	y-point	Intercepts $y-bx$	Slopes	y-fitted $a+bx$	Residuals $y-(a+bx)$	Percent Dev
5	0.00080	0.00841	0.00471	1.592	0.01084	-0.00242	-28.8
10	0.00091	0.01201	0.00782	5.361	0.01132	0.00069	5.7
15	0.00112	0.01397	0.00883	6.125	0.01227	0.00170	12.2
20	0.00136	0.01347	0.00722	4.674	0.01338	0.00009	0.7
25	0.00162	0.01430	0.00683	4.416	0.01460	-0.00030	-2.1
30	0.00195	0.01602	0.00704	4.559	0.01611	-0.00009	-0.5
35	0.00231	0.01747	0.00684	4.477	0.01776	-0.00029	-1.7
40	0.00271	0.01924	0.00674	4.462	0.01962	-0.00039	-2.0
45	0.00325	0.02452	0.00954	5.345	0.02211	0.00241	9.8
50	0.00396	0.02899	0.01076	5.522	0.02535	0.00363	12.5
55	0.00495	0.03253	0.00975	5.134	0.02991	0.00262	8.1
60	0.00624	0.03704	0.00830	4.791	0.03587	0.00117	3.2
65	0.00804	0.04385	0.00684	4.568	0.04413	-0.00029	-0.7
70	0.01088	0.05526	0.00519	4.426	0.05720	-0.00194	-3.5
		Median	0.00713	4.621			
		0.5*IQR	0.00093	0.413			
		Percent	13.0	8.9			

The last column in Table 4.5 above indicates percent deviations from the line of best fit, depicting undercounts (largest deviations) concentrated at age groups 5-9, 15-19 and 50-54. Age misreporting and heaping may have been higher in these ages. Figure 4.1 illustrates the same.

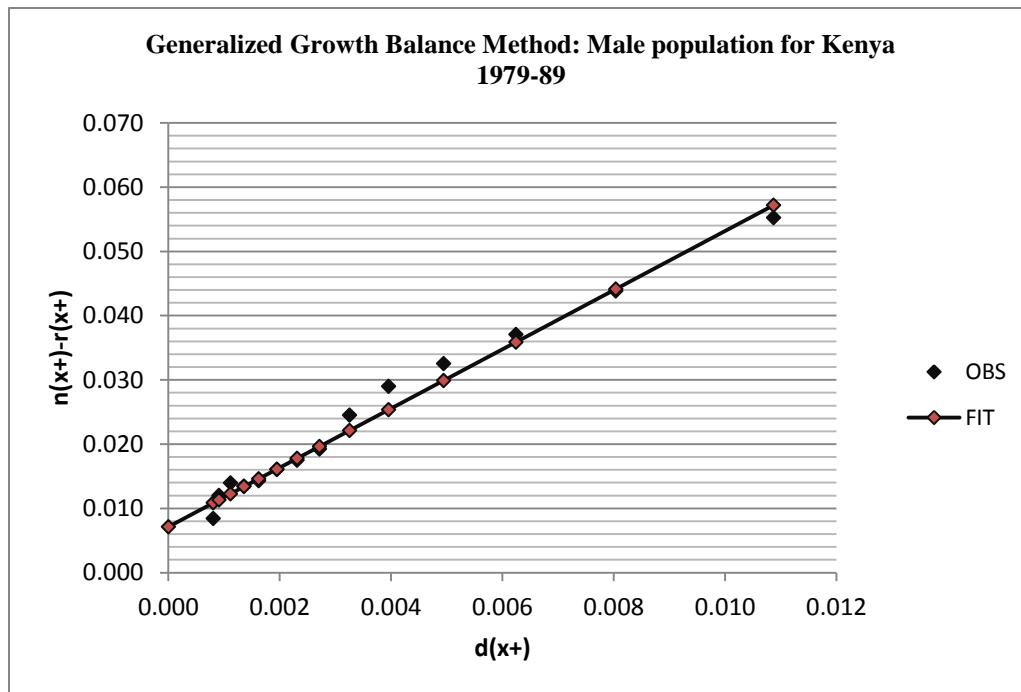


Figure 4.1: Male population for Kenya 1979-89: Data points and fitted line

Table 4.6: Kenya females 1979-89; fitting a straight line to the data points

Age	x-point	y-point	Intercepts $y-bx$	Slopes	y-fitted $a+bx$	Residuals $y-(a+bx)$	Percent Dev
5	0.00065	0.00669	0.00420	-3.974	0.01176	-0.00507	-75.9
10	0.00073	0.00945	0.00664	0.245	0.01208	-0.00263	-27.9
15	0.00089	0.01104	0.00762	1.983	0.01269	-0.00165	-14.9
20	0.00108	0.01388	0.00974	4.268	0.01341	0.00047	3.4
25	0.00127	0.01631	0.01144	5.540	0.01414	0.00217	13.3
30	0.00149	0.01668	0.01099	4.985	0.01496	0.00172	10.3
35	0.00173	0.01652	0.00990	4.198	0.01589	0.00063	3.8
40	0.00204	0.01765	0.00985	4.117	0.01707	0.00058	3.3
45	0.00245	0.01998	0.01059	4.371	0.01866	0.00132	6.6
50	0.00301	0.02223	0.01069	4.302	0.02081	0.00142	6.4
55	0.00383	0.02347	0.00880	3.707	0.02394	-0.00047	-2.0
60	0.00486	0.02625	0.00763	3.493	0.02790	-0.00164	-6.3
65	0.00645	0.03307	0.00834	3.686	0.03400	-0.00093	-2.8
70	0.00866	0.04055	0.00736	3.611	0.04245	-0.00191	-4.7
		Median	0.00927	3.912			
		0.5*IQR	0.00140	0.385			
		Percent	15.1	9.8			

The last column in Table 4.6 above indicates percent deviations from the line of best fit with undercounts (largest deviations) concentrated at age groups 5-9, 10-14, 15-19 and 25-34. Age misreporting and heaping may have been higher in children and young adults. This is also shown in Figure 4.2.

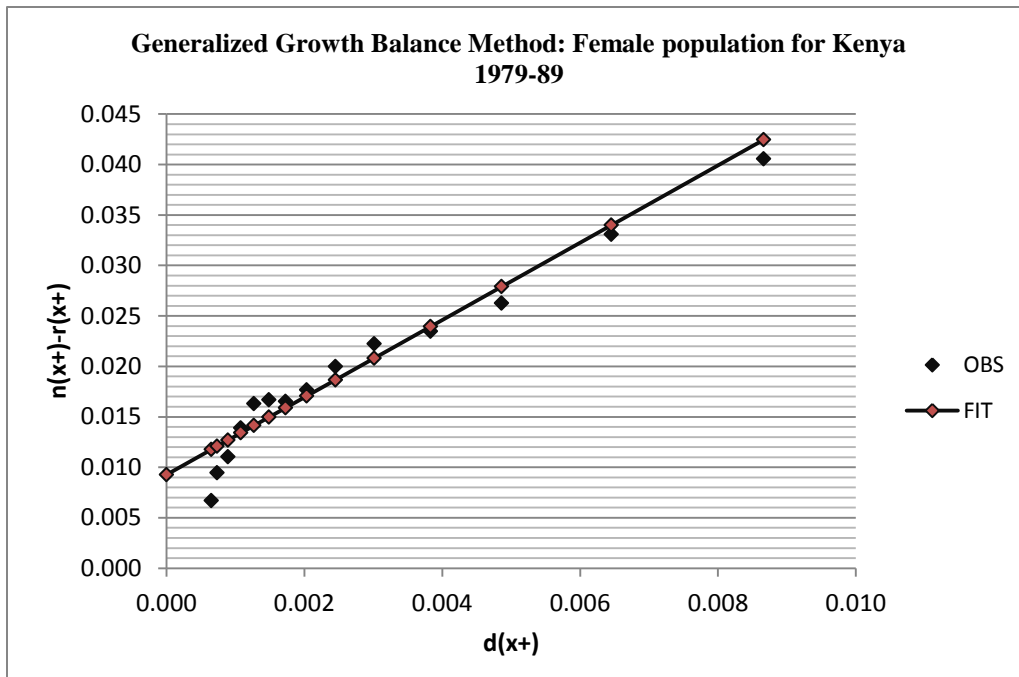


Figure 4.2: Female population for Kenya 1979-89: Data points and fitted line

Table 4.7: Kenya both sexes 1979-89; fitting a straight line to the data points

Age	x-point	y-point	Intercepts $y-bx$	Slopes	y-fitted $a+bx$	Residuals $y-(a+bx)$	Percent Dev
5	0.00073	0.00754	0.00448	-1.280	0.01153	-0.00399	-53.0
10	0.00082	0.01071	0.00725	2.730	0.01193	-0.00122	-11.4
15	0.00100	0.01248	0.00825	3.998	0.01270	-0.00022	-1.8
20	0.00122	0.01369	0.00857	4.298	0.01360	0.00010	0.7
25	0.00144	0.01532	0.00923	4.741	0.01456	0.00076	4.9
30	0.00172	0.01636	0.00912	4.597	0.01571	0.00065	4.0
35	0.00202	0.01699	0.00849	4.229	0.01697	0.00002	0.1
40	0.00237	0.01846	0.00846	4.212	0.01848	-0.00001	-0.1
45	0.00285	0.02223	0.01022	4.831	0.02049	0.00175	7.9
50	0.00348	0.02559	0.01090	4.916	0.02316	0.00243	9.5
55	0.00439	0.02799	0.00949	4.450	0.02697	0.00102	3.6
60	0.00555	0.03167	0.00827	4.182	0.03187	-0.00020	-0.6
65	0.00725	0.03849	0.00791	4.140	0.03905	-0.00056	-1.5
70	0.00976	0.04807	0.00691	4.058	0.04963	-0.00156	-3.3
		Median	0.00847	4.220			
		0.5*IQR	0.00060	0.241			
		Percent	7.1	5.7			

Table 4.7 (last column) above shows the percent deviations from the line of best fit and indicates that undercounts (largest deviations) are concentrated at age groups 5-9, 10-14, 45-49 and 50-54. Age misreporting and heaping may have been higher in non-child-bearing ages. This is also shown in Figure 4.3.

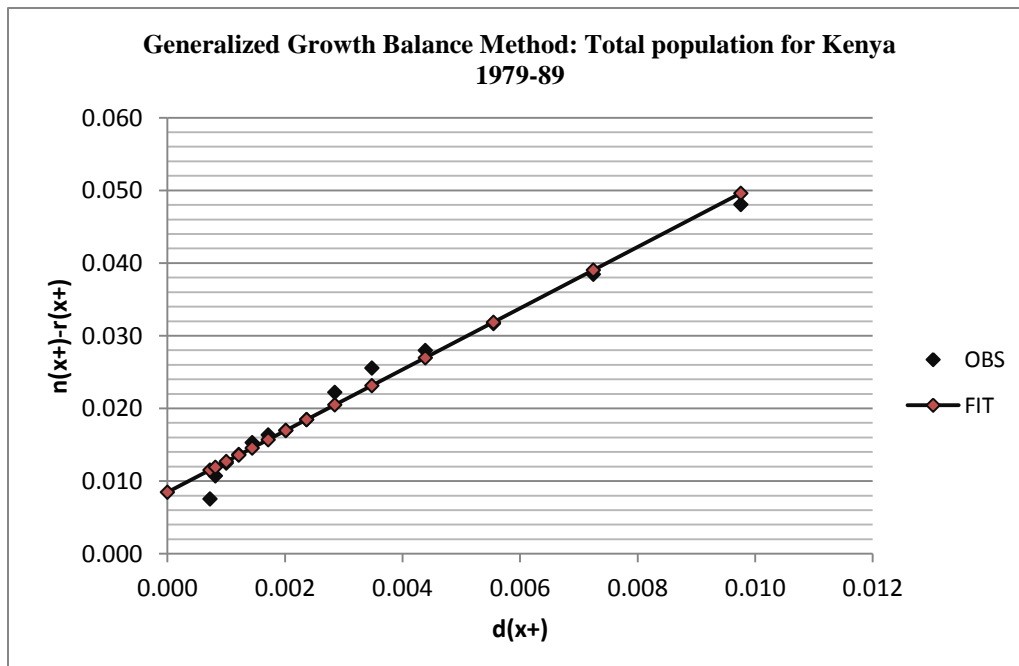


Figure 4.3: Total population for Kenya 1979-89: Data points and fitted line

4.3 Estimation of completeness of census enumeration and mortality for Kenya 1989-99 inter-censal period

Similar to the 1979-89 period, Hill's method was applied to estimate completeness of census enumeration and mortality estimates for the 1989-1999 inter-censal period. Appendices 4, 5 and 6 show the results of applying the general growth balance method to data for various sexes for this period using the procedures described in section 3.3.3 of Chapter 3. The calculations follow the formulas developed in section 3.3.1 and 3.3.2 of the same Chapter. Estimates of death used in this study are those obtained for hypothetical cohorts of life tables hence do not represent recorded deaths from civil registration systems. Similar to the application to 1979-89 inter-censal period, the GGB method application to the Kenya 1989-99 inter-censal population involves calculation of plotting points x and y , fitting a straight line of these points and calculation of the slope k . This slope, k , of the line relating the entry rate (birth rate at age x) and the exit rate (death rate at age x) estimates the completeness of population recording relative to death recording and provides an adjustment factor, c , for the deaths.

