Estimates of the Level and Shape of Mortality Rates in South Africa Around 1985 and 1990 Derived by Applying Indirect Demographic Techniques to Reported Deaths

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Forward

The inadequacy of vital statistics in South Africa has made it necessary to undertake detailed analyses of available data in order to derive estimates of the level and shape of mortality experienced. In this technical report historical estimates have been derived for 1985 and 1990 based on indirect demographic techniques applied to reported deaths. High levels of adult mortality were found even though this was a period preceding the impact of HIV/AIDS.

Aside from providing an estimate of the extent of mortality, the study has reiterated the need to improve vital registration. It is heartening to note government's initiative in this direction. The study has also highlighted potential avenues of research to improve the methodologies which can be used for such data.

The findings from this study will not only contribute to describing the demographic changes in South Africa, but they will also contribute to the National Burden of Disease Study which has been initiated by the Medical Research Council in an attempt to derive coherent estimates of the extent of ill health in the Country.

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Abstract

South African death data are known to be incomplete and the level of mortality is unknown for Blacks. This research attempts firstly to estimate both the level and shape of the mortality curve of the Black South African population group circa 1985 by the application of indirect demographic techniques to the reported deaths for the period 1984-86 and an estimate of the Black population in mid-1985. The life tables thus produced are then combined with the official South African Life Tables for Whites, Coloureds and Asians to produce a weighted average national life tables circa 1985. These national life tables are then compared with those produced by applying the Bennett and Horiuchi method to national data for the 1984-86 period in order to decide on suitable adjustments to make when applying the Bennett and Horiuchi method to national data for the period 1989-91 and beyond.

The analysis of the 1984-86 data shows that only 56% of male and 44% female deaths were recorded for the Black population group. Adjusting for this under-reporting the life expectancy at birth for Black South Africans was 56,1 and 63,3 for men and women respectively. Adult mortality as measured by 45Q15 was estimated to be 39% for Black men and 24% for Black women. These estimates suggest higher levels of mortality than previously derived. Comparison with the estimates derived for 1990-91, suggest that there was no improvement in national mortality over the period between the two investigations, both prior to the expected impact of the AIDS epidemic.

The need to improve death registration in general and to obtain more reliable estimates of child mortality were highlighted by the results of this investigation as well as the need to develop improved methods of estimation for such data.

Acknowledgements

Thanks must also go to Ria Laubscher of the South African Medical Research Council for compiling the death data according to year of occurrence, and Basia Zaba and Dr. Ian Timaeus for helpful comments on the thesis upon which this work was based. However these thanks in no way imply responsibility for the end product.

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Notation

N_x	the number of persons aged *x* (e.g. *x* last birthday) at a given point in time (e.g. census date) based on a census or estimate of the population
${}_nN_x$	as above but aged between *x* and *x*+*n*
N_{x+}	as above but aged *x* and over
$\hat{N}$	estimated numbers of persons derived from the registered number of deaths
$N_{x,t}$	the number of persons aged *x* at a point in time *t* years from a given point of time
${}_nN_{x,t}$	${}_nN_x$ at time *t*
D_x	the number of deaths aged *x* (e.g. *x* last birthday) per annum
${}_nD_x$	as above but aged between *x* and *x*+*n*
D_{x+}	as above but aged *x* and over
$D_{x,t}$	the number of deaths aged *x* per annum occurring *t* years from a given point of time
C	the completeness of death registration in relation to a given population estimate
C_x	as above but in the aged *x*
r	the growth rate in a stable population (= *b*-*d*)
r_x	the growth rate of the number of lives aged *x*
${}_nr_x$	the growth rate of the number of lives aged *x* to *x*+*n*
r_{x+}	the growth rate of the number of lives aged *x* and over
b	the birth rate in a stable population ($= N_0/N_{0+}$)
d	the death rate in a stable population ($= D_{0+}/N_{0+}$)
${}_yp_x$	the probability of a life aged *x* surviving to age x + *y* exact according to a particular life table
${}_yq_x$	the probability of a life aged *x* dying before age x + *y* exact according to a particular life table
$c(x)$	the proportion of the population aged between *x* and $x+\delta x$ where δx is an infinitesimal increase in age
l_x	the number of lives surviving to age *x* exact in a life table with radix of $l_0 = 1$ (i.e. $l_x = {}_xp_0$)

Chapter 1

Introduction

There is a dearth of mortality statistics in South Africa particularly as far as the Black population group[1] is concerned. The poor quality of routinely collected vital statistics and the misclassification of causes of death amongst this group have been documented in, for example, Botha and Bradshaw (1985), Bradshaw *et al* (1987) and Bradshaw and Schneider (1995). However, the problem is not confined to only this population group alone. For example, the most recent official life tables for South Africa are the South African Life Tables (SALT) covering the period 1984-86. In addition these are only available for the White, Coloured and Asian population groups and even these estimates are suspect (Bah 1997).

The new government of South Africa has recognised the problem with the mortality statistics (see for example the Draft White Paper on Population Policy (Ministry for Welfare and Population Development 1997)) and efforts are being made by the Departments of Home Affairs and Health to improve vital registration. As this is likely to be a slow process the available data need to be analysed as best as possible. Furthermore, an appreciation of the historical levels and patterns of mortality will be useful in estimating current life tables.

Although not nearly as important as fertility in terms of estimating the population growth and age structure, mortality is nonetheless important. This is especially true if, as is currently the case, demographers are having to project from as far back as 1970 to corroborate current population estimates. In addition to the importance of mortality for population estimation, the level (and shape) of mortality is an important barometer of health and the success of various health interventions. In particular, having a reasonably accurate measure of the level of mortality in young adults could be very useful for monitoring the extent of the AIDS epidemic. Apart from this, more accurate measuring of mortality would assist in improving estimates of the number of pensioners, which would be particularly useful for the costing of such things as social old age pensions.

Until recently the estimation of mortality rates for the Black population group was confined to being a by-product of survival probabilities used to "reconstruct" and reconcile population estimates by, for example, the Human Sciences Research Council (HSRC) (Mostert et al 1987), and Sadie (1988). More recently demographers have focused attention directly on estimation of mortality rates and using indirect techniques (e.g. Dorrington (1989) and Dorrington, Martens and Slawski (1991)) and

[1] The use of designation by population group should not in anyway be construed as support for apartheid or its system of racial classification. It is merely used in this research primarily because the available data are so classified and it is thought working with disaggregated heterogeneous (on account of the vast differences in socio-economic status) data would produce more accurate and useful results than working with aggregated data.

other data sources such as the October Household Surveys conducted by the Central Statistical Services (e.g. Nannan (1996) and Udjo (1997)). However, generally, these estimates have not proved to be very satisfactory.

Ideally mortality rates should be calculated directly using the information on deaths by age and sex produced by the vital registration system. However, often death registration is incomplete and inconsistent. Indirect techniques of mortality estimation have been developed to adjust the results arising from direct estimation using faulty data or (in the case where registration is too poor to be at all useful) to produce rates where none otherwise could be calculated.

Indirect demographic techniques can be broadly divided into two categories. The first comprises those techniques which make use of conventional data (i.e. deaths by age and sex from vital registration and population by age and sex from a census or series of censuses). Examples of these methods are Brass's "growth balance equation" and Preston and Coale's "death distribution method".

The second category comprises those methods which make use of unconventional indicators of mortality (e.g. children ever born and surviving, survival of the most recent live birth and survivorship of spouses).

This research focuses on the application of the first of these categories of techniques. Its primary purpose is to estimate both the level and shape of the Black population group circa 1985. Adult mortality is estimated by the application of these techniques to the reported deaths and as accurate an estimate of the Black population as can be found. For childhood rates the estimates of a wide range of demographers are reviewed and on the basis of this review the best estimates are decided upon. These estimates of childhood and adult mortality are then combined and graduated to produce a set of complete mortality tables for the Black population circa 1985.

After this the research uses these estimated rates together with the SALT for 1984-86 to provide a set of national life tables circa 1985. Comparison of these tables with those that would have been produced using indirect techniques and data covering the country as a whole are then used to provide an improved estimate of the national mortality rates circa 1990.

The report is structured as follows. In Chapter 2 the data to be used are discussed and in Chapter 3 the various indirect techniques for estimating mortality are reviewed with a view to deciding which is best for our purposes.

In Chapter 4 the chosen techniques (those devised by Brass, Preston and Coale, and Bennett and Horiuchi) are applied to the data to estimate the Black adult mortality circa 1985 on two assumptions. First, that the TBVC deaths (that is deaths of people living in the Transkei, Bophuthatswana, Venda and Ciskei - the so-called TBVC "countries") all occurred and were reported in the RSA (defined for our purposes to be the non-TBVC part of the country). Second, that no TBVC deaths have been reported but that the mortality rates are the same in the TBVC and RSA populations. The resultant sets of rates were then averaged to produce a single set of ungraduated adult mortality rates.

Chapter 5 is devoted to a review of all attempts that have been made to estimate infant and childhood mortality for the Black population group with a view to deciding on the best estimates.

Chapter 6 combines the results derived in Chapters 4 and 5 and graduates the crude rates to produce life tables for the Black population group circa 1985 which are then combined with the SALT for the White, Coloured and Asian population groups to produce national life tables circa 1985.

Chapter 7 uses the comparison of the national life tables derived in Chapter 6 with those that would have been derived by applying the Bennett and Horiuchi technique without any adjustment to national data to suggest how the estimate of the percentage of deaths reported need to be adjusted in order to allow for the fact that the percentage of adult deaths that are reported is not constant with respect to age. This adjustment is then applied to the estimates derived by applying the Bennett and Horiuchi method to the data for 1989-91.

Chapter 8 discusses the methods used and results obtained, and draws conclusions from the research. This is then followed by a number of Appendices the last of which contains samples of the spreadsheets used (based on the unadjusted population and death data) in an effort to assist those wishing to replicate the results.

Chapter 2

The data

This chapter briefly identifies the main sources of data to be used, discusses various problems with the data and compares various estimates of the population in order to select one as an estimate of those exposed to the risk of dying.

2.1 Data Sources

South Africa has a vital registration system framed by the legislation in various Births, Deaths Registration and Statistics Acts. Vital events are registered with the Department of Home Affairs and the deaths statistics are compiled by the Central Statistical Service. Census data are collected and compiled by the Central Statistical Service.

A complete bibliography of South African mortality data for the period 1910-1992 can be found in Bourne (1995). It is interesting to note from this that the data have not always been poor, with that for the period 1926-1938 being described by him as being "exceptionally detailed".

One of the many consequences of the apartheid regime's ideology was the hiving off of sections of the population into so-called self-governing homelands. By 1985 four of these (Transkei, Bophuthatswana, Venda and Ciskei - the so-called TBVC "countries") were deemed by the South African government to be independent and hence, in the case of vital registration, responsible for their own data capture and maintenance. However, in any serious demographic analysis, as in many other areas, the farce was apparent in that the TBVC "countries" were always amalgamated with the RSA (in this case used to refer to South Africa excluding the TBVC "countries"). In addition, these "countries" were largely incapable of collecting and maintaining even the simplest form of registration data.

2.1.1 Population

Thus in order to investigate the mortality experience of the Black population in South Africa we need to include the TBVC "countries" in our analysis and to this end the census figures for 1985 for South Africa (as summarised in Appendix 1) are the result of five separate censuses, one covering the RSA (as reported in Mostert, et al (1987)), and one each covering each of the TBVC "countries" (Transkei (1987), Bophuthatswana (1987), Venda (1987) and Ciskei (1986)). (Appendix 1 also contains quinquennially summarised estimates (as opposed to census enumerations which significantly under estimate the population) of the population for the years 1980, 1985 and 1990.)

2.1.2 Deaths

Similarly for the deaths, five sources had to be canvassed. However, whereas detailed record of the deaths registered in the RSA[2] were available, repeated attempts[3] to find records of deaths in the TBVC "countries" bore little fruit. Some aggregate numbers were obtained for Transkei and Venda but these figures accounted for less than a quarter of the expected number of deaths and did not cover the whole period, were not split by age, and for the most part were not even split by sex. Therefore for the purposes of this exercise it was decided to disregard these data and to regard the TBVC-deaths as being effectively institutionalised under-reporting. (Although it is possible that this could jeopardise the assumption that under-registration of deaths is age-invariant in that the proportion of the population in the RSA is not constant throughout the age range, it is likely that some of the TBVC-deaths probably took place in the RSA and many of these were probably registered as deaths in this area).

In addition to these difficulties there is the question of whether to use the deaths as recorded by year reported (the published data (CSS 1986a, 1986b, 1987a to 1987d, 1991a, 1991b, 1992a, 1992b, 1993a, 1993b)) or by year of occurrence (derived from the computerised records[4]). As can be seen from Figure 2.1 there is a big difference between these figures for 1986. Furthermore, this difference was not only confined to the level of reporting but, as can be seen from the comparison in Tables 8.1(a) and 8.1(b), there was also a difference in the pattern of deaths recorded by age.

Figure 2.1: Ratio of total deaths by year of occurrence to that by year reported

[2] According to the Births and Deaths Acts of 1974 and 1992 all deaths must be registered with the Department of Home Affairs. These data are then collated by the Central Statistical Services.

[3] Letters were written and phone calls made to, amongst others, the Departments of Commerce, Industry and Tourism (Transkei), Economic Affairs (Bophuthatswana), Internal Affairs and Manpower (Venda) and the Directorate of Planing - Statistical Branch (Ciskei) and the Development Bank of South Africa.