4.3.1 Completeness of male enumeration and mortality 1989-99

The last two columns of appendix 4 display the results of calculation of the x and y points which are used to estimate values of K and C . Figure 4.4 shows the scatter plot and the fitted line of the (x,y) points $d(x+)$ and $n(x)-r(x+)$. The results indicate a value of 94.3% as completeness (K_2) of male enumeration in the 1999 census in comparison to the 1989 census. This implies that male enumeration in the 1999 census was 5.7% less complete than that of 1989. Further results in Table 4.8 (last column) indicate that the undercount was mostly concentrated around ages 5-9 and 25-29. Age misreporting was high among young adults. Completeness of death estimates (C) on the other hand was 21.9% meaning that deaths were under-estimated by 78.1 per cent in 1999 compared to 1989.

4.3.2 Completeness of female enumeration and mortality 1989-99

The results of applying the GGB method to female data for 1989-99 inter censal period are shown in appendix 5 while Figure 4.5 shows the scatter plot and the fitted line of the (x,y) points $d(x+)$ and $n(x)-r(x+)$. The estimate of completeness of enumeration (K_2) was 94.8%. This implies that female enumeration in the 1999 census was 5.2% less complete compared to that of 1989.

Deviations from the line of best fit (last column of Table 4.9) are concentrated among ages 5-14 and 25-34 indicating larger undercounts in these ages perhaps due to age mis-reporting. Female death estimates on the other hand were 78.7% less complete in 1999 compared to 1989.

4.3.3 Completeness enumeration and mortality of combined sexes 1989-99

Detailed results are shown in appendix 6. Figure 4.6 further displays the fitted line with values of $d(x+)$ and $n(x)-r(x+)$. Results indicate that total enumeration for both sexes was 94.47% complete (K_2) in 1999 compared to 1989. This means that total census enumeration (both sexes) in 1999 was 5.53% less complete compared to the 1989 enumeration. Table 4.10 (last column) and Figure 4.6 indicate that undercounts were concentrated around ages 5-9 and 10-14 possibly due to age misreporting and age heaping. Estimates of death for both sexes in 1999 were 78.4% less complete compared to those of 1989.

In summary, for all the sexes in the 1989-99 inter-censal period, completeness of enumeration varies across ages and across sexes. However, a common observation in this period is that ages 5-9 and 25-34 for both males and females have shown a deviation from the line of best fit, indicating possible higher age misreporting and heaping amongst these age groups. Further possible explanations are discussed in section 6.2 of Chapter 6. In addition, incompleteness of death estimates is quite high, mainly because life table estimates of death are simply a hypothetical cohort but which are the closest estimate of deaths by age. It is based on available data and given that mortality data is quite scanty in Kenya, such mortality estimates have shown large values of incompleteness, but can still be used to depict a general picture of mortality in Kenya.

Table 4.8: Kenya males 1989-99; fitting a straight line to the data points

Age	x-point	y-point	Intercepts y-bx	Slopes	y-fitted a+bx	Residuals y-(a+bx)	Percent Dev
5	0.00114	0.00792	0.00287	1.802	0.01092	-0.00300	-37.9
10	0.00128	0.01109	0.00542	4.085	0.01155	-0.00045	-4.1
15	0.00157	0.01322	0.00627	4.698	0.01282	0.00040	3.1
20	0.00190	0.01344	0.00502	3.994	0.01429	-0.00085	-6.3
25	0.00227	0.01486	0.00479	3.963	0.01594	-0.00108	-7.3
30	0.00273	0.01804	0.00591	4.456	0.01799	0.00004	0.2
35	0.00322	0.01952	0.00521	4.235	0.02017	-0.00066	-3.4
40	0.00382	0.02207	0.00513	4.245	0.02281	-0.00074	-3.4
45	0.00455	0.02603	0.00584	4.433	0.02606	-0.00003	-0.1
50	0.00548	0.03223	0.00788	4.807	0.03022	0.00201	6.2
55	0.00679	0.03720	0.00708	4.618	0.03600	0.00121	3.2
60	0.00830	0.04310	0.00624	4.485	0.04273	0.00037	0.9
65	0.01040	0.05236	0.00616	4.468	0.05207	0.00029	0.6
70	0.01292	0.06559	0.00823	4.623	0.06323	0.00236	3.6
		Median	0.00587	4.444			
		0.5*IQR	0.00056	0.231			
		Percent	9.5	5.2			

The last column in Table 4.8 above indicates percent deviations from the line of best fit, depicting undercounts (largest deviations) concentrated at age groups 5-9 and 20-29. Age misreporting and heaping may have been higher in these ages. Figure 4.4 illustrates the same.

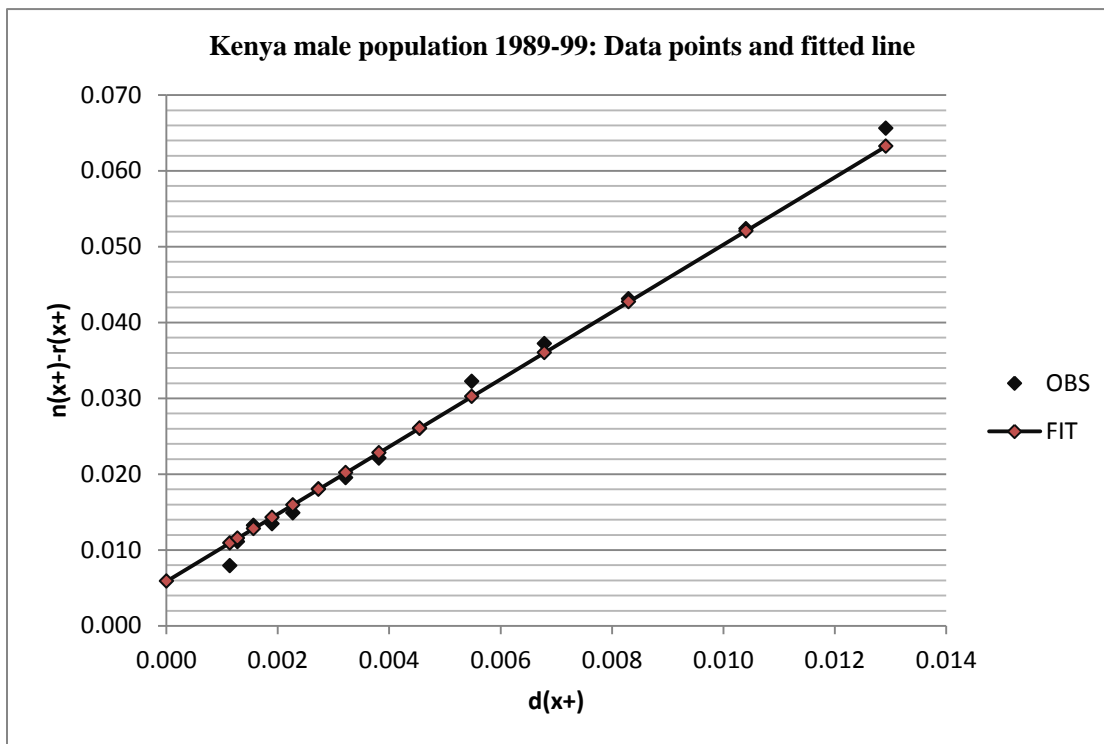


Figure 4.4: Male population for Kenya 1989-99: Data points and fitted line

Table 4.9: Kenya females 1989-99; fitting a straight line to the data points

Age	x-point	y-point	Intercepts y-bx	Slopes	y-fitted a+bx	Residuals y-(a+bx)	Percent Dev
5	0.00097	0.00592	0.00150	0.595	0.00975	-0.00384	-64.9
10	0.00109	0.00842	0.00346	2.838	0.01030	-0.00188	-22.3
15	0.00132	0.01051	0.00450	3.926	0.01136	-0.00084	-8.0
20	0.00159	0.01351	0.00626	5.144	0.01259	0.00092	6.8
25	0.00188	0.01693	0.00836	6.173	0.01391	0.00302	17.8
30	0.00220	0.01710	0.00705	5.341	0.01539	0.00171	10.0
35	0.00255	0.01658	0.00495	4.412	0.01697	-0.00039	-2.4
40	0.00300	0.01888	0.00517	4.508	0.01905	-0.00017	-0.9
45	0.00357	0.02182	0.00551	4.613	0.02165	0.00017	0.8
50	0.00433	0.02657	0.00682	4.906	0.02510	0.00148	5.6
55	0.00535	0.02909	0.00465	4.437	0.02977	-0.00069	-2.4
60	0.00656	0.03443	0.00450	4.437	0.03527	-0.00084	-2.4
65	0.00837	0.04524	0.00704	4.768	0.04354	0.00170	3.7
70	0.01053	0.05529	0.00723	4.745	0.05340	0.00189	3.4
		Median	0.00534	4.561			
		0.5*IQR	0.00122	0.227			
		Percent	22.8	5.0			

The last column in Table 4.9 above indicates percent deviations from the line of best fit with undercounts (largest deviations) concentrated at age groups 5-9, 10-14, 25-29 and 30-34. Age misreporting and heaping may have been higher in children and young adults, a trend similar to that of females in 1979-89 inter-censal period. This is also shown in Figure 4.5 below.

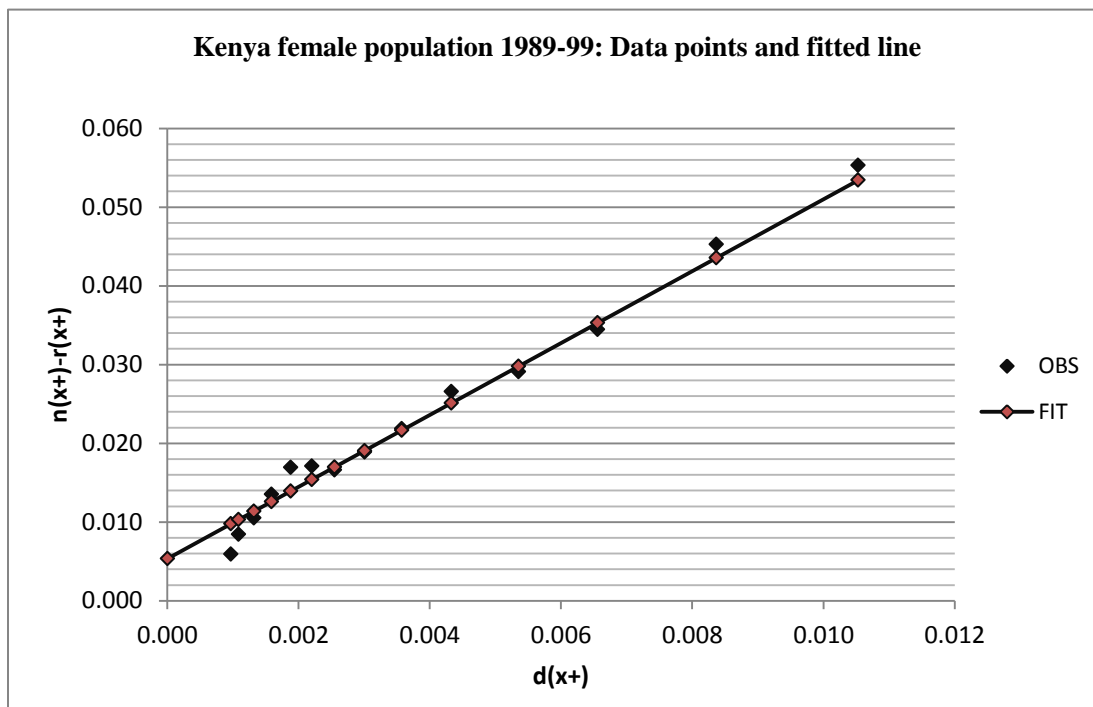


Figure 4.5: Female population for Kenya 1989-99: Data points and fitted line

Table 4.10: Kenya both sexes 1989-99; fitting a straight line to the data points

Age	x-point	y-point	Intercepts y-bx	Slopes	y-itted a+bx	Residuals y-(a+bx)	Percent Dev
5	0.00105	0.00691	0.00218	1.156	0.01041	-0.00351	-50.8
10	0.00118	0.00973	0.00443	3.426	0.01099	-0.00126	-12.9
15	0.00144	0.01184	0.00538	4.274	0.01215	-0.00031	-2.6
20	0.00174	0.01349	0.00569	4.490	0.01349	0.00000	0.0
25	0.00207	0.01592	0.00663	4.943	0.01499	0.00094	5.9
30	0.00246	0.01757	0.00651	4.824	0.01675	0.00082	4.7
35	0.00288	0.01803	0.00510	4.285	0.01862	-0.00059	-3.3
40	0.00340	0.02045	0.00517	4.337	0.02097	-0.00052	-2.6
45	0.00405	0.02387	0.00569	4.492	0.02387	0.00000	0.0
50	0.00489	0.02932	0.00737	4.834	0.02764	0.00168	5.7
55	0.00604	0.03298	0.00586	4.519	0.03281	0.00017	0.5
60	0.00739	0.03856	0.00539	4.451	0.03886	-0.00030	-0.8
65	0.00934	0.04862	0.00669	4.598	0.04762	0.00100	2.1
70	0.01166	0.06020	0.00783	4.675	0.05806	0.00214	3.6
		Median	0.00569	4.491			
		0.5*IQ Range	0.00069	0.179			
		Percent	12.1	4.0			

Table 4.10 (last column) above shows the percent deviations from the line of best fit and indicates that undercounts (largest deviations) are concentrated at age groups 5-9 and 10-14. Age misreporting and heaping may have been higher among children. This is also shown in Figure 4.6 below.

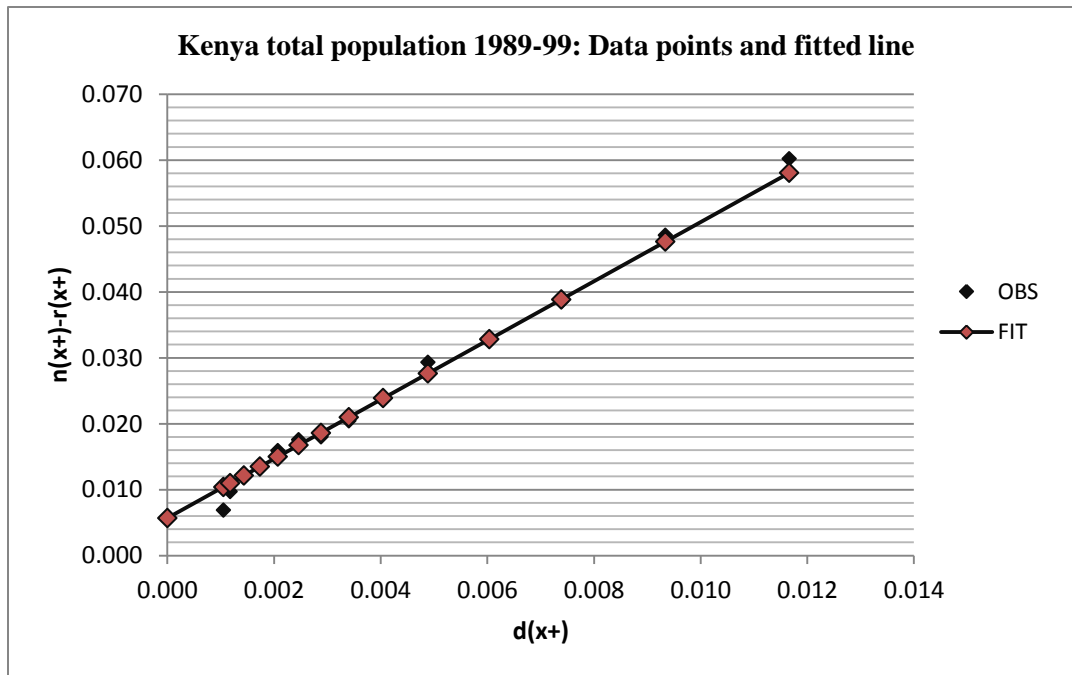


Figure 4.6: Total population for Kenya 1989-99: Data points and fitted line

4.4 Trends in completeness of census enumeration and mortality

The results indicate a decline in the completeness of censuses over 3 inter-censal periods for all the sexes. Completeness of census for the 1969-79 inter-censal period using Hill's technique was 97.11% and 98.79% for females and males respectively (Magadi, 1990). Females had a less complete enumeration than males, indicating more errors (possibly higher age heaping and misreporting) in female data than in males. This conforms to other trends observed in previous studies which have shown that women may be more likely to have their information reported by a proxy, hence increasing errors (Fajardo-Gonzalez.et.al, 2014). On the other hand completeness of death estimates was higher for males than females at 26.18% and 18.25% respectively. In the 1979-89 period, census completeness was 93.12% and 91.15% for males and females respectively, indicating a significant decline from the 1969-79 period. Completeness of death estimates was 21% and 24.9% for males and females individually. This was a decline for males and an increase for female completeness of death estimates. In the 1989-99 period, completeness of census was almost at par for both sexes with males at 94.3% and females at 94.8%. Compared to 1979-89 period, completeness improved significantly, indicating fewer errors in final counts. Death estimates in the same period were 21.9% and 21.3% complete for males and females respectively; showing a slight improvement for males but a decline in completeness of female death estimates. Overall trends show a decline in completeness of census enumeration over three consecutive inter-censal periods (Table 4.11 and Figure 4.7). Death estimates for males declined slightly while the same improved slightly for females (Figure 4.8).

Table 4.11: Trends of completeness of enumeration and mortality using Hill's technique

Sex	Completeness of census enumeration (%)			Completeness of death estimates (%)		
	1969-79	1979-89	1989-99	1969-79	1979-89	1989-99
Males	98.79	93.12	94.3	26.18	21	21.9
Females	97.11	91.15	94.8	18.25	24.9	21.3
Both sexes	97.95	91.88	94.47	22.22	22.70	21.6

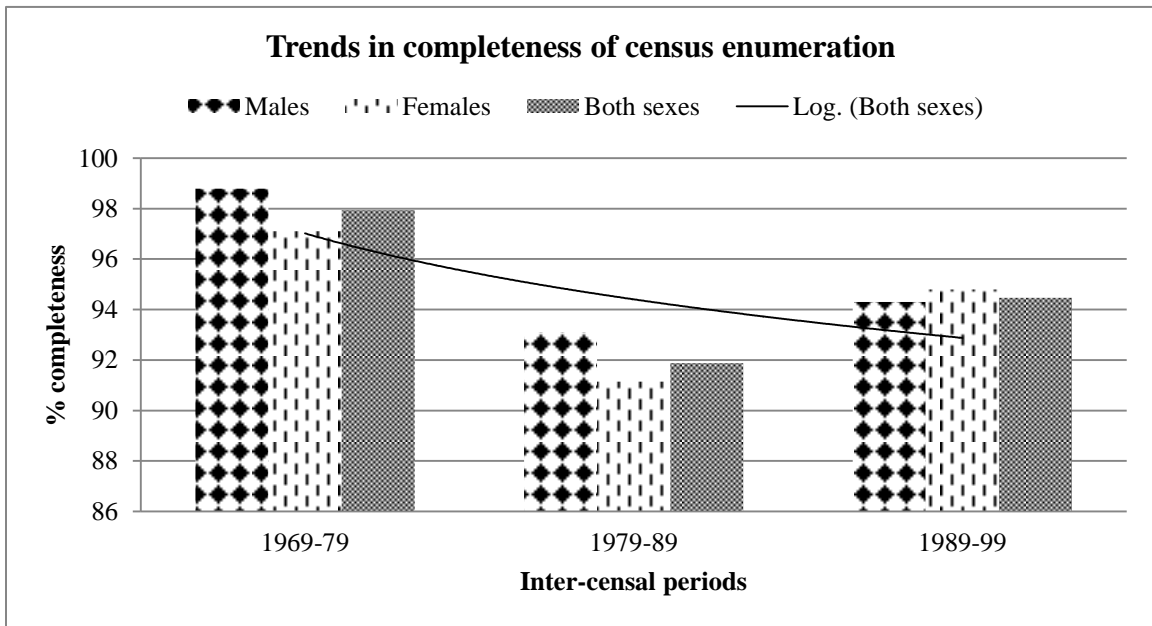


Figure 4.7: Showing trends in completeness of census enumeration

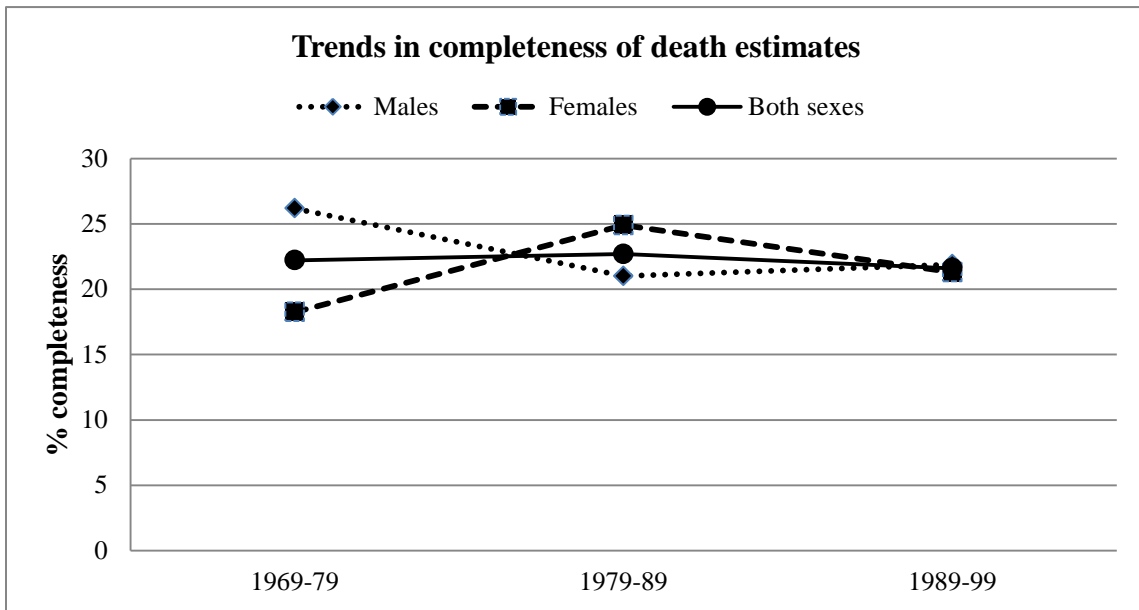


Figure 4.8: Showing trends in completeness of death estimates

A comparison of the trend in completeness using Hill's technique with results of other indices including UN age-sex ratio and Myers' index shows similar trends in data accuracy for both sexes as shown in Figure 4.9 below. Using the UN Sex-Age Accuracy Ratio showed inaccurate data for both males and females. This comparison serves the purpose of checking and validating the results obtained in this study and trends have shown a high level of similarity.

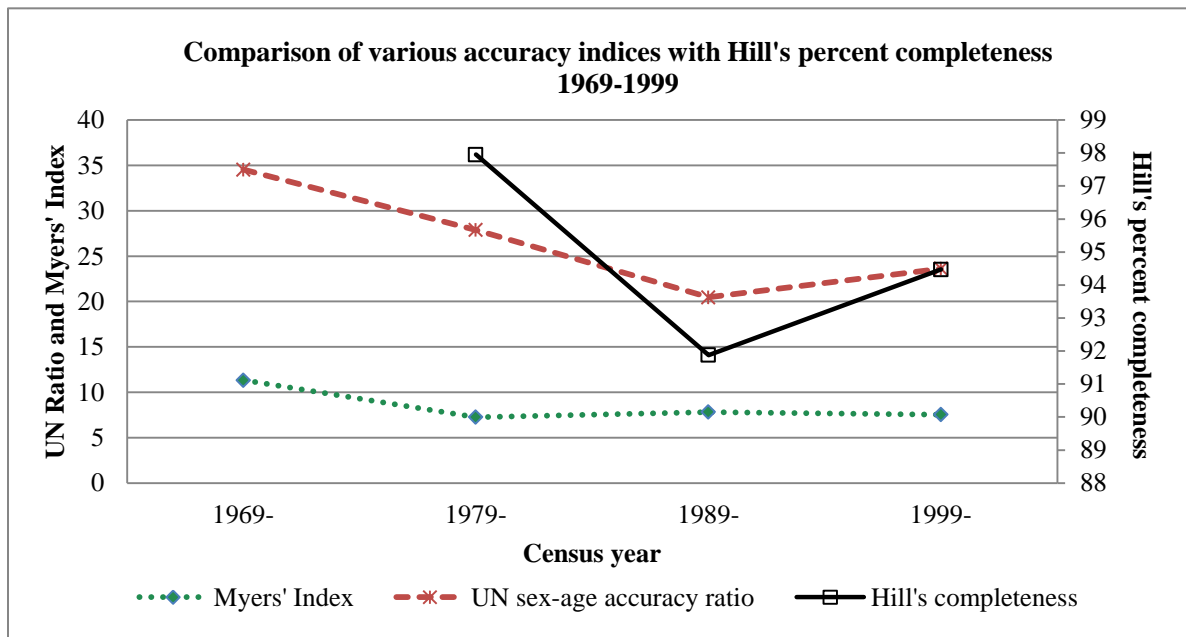


Figure 4.9: Comparing Hill's completeness and other accuracy indices

CHAPTER 5

ADJUSTING AGE-SEX DISTRIBUTION AND MORTALITY

5.1 Introduction

This Chapter discusses the process of adjusting the age-sex distribution and mortality based on the adjustment factors calculated in Chapter 4. The adjusted distributions and mortality rates by sex are shown in successive sub-sections. Overall findings are also discussed in sub-section 5.9.