[4] Obtained from the MRC databank of the annual death data provided by the CSS.

Although, all other things being equal, the preference would be to use deaths by year of occurrence, as these data might be expected to be more complete, for this research it was decided to use the deaths as reported by the Central Statistical Services (in other words by year reported) for the following reasons:

1. No reasonable explanation for the difference could be found. Investigation into the hypothesis that the extra deaths could be due to an increase in deaths due to "external" (or even "ill-defined") causes proved inconclusive. In addition, the differences were not confined to the Black population group alone.
2. Deaths by year reported were used to produce the South African Life Tables (Clothier 1989) and it was thought that consistency was desirable, particularly since the SALT are used to produce national life tables for 1984-86 and 1989-91.
3. Application of the indirect techniques discussed in this thesis invariably make use of deaths by year reported, mainly because these are the data which are most readily (and speedily) available. (Investigation suggests that deaths can take anything up to four years and occasionally longer to be reported.)

Thus the data used in this study (reproduced in Appendix 2) are those reported in the RSA alone, recorded by year reported.

2.2 Problems with the data

The mortality rates derived by dividing these deaths at each age by the relevant census enumeration in 1985 are presented together with, for comparative purposes, the SALT for 1984-86 for Coloureds (CSS 1987e) in Figures 2.2 and 2.3 for males and females respectively.

Apart from the fact that the direct estimates produce implausible estimates of the true mortality, a number of other features can be noted.

1. There was significant under-reporting of deaths relative to the census enumeration. A rough comparison of the crude rates against those of the Coloureds suggests that <u>at most</u>[5] only 65% of male deaths and 54% of female deaths were recorded.
2. There is obvious digit preference of the deaths relative to the enumerated population (which, as can be seen from Appendix 1, was itself prone to digit preference). Age 10 in childhood and ages 30, 40, … 70 in adulthood appear to be most favoured (although a number of ages ending in 5, 2 and 8 were also favoured). Most of this digit preference can be eliminated by grouping the data quinquennially.
3. The ratio of the Black mortality rates to those of the Coloureds falls with increasing age. Although this could be the result of increasing under-reporting of deaths as age increases it is more likely to be the result of age exaggeration in the census relative to that in the reported deaths.

Thus, in order to estimate mortality rates we will need to resort to indirect techniques.

[5] Both because the population is likely to be significantly under-enumerated and because it is unlikely that the mortality rates of Blacks would be significantly below those of Coloureds for most ages.

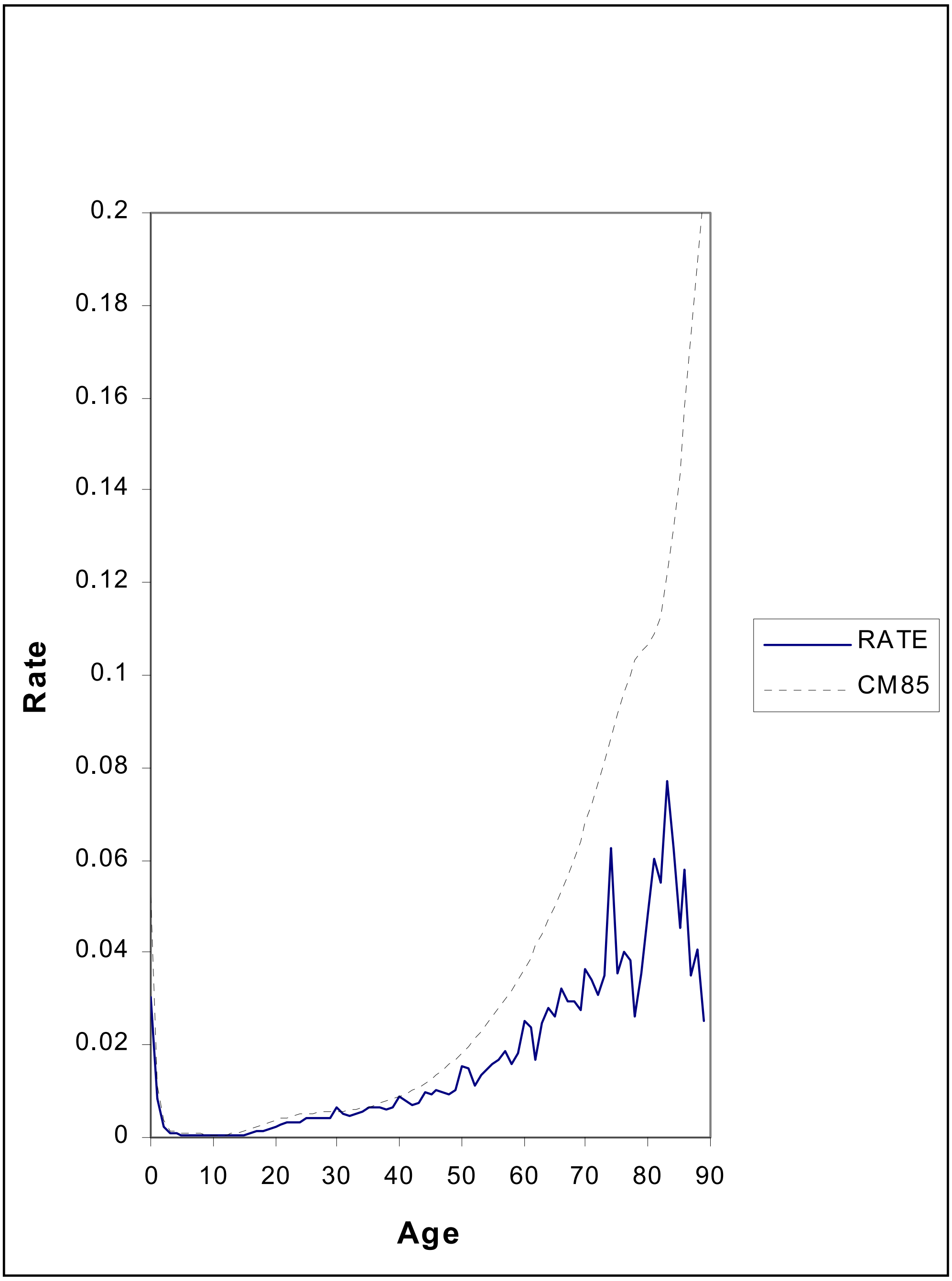

Figure 2.2: Crude rates: Males circa 1985

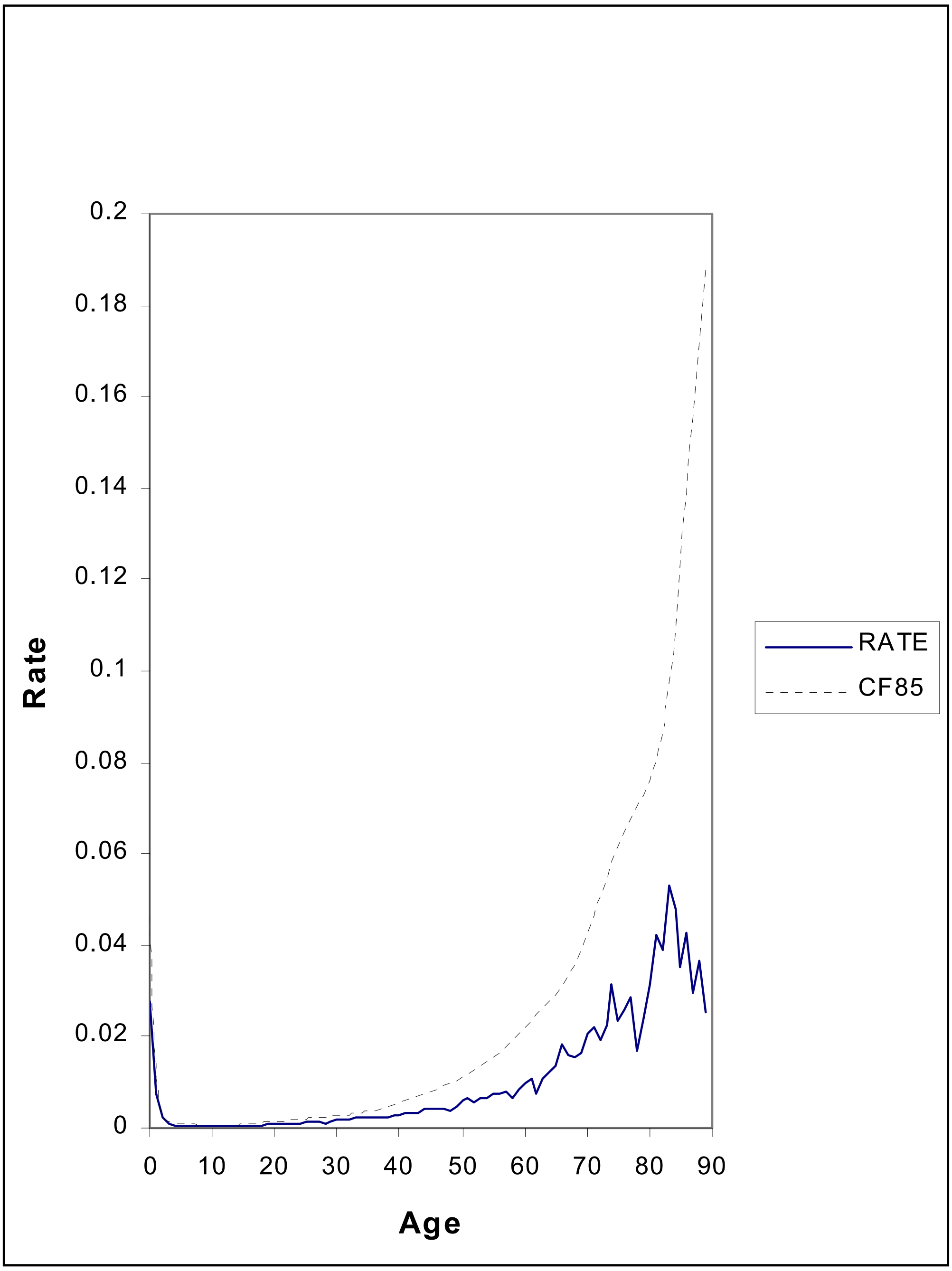

Figure 2.3: Crude rates: Females circa 1985

2.3 Selection of the population estimate

In order to estimate the mortality rates it is necessary to have an estimate of the population exposed to the risk of dying. For this investigation we have three potential sets of estimates to consider. Firstly, there are the census enumerations of the *de jure* population, as used above. However, in addition to these there are two attempts at estimating the South African-born population; those by the HSRC for the census years

1936-85 (Mostert, *et al* 1987) and those by Sadie (1988) up to 1985 together with his estimate of the 1991 population (CSS 1993c).

Figures 2.4 and 2.5 show for 1985 a comparison of the HSRC estimate and that of Sadie with the enumerated censuses for males and females respectively. The HSRC estimates suggest that the 1985 census under-enumerated the population by some 20% whereas Sadie's estimates suggest the figure is more in the region of 14%. In both cases the female population appears to have been better enumerated than the male population.

Typically, applications of indirect techniques for estimating mortality make use of census enumerations. For this research, however, it was decided to use one of the estimates of the population, since, as is indicated below, the under-enumeration is quite extensive. In addition it was thought that making use of the demographic expertise implicit in the population estimates (none of which relied upon reported deaths) would result in substantially improved estimates of mortality rates, particularly at the older ages.