The calculation of adjusted intercensal death rates involves adjusting for the completeness of the census count and for the completeness of death registration. We divide the number of persons in each age group at the second census by K_2 to adjust for the estimated lesser completeness of enumeration in the latter census. Estimated registered deaths for the intercensal period are also divided by 'C' to adjust for incomplete death registration. Death rates are then calculated in the usual way from the adjusted numbers of deaths and person years lived computed from the two-census age distributions. A life-table can then be calculated from the adjusted death rates.

5.2 Adjusted male population and mortality 1979-89

The results indicate a slightly higher total male population of 11,397,796 after an adjustment using a factor of 0.9312 or 93.12% as indicated in row 2 of Table 5.1. This means that the males were under-enumerated in 1989 and after the adjustment, the population increases by 6.9%. This also means that the male exponential population growth rate in 1989 increases to 3.95% compared to the recorded 3.24% before adjustment. Death rates on the other hand are also adjusted by a factor of 0.21, resulting in higher adjusted age specific death rates as seen in column 7 of the same table. The adjusted life table using the adjusted ASDRs is shown in Table 5.2. It shows that life expectancy at birth increases from 57.88 years as initially estimated to 67.6 years after adjusting for incomplete estimates of death.

Table 5.1: Calculation of adjusted male inter-censal death rates 1979-89

Age Group	Census Population 1979	Census Population 1989	Inter-censal Deaths	Base Population 1979	Adjusted Population 1989	Adjusted inter-censal Deaths	Adjusted Inter-censal Person Years Lived	Adjusted inter-censal Death Rate
Adjustment factors					0.9312	0.210		
0-4	1,422,024	1,911,216	42,578	1,422,024	2,052,423	202,750	17,083,895	0.011868
5- 9	1,247,091	1,743,646	5,730	1,247,091	1,872,472	27,285	15,281,175	0.001786
10-14	1,050,932	1,504,044	1,919	1,050,932	1,615,168	9,140	13,028,552	0.000702
15-19	854,123	1,177,984	2,586	854,123	1,265,017	12,313	10,394,615	0.001185
20-24	641,401	889,594	2,687	641,401	955,320	12,797	7,827,792	0.001635
25-29	514,451	782,474	3,099	514,451	840,286	14,759	6,574,846	0.002245
30-34	405,385	583,773	3,326	405,385	626,904	15,836	5,041,205	0.003141
35-39	290,227	460,950	3,025	290,227	495,006	14,403	3,790,305	0.003800
40-44	261,480	367,934	2,815	261,480	395,118	13,405	3,214,272	0.004170
45-49	218,914	281,127	2,507	218,914	301,898	11,937	2,570,792	0.004643
50-54	182,908	235,906	2,462	182,908	253,335	11,725	2,152,603	0.005447
55-59	140,777	179,017	2,370	140,777	192,243	11,284	1,645,096	0.006859
60-64	107,710	150,496	2,634	107,710	161,615	12,543	1,319,377	0.009507
65-69	99,906	113,690	3,256	99,906	122,090	15,504	1,104,424	0.014038
70-74	66,369	82,966	3,606	66,369	89,096	17,170	768,974	0.022328
75+	87,766	148,810	16,949	87,766	159,805	80,712	1,184,291	0.068152
Total	7,591,464	10,613,627	101,548	7,591,464	11,397,796	483,563	92,982,212	

Table 5.2: Life table based on adjusted death rates for males 1979-89

Age Group	Adjusted Death Rate	${}_5q_x$	l_x/l_5	${}_5L_x/l_5$	T_x/l_5	e_x
0-4	0.011868	NA	NA	NA	NA	NA
5- 9	0.001786	0.008970	1.000000	4.9776	67.6433	67.6
10-14	0.000702	0.003516	0.991030	4.9464	62.6657	63.2
15-19	0.001185	0.005943	0.987545	4.9231	57.7193	58.4
20-24	0.001635	0.008209	0.981677	4.8882	52.7962	53.8
25-29	0.002245	0.011288	0.973619	4.8406	47.9080	49.2
30-34	0.003141	0.015829	0.962628	4.7750	43.0674	44.7
35-39	0.003800	0.019182	0.947390	4.6915	38.2923	40.4
40-44	0.004170	0.021070	0.929217	4.5971	33.6008	36.2
45-49	0.004643	0.023488	0.909639	4.4948	29.0037	31.9
50-54	0.005447	0.027611	0.888274	4.3801	24.5089	27.6
55-59	0.006859	0.034893	0.863748	4.2434	20.1288	23.3
60-64	0.009507	0.048692	0.833609	4.0666	15.8854	19.1
65-69	0.014038	0.072743	0.793018	3.8209	11.8189	14.9
70-74	0.022328	0.118240	0.735332	3.4593	7.9980	10.9
75+	0.068152	1.000000	0.648386	NA	4.5387	7.00

5.3 Adjusted female population and mortality 1979-89

The adjusted female population for 1989 becomes 11,854,041 following an adjustment using a factor of 0.9115 as indicated in row 2 of Table 5.3. This means that the female population was under-enumerated in 1989 by 8.85%. After the adjustment, the population increases by this same factor implying that the female exponential population growth rate in 1989 increases to 4.44% compared to the recorded 3.51% before adjustment. Death rates on the other hand are also adjusted by a factor of 0.249, resulting in higher adjusted age specific death rates as seen in column 7 of the same table. The adjusted life table using the adjusted ASDRs is shown in Table 5.4. It shows that life expectancy at birth increases from 61.75 years as initially estimated to 70.7 years after adjusting for incomplete estimates of death.

Table 5.3: Calculation of adjusted female inter-censal death rates 1979-89

Age Group	Census Population 1979	Census Population 1989	Inter-censal Deaths	Base Population 1979	Adjusted Population 1989	Adjusted inter-censal Deaths	Adjusted Inter-censal Person Years Lived	Adjusted inter-censal Death Rate
Adjustment factors					0.9115	0.249		
0-4	1,421,385	1,888,828	38,959	1,421,385	2,072,219	156,463	17,162,229	0.009117
5- 9	1,244,749	1,725,292	4,461	1,244,749	1,892,805	17,915	15,349,486	0.001167
10-14	1,023,839	1,485,648	1,461	1,023,839	1,629,894	5,866	12,918,007	0.000454
15-19	887,722	1,200,712	2,188	887,722	1,317,292	8,788	10,813,830	0.000813
20-24	686,003	1,013,540	3,432	686,003	1,111,947	13,784	8,733,836	0.001578
25-29	541,261	847,287	3,800	541,261	929,552	15,260	7,093,167	0.002151
30-34	412,691	575,651	2,991	412,691	631,543	12,010	5,105,214	0.002352
35-39	325,367	457,942	2,463	325,367	502,405	9,891	4,043,093	0.002446
40-44	273,702	364,244	2,061	273,702	399,609	8,278	3,307,171	0.002503
45-49	221,965	293,405	1,781	221,965	321,892	7,152	2,672,990	0.002676
50-54	191,022	240,617	1,715	191,022	263,979	6,886	2,245,569	0.003066
55-59	134,534	181,155	1,594	134,534	198,744	6,400	1,635,170	0.003914
60-64	109,518	167,901	1,968	109,518	184,203	7,905	1,420,336	0.005566
65-69	83,221	116,980	2,156	83,221	128,338	8,660	1,033,461	0.008380
70-74	62,539	91,212	2,665	62,539	100,068	10,703	791,085	0.013530
75+	86,597	154,546	13,918	86,597	169,551	55,896	1,211,718	0.046130
Total	7,706,115	10,804,960	87,612	7,706,115	11,854,041	351,857	95,536,362	

Table 5.4: Life table based on adjusted death rates for females 1979-89

Age Group	Adjusted Death Rate	${}_5q_x$	l_x/l_5	${}_5L_x/l_5$	T_x/l_5	e_x
0-4	0.009117	NA	NA	NA	NA	NA
5- 9	0.001167	0.005852	1.000000	4.9854	70.6705	70.7
10-14	0.000454	0.002273	0.994148	4.9651	65.6851	66.1
15-19	0.000813	0.004073	0.991889	4.9493	60.7200	61.2
20-24	0.001578	0.007921	0.987848	4.9197	55.7707	56.5
25-29	0.002151	0.010813	0.980023	4.8736	50.8510	51.9
30-34	0.002352	0.011830	0.969426	4.8185	45.9774	47.4
35-39	0.002446	0.012305	0.957958	4.7603	41.1589	43.0
40-44	0.002503	0.012594	0.946170	4.7011	36.3986	38.5
45-49	0.002676	0.013470	0.934255	4.6398	31.6975	33.9
50-54	0.003066	0.015448	0.921670	4.5728	27.0577	29.4
55-59	0.003914	0.019763	0.907432	4.4923	22.4850	24.8
60-64	0.005566	0.028223	0.889498	4.3847	17.9927	20.2
65-69	0.008380	0.042797	0.864394	4.2295	13.6079	15.7
70-74	0.013530	0.070018	0.827401	3.9922	9.3784	11.3
75+	0.046130	1.000000	0.769467	NA	5.3863	7.00

5.4 Adjusted total (combined sexes) population and mortality 1979-89

The adjusted total population (both sexes) for 1989 becomes 23,311,478 following an adjustment using a factor of 0.9188 as indicated in row 2 of Table 5.5. This means that the total population was under-enumerated in 1989 by 8.12%. After the adjustment, the population increases by this same factor implying that the total exponential population growth rate for both sexes in 1989 increases to 4.22% compared to the recorded 3.37% before adjustment. Death rates are adjusted by a factor of 0.227, resulting in higher adjusted age specific death rates as seen in column 7 of the same table. The adjusted life table is shown in Table 5.6 indicating a life expectancy at birth of 69.2 years after adjusting for incomplete estimates of death, up from an initial estimate of 59.8 years.

Table 5.5: Calculation of adjusted total inter-censal death rates for both sexes 1979-89

Age Group	Census Population 1979	Census Population 1989	Inter-censal Deaths	Base Population 1979	Adjusted Population 1989	Adjusted inter-censal Deaths	Adjusted Inter-censal Person Years Lived	Adjusted inter-censal Death Rate
Adjustment factors				1.0000	0.9188	0.227		
0-4	2,843,409	3,800,044	81,537	2,843,409	4,135,877	359,193	34,292,842	0.010474
5-9	2,491,840	3,468,938	10,191	2,491,840	3,775,509	44,893	30,672,405	0.001464
10-14	2,074,771	2,989,692	3,380	2,074,771	3,253,909	14,890	25,982,910	0.000573
15-19	1,741,845	2,378,696	4,774	1,741,845	2,588,916	21,031	21,235,561	0.000990
20-24	1,327,404	1,903,134	6,120	1,327,404	2,071,326	26,958	16,581,575	0.001626
25-29	1,055,712	1,629,761	6,899	1,055,712	1,773,793	30,393	13,684,351	0.002221
30-34	818,076	1,159,424	6,316	818,076	1,261,889	27,824	10,160,320	0.002738
35-39	615,594	918,892	5,487	615,594	1,000,100	24,173	7,846,372	0.003081
40-44	535,182	732,178	4,876	535,182	796,885	21,482	6,530,532	0.003289
45-49	440,879	574,532	4,288	440,879	625,307	18,888	5,250,569	0.003597
50-54	373,930	476,523	4,177	373,930	518,636	18,400	4,403,789	0.004178
55-59	275,311	360,172	3,963	275,311	392,003	17,459	3,285,160	0.005315
60-64	217,228	318,397	4,602	217,228	346,536	20,274	2,743,671	0.007389
65-69	183,127	230,670	5,412	183,127	251,056	23,842	2,144,181	0.011119
70-74	128,908	174,178	6,271	128,908	189,571	27,624	1,563,241	0.017671
75+	174,363	303,356	30,868	174,363	330,165	135,980	2,399,345	0.056674
Total	15,297,579	21,418,587	189,160	15,297,579	23,311,478	833,304	188,776,824	

Table 5.6: Life table based on adjusted death rates for both sexes 1979-89

Age Group	Adjusted Death Rate	${}_5q_x$	l_x/l_5	${}_5L_x/l_5$	T_x/l_5	e_x
0-4	0.010474	NA	NA	NA	NA	NA
5-9	0.001464	0.007347	1.000000	4.9816	69.1986	69.2
10-14	0.000573	0.002869	0.992653	4.9561	64.2169	64.7
15-19	0.000990	0.004962	0.989805	4.9367	59.2608	59.9
20-24	0.001626	0.008163	0.984893	4.9044	54.3240	55.2
25-29	0.002221	0.011167	0.976854	4.8570	49.4197	50.6
30-34	0.002738	0.013784	0.965945	4.7964	44.5627	46.1
35-39	0.003081	0.015525	0.952630	4.7262	39.7662	41.7
40-44	0.003289	0.016581	0.937841	4.6503	35.0401	37.4
45-49	0.003597	0.018148	0.922290	4.5696	30.3897	33.0
50-54	0.004178	0.021110	0.905552	4.4800	25.8201	28.5
55-59	0.005315	0.026933	0.886436	4.3725	21.3402	24.1
60-64	0.007389	0.037640	0.862561	4.2316	16.9677	19.7
65-69	0.011119	0.057185	0.830094	4.0318	12.7360	15.3
70-74	0.017671	0.092439	0.782626	3.7323	8.7042	11.1
75+	0.056674	1.000000	0.710281	NA	4.9720	7.00

5.5 Adjusted male population and mortality 1989-99

The male population increased to 14,954,507 persons after an adjustment using a factor of 0.943 or 94.3% as indicated in row 2 of Table 5.7 implying that males were under-enumerated in 1999 and after the adjustment, the population increases by 5.7%. This also means that the male exponential population growth rate in 1999 increases to 3.6% compared to the recorded 3.01% before adjustment. Death rates are adjusted by a factor of 0.219, resulting in higher adjusted age specific death rates as seen in column 7 of the same table. The adjusted life table using the adjusted ASDRs is shown in Table 5.8. It shows that life expectancy at birth increases from 51.36 years as initially estimated to 63.3 years after adjusting for incomplete estimates of death.

Table 5.7: Calculation of adjusted male inter-censal death rates 1989-99

Age Group	Census population 1989	Census population 1999	Inter-censal Deaths	Base Population 1989	Adjusted Population 1999	Adjusted inter-censal Deaths	Adjusted inter-censal Person Years Lived	Adjusted inter-censal Death Rate
Adjustment factors					0.9430	0.219		
0-4	1,911,216	2,291,943	56,684	1,911,216	2,430,480	258,831	21,552,662	0.012009
5- 9	1,743,646	2,000,580	9,734	1,743,646	2,121,506	44,450	19,233,189	0.002311
10-14	1,504,044	2,034,980	3,704	1,504,044	2,157,985	16,914	18,015,839	0.000939
15-19	1,177,984	1,681,984	5,162	1,177,984	1,783,652	23,570	14,495,218	0.001626
20-24	889,594	1,328,529	5,656	889,594	1,408,832	25,825	11,195,037	0.002307
25-29	782,474	1,094,909	6,703	782,474	1,161,091	30,609	9,531,650	0.003211
30-34	583,773	840,692	7,388	583,773	891,508	33,736	7,214,141	0.004676
35-39	460,950	695,263	7,415	460,950	737,288	33,860	5,829,690	0.005808
40-44	367,934	516,502	6,474	367,934	547,722	29,562	4,489,160	0.006585
45-49	281,127	419,841	5,875	281,127	445,218	26,827	3,537,836	0.007583
50-54	235,906	344,639	5,797	235,906	365,471	26,470	2,936,270	0.009015
55-59	179,017	223,691	5,120	179,017	237,212	23,380	2,060,703	0.011346
60-64	150,496	194,513	6,056	150,496	206,270	27,653	1,761,897	0.015695
65-69	113,690	140,969	6,619	113,690	149,490	30,223	1,303,669	0.023183
70-74	82,966	118,601	8,056	82,966	125,770	36,786	1,021,501	0.036012
75+	148,810	174,466	25,615	148,810	185,012	116,961	1,659,266	0.070490
Total	10,613,627	14,102,102	172,059	10,613,627	14,954,507	785,657	125,837,726	

Table 5.8: Life table based on adjusted male death rates 1989-99

Age Group	Adjusted Death Rate	${}_5q_x$	l_x/l_5	${}_5L_x/l_5$	T_x/l_5	e_x
0-4	0.012009	NA	NA	NA	NA	NA
5-9	0.002311	0.011622	1.000000	4.9709	63.2592	63.3
10-14	0.000939	0.004706	0.988378	4.9303	58.2883	59.0
15-19	0.001626	0.008163	0.983726	4.8986	53.3580	54.2
20-24	0.002307	0.011602	0.975696	4.8502	48.4594	49.7
25-29	0.003211	0.016185	0.964376	4.7829	43.6093	45.2
30-34	0.004676	0.023657	0.948768	4.6877	38.8264	40.9
35-39	0.005808	0.029468	0.926323	4.5634	34.1387	36.9
40-44	0.006585	0.033476	0.899027	4.4199	29.5753	32.9
45-49	0.007583	0.038648	0.868931	4.2607	25.1554	28.9
50-54	0.009015	0.046114	0.835348	4.0804	20.8947	25.0
55-59	0.011346	0.058386	0.796827	3.8678	16.8143	21.1
60-64	0.015695	0.081680	0.750303	3.5983	12.9464	17.3
65-69	0.023183	0.123046	0.689019	3.2331	9.3481	13.6
70-74	0.036012	0.197875	0.604237	2.7223	6.1150	10.1
75+	0.070490	1.000000	0.484674	NA	3.3927	7.00

5.6 Adjusted female population and mortality 1989-99

The adjusted female population for 1999 becomes 15,183,609 persons following an adjustment using a factor of 0.948 as indicated in row 2 of Table 5.9. This means that the female population was under-enumerated in 1999 by 5.2%. After the adjustment, the population increases by this same factor implying that the female exponential population growth rate in 1999 increases to 3.7% compared to the recorded 3.16% before adjustment. Death rates on the other hand are adjusted by a factor of 0.213, resulting in higher adjusted age specific death rates as seen in column 7 of Table 5.9. The adjusted life table using the adjusted ASDRs is shown in Table 5.10. It shows that life expectancy at birth increases from 54.74 years as initially estimated to 65.4 years after adjusting for incomplete estimates of death.

Table 5.9: Calculation of adjusted female inter-censal death rates 1989-99

Age Group	Census Population 1989	Census Population 1999	Inter-censal Deaths	Base Population 1989	Adjusted Population 1999	Adjusted inter-censal Deaths	Adjusted Inter-censal Person Years Lived	Adjusted Inter-censal Death Rate
Adjustment factors				1.0000	0.9480	0.213		
0-4	1,888,828	2,242,966	53,119	1,888,828	2,365,998	249,384	21,139,923	0.011797
5-9	1,725,292	1,962,556	7,677	1,725,292	2,070,207	36,043	18,898,972	0.001907
10-14	1,485,648	2,003,655	2,879	1,485,648	2,113,560	13,515	17,720,063	0.000763
15-19	1,200,712	1,721,194	4,408	1,200,712	1,815,605	20,697	14,764,886	0.001402
20-24	1,013,540	1,504,389	7,518	1,013,540	1,586,908	35,298	12,682,250	0.002783
25-29	847,287	1,164,594	8,426	847,287	1,228,475	39,557	10,202,308	0.003877
30-34	575,651	845,230	6,803	575,651	891,593	31,937	7,164,122	0.004458
35-39	457,942	723,749	6,045	457,942	763,448	28,378	5,912,824	0.004799
40-44	364,244	516,989	4,737	364,244	545,347	22,238	4,456,898	0.004990
45-49	293,405	418,987	4,168	293,405	441,969	19,567	3,601,054	0.005434
50-54	240,617	340,167	3,962	240,617	358,826	18,603	2,938,361	0.006331
55-59	181,155	236,325	3,662	181,155	249,288	17,191	2,125,083	0.008090
60-64	167,901	214,715	4,754	167,901	226,493	22,321	1,950,087	0.011446
65-69	116,980	160,364	5,235	116,980	169,160	24,579	1,406,710	0.017473
70-74	91,212	135,524	6,787	91,212	142,958	31,863	1,141,906	0.027903
75+	154,546	202,658	23,564	154,546	213,774	110,628	1,817,634	0.060864
Total	10,804,960	14,394,062	153,743	10,804,960	15,183,609	721,799	127,923,080	

Table 5.10: Life table based on adjusted female death rates 1989-99

Age Group	Adjusted Death Rate	${}_5q_x$	l_x/l_5	${}_5L_x/l_5$	T_x/l_5	e_x
0-4	0.011797	NA	NA	NA	NA	NA
5-9	0.001907	0.009581	1.000000	4.9760	65.4116	65.4
10-14	0.000763	0.003822	0.990419	4.9426	60.4356	61.0
15-19	0.001402	0.007035	0.986634	4.9158	55.4929	56.2
20-24	0.002783	0.014012	0.979693	4.8641	50.5771	51.6
25-29	0.003877	0.019575	0.965965	4.7826	45.7130	47.3
30-34	0.004458	0.022541	0.947057	4.6819	40.9304	43.2
35-39	0.004799	0.024286	0.925709	4.5723	36.2485	39.2
40-44	0.004990	0.025265	0.903227	4.4591	31.6762	35.1
45-49	0.005434	0.027544	0.880406	4.3414	27.2171	30.9
50-54	0.006331	0.032164	0.856156	4.2119	22.8757	26.7
55-59	0.008090	0.041285	0.828619	4.0576	18.6637	22.5
60-64	0.011446	0.058916	0.794409	3.8550	14.6062	18.4
65-69	0.017473	0.091356	0.747606	3.5673	10.7511	14.4
70-74	0.027903	0.149977	0.679308	3.1418	7.1838	10.6
75+	0.060864	1.000000	0.577427	NA	4.0420	7.00

5.7 Adjusted total (combined sexes) population and mortality 1989-99

The adjusted total population (both sexes) for 1999 becomes 30,164,248 persons following an adjustment using a factor of 0.9447 as indicated in row 2 of Table 5.11. This means that the total population was under-enumerated in 1999 by 5.53%. After the adjustment, the population increases by this same factor implying that the total exponential population growth rate for both sexes in 1999 increases to 3.66% compared to the recorded 3.09% before adjustment. Death rates are adjusted by a factor of 0.216, resulting in higher adjusted age specific death rates as seen in column 7 of Table 5.11. The adjusted life table is shown in Table 5.12 indicating a life expectancy at birth of 64.3 years after adjusting for incomplete estimates of death, up from an initial estimate of 53.1 years.