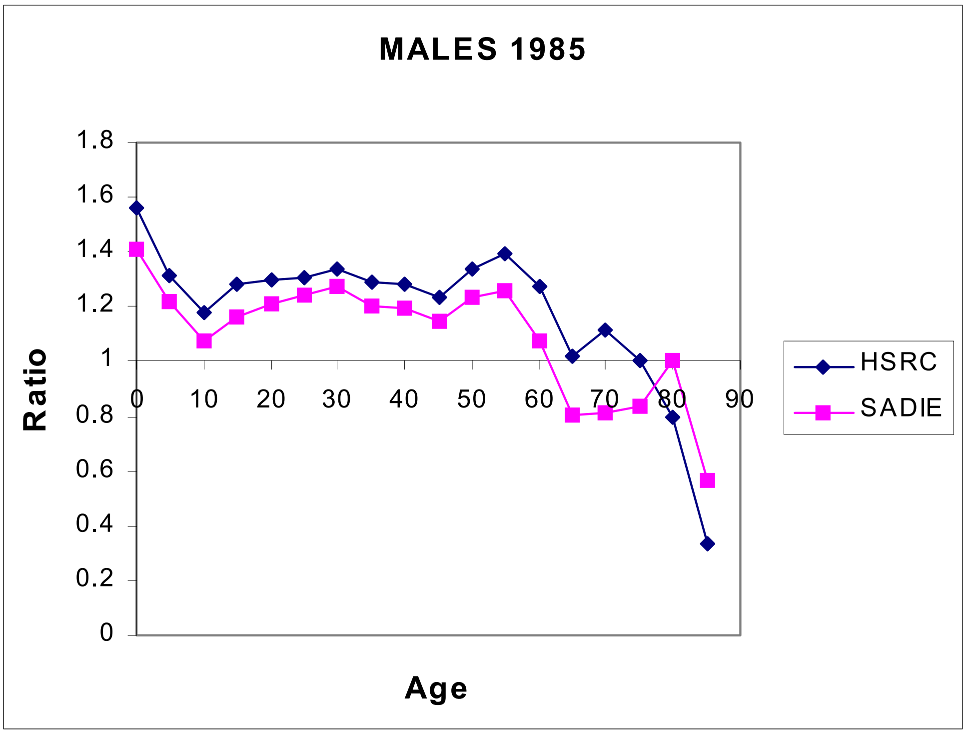

Figure 2.4: Ratio of population estimates to the census enumeration: Males 1985

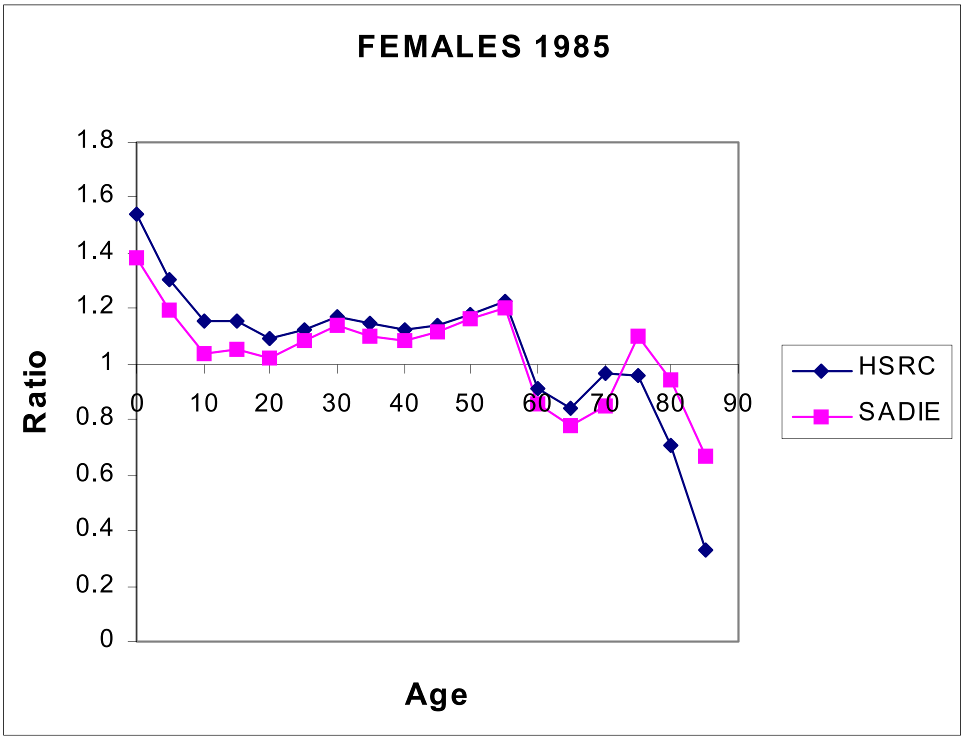

Figure 2.5: Ratio of population estimates to the census enumeration: Females 1985

From the comparisons in Figures 2.4 and 2.5 we can note the following:

1. The apparent age exaggeration at the older ages (particularly ages 60 to 75) in the enumerated population which is confirmed by the pattern of crude mortality rates produced above (on the assumption that the level of under-reporting of deaths is age invariant over the adult ages). Sadie's estimates correct for this to a greater extent than the HSRC's (particularly for males) with the exception of the oldest ages (where the HSRC's estimates border on the implausible). In addition in the case of Sadie's estimates there appears to be a correspondence in the pattern of age exaggeration between males and females (with the effect being noticeable five years older in males) whereas with the HSRC estimates there is no such correspondence.
2. As might be expected there is relatively larger under-enumeration at the youngest ages. (Although we may not be able to confirm the actual extent of this under-enumeration this is not of much concern since we will be estimating childhood mortality as a separate exercise.)
3. With the exception of the age exaggeration at the older ages the shape of the three populations above age 10 are very similar which means that they would probably produce similar estimates of adult mortality (provided a suitable open interval was chosen) using indirect estimation techniques.

For these reasons and because Sadie's estimates span a wider range (in particular since his are the only estimates available for the whole of South Africa for 1991[6]) and since consistency is desirable it was decided to use Sadie's estimate of population for this research. However, such a decision should not be seen to imply that his estimates are regarded as being without fault. (Indeed certain inconsistencies in his implied growth rates are discussed in Chapter 4.)

[6] Although censuses were undertaken in each of the TBVC "countries" in 1991 only two were published (Transkei 1994 and Bophuthatswana, n.d.).

Chapter 3

Methodology

This chapter describes the Brass, Preston and Coale, and Bennett and Horiuchi indirect techniques for estimating mortality rates making use of conventional data (i.e. deaths by age and sex from vital registration and population by age and sex from a census or series of censuses). It starts with a fairly detailed description of the Brass, and Preston and Coale methods. Then the chapter considers the impact of violations of the various assumptions underlying these methods and how to cope with such violations, in particular, the generalisation of the Preston and Coale method by Bennett and Horiuchi to allow for non-stable populations. For this research it was decided to apply the Brass and the Preston and Coale methods, on the assumption that the population is at least quasi-stable, and for their easy to interpret diagnostic patterns, and the Bennett and Horiuchi method to allow for departures from stability and to investigate whether it leads to significantly improved estimates of completeness.

3.1 Indirect demographic techniques

Conventional infant and child mortality data (i.e. births, infant and child deaths and child population by age) are subject to potentially large and unpredictable errors and no well-established method for producing infant and child mortality rates by correcting for errors in these data has been developed. Thus the indirect methods making use of conventional data are really only useful for estimating adult mortality. (Infant and child mortality estimation is dealt with in Chapter 5.)

The early methods developed were based on the 'convenient' assumptions that the population is both closed (i.e. no migration) and stable (i.e. has been subject to constant fertility and mortality for a long time and as a result the rate of (exponential) growth of the population and deaths at all ages and births is constant over time). The assumptions are convenient because for a closed population the age distribution is determined by the births and age-specific death rates and in a stable population the proportion in various age groups remain invariant over time thus providing various consistency checks[7]. Also in countries where such methods are needed age-specific growth rates (and age-specific migration) cannot be generally accurately measured directly.

[7] As was first shown by Lotka (Lotka and Sharpe 1911) a closed population subjected for an extended period to unchanging fertility and mortality acquires an unchanging age distribution determined solely by the constant rate of growth and mortality rates. In other words $c(x)$, the proportion of the population aged between x and $x + \delta x$ (where δx is an infinitesimal addition to age) is given by $c(x) = be^{-rx}\,{}_x p_0$. Such a population is known as a stable population.

These assumptions are usually justified by the observation that in many of the countries where these methods are applied the populations are indeed "quasi-stable" in that fertility and mortality have remained fairly level, with fertility only dropping within the previous 15 or so years and mortality improving at a slow steady rate. It is also argued that the methods are fairly robust to this sort of violation of the stability assumption.

In addition the methods assume that coverage of death registration does not vary with age after childhood and that reporting of age at death and in the censuses is accurate.

Although these assumptions are somewhat unrealistic, some of the procedures give diagnostic indications of the acceptability or otherwise of these assumptions. Further, there are both internal consistency (e.g. agreement between the sexes of growth rate estimates, or the closeness of fit of the data to the model) and external consistency (plausibility of age pattern of mortality or agreement with other estimates) checks that can be carried out on the results.

3.2 Brass growth balance method

Carrier (1958) first proposed a method for estimating mortality from the age distribution of deaths but it wasn't until 1975 that Brass developed his growth balance equation. He pointed out that in a stable, closed, population the rate at which new members enter the age group *x* and over (i.e. turn *x*) is equal to the rate at which they depart from this age group from death plus the stable population growth rate.

i.e. $$b_{x+} = r + d_{x+} \quad \text{or} \quad \frac{N_x}{N_{x+}} = r + \frac{D_{x+}}{N_{x+}} \qquad (3.1)$$

In other words N_x / N_{x+} (i.e. the number of people reaching age *x* in a year divided by the mid-year population aged *x* and over) can be thought of as being the *segmental birth rate* and D_{x+} / N_{x+} as the *segmental death rate*.

Now suppose that instead of D_{x+} we had D^r_{x+}, the recorded number of deaths over age *x*, i.e. $D_{x+} = C_{x+} D^r_{x+}$ where C_{x+} is the measure of completeness of registration of deaths at age *x* and over. If it is assumed that the completeness of registration is invariant with age, at least for the adult ages, then $C_{x+} = C$ and equation (3.1) can be rewritten as

$$\frac{N_x}{N_{x+}} = r + K \frac{D^r_{x+}}{N_{x+}} \quad \text{where } K = 1/C \qquad (3.2)$$

Thus provided the population is closed and stable and that age-reporting is accurate we have a method for estimating the completeness of registration (i.e. the reciprocal of the slope that results from regressing D^r_{x+} / N_{x+} against N_x / N_{x+}).

In practice, in order to ameliorate the effects of random fluctuations and, to a certain extent, age misreporting, the population and death data are usually grouped quinquennially and N_x is usually estimated by $({}_5N_{x-5} + {}_5N_x)/10$. In addition the straight line is usually fitted using some "robust" method such as either the "mean" line (i.e. the line defined as that joining the two points represented by the mean of the vertical axis values and the mean of the ages of the first half and the second half of the age range) or the "trimmed mean" line (i.e. the same as the mean line except that the average of the points is a weighted average - weighting the less reliable points, usually at the extremes, less than the other points). Least squares fit without some adjustment for extreme outliers is generally not favoured since it exaggerates the importance of outliers.

It is sometimes suggested that if a reliable independent estimate of r exists (and the population is stable) then one could replace K with $K_{x+} = (N_x - rN_{x+}) / D^r_{x+}$ and thus be able to estimate the extent of under-registration of each open ended group. However, in practice it is rare to find a sufficiently stable population with sufficiently accurate age reporting to make such an exercise worthwhile. Nevertheless, it is generally assumed that the more credible the estimate of r the greater will be the confidence in the estimate of C.

This method is less vulnerable to age misreporting than the Preston and Coale method discussed below. (In particular, for example, a consistent tendency to exaggerate the age reported at death (relative to that recorded at census) will manifest itself by the plotted points curving off to the right over the range of exaggerated ages and this can be allowed for.) It is, however, more vulnerable to the effects of destabilisation resulting from a rapid decline in mortality (Martin 1980), in which case it tends to underestimate the extent of completeness since the lighter mortality is "interpreted" by the model as increased under-reporting (i.e. steeper slope). However, simulation has shown (Rachad 1978) that the effect of a slow steady improvement in mortality (as is often experienced by developing countries) is quite small.

As far as changes in fertility rates are concerned, provided these have occurred only fairly recently these changes will have little impact on the performance of the method since they affect mainly the youngest age groups.

Migration is likely to effect the young adult population but to have much less effect on deaths which largely occur in old age. Immigration will tend to lower the slope and hence lead to an over estimate of the extent of death registration and an under-estimate of mortality rates. Emigration will have the opposite effect.

Fluctuations with age in the completeness of death registration are likely to introduce curvature in the pattern of points.

Consequently, it is one of the strengths of this method that if the points for successive age boundaries fall on a reasonably straight line then most of the assumptions are probably acceptably valid and the method can be applied. However, where some but not all the points lie on a straight line one way of deciding which points to discard is to calculate the segmental growth rate for each successive open interval and then use those points for which the values of r_{a+} are reasonably consistent.

3.3 Preston and Coale death distribution method

This method which arises out of work by Preston and Hill (1980) further developed by Preston *et al* (1980), has its origins in the method of extinct generations set forth by Vincent (1951). It is based on the simple idea that the number of persons at a particular age at a point in time will be equal to the total number of deaths arising from this population from that time until the last survivor has died.

In a stable and closed population the relationship is:

$$N_x = \sum_{a=x}^{\varpi} D_a e^{r(a-x)} \qquad (3.3)$$

where D_a are the deaths at the same point in time as N_x (since in a stable closed population $D_{a,t}$, the deaths aged *a* which are expected to occur *t* years from the year in which the deaths were reported, is equal to $D_a e^{rt}$).

Now if instead of D_a we have D_a^r, the <u>recorded</u> number of deaths aged *x* last birthday, and if we estimate the population aged *x*, $\hat{N}_x$, by $\hat{N}_x = \sum_{a=x}^{\varpi} D_a^r e^{r(a-x)}$ then $\hat{N}_x / N_x$, where N_x is the population at the mid-point of the period over which the deaths have been recorded, gives an indication of the percentage registration for ages *x* and over, C_{x+}. If the N_x are available at some other point in time then they can simply be adjusted for the growth over the period between the two times using the growth rate *r*, although if the level of completeness is to be used to estimate mortality rates (as is the case with this study) the same correction would, in effect, be made to both the numerator and the denominator and thus could be ignored.

There is, however, a problem in computing $\hat{N}_x$ in practice and that is that the D_a^r are unlikely to be available beyond a certain age (and even if they are, are unlikely to be very accurate) with all reported deaths above that age being grouped together in an open interval, D_{A+}^r where *A*+ is the lower bound of the age interval. However, it has been shown (UN 1983, 134) that by assuming that the pattern of mortality fits one of the Coale and Demeny (Coale and Demeny 1966) life tables $\hat{N}_A$ can be estimated as follows:

$$\hat{N}_A = D_{A+} e^{rz(A)} \text{ where } z(A) = a(A) + b(A) + c(A) e^{[D_{45+}/D_{10+}]}.$$

The coefficients have been tabulated (Table 123, UN (1983, 134)) and D_{45+}/D_{10+} is estimated by D_{45+}^r / D_{10+}^r. Since $\hat{N}_x$ can be approximated by

$$N_{x+5} e^{5r} + {}_5D_x^r e^{2.5r}, \qquad (3.4)$$

once $\hat{N}_A$ has been estimated the $\hat{N}_x$ can be estimated from the ${}_5D_x^r$.

In practice in order to correct, to some extent, the effects of digit preference in age reporting and also to be consistent with the age grouping in the population it is usual to compute ${}_5\hat{N}_x = 2.5(\hat{N}_x + \hat{N}_{x+5})$. Further, since the sequence of ${}_5\hat{N}_x / {}_5N_x$ is usually still somewhat erratic (because of age misreporting and differential omission of persons in particular age spans) it is usual to assume that the percentage reported may be expected to be roughly constant with respect to age for ages greater than, say, 10 and to estimate this fixed proportion C by either the mean or median of the ${}_5\hat{N}_x / {}_5N_x$ values over a representative span of ages. The sequence of ${}_5\hat{N}_x / {}_5N_x$ values is usually plotted together with that of ${}_A\hat{N}_x / {}_AN_x$, where ${}_A\hat{N}_x = \sum_{a=x}^{A-5} {}_5\hat{N}_a$, which tends to be more stable.

In practice both the sequences of ${}_5\hat{N}_x / {}_5N_x$ and ${}_A\hat{N}_x / {}_AN_x$ are affected by violations of the assumptions. However, part of the power of this technique is that most of the typical violations of assumptions produce fairly distinctive characteristic deviations from the expected horizontal plot and in certain circumstances these patterns are interpretable. The following are examples:

(a) *Incorrect growth rate*: If r is too high the sequences fall nearly linearly with increasing age towards the underlying value of completeness and vice versa, as can be easily concluded from inspection of equation (3.3). The effect is greater for ${}_5\hat{N}_x / {}_5N_x$ than for ${}_A\hat{N}_x / {}_AN_x$.

(b) *Exaggeration of reported age*: Typically age exaggeration is greater at death than in the living and this produces rising sequences which are imperceptible up to the age at which exaggeration begins followed by a sharp upward curve thereafter. Again this can be seen from inspection of equation (3.3) in that age exaggeration not only leads to an increase in the number of deaths in the older age categories, but, in addition, transfers within a category lead to those deaths being multiplied by a larger exponential term, although this effect is far smaller. Although such a pattern would also be produced by rising completeness in death registration with age beyond a certain age there appears to be no evidence of this (or indeed any systematic variation with age) in practice (Preston *et al* 1980).

(c) *Departures from stability*: Any disruption to the regular growth in cohort size will be reflected in an other than expected value for ${}_5N_x$. For example, either a general decline in fertility in recent years or spasmodic events such as war, famine, etc. which impact on the size of a cohort, will be reflected by lower than expected (on the basis of the stability assumption) ${}_5N_x$ values and hence higher than average values of ${}_5\hat{N}_x / {}_5N_x$ for these age intervals. Provided these distortions can be identified the value of the ratio at these points can be ignored for the purposes of estimating completeness. A more frequent occurrence in developing countries is slow steady declining mortality over the past 30 to 40 years which causes a limited departure from the stable age distribution which results in a sequence of ${}_5\hat{N}_x / {}_5N_x$ which first rises then falls while the sequence of ${}_A\hat{N}_x / {}_AN_x$ falls steadily with increasing age.

Unfortunately because misstatement of reported age by the population will cause the ${}_5\hat{N}_x / {}_5N_x$ ratios to be somewhat erratic it is not always easy to distinguish between the effects of the different violations of the underlying assumptions. Since ${}_5\hat{N}_x$ is cumulative in form it tends to follow the stable age distribution quite closely and hence if there are zigzags it is likely that the peaks may be associated with under-enumeration in the population estimates and troughs with over-enumeration. Any evidence to support the pattern of under- and over-enumeration would allow one to disregard or adjust those points in determining the overall completeness of registration.

Generally the effect of overstated ages can be largely removed by beginning the open interval at a lower age so as to confine most of the overstatement to the open interval.

As far as distinguishing a declining sequence of ratios due to improving mortality from that due to the choice of too high a growth rate, one needs to look to other grounds to decide. If the population has experienced a decline in mortality the median of the ratios of cumulated populations from 10 to, say, 45 ought still to provide a reasonable estimate of the completeness of death registration. Although this method has a lot to recommend it and is more robust to departure from stability than the Brass method, it is more sensitive to certain types of age misreporting and it will not always be possible to obtain one single unambiguous estimate of completeness unless one can confirm the assumptions (particularly the growth assumption) by other means.

3.4 Relaxing the assumptions

As already mentioned, the above two procedures rely on a number of assumptions, namely, that the population is closed, that the ages are reported accurately, that completeness of death registration is invariant with respect to age and that the population is stable. Each of these is examined in more detail below.

3.4.1 International migration

Although provided one has age-specific net migration rates one can adjust an open population so that it models a closed population. In practice such information is rarely available and the best that can be done is to limit the application of these techniques to populations which haven't been subjected to substantial net migration.

In the case of this investigation we can ignore the effect of migration since the population estimates being used are those of the *de jure* population. (In any case, given South Africa's apartheid history, it is to be expected that net migration of, at least, African lives has been negligible.)

3.4.2 Age overstatement of deaths at higher ages

Although it is known that age is exaggerated in both census and death reporting, for our purposes we can assume that to a large extent this exaggeration has been removed from the population estimate and our concern is that too high a proportion of deaths appear at the older ages (for a given age distribution). This would result in the estimate of the completeness of death registration being biased upward and hence in the mortality being underestimated.

As indicated above, for the Brass technique this can be dealt with by simply ignoring the observations at these ages. For the Preston and Coale and the Bennett and Horiuchi (see section 3.4.4) methods the recommended procedure is to employ an open-ended interval that begins at an age below that beyond which age exaggeration is thought to take place (and estimating the mortality in this open interval by assuming some sort of model age distribution).

3.4.3 Death registration completeness varying with age

In the Brass method if completeness of registration increases with age, the estimate of *C* (derived from the slope of the line) will be biased upward and vice versa. However, in the Preston and Coale (and the Bennett and Horiuchi) methods the estimated value of *C* is a weighted average of the age-specific values of *C* actually prevailing (Preston 1984). Thus, if there is thought to be some consistent trend in completeness of death registration with respect to age then the results of these methods are to be preferred to that of Brass (although marked variation in completeness would make refinement of growth estimates problematic).

3.4.4 Relaxing the stability assumption

Equations (3.1) and (3.3) can be modified to be applicable to non-stable populations by replacing *r* with age-specific growth rates as follows.

For the Brass method: $\frac{N_x}{N_{x+}} = r_{x+} + \frac{D_{x+}}{N_{x+}}$ (3.5)

as suggested in UN (1979).

For the Preston and Coale method: $N_x = \sum_{a=x}^{\varpi} D_a e^{\int_x^a r_u du}$ (3.6)

as suggested by Bennett and Horiuchi (1981).

3.5 Bennett and Horiuchi method

The computational form of equation (3.6) is

$$N_x = N_{x+5} \exp[5 \cdot {}_5r_x] + {}_5D_x \exp[2.5 \cdot {}_5r_x]. \quad (3.7)$$

This is, of course, simply a more general form of the expression given in equation (3.4).

However, Bennett and Horiuchi (1981 and 1984) propose using the age group specific growth rates to improve both the $\hat{N}_x$ at the older ages and $\hat{N}_A$ where *A* is the age at the start of the open interval. They suggest calculating $\hat{N}_A$ as follows:

$$\hat{N}_A = D^r_{A+}\left[\exp(r_{A+} \cdot e_A) - (r_{A+} \cdot e_A)^2 / 6\right].$$

They also suggest that in order to allow for the greater curvature at the older ages equation (3.7) be modified as follows:

$$\hat{N}_x = \hat{N}_{x+5} \exp[5 \cdot {}_5r_x] + {}_5\gamma_x \cdot {}_5D^r_x \exp[2.5 \cdot {}_5r_x]$$

where ${}_5\gamma_x = 1.00 - 2.26 \cdot {}_5r_x \cdot \frac{{}_5D^r_x}{{}_5N_x} + 0.218 \cdot {}_5r_x - 0.826 \cdot ({}_5r_x)^2$.

In addition to this they suggest that the ${}_5\hat{N}_x$ above age 60 be approximated by "imposing a stable population curve over the five-year span and then determining the area under the curve accordingly".

Finally they suggest that completeness can be measured from the median of the series of ${}_{10}\hat{N}_{x-5} / {}_{10}N_{x-5}$ (after, if necessary, correcting the age group specific growth rates by a constant factor, δ, to produce a "flat sequence"[8] of ${}_{10}\hat{N}_{x-5} / {}_{10}N_{x-5}$.

Usually in order to estimate age-specific growth rates one needs two censuses (preferably one either side of the period over which the deaths have been recorded). However, in practice, it is often the case that errors in the census enumerations (particularly differential under-enumeration) render such estimates unreliable.

For our purposes, however, we have access to a more useful set of age-specific growth rates - those implied by the population estimates at the various census dates. It may be assumed that these rates have been fairly extensively investigated by the demographers concerned to ensure that their population estimates are consistent with known data about the population.

[8] $1 - \delta t$, where t is the length of the intercensal period, gives an indication of the differential completeness between the two estimates of the population used to estimate the age group specific growth rates.

Chapter 4

Adult mortality for Blacks: 1984-86

This chapter is concerned with the estimation of the adult mortality rates of the Black population group. It starts with a discussion of the problem of the missing TBVC deaths. This is then followed by an investigation of the reasonableness of the stability assumption. After this the Brass, Preston and Coale, and Bennett and Horiuchi methods are applied to the data assuming that TBVC deaths occurred in (and if they were registered, were registered in) the RSA. Following this the Bennett and Horiuchi method alone is applied to the data scaled up on the assumption that no TBVC deaths occurred in the RSA but that the mortality rate can be assumed to be the same in the two regions. These estimates are then combined to produce a single set of estimated rates.

4.1 The missing TBVC deaths

As was mentioned in Chapter 2 the deaths which occurred in the TBVC area are effectively excluded from the data. As the proportion of the population resident in the TBVC area does not remain constant with respect to age (see Table 4.3) it is possible that the omission of the deaths arising from this population could lead to the incorrect estimation of the growth rate and hence the extent of under-reporting. In this chapter two different strategies for estimating the extent of under-reporting are considered. In the first, as is usually the case in practice, the various indirect techniques are applied to the deaths as recorded, without any adjustment. In effect this assumes that most of the TBVC deaths (i.e. those arising out of the population resident in the TBVC area) occurred in the RSA and were recorded (to the same extent as the RSA deaths) as such.

The second approach is to assume that none of the TBVC deaths were recorded and hence that all recorded deaths correspond to the RSA population alone. Thus an estimate of the total deaths which could have been reported had the TBVC been subjected to the same mortality rates and level of reporting as the RSA is obtained by scaling up the RSA reported deaths by the total population divided by that for the RSA.

In the first case all three of the techniques (Brass, Preston and Coale, and Bennett and Horiuchi) are applied to the data. In the second, the Bennett and Horiuchi method only is applied to the scaled up deaths. The results are then compared with a view to deciding on the best estimate of mortality rates.

4.2 The question of stability

The next step in applying the various indirect techniques is to decide whether the population is stable (or at least quasi-stable) and if not then to get an idea of the age-group specific growth rates in order to apply the Bennett and Horiuchi method.

Figures 4.1 and 4.2 compare the age-group specific exponential growth rates over the period 1980 to 1985 for the three population estimates (census, HSRC and Sadie) for males and females respectively.