Table 5.11: Calculation of adjusted inter-censal death rates for both sexes 1989-99

Age Group	Census Population 1989	Census Population 1999	Inter-censal Deaths	Base Population 1989	Adjusted Population 1999	Adjusted Inter-censal Deaths	Adjusted Inter-censal Person Years Lived	Adjusted Inter-censal Death Rate
Adjustment factors					0.9447	0.216		
0-4	3,800,044	4,534,909	109,803	3,800,044	4,800,369	508,346	42,710,202	0.011902
5-9	3,468,938	3,963,136	17,412	3,468,938	4,195,126	80,610	38,147,912	0.002113
10-14	2,989,692	4,038,635	6,583	2,989,692	4,275,045	30,477	35,750,619	0.000852
15-19	2,378,696	3,403,178	9,570	2,378,696	3,602,390	44,307	29,272,838	0.001514
20-24	1,903,134	2,832,918	13,174	1,903,134	2,998,749	60,992	23,889,372	0.002553
25-29	1,629,761	2,259,503	15,129	1,629,761	2,391,768	70,041	19,743,379	0.003548
30-34	1,159,424	1,685,922	14,191	1,159,424	1,784,611	65,698	14,384,439	0.004567
35-39	918,892	1,419,012	13,460	918,892	1,502,077	62,314	11,748,389	0.005304
40-44	732,178	1,033,491	11,211	732,178	1,093,989	51,902	8,949,831	0.005799
45-49	574,532	838,828	10,043	574,532	887,931	46,495	7,142,442	0.006510
50-54	476,523	684,806	9,759	476,523	724,893	45,183	5,877,314	0.007688
55-59	360,172	460,016	8,782	360,172	486,944	40,657	4,187,882	0.009708
60-64	318,397	409,228	10,810	318,397	433,183	50,048	3,713,814	0.013476
65-69	230,670	301,333	11,854	230,670	318,972	54,881	2,712,513	0.020233
70-74	174,178	254,125	14,843	174,178	269,001	68,717	2,164,580	0.031746
75+	303,356	377,124	49,178	303,356	399,200	227,677	3,479,938	0.065426
Total	21,418,587	28,496,164	325,802	21,418,587	30,164,248	1,508,345	253,875,466	

Table 5.12: Life table based on adjusted death rates for both sexes 1989-99

Age Group	Adjusted death Rate	${}_5q_x$	l_x/l_5	${}_5L_x/l_5$	T_x/l_5	e_x
0-4	0.011902	NA	NA	NA	NA	NA
5-9	0.002113	0.010621	1.000000	4.9734	64.3285	64.3
10-14	0.000852	0.004269	0.989379	4.9363	59.3550	60.0
15-19	0.001514	0.007599	0.985155	4.9071	54.4187	55.2
20-24	0.002553	0.012847	0.977669	4.8569	49.5116	50.6
25-29	0.003548	0.017899	0.965109	4.7824	44.6547	46.3
30-34	0.004567	0.023099	0.947835	4.6844	39.8723	42.1
35-39	0.005304	0.026876	0.925941	4.5675	35.1879	38.0
40-44	0.005799	0.029422	0.901055	4.4390	30.6204	34.0
45-49	0.006510	0.033089	0.874545	4.3004	26.1814	29.9
50-54	0.007688	0.039193	0.845607	4.1452	21.8810	25.9
55-59	0.009708	0.049747	0.812465	3.9613	17.7358	21.8
60-64	0.013476	0.069729	0.772047	3.7257	13.7746	17.8
65-69	0.020233	0.106555	0.718213	3.3997	10.0489	14.0
70-74	0.031746	0.172414	0.641684	2.9318	6.6492	10.4
75+	0.065426	1.000000	0.531049	NA	3.7173	7.00

5.8 Trends of adjusted mortality

Age-specific death rates (ASDRs) are used to measure variations in mortality by age. ASDR is defined as the number of deaths of persons in a given age during a year per 1000 of the mid-year population at that age. The adjusted ASDRs for Kenya for the 1979-89 and 1989-99 inter-censal periods are illustrated in Figures 5.1 and 5.2 below. Trends depict an almost U-shaped curve for the 2 inter-censal periods with peaks at ages under 1 and between 1 and 4 years indicating high child mortality. The curve further peaks at ages 70+, representing higher deaths at old age. The graphs point to an increase in mortality for both males and females during the 1989-99 period as compared to the 1979-89 inter-censal period. This is more pronounced especially for females between 25 and 50 years and implies that mortality between these ages has increased to levels higher than those observed in the 1980s. The graph illustrating ratios of male: female death rates (Figure 5.3) demonstrates a trough between ages 20 and 29. This shows that female death rates increased significantly in this age group for both inter-censal periods. This could be attributed to deaths as a result of prevalence of HIV/AIDS which is normally higher amongst females of this age group.

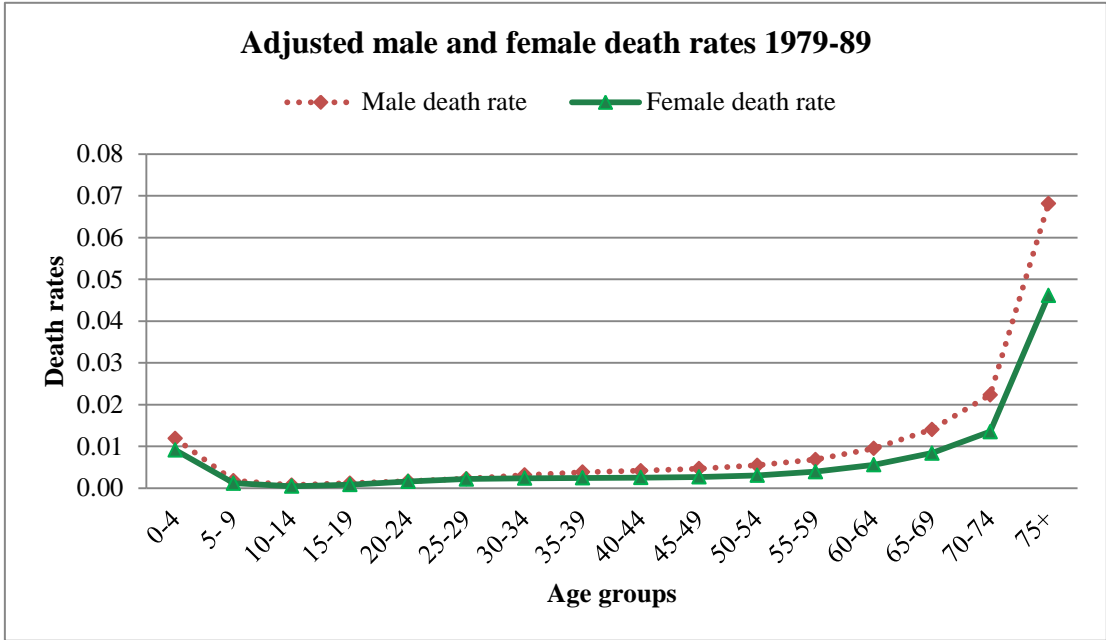


Figure 5.1: Showing trends of adjusted death rates 1979-89

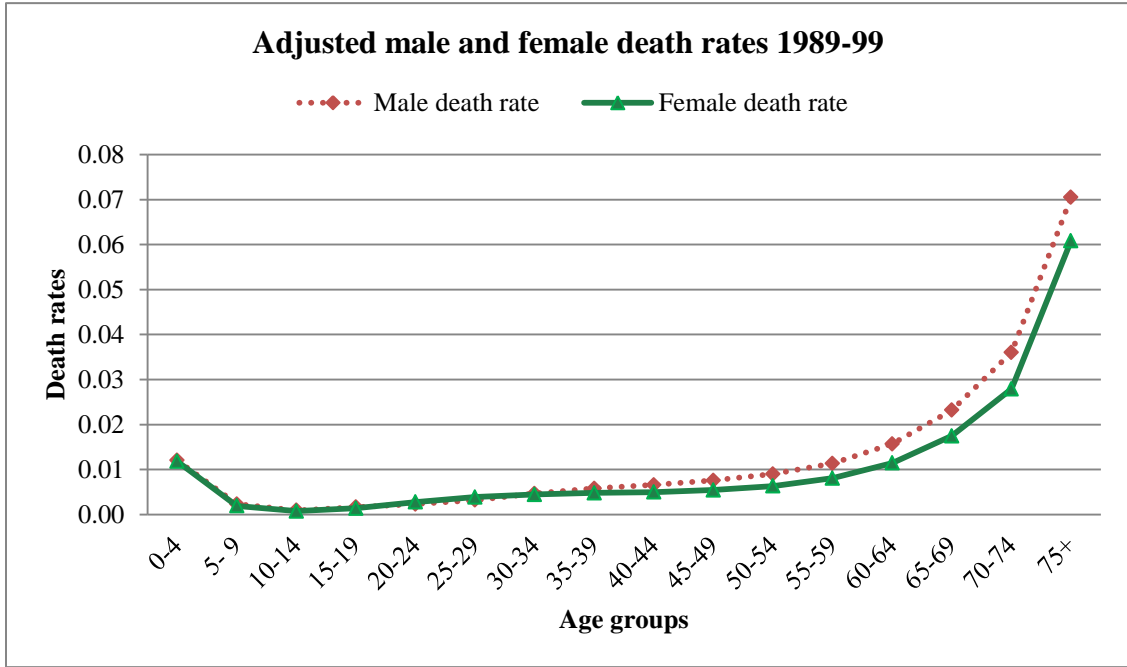


Figure 5.2: Showing trends of adjusted death rates 1989-99

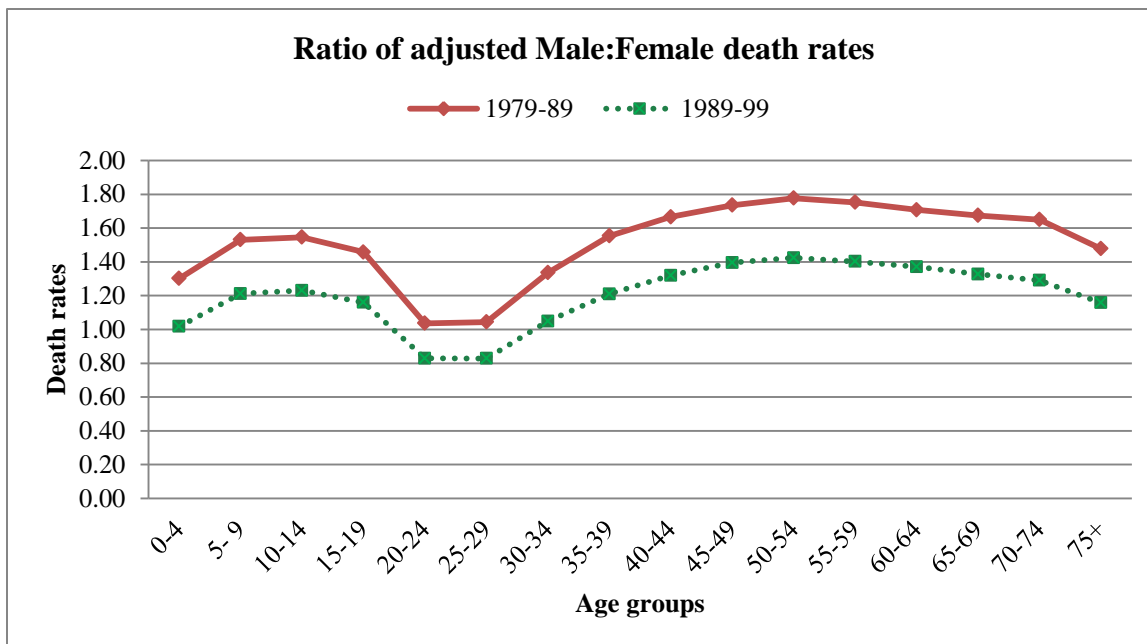


Figure 5.3: Showing trends in ratio of adjusted inter-censal M: F death rates

5.9 DISCUSSION OF FINDINGS

The study estimated the completeness of census results for 2 inter-censal periods 1979-89 and 1989-99 using Hill's General Growth Balance (GGB) technique. The method simultaneously estimated completeness of death estimates and census enumeration. In summary, trends of census completeness from 1969-79 through to 1989-99 have illustrated a decline in completeness of census enumeration. Female enumeration indicated lower levels than males in the three inter-censal periods. This is consistent with the findings of (Ayad.et.al, 1994) which showed evidence of higher age heaping at 0, 1, 2, 3, 4 and 5 digits among females compared to males in Kenya. Further, an evaluation of the accuracy of census IPUMS data by (Fajardo-Gonzalez.et.al, 2014) indicated rough data with higher Whipple's and Myers' indices for females compared to males for all censuses from 1969 through to 1999. These substantial sex differences in the degree of completeness could be caused by sex differences in literacy rates, education, or other factors. For example, women may be more likely to have their information reported by a proxy (such as the head of the household) than men (Fajardo-Gonzalez.et.al, 2014). Table 5.13 contains data for Whipple's and Myers' indices and UN age-sex ratios for various census years from 1969 to

1999. The last column is a comparison with Hill's percent completeness as obtained in this research.

Table 5.13: Hill's completeness and other accuracy indices

Census Year	Whipple's Index			Myers' Index			UN sex-age accuracy ratio	Hill's percent completeness		
	Both sexes	Females	Males	Both sexes	Females	Males	Both sexes	Both sexes	Females	Males
1969	162.82	165.91	159.93	11.34	12.14	10.64	34.53			
1979	144.53	148.31	140.6	7.26	8.04	6.67	27.89	97.95	97.11	98.79
1989	147.88	153.45	142.1	7.82	8.86	6.74	20.46	91.88	91.15	93.12
1999	149.35	153.82	144.61	7.54	8.34	6.74	23.62	94.47	94.8	94.3

Source: Data for Whipple's, Myer's and UN indices obtained from (Fajardo-Gonzalez.et.al, 2014)

Completeness of estimates of death on the other hand indicated an improvement over time. However, large variations in the completeness of death estimates have a relatively large effect on the estimated expectation of life at birth. For example, a 78.7 per cent less completeness of death estimates among females in 1989-99 decreases the estimated e_5 from 65.4 to 54.74 years, a drop of over 10 years. Similarly, a 78.1% less completeness would lead to a drop from 63.3 to 51.36 years amongst males of the 1989-99 inter-censal period. Completeness of female death estimates was generally lower than males. It should be noted that the deaths used as input in this study were estimated from model life tables and do not represent actual registered deaths. Therefore estimates only measure completeness of life table deaths, but which can be used to depict a general picture of mortality in Kenya.