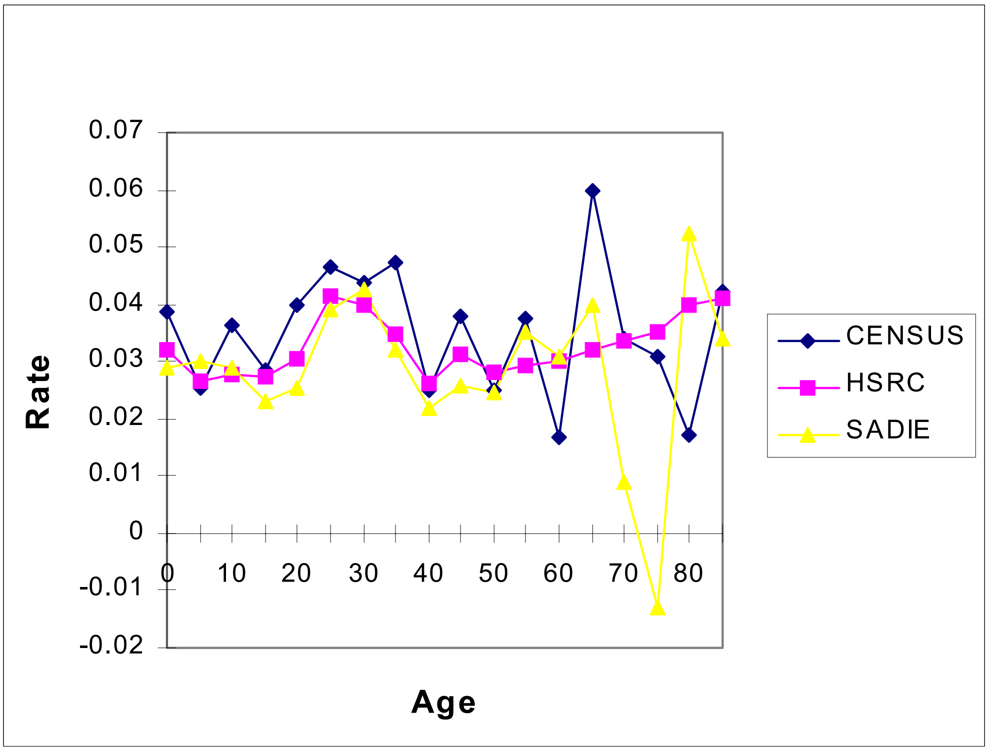

Figure 4.1 Growth rates: Males 1980-85

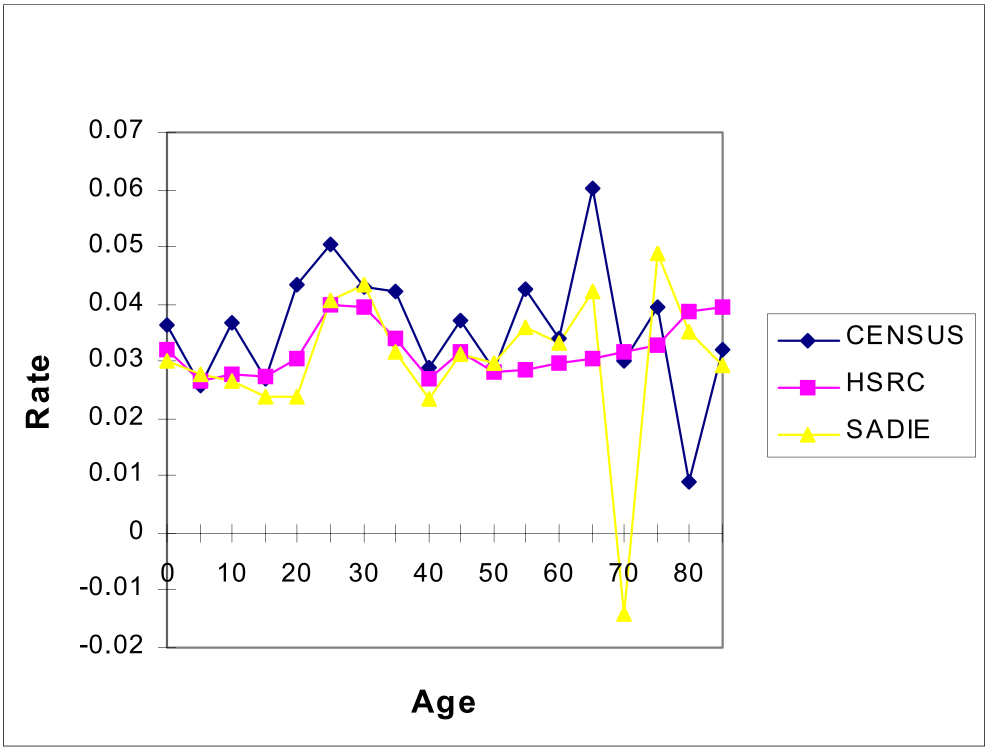

Figure 4.2 Growth rates: Females 1980-85

From these comparisons the following can be noted.

1. The pattern of growth rates are remarkably consistent (taking into account that the census growth rates need to be corrected - by a deduction of about 0,4% p.a. - for an estimated improvement in enumeration in the 1985 census of over 2%) particularly since the two estimated populations were carried out independently one of the other and using different methods.
2. Apart from growth rates at the oldest ages implied by Sadie's estimates (which seem improbable) the population may be regarded, for the purposes of most indirect techniques (where data are usually aggregated over open age intervals) as being stable. For the most part the population grew at around 3% until the early 1940s when the growth rate increased owing to a rapid fall in the Infant Mortality Rate (IMR) until the late 1950s. After that point the growth rate began to fall with the decline in the fertility rate which appears to have peaked around 1960 (Sadie 1988).

4.3 Brass growth balance method

Figures 4.3 and 4.4 illustrate the application of Brass's growth balance method to the data for 1984-86 for males and females respectively[9]. The straight line is the least squares regression[10] of the first 14 points (i.e. up to x=70).

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[9] As there is usually a significant amount of curvature in the older portion of the age distribution, N_x for x = 80 and 85 were estimated by assuming the population curve over the age range x-5 to x+4 was stable and the force of mortality followed a Gompertz curve, and approximating $\mu_{x+2.5}$ by

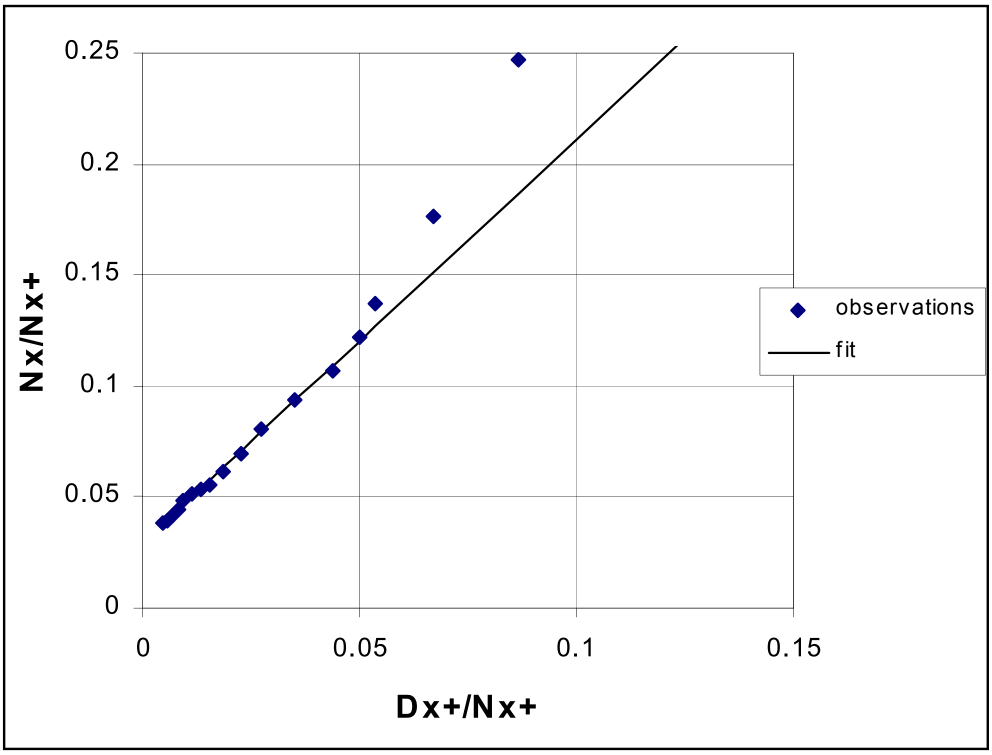

Figure 4.3 Plot of partial birth rates against partial death rates: Males

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$\frac{\ln c}{1-c^5}\left[\ln\left(\frac{{}_5N_{x+5}}{{}_5N_x}\right)+{}_{10}r_x\right]$ where c was arbitrarily chosen to be 1.1 (Bennett and Horiuchi 1981) and ${}_{10}r_x = r$.

[10] A "mean line" was fitted to both the first 14 as well as the second seven points (on the grounds that the early points represented a move away from stability). The three lines were very close, with the regression lying between the other two. The regression was preferred on the grounds that the mean line fit to the first 14 points was probably biased by the higher growth rates in more recent years while the mean line fit to the second 7 points was felt to be less robust.

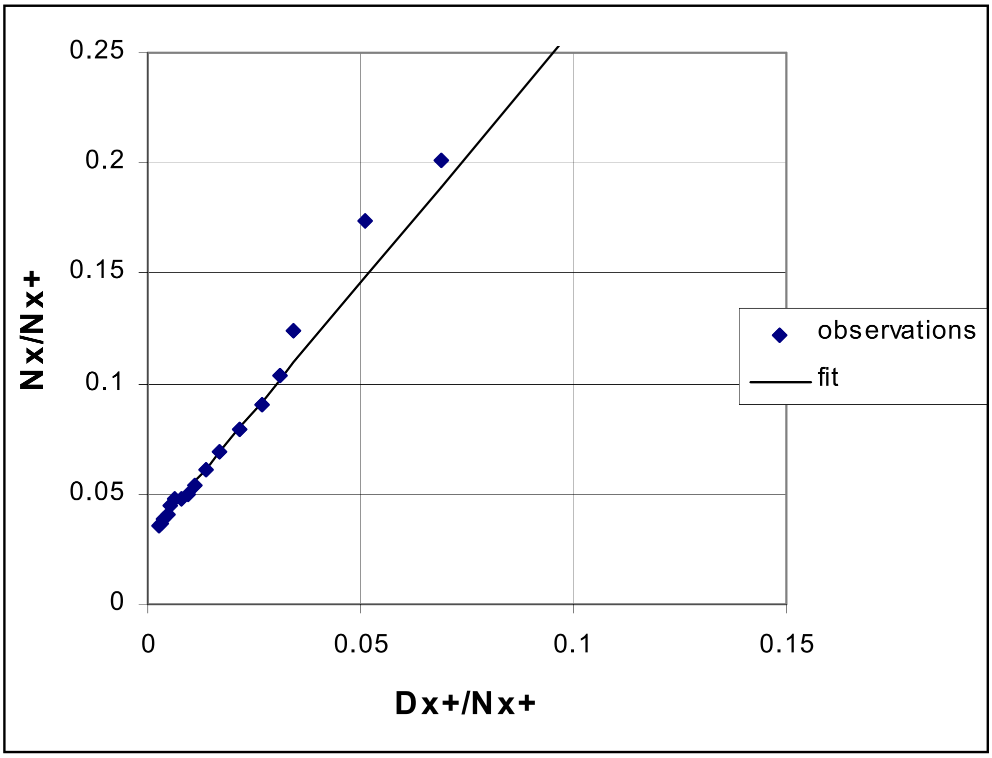

Figure 4.4 Plot of partial birth rates against partial death rates: Females

The following can be observed from these figures.

1. The equations for the fitted lines are:
   Males: $b_{x+} = 0.0293 + 1.8212 d_{x+}$
   Females: $b_{x+} = 0.0300 + 2.3097 d_{x+}$
   This suggests a population growth rate of about 2.9%-3.0% and that 54.9% of male and 43.3% of female deaths were reported.
2. The points up to the age 70 fit the straight line very closely and the growth rates (2.93% for males and 3.00% for females) are consistent not only with the previous (and subsequent) estimates but also consistent one with the other.
3. The last three points, representing the open age groups 75+, 80+ and 85+, lie distinctly above the straight line. This is somewhat unexpected since, if anything, one might have expected the points to curve to the right (showing age exaggeration of deaths relative to the population, which has been adjusted to remove all age exaggeration).

There are two possible explanations for the pattern observed above. The first is that the ages of the deaths have been understated and the second is that the deaths in these age groups are under-reported to a significantly greater extent than is the case for the younger age groups.

On the face of it neither of these explanations seems very plausible. However, further investigation revealed that a not insignificant number of deaths have no age recorded[11] on the death certificate and that the Central Statistical Services were in the habit of imputing an age at death that was thought to be consistent with the cause of death. In such a situation it is entirely feasible that such imputed ages could be biased towards understatement, particularly at the very old ages. In the case of males it would require the net transfer of only some 568 deaths from the age groups below age 80 to the age groups 80-84 (119) and 85+ (449) to move the observed points to the straight line. This represents less than 4.5% of the deaths in the 65+ age groups. In the case of females the comparable figure is 817 (668 to the 80-84 age group and 149 to the 85+ age group) which is less than 7% of deaths in the 65+ age group.

As further corroboration of this hypothesis it is interesting to note that a comparison of the ungraduated death rates, corrected for under-reporting, with the graduated curve fitted in an earlier study (Dorrington, Martens and Slawski 1991) shows the points for groups 65-69 and 70-74 lie above the curve while the next three points for males and the next two points for females lie significantly below the curve.

Finally, before we can draw any conclusions we need to consider whether the exclusion of TBVC deaths lead to a violation of the assumption of uniform under-reporting of adult deaths. Since the proportion of the total Black population resident in the RSA area (i.e. SA excluding the TBVC area) is at its highest (over 80% for males and 75% for females) between the ages of 20 and 50-55 and then falls to around 65-67% from age 65 onwards one might expect the bias introduced by non-recording the deaths in the TBVC area to be reflected in a rising K_{x+}, suggesting an increasing underreporting of deaths in the open interval $x+$ of deaths as age increases. The pattern of K_{x+} did not give a clear signal one way or the other suggesting that if there is bias it probably does not affect the results too significantly.

Thus on the assumption that the practice of imputing age explains the divergence from the straight line at the older ages we can conclude that according to the Brass method some 55% of the Black male deaths and 43% of the Black female deaths were reported over the period 1984-86.

There are two things that are disturbing about these estimates. Firstly, the estimated percentage reported for the females is significantly lower that that for males, although this can probably be explained by the differences between the sexes in the degree of participation in the formal economy[12].

The second problem is that both of the estimates are below the 60% or more "rule of thumb" recommended by Preston (1984) to ensure that such data represent a "very useful source of mortality information". Unfortunately there is little that can be done to remedy this problem except to note that a significant part of the under-reporting is systematic in that no deaths which occurred in the TBVC area are included. To the

[11] Shisana and Bradshaw (1992) suggest that some 9.3% of <u>all</u> deaths in South Africa in 1989 had no age recorded on the death certificate.

[12] From the 1985 Census it would appear that some 67% of the total male population over 20 but only 30% of the total female population over 20 were employed in the formal sector of the RSA. If we were to assume that there was a greater incentive to report deaths arising from those employed in the formal sector then, using these figures, only some 66% of deaths in the formal sector as opposed to 33% of deaths not in the formal sector would need to be reported to produce such a discrepancy.

extent that this research is able to correct for this bias (see section 4.6 and following) presumably the data are more useful than would otherwise appear to be the case[13].

4.4 Preston and Coale method

In order to apply the Preston and Coale method we first need to estimate $\hat{N}_A$ for some suitably high age, A, on the basis of the reported deaths in the open interval $A+$, D_{A+}. The problem being, as was discussed in Chapter 3, that we do not have the distribution of deaths in that open interval. However, before we can apply the approximation described in Chapter 3 we first have to decide on a suitable value for $A+$. The higher the value the less prone the estimate is to the approximations (both in the assumed age point to which the deaths apply and the pattern of mortality beyond that age) but the more prone it is to errors in death reporting.

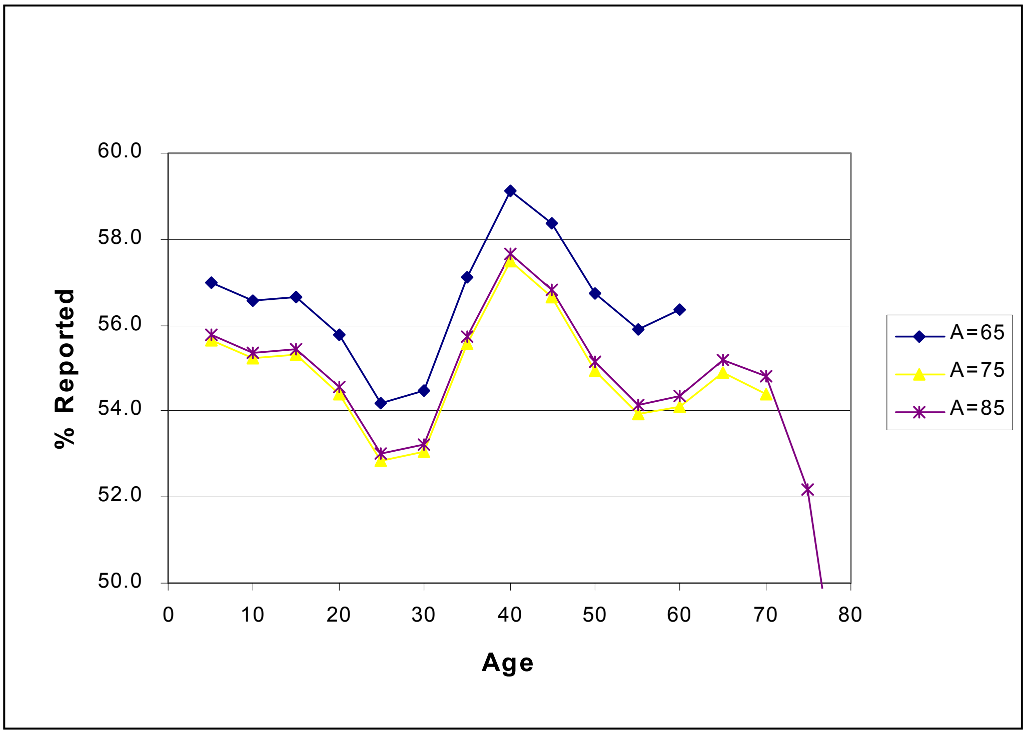

Figure 4.5 Percentage reported (${}_{10}\hat{N}_{x-5} / {}_{10}N_{x-5}$): Males

[13] For example, if the assumptions outlined in section 4.6 hold then the equivalent percentage reported would be 80% and 69% for males and females respectively.

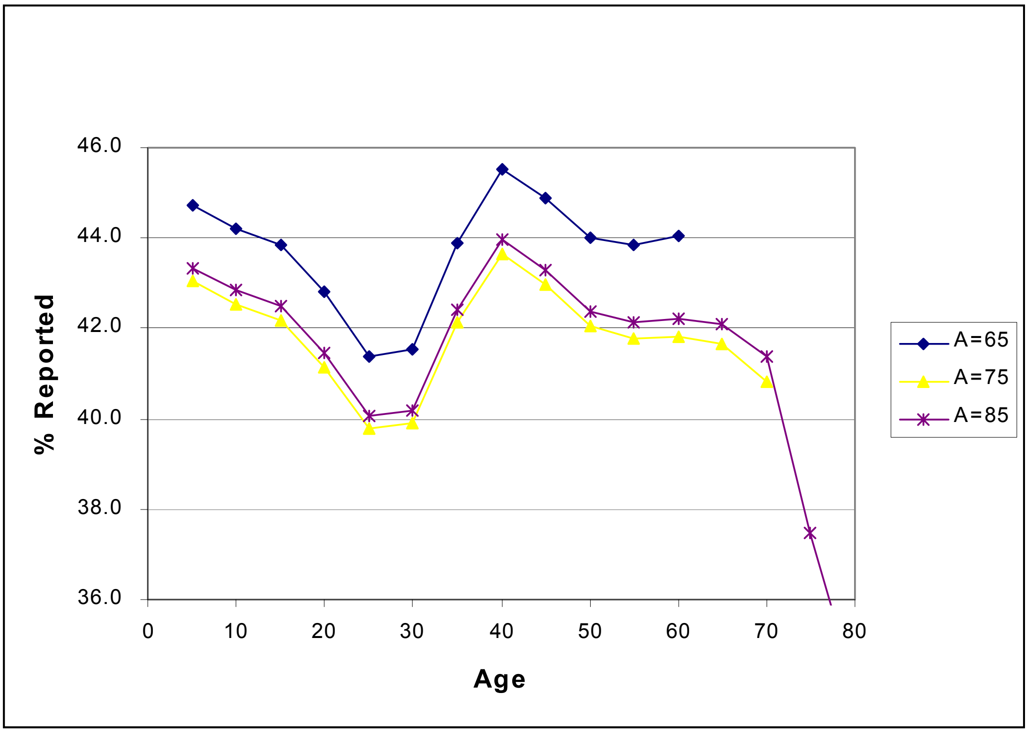

Figure 4.6 Percentage reported (${}_{10}\hat{N}_{x-5} \big/ {}_{10}N_{x-5}$): Females

Figures 4.5 and 4.6 present the results of applying this method with A set to 65, 75 and 85. The growth rates (2.94% for males and 2.98% for females) were chosen to produce the most horizontal sequence of the ratio ${}_{10}\hat{N}_{x-5} \big/ {}_{10}N_{x-5}$ for the sequence where A=75[14]. These growth rates correspond almost exactly with those derived using the Brass method.

From these figures we can notice the following.

1. The sequences for A=75 and A=85 are very consistent (up to age group 70-74 for the ${}_{10}\hat{N}_{x-5} \big/ {}_{10}N_{x-5}$ sequences.
2. The sequences for A = 65 gave an estimate of under-reporting 1.5% to 2% higher than that for the other two open intervals. Although this could be, in part, the result of the approximations which had to be made in arriving at $\hat{N}_{65}$, it could also be explained by the possible understatement of age of the deaths (identified earlier) at ages above 80 (the maldistribution being confined to the open interval 65+).
3. The sequences for A=85 fall off with advancing age – again indicating age understatement of deaths relative to the population at the older ages. (In fact the sequences for A=75 shows little fall off between the ages 65 and 75 and yet are otherwise similar to those with A=85 suggesting that, given this population age distribution, the understatement of age of deaths is predominantly at ages above 75.)

[14] This was assumed to be the rate which minimised the absolute deviations from the mean of the sequence between ages 5 and 65.

The median of the ${}_{10}\hat{N}_{x-5} / {}_{10}N_{x-5}$ sequence where A=75 for males was 54.7% which is remarkably consistent with the previous estimate. For females the median is 41.6% which is slightly lower than the previous estimate.

Adjusting the deaths in the age groups above 65 so that the segmental death rates, d_{x+}, are consistent with the regression line fitted previously would remove most of the fall off at older ages. This results in an estimate of the extent of reporting of 55.9% for males and 43.8% for females (and growth rates of 0.0298 for males and 0.0306 for females) when A=75. The sequences for A=65 would lie about 1% above those where A=75, whereas the sequence where A=85 would lie between the two. Although this could be due to errors in the approximation of $\hat{N}_A$ it might also suggest that the adjustment to the deaths for understatement may not be entirely correct.

From these calculations it would thus appear that the extent of reporting of deaths for males lies somewhere between 55% and 56%, and that of females between 42% and 44%, depending on whether or not we adjust for under-statement of age in the deaths.

4.5 Bennett and Horiuchi method

In order to apply the Bennett and Horiuchi method it is necessary to estimate the age-group-specific growth rates of the population around 1985. For our purposes we have estimated these rates from the growth of the 1990 population estimates from that of 1980. These rates are shown in Table 4.1.

	MALE			FEMALES		
Age	*80-85*	*85-90*	*80-90*	*80-85*	*85-90*	*80-90*
0	0.029	0.024	0.027	0.030	0.024	0.027
5	0.030	0.029	0.030	0.028	0.030	0.029
10	0.029	0.030	0.030	0.027	0.030	0.028
15	0.023	0.029	0.026	0.024	0.027	0.025
20	0.026	0.023	0.024	0.024	0.024	0.024
25	0.039	0.026	0.033	0.041	0.024	0.032
30	0.043	0.040	0.041	0.043	0.041	0.042
35	0.032	0.043	0.037	0.032	0.044	0.038
40	0.022	0.033	0.027	0.024	0.032	0.028
45	0.026	0.023	0.025	0.031	0.024	0.028
50	0.025	0.028	0.026	0.030	0.032	0.031
55	0.035	0.027	0.031	0.036	0.031	0.033
60	0.031	0.038	0.034	0.033	0.037	0.035
65	0.040	0.035	0.037	0.042	0.035	0.039
70	0.009	0.044	0.026	-0.014	0.045	0.015
75	-0.013	0.012	-0.001	0.049	-0.012	0.019
80	0.052	-0.010	0.021	0.035	0.051	0.043
85	0.034	0.035	0.035	0.029	0.033	0.031
TOTAL	0.029	0.029	0.029	0.030	0.029	0.029

Table 4.1 Age-group specific growth rates

Figures 4.7 and 4.8 present the results of applying the Bennett and Horiuchi method with A set to 65, 75 and 85. Although having age-specific growth rates means that the approximation of N_A ought to be more reliable than that used in the Preston and Coale method, there is still some element of the same trade off experienced with that method. The estimate is not only dependent on the estimate of e_A (which in this case was derived from the rates in Dorrington, Martens and Slawski (1991)) but more significantly on the estimate of the growth rate for the open interval starting at age A.

The growth rates (1980-90 from Table 4.1) had to be decreased by about 0.15% in order to produce the most horizontal sequence of the ratio ${}_{10}\hat{N}_{x-5} / {}_{10}N_{x-5}$ [15]. This adjustment would suggest that the 1990 population estimates were some 1,5% too high relative to the 1980 estimates.

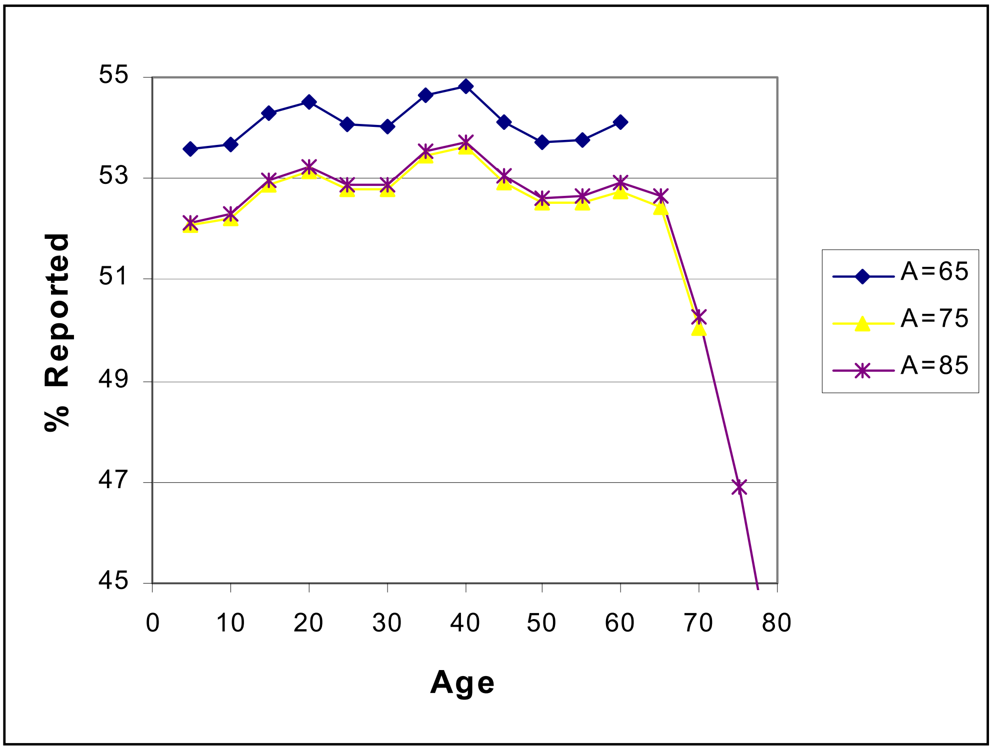

Figure 4.7 Percentage reported (${}_{10}\hat{N}_{x-5} / {}_{10}N_{x-5}$): Males

[15] This being the sequence suggested by Bennett and Horiuchi (1981). The most horizontal was taken to be that sequence which minimized the absolute deviations of the sequence from its mean over the ages 5 to 64.