Adjustment of the inter-censal age distributions for the Kenya population yields higher deaths for all ages. This is even higher for ages 0-4 and ages 75+, indicating less completeness of death estimates in these age groups. A similar trend is observed in the census age-specific populations, implying that the adjusted exponential population growth rate over the 1989-99 inter-censal period averaged 3.66% compared to the reported 3.09%; while the adjusted exponential growth rate for the 1979-89 inter-censal period was 4.2% compared to the initially estimated 3.4%. These adjustments lead to higher life expectancy than was initially recorded in the life table estimates for all ages.

In conclusion, the method works well in estimating completeness of census enumeration and the results obtained indicate an overall decline in the level of completeness of census enumeration from 1969-79 period up to 1989-99 inter-censal period. This indicates an increasing level of data

inaccuracy (diminishing data quality) over time as a result of incompleteness; and implies that estimates of population growth rates could be inaccurate. Thus there is need to consider possible explanations for the inaccuracies in the age-sex structure of the Kenya population in addition to the summary of levels of completeness.

CHAPTER 6

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This Chapter presents a discussion of the findings, summary, conclusion and recommendations of the study. It summarizes the objectives that the study set out to achieve, and discusses whether these have been met.

6.2 Summary

The general objective of the study was to establish the levels and trends of completeness of the Kenya census data sets, specifically the 1999 and 1989 censuses. The specific objectives were to estimate the completeness of Kenya's 1999 and 1989 censuses relative to the respective previous censuses and; to make appropriate adjustments for coverage, and thus estimate age-specific distributions. The study utilized secondary data from the KNBS population and housing censuses of 1999 and 1989. The focus of the study was on these populations, distributed by age and sex and the mortality patterns of the populations. The method of analysis involved Hill's generalized version of the Brass Growth Balance model to estimate completeness of the 1999 census relative to the 1989 census; and completeness of 1989 census relative to the 1979 census by age and sex. Estimates of mortality were generated using the African Standard model life table and estimates of census and mortality completeness were generated using the UN Mortpak software and comparisons between generated and reported values made. Findings of census completeness from 1969-79 through to 1989-99 have illustrated a decline over time. Female enumeration indicated lower levels than males in the three inter-censal periods while completeness of estimates of death indicated an improvement over time. Adjustment of the inter-censal age distributions for the Kenya population yielded higher deaths for all ages particularly for ages 0-4 and ages 75+, indicating less completeness of death estimates in these age groups. A similar trend is observed in the census age-specific populations, implying that the adjusted exponential population growth rate over the 1989-99 inter-censal period averaged 3.66% compared to the reported 3.09%; while the adjusted exponential growth rate for the 1979-89 inter-censal period was 4.2% compared to the initially reported 3.4%.

6.3 Conclusion

The results yielded completeness of both census enumeration and death estimates and enabled us to adjust for incompleteness as set out in the objectives of the study. Trends of completeness have also been illustrated, indicating a decline in the data quality. Where two census age distributions and inter-censal deaths by age are available, (Hill, 1987) stated that a simple reformulation of Brass's method eliminates the need for the assumption on stability (which is untenable in the Kenya context). The two-census formulation has the further advantage of allowing the estimation of the differential completeness of enumeration between two censuses. Its advantage rests on its ability to estimate completeness and adjust deaths and total populations by age. The method singled out age groups that are vulnerable to death relative to others. Further, examining the age-sex distribution for multiple census years allowed us to see patterns of Kenya's age-sex structure that are not reflected by such summary indices as Whipple's and Myers' indices that are also used in estimating accuracy of data. The UN age-sex ratio and these indices are usually the first step in assessing the quality of census data. Hill's General Growth Balance method allowed for identifying age specific anomalies and adjusted the same using various factors.

The findings of this study are consistent with those of other studies such as (Fajardo-Gonzalez.et.al, 2014) which showed that substantial sex differences in the degree of completeness could be caused by sex differences in literacy rates, education, or other factors. For example, women may be more likely to have their information reported by a proxy than men, meaning that chances of inaccuracy are higher. In addition, the trends of adjusted mortality and age-sex distribution observed in this study follow similar trends as those seen in Kenya census analytical reports (KNBS, 2002). Additionally, (Ayad.et.al, 1994) have also shown evidence of higher age heaping at 0, 1, 2, 3, 4 and 5 digits among females compared to males in Kenya. Levels of completeness obtained in this study do not vary much from those obtained in Magadi (1990) for the inter-censal period 1969-79. Comparison with other data quality measures such as UN Age-sex Accuracy Index, Myers Index and Whipple's Index have also shown similar trends in data quality as those obtained in the application of Hill's method. These consistencies eliminate any reasons to doubt the findings and trends obtained in this study.

6.4 Policy recommendations

This technique is appropriate where age-specific data is needed. Specifically, adjustment of age distribution is helpful for policy makers who need accurate age-specific data compared to the use of single indices to assess quality. However, such adjustments are only possible when accurate data on mortality is available. The study was unable to use actual deaths from civil registration due to unavailability or incompleteness of the same. The government of Kenya ought to review its vital registration policies in order to improve on systems for capture and access of the data.

6.5 Recommendations for further research

The study used mortality estimates from Model Life Tables for the two inter-censal periods. Incompleteness of death estimates were high, mainly because life table estimates of death are simply a hypothetical cohort but which are the closest estimate of deaths by age. It is based on available data and given that mortality data is quite scanty in Kenya, such mortality estimates have shown high levels of incompleteness, but can still be used to depict a general picture of mortality in Kenya. Further studies should endeavor to use actual deaths from civil registration records where available to improve on quality of findings of completeness of death registration

This study failed to use data from the most recent census of 2009. This is due to a pending court case challenging the quality of the data generated from the census. Further research should seek to use this data after the determination of this case to further understand trends in data quality.

While this technique allows for adjustment of age distributions it assumes that the population experiences no or negligible migration and that the completeness of enumeration in the two censuses does not vary by age just like Brass's method. The assumption of non-migration makes the technique weak in providing actual estimates of completeness. However, it applies to persons above some specified lower age limit. This lower age limit can vary and when the age limit is as high as 50 years better results are obtained. Migration is higher among young adults and so the assumption may not be as limiting as it would otherwise be if this age limit is set above young adulthood. Hill (2004) has proposed a technique for adjusting the general growth balance equation for migration. Future analysis should put into consideration applying this technique while estimating completeness of census. However, even then, the procedure proposed by Hill and Queiroz works reasonably well in populations that have generally good data and rather high

net migration rates meaning that the method is applicable to open populations but only when accurate data on migration is available.

6.6 Other recommendations

This study has indicted that completeness of census enumeration has declined over time. Demographic analysts and census experts therefore ought to re-examine data quality and institute specific measures to improve on the same, particularly at age groups 5-9, 10-14 and 50+, based on the results of this study.

APPENDIX 1: GGB method and calculation of plotting points: Kenya males 1979-89

Age Group	Population 1979	Population 1989	Intercensal Deaths	Population Over age x 1979	Population Over age x 1989	Deaths Over Age x	Person Years Lived Over Age x	Persons Reaching Age x	Entry Rate: Population Over Age x	Growth rate: Population Over Age x	x-point	y-point
	$P1(x,5)$	$P2(x,5)$	$D(x,5)$	$P!(x+)$	$P2(x+)$	$D(x+)$	$PYL(x+)$	$N(x)$	$n(x+)$	$r(x+)$	$d(x+)$	$n(x+)-r(x+)$
0-4	1,422,024	1,911,216	42,578	7,591,464	10,613,627	101,548	89,762,446	NA	NA	0.03367	0.00113	NA
5- 9	1247091	1743646	5730	6,169,440	8,702,411	58,970	73,272,780	3,149,290	0.04298	0.03457	0.00080	0.00841
10-14	1050932	1504044	1919	4,922,349	6,958,765	53,241	58,526,464	2,739,109	0.04680	0.03479	0.00091	0.01201
15-19	854123	1177984	2586	3,871,417	5,454,721	51,321	45,953,781	2,225,292	0.04842	0.03445	0.00112	0.01397
20-24	641401	889594	2687	3,017,294	4,276,737	48,736	35,922,379	1,743,356	0.04853	0.03506	0.00136	0.01347
25-29	514451	782474	3099	2,375,893	3,387,143	46,048	28,368,097	1,416,869	0.04995	0.03565	0.00162	0.01430
30-34	405385	583773	3326	1,861,442	2,604,669	42,949	22,019,174	1,096,034	0.04978	0.03375	0.00195	0.01602
35-39	290227	460950	3025	1,456,057	2,020,896	39,623	17,153,833	864,551	0.05040	0.03293	0.00231	0.01747
40-44	261480	367934	2815	1,165,830	1,559,946	36,599	13,485,666	653,558	0.04846	0.02922	0.00271	0.01924
45-49	218914	281127	2507	904,350	1,192,012	33,784	10,382,659	542,251	0.05223	0.02771	0.00325	0.02452
50-54	182908	235906	2462	685,436	910,885	31,277	7,901,603	454,502	0.05752	0.02853	0.00396	0.02899
55-59	140777	179017	2370	502,528	674,979	28,815	5,824,052	361,904	0.06214	0.02961	0.00495	0.03253
60-64	107710	150496	2634	361,751	495,962	26,445	4,235,738	291,111	0.06873	0.03169	0.00624	0.03704
65-69	99906	113690	3256	254,041	345,466	23,811	2,962,474	221,319	0.07471	0.03086	0.00804	0.04385
70-74	66369	82966	3606	154,135	231,776	20,555	1,890,100	182,086	0.09634	0.04108	0.01088	0.05526
75+	87,766	148810	16,949	87,766	148,810	16,949	1,142,824	NA	NA	0.05342	NA	NA
Total	7,591,464	10,613,627	101,548									

This table represents the calculation procedure and displays values of x and y points (last two columns) which are later used in estimating values of k and c in Table 4.6 below.

APPENDIX 2: GGB method and calculation of plotting points: Kenya females 1979-89

Age Group	Population 1979	Population 1989	Intercensal Deaths	Population Over Age x 1979	Population Over Age x 1989	Deaths Over Age x	Person Years Lived Over Age x	Persons Reaching Age x	Entry Rate: Population Over Age x	Growth Rate: Population Over Age x	x-point	y-point
Group	$PI(x,5)$	$P2(x,5)$	$D(x,5)$	$P!(x+)$	$P2(x+)$	$D(x+)$	$PYL(x+)$	$N(x)$	$n(x+)$	$r(x+)$	$d(x+)$	$n(x+)-r(x+)$
0-4	1,421,385	1,888,828	38,959	7,706,115	10,804,960	87,612	91,249,254	NA	NA	0.03396	0.00096	NA
5- 9	1244749	1725292	4461	6,284,730	8,916,132	48,653	74,856,852	3,131,967	0.04184	0.03515	0.00065	0.00669
10-14	1023839	1485648	1461	5,039,981	7,190,840	44,192	60,201,077	2,719,749	0.04518	0.03573	0.00073	0.00945
15-19	887722	1200712	2188	4,016,142	5,705,192	42,732	47,867,381	2,217,508	0.04633	0.03529	0.00089	0.01104
20-24	686003	1013540	3432	3,128,420	4,504,480	40,543	37,539,187	1,897,094	0.05054	0.03666	0.00108	0.01388
25-29	541261	847287	3800	2,442,417	3,490,940	37,111	29,199,882	1,524,784	0.05222	0.03591	0.00127	0.01631
30-34	412691	575651	2991	1,901,156	2,643,653	33,311	22,418,735	1,116,382	0.04980	0.03312	0.00149	0.01668
35-39	325367	457942	2463	1,488,465	2,068,002	30,321	17,544,653	869,456	0.04956	0.03303	0.00173	0.01652
40-44	273702	364244	2061	1,163,098	1,610,060	27,858	13,684,508	688,514	0.05031	0.03266	0.00204	0.01765
45-49	221965	293405	1781	889,396	1,245,816	25,797	10,526,271	566,765	0.05384	0.03386	0.00245	0.01998
50-54	191022	240617	1715	667,431	952,411	24,016	7,972,883	462,206	0.05797	0.03574	0.00301	0.02223
55-59	134534	181155	1594	476,409	711,794	22,301	5,823,273	372,046	0.06389	0.04042	0.00383	0.02347
60-64	109518	167901	1968	341,875	530,639	20,708	4,259,251	300,589	0.07057	0.04432	0.00486	0.02625
65-69	83221	116980	2156	232,357	362,738	18,739	2,903,183	226,375	0.07797	0.04491	0.00645	0.03307
70-74	62539	91212	2665	149,136	245,758	16,583	1,914,455	174,250	0.09102	0.05047	0.00866	0.04055
75+	86597	154546	13,918	86,597	154,546	13,918	1,156,859	NA	NA	0.05874	NA	NA
Total	7,706,115	10,804,960	87,612									

This table represents the calculation procedure and displays values of x and y points (last two columns) which are later used in estimating values of k and c .