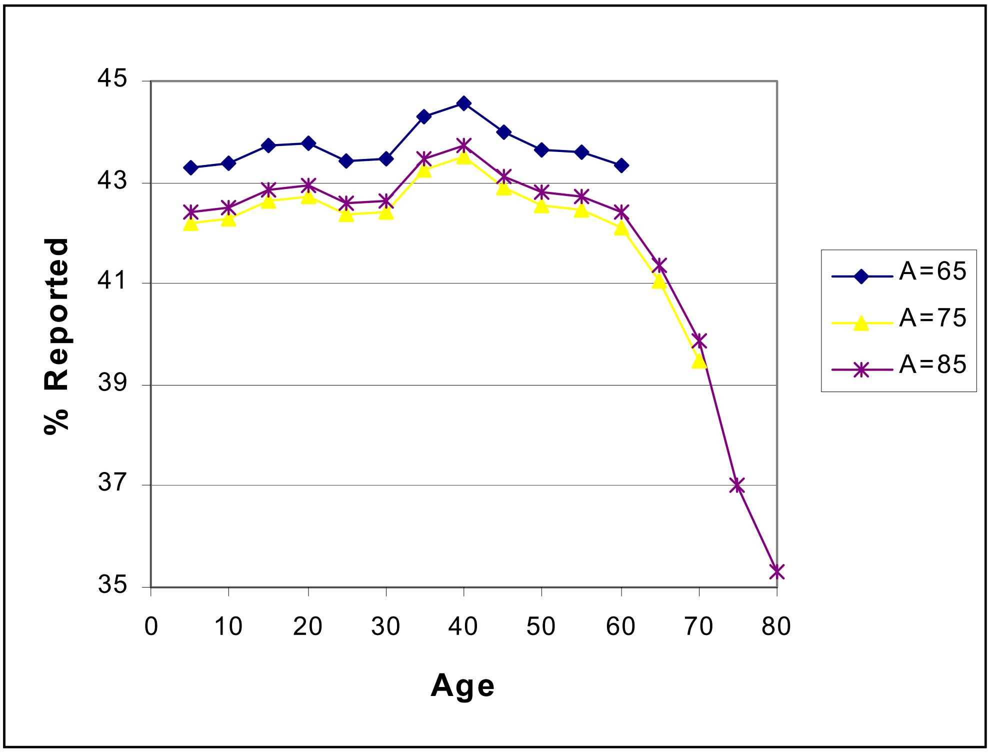

Figure 4.8 Percentage reported (${}_{10}\hat{N}_{x-5} \big/ {}_{10}N_{x-5}$): Females

From these figures we can notice the following.

1. A great deal of the variation in the various sequences has been removed by using the age-group specific growth rates.
2. Again the sequences with A=75 and A=85 are fairly consistent, with those for A=65 lying about 1% above the other two.
3. The above point together with the falling off of both the A=75 and A=85 sequences with advancing age again suggest that the age at death has been understated at the older ages.
4. This method results in significantly lower estimates of the extent of reporting. For males the estimates range from 52.9% for A=85 to 54.1% for A=65 and for females from 42.8% for A=85 to 43.6% for A=65.

The reason the estimates are lower than those derived using the Preston and Coale method can be traced to the extremely low growth rates in the 75-79 year age groups for males and the 75-84 year age groups for females.

Since there is no reasonable explanation for these low growth rates and in addition the growth rates for males and females are inconsistent at the older ages, it was decided to re-estimate the population and growth rates at the older ages. (Details of this exercise are described in Appendix 3.)

Applying the Bennett and Horiuchi method using these new data gave the following estimates of the extent of reporting of deaths:

A	*Male*	*Female*
65	55.5%	43.6%
75	54.2%	42.5%
85	54.5%	42.7%

Once again the differences in estimates as *A* increases are probably due to age under-statement. Thus from these figures it would appear that the best estimate of the extent of reporting of deaths is 55.5% for males and 43.6% for females.

As confirmation of these estimates and in order to improve the estimate of the ungraduated rates in the 65 year and older age groups, the deaths in this age range were redistributed so that they were consistent with the straight line fitted using the Brass method with C = 55.5% for males and 43.6% for females. The extent of the adjustment and the adjusted numbers of deaths appear in Table 4.2.

Age	Males			Females		
	Original	Adjustment	Adjusted deaths	Original	Adjustment	Adjusted deaths
60				2 672	-119	2 553
65	4 404	-724	3 680	3 367	-850	2 517
70	3 402	-262	3 140	2905	+331	2 574
75	1 962	+694	2 656	1 829	+804	2 633
80	1 607	+89	1 696	1 763	+350	2 113
85+	1 167	+203	1 370	1 924	+146	2 070

Table 4.2: Deaths adjusted for under-statement of age

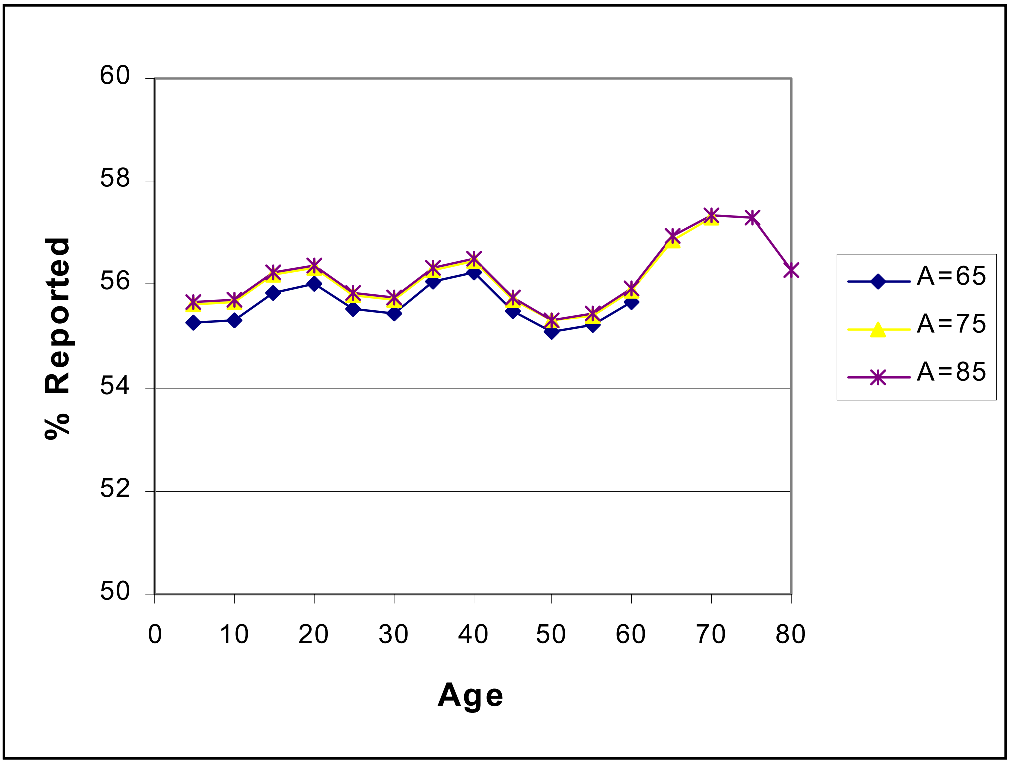

Figure 4.9 Percentage reported ($_{10}\hat{N}_{x-5} / {}_{10}N_{x-5}$): Males

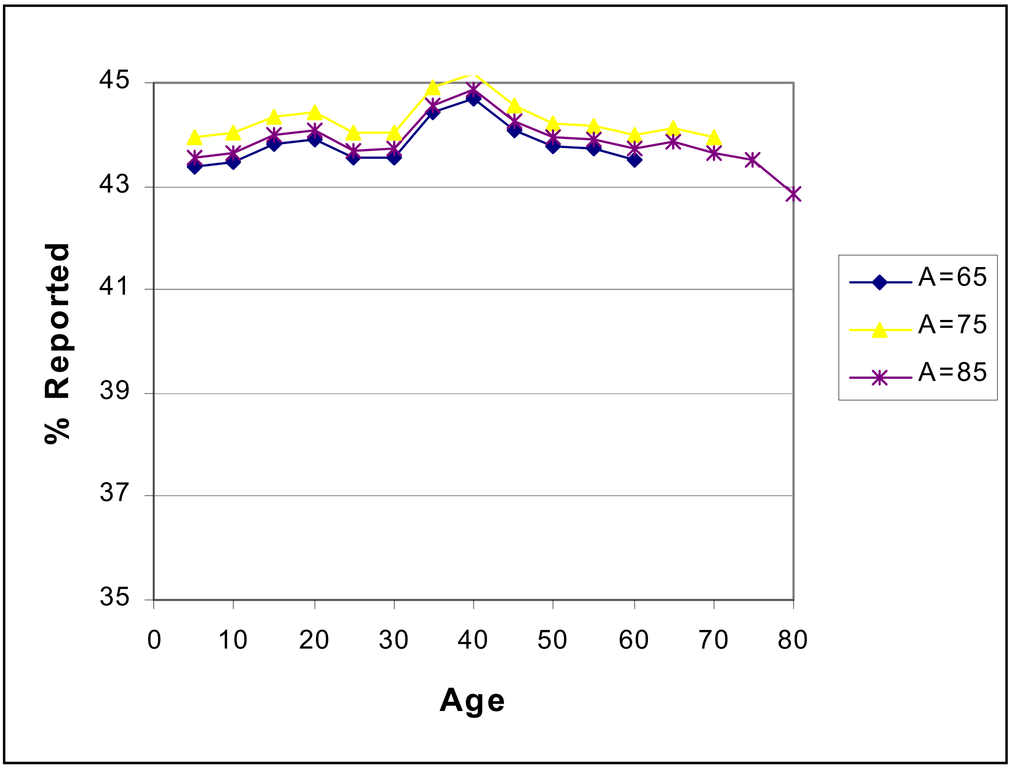

Figure 4.10 Percentage reported (${}_{10}\hat{N}_{x-5} \big/ {}_{10}N_{x-5}$): Females

Figures 4.9 and 4.10 show the effect of redistributing the deaths in the 65 year and older age range for males and females respectively[16]. From these figures it appears as if the correction may have been overdone for males. However, any further adjustment would be spurious.

The percentage reported for the sequences with A=85 and A=75 was 55.8% for males, and 43.9% and 44.2% respectively for females (and for A=65 it increases to 44,2%), and thus it was decided that the best estimate of the percentage of deaths reported taking into account the adjusted deaths was 56% for males and 44% for females.

4.6 The estimate assuming none of the TBVC deaths have been recorded

Before applying the Bennett and Horiuchi method the deaths were adjusted to first remove the effect on the pattern of deaths of the differential distribution of the population between the RSA area and the TBVC area. This was achieved by assuming that the same mortality rate and extent of reporting for both the RSA and TBVC areas – in other words scaling up the number of deaths by the total population divided by the RSA population. The results of this exercise appear in Table 4.3.

[16] The growth rates needed to be decreased by about 0.10%-0.12% to produce horizontal sequesnces, implying, on the assumptions underlying this case, that the 1990 population is about 1% too high relative to that of 1980.

Age	MALE			FEMALES		
	Proportion in RSA[1]	Reported Deaths	Scaled up Deaths	Proportion in RSA[1]	Reported Deaths	Scaled up Deaths
0	69%	11920	17209.9	69%	11044	15944.6
5	69%	726	1050.5	69%	577	834.9
10	69%	674	969.4	69%	476	690.0
15	75%	1308	1736.5	70%	726	1039.3
20	82%	2708	3310.2	72%	1035	1437.1
25	84%	3196	3789.9	73%	1174	1596.9
30	85%	3337	3927.3	74%	1393	1882.1
35	84%	3185	3780.6	74%	1368	1857.7
40	83%	3339	4030.3	73%	1546	2122.3
45	82%	3416	4177.6	72%	1651	2286.3
50	81%	3746	4644.4	71%	1928	2710.8
55	79%	3450	4350.5	69%	1867	2713.2
60	77%	4071	5276.7	66%	2672	4063.2
65	69%	4404	6417.0	64%	3367	5297.1
70	66%	3402	5149.4	63%	2905	4615.8
75	65%	1962	3032.7	62%	1829	2944.0
80	68%	1607	2376.6	65%	1763	2716.2
85	68%	1167	1726.4	65%	1924	2964.8

(1) From Mostert et al (1987)

Table 4.3: Deaths scaled up for the proportion living in the RSA area

Figures 4.11 and 4.12 show the results of applying the Bennett and Horiuchi method using these deaths and the adjusted population and growth rates estimates from Appendix 3.