APPENDIX 3: GGB method and calculation of plotting points: Kenya both sexes 1979-89

Age Group	Population 1979	Population 1989	Intercensal Deaths	Population Over Age x 1979	Population Over Age x 1989	Deaths Over Age x	Person Years Lived Over Age x	Persons Reaching Age x	Entry Rate: Population Over Age x	Growth Rate: Population Over Age x	x-point	y-point
	$P1(x,5)$	$P2(x,5)$	$D(x,5)$	$P!(x+)$	$P2(x+)$	$D(x+)$	$PYL(x+)$	$N(x)$	$n(x+)$	$r(x+)$	$d(x+)$	$n(x+)-r(x+)$
0-4	2,843,409	3,800,044	81,537	15,297,579	21,418,587	189,160	181,011,747	NA	NA	0.03382	0.00105	NA
5-9	2491840	3468938	10191	12,454,170	17,618,543	107,624	148,129,784	6,281,277	0.04240	0.03486	0.00073	0.00754
10-14	2074771	2989692	3380	9,962,330	14,149,605	97,433	118,727,855	5,458,877	0.04598	0.03527	0.00082	0.01071
15-19	1741845	2378696	4774	7,887,559	11,159,913	94,053	93,821,358	4,443,084	0.04736	0.03488	0.00100	0.01248
20-24	1327404	1903134	6120	6,145,714	8,781,217	89,279	73,462,132	3,641,409	0.04957	0.03588	0.00122	0.01369
25-29	1055712	1629761	6899	4,818,310	6,878,083	83,159	57,567,991	2,941,667	0.05110	0.03578	0.00144	0.01532
30-34	818076	1159424	6316	3,762,598	5,248,322	76,260	44,437,963	2,212,707	0.04979	0.03343	0.00172	0.01636
35-39	615594	918892	5487	2,944,522	4,088,898	69,944	34,698,487	1,734,040	0.04997	0.03298	0.00202	0.01699
40-44	535182	732178	4876	2,328,928	3,170,006	64,457	27,171,153	1,342,720	0.04942	0.03095	0.00237	0.01846
45-49	440879	574532	4288	1,793,746	2,437,828	59,580	20,911,347	1,109,016	0.05303	0.03080	0.00285	0.02223
50-54	373930	476523	4177	1,352,867	1,863,296	55,293	15,877,001	916,709	0.05774	0.03215	0.00348	0.02559
55-59	275311	360172	3963	978,937	1,386,773	51,116	11,651,452	733,973	0.06299	0.03500	0.00439	0.02799
60-64	217228	318397	4602	703,626	1,026,601	47,153	8,499,077	592,143	0.06967	0.03800	0.00555	0.03167
65-69	183127	230670	5412	486,398	708,204	42,550	5,869,148	447,696	0.07628	0.03779	0.00725	0.03849
70-74	128908	174178	6271	303,271	477,534	37,138	3,805,551	357,193	0.09386	0.04579	0.00976	0.04807
75+	174363	303356	30,868	174,363	303,356	30,868	2,299,871	NA	NA	0.05609	NA	NA
Total	15,297,579	21,418,587	189,160									

This table represents the calculation procedure and displays values of x and y points (last two columns) which are later used in estimating values of k and c .

APPENDIX 4: GGB method and calculation of plotting points: Kenya males 1989-99

Age	Population 1989	Population 1999	Intercensal Deaths	Population Over Age x 1989	Population Over Age x 1999	Deaths Over Age x	Person Years Lived Over Age x	Persons Reaching Age x	Entry Rate: Population Over Age x	Growth Rate: Population Over Age x	x-point	y-point
Group	$P1(x,5)$	$P2(x,5)$	$D(x,5)$	$P!(x+)$	$P2(x+)$	$D(x+)$	$PYL(x+)$	$N(x)$	$n(x+)$	$r(x+)$	$d(x+)$	$n(x+)-r(x+)$
0-4	1,911,216	2,291,943	56,684	10,613,627	14,102,102	172,059	122,341,510	NA	NA	0.02851	0.00141	NA
5- 9	1743646	2000580	9734	8,702,411	11,810,159	115,375	101,378,922	3,910,775	0.03858	0.03065	0.00114	0.00792
10-14	1504044	2034980	3704	6,958,765	9,809,579	105,641	82,621,156	3,767,378	0.04560	0.03450	0.00128	0.01109
15-19	1177984	1681984	5162	5,454,721	7,774,599	101,936	65,121,631	3,181,055	0.04885	0.03562	0.00157	0.01322
20-24	889594	1328529	5656	4,276,737	6,092,615	96,775	51,045,580	2,501,988	0.04901	0.03557	0.00190	0.01344
25-29	782474	1094909	6703	3,387,143	4,764,086	91,119	40,170,438	1,973,854	0.04914	0.03428	0.00227	0.01486
30-34	583773	840692	7388	2,604,669	3,669,177	84,416	30,914,384	1,622,122	0.05247	0.03443	0.00273	0.01804
35-39	460950	695263	7415	2,020,896	2,828,485	77,027	23,908,312	1,274,168	0.05329	0.03378	0.00322	0.01952
40-44	367934	516502	6474	1,559,946	2,133,222	69,612	18,242,015	975,872	0.05350	0.03143	0.00382	0.02207
45-49	281127	419841	5875	1,192,012	1,616,720	63,138	13,882,182	786,063	0.05662	0.03059	0.00455	0.02603
50-54	235906	344639	5797	910,885	1,196,879	57,263	10,441,356	622,535	0.05962	0.02739	0.00548	0.03223
55-59	179017	223691	5120	674,979	852,240	51,466	7,584,485	459,435	0.06058	0.02337	0.00679	0.03720
60-64	150496	194513	6056	495,962	628,549	46,346	5,583,336	373,208	0.06684	0.02375	0.00830	0.04310
65-69	113690	140969	6619	345,466	434,036	40,290	3,872,269	291,309	0.07523	0.02287	0.01040	0.05236
70-74	82966	118601	8056	231,776	293,067	33,671	2,606,260	232,239	0.08911	0.02352	0.01292	0.06559
75+	148,810	174,466	25,615	148,810	174,466	25,615	1,611,282	NA	NA	0.01592	NA	NA
Total	10,613,627	14,102,102	172,059									

This table represents the calculation procedure and displays values of x and y points (last two columns) which are later used in estimating values of k and c .

APPENDIX 5: GGB method and calculation of plotting points: Kenya females 1989-99

Age Group	Population 1989	Population 1999	Inter-censal Deaths	Population Over Age x 1989	Population Over Age x 1999	Deaths Over Age x	Person Years Lived Over Age x	Persons Reaching Age x	Entry Rate: Population Over Age x	Growth rate: Population Over Age x	x-point	y-point
	$P1(x,5)$	$P2(x,5)$	$D(x,5)$	$P!(x+)$	$P2(x+)$	$D(x+)$	$PYL(x+)$	$N(x)$	$n(x+)$	$r(x+)$	$d(x+)$	$n(x+)-r(x+)$
0-4	1,888,828	2,242,966	53,119	10,804,960	14,394,062	153,743	124,710,571	NA	NA	0.02878	0.00123	NA
5- 9	1725292	1962556	7677	8,916,132	12,151,096	100,624	104,086,875	3,850,678	0.03699	0.03108	0.00097	0.00592
10-14	1485648	2003655	2879	7,190,840	10,188,540	92,947	85,594,486	3,718,543	0.04344	0.03502	0.00109	0.00842
15-19	1200712	1721194	4408	5,705,192	8,184,885	90,068	68,334,721	3,198,180	0.04680	0.03629	0.00132	0.01051
20-24	1013540	1504389	7518	4,504,480	6,463,691	85,660	53,958,842	2,688,001	0.04982	0.03631	0.00159	0.01351
25-29	847287	1164594	8426	3,490,940	4,959,302	78,141	41,608,444	2,172,890	0.05222	0.03529	0.00188	0.01693
30-34	575651	845230	6803	2,643,653	3,794,708	69,716	31,673,161	1,692,516	0.05344	0.03634	0.00220	0.01710
35-39	457942	723749	6045	2,068,002	2,949,478	62,913	24,697,219	1,290,933	0.05227	0.03569	0.00255	0.01658
40-44	364244	516989	4737	1,610,060	2,225,729	56,869	18,930,286	973,141	0.05141	0.03252	0.00300	0.01888
45-49	293405	418987	4168	1,245,816	1,708,740	52,132	14,590,324	781,316	0.05355	0.03173	0.00357	0.02182
50-54	240617	340167	3962	952,411	1,289,753	47,964	11,083,208	631,844	0.05701	0.03044	0.00433	0.02657
55-59	181155	236325	3662	711,794	949,586	44,002	8,221,372	476,923	0.05801	0.02892	0.00535	0.02909
60-64	167901	214715	4754	530,639	713,261	40,340	6,152,106	394,445	0.06412	0.02968	0.00656	0.03443
65-69	116980	160364	5235	362,738	498,546	35,586	4,252,547	328,178	0.07717	0.03194	0.00837	0.04524
70-74	91212	135524	6787	245,758	338,182	30,351	2,882,897	251,822	0.08735	0.03206	0.01053	0.05529
75+	154,546	202,658	23,564	154,546	202,658	23,564	1,769,745	NA	NA	0.02719	NA	NA
Total	10,804,960	14,394,062	153,743									

This table represents the calculation procedure and displays values of x and y points (last two columns) which are later used in estimating values of k and c .

APPENDIX 6: GGB method and calculation of plotting points: Kenya both sexes 1989-99

Age Group	Population 1989	Population 1999	Intercensal Deaths	Population Over Age x 1989	Population Over Age x 1999	Deaths Over Age x	Person Years Lived Over Age x	Persons Reaching Age x	Entry Rate: Population Over Age x	Growth Rate: Population Over Age x	x-point	y-point
	$P1(x,5)$	$P2(x,5)$	$D(x,5)$	$P!(x+)$	$P2(x+)$	$D(x+)$	$PYL(x+)$	$N(x)$	$n(x+)$	$r(x+)$	$d(x+)$	$n(x+)-r(x+)$
0-4	3,800,044	4,534,909	109,803	21,418,587	28,496,164	325,802	247,052,134	NA	NA	0.02865	0.00132	NA
5- 9	3468938	3963136	17412	17,618,543	23,961,255	215,999	205,465,910	7,761,467	0.03777	0.03087	0.00105	0.00691
10-14	2989692	4038635	6583	14,149,605	19,998,119	198,588	168,215,779	7,485,927	0.04450	0.03477	0.00118	0.00973
15-19	2378696	3403178	9570	11,159,913	15,959,484	192,005	133,456,530	6,379,484	0.04780	0.03596	0.00144	0.01184
20-24	1903134	2832918	13174	8,781,217	12,556,306	182,434	105,004,594	5,191,782	0.04944	0.03595	0.00174	0.01349
25-29	1629761	2259503	15129	6,878,083	9,723,388	169,260	81,779,135	4,147,354	0.05071	0.03479	0.00207	0.01592
30-34	1159424	1685922	14191	5,248,322	7,463,885	154,131	62,588,235	3,315,207	0.05297	0.03540	0.00246	0.01757
35-39	918892	1419012	13460	4,088,898	5,777,963	139,941	48,606,071	2,565,336	0.05278	0.03475	0.00288	0.01803
40-44	732178	1033491	11211	3,170,006	4,358,951	126,481	37,172,437	1,949,017	0.05243	0.03198	0.00340	0.02045
45-49	574532	838828	10043	2,437,828	3,325,460	115,270	28,472,618	1,567,382	0.05505	0.03117	0.00405	0.02387
50-54	476523	684806	9759	1,863,296	2,486,632	105,227	21,525,175	1,254,501	0.05828	0.02896	0.00489	0.02932
55-59	360172	460016	8782	1,386,773	1,801,826	95,468	15,807,352	936,394	0.05924	0.02626	0.00604	0.03298
60-64	318397	409228	10810	1,026,601	1,341,810	86,686	11,736,709	767,835	0.06542	0.02686	0.00739	0.03856
65-69	230670	301333	11854	708,204	932,582	75,875	8,126,859	619,495	0.07623	0.02761	0.00934	0.04862
70-74	174178	254125	14843	477,534	631,249	64,021	5,490,381	484,227	0.08820	0.02800	0.01166	0.06020
75+	303,356	377,124	49,178	303,356	377,124	49,178	3,382,349	NA	NA	0.02181	NA	NA
Total	21,418,587	28,496,164	325,802									

This table represents the calculation procedure and displays values of x and y points (last two columns) which are later used in estimating values of k and c .

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