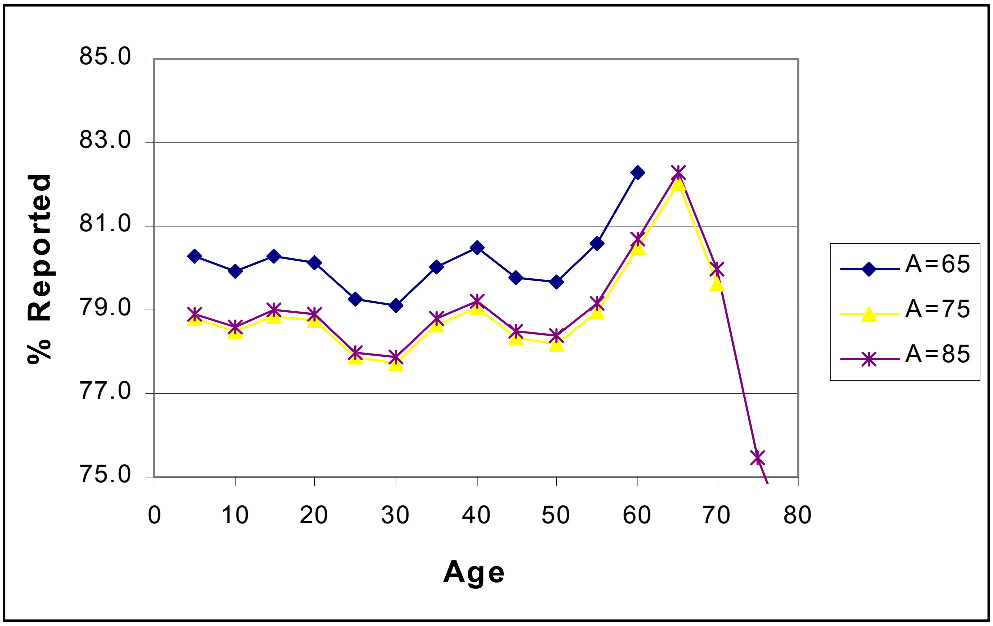

Figure 4.11 Percentage reported ($_{10}\hat{N}_{x-5} / _{10}N_{x-5}$): Males

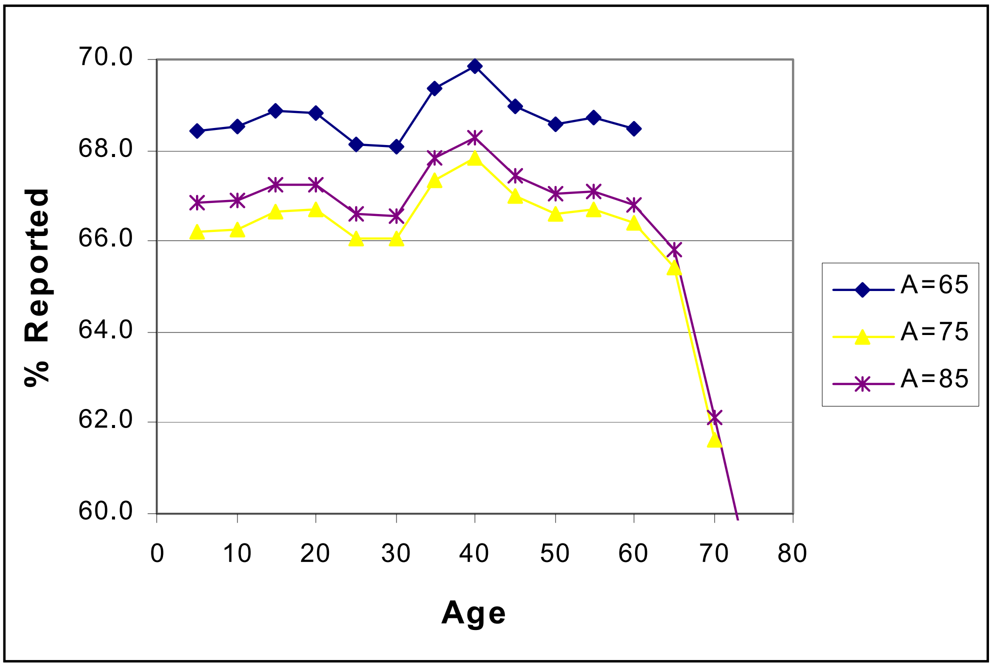

Figure 4.12 Percentage reported (${}_{10}\hat{N}_{x-5} / {}_{10}N_{x-5}$): Females

From these figures the following can be noted.

1. Again the sequences with A=75 and A=85 are fairly consistent with those for A=65 lying 1 to 2% above the other two.
2. Again there is evidence of apparent understatement of age at death at the advanced ages.
3. This method results in significantly higher estimates of percentage reported. For males the estimates range from 78.7% for A=75 to 80.1% for A=65. For females the range is from 66.6% for A=75 to 68.6% for A=65[17]. However, it should be remembered that these are essentially estimates of the extent of reporting of deaths in the RSA area and not the country as a whole. (In addition the deaths appear to be exaggerated, in the case of males, in the 65-74 age group which could bias the estimate upward. This is discussed in more detail below.)

Once again in order to improve the estimate of the crude rates in the 65 year and older age groups the deaths in this age range were redistributed so that they were consistent with the straight line fitted using the Brass method with C = 80.1% for males and 68.6% for females. The extent of the adjustment and the adjusted numbers of deaths appear in Table 4.4.

[17] δ (the extent by which the growth rates need to be adjusted to produce a horizontal curve) was close to 0 implying that the growth rates and the pattern of deaths were almost entirely consistent.

Age	Males			Females		
	Original	Adjustment	Adjusted deaths	Original	Adjustment	Adjusted deaths
60				4 063	-193	3 870
65	6 417	-505	5 912	5 297	-1 337	3 960
70	5 150	-618	4 532	4 616	-567	4 049
75	3 033	+801	3 834	2 944	+1 198	4 142
80	2 377	+71	2 448	2 716	+608	3 324
85+	1 726	+251	1 977	2 965	+291	3 256

Table 4.4: Deaths adjusted for under-statement of age

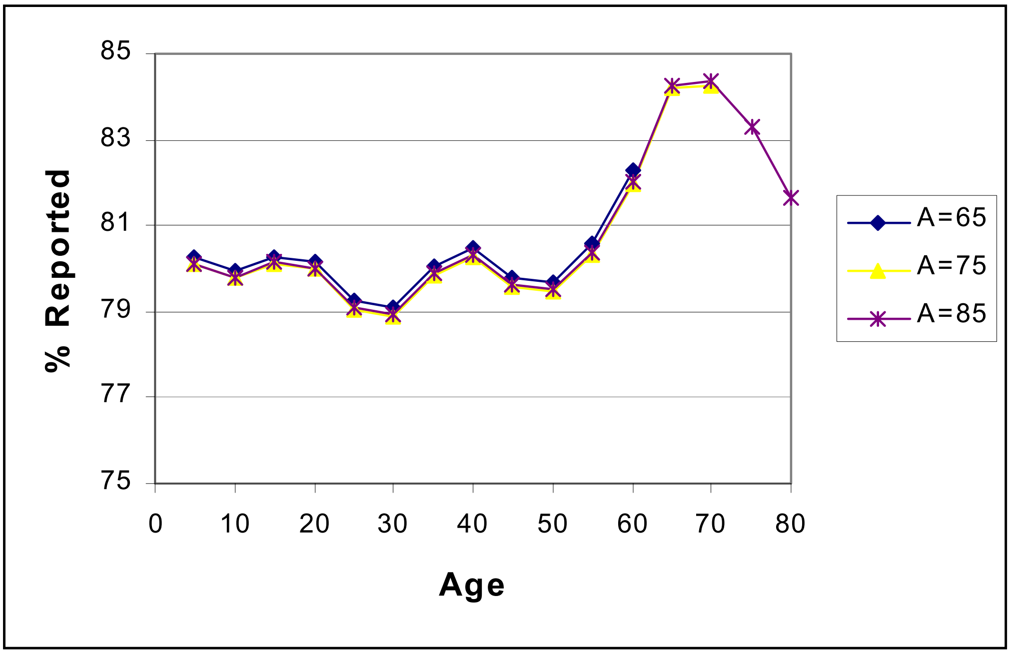

Figure 4.13 Percentage reported (${}_{10}\hat{N}_{x-5} / {}_{10}N_{x-5}$): Males

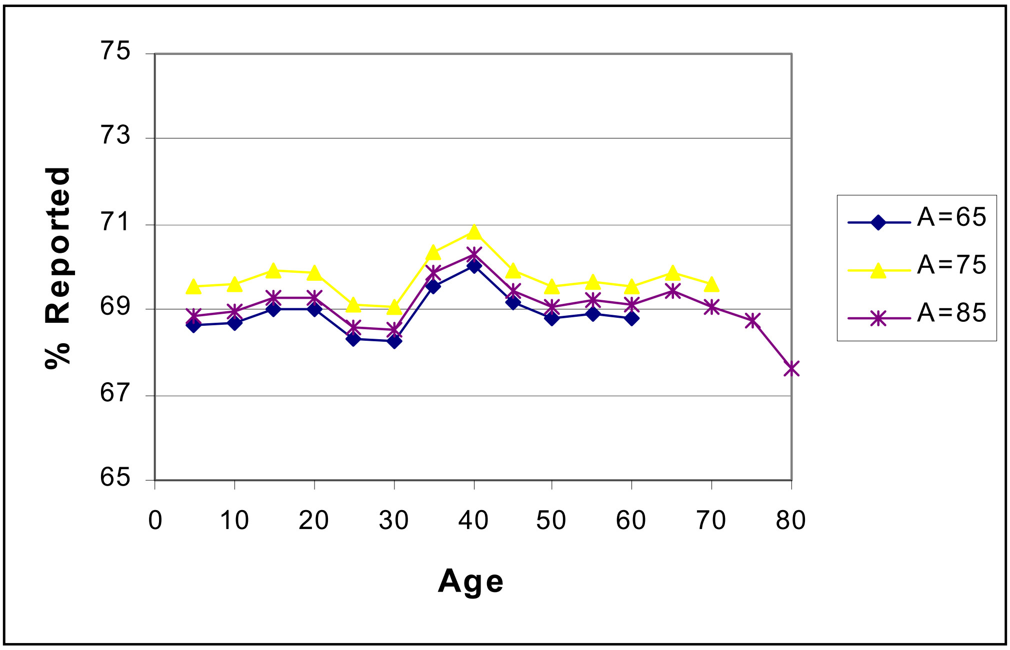

Figure 4.14 Percentage reported ($_{10}\hat{N}_{x-5} / _{10}N_{x-5}$): Females

Figures 4.13 and 4.14 show the results of applying the Bennett and Horiuchi method using these adjusted deaths. An interesting feature to note is the "hump" in the male curve starting at age 65. This suggests that perhaps the number of deaths in this age range has been exaggerated by the scaling up. However, since there was no way of knowing if this is indeed the case and since, as will be apparent later, the estimates of the mortality rates in this age range are very similar to those derived under the assumption that the TBVC deaths had been recorded, no further adjustment was thought necessary.

The estimate of the extent of reporting when A=75 and A=85 has increased to around 79.9% for males and to around 69.4% for females. Thus it was decided that the best estimate of the extent of reporting was 80% for males and 69% for females and that this would be applied to the adjusted deaths.

4.7 Conclusion

From the above we have two estimates of the extent of reporting of deaths. The first suggests that, as far as adults are concerned, reported deaths (i.e. excluding deaths which arose out of the population living in the TBVC area) represent about 56% of the total deaths in South Africa in the case of males and 44% in the case of females. The second suggests that the reported adult deaths scaled up to allow, proportionally, for the deaths which may have occurred in the TBVC area but not been recorded represent some 80% of all adult deaths in South Africa in the case of males and 69% in the case of females.

Two sets of adjusted ungraduated adult mortality rates were produced one each based on the respective deaths adjusted for under-reporting[18]. These are shown in Tables 4.5 and 4.6.

Although at the outset it might have been tempting to think that the assumption that the TBVC deaths are unrecorded might produce the more reliable result, the obvious exaggeration of deaths at the older ages in the case of males calls into question the reliability of either the estimates of the proportion of the population in the RSA or the assumption that TBVC deaths occur only in the TBVC area, or both[19].
On the other hand it could probably be argued that the rates are likely to lie somewhere between the two estimates. The first set of assumptions is likely to lead to estimates on the high side since the percentage of the population residing in the RSA (and hence presumably the percentage of the reported deaths) falls with increasing age from about the 45-49 year age group to the 65+ ages, leading to an underestimate of r and hence the percentage reported and an overestimate, to some extent, of mortality. The second assumption is likely to lead to an underestimate of rates since it might be expected that rates in the TBVC (certainly in the working ages) for various reasons might be expected to be higher than the allowance on the basis of scaling up deaths in the RSA.

Thus, in order to arrive at a single estimate of the mortality rates, it was decided to average the two sets of estimates.

[18] For this purpose it was assumed that deaths in the age range 5 -19 were under-reported to the same extent as adult deaths. Although it is quite likely that the extent of under-reporting could have differed it was thought that graduation would smooth out any anomalies produced by this assumption.
[19] As an experiment the estimates of the proportion of the population in the RSA at ages 65 and older for males were replaced by estimates derived from the 1991 census adjusted for undercount (CSS 1992c), which were five to 10% higher. The graduation resulted in rates which were very similar (less than 2% lighter) to those of the average produced above but fit the data much better. The estimate of the percentage of deaths reported in this case was still 80%.

Age(x)	Adjusted Population	Adjusted Deaths (1)	Adjusted Deaths (2)	$_5m_x$ (1)	$_5m_x$ (2)	$_5m_x$ Average
0	2010400	21285.7	21512.4			
5	1713200	1297.0	1313.1	0.00076	0.00077	0.00076
10	1466100	1203.0	1211.7	0.00082	0.00083	0.00082
15	1260200	2335.1	2170.6	0.00185	0.00172	0.00179
20	1106600	4835.1	4137.7	0.00437	0.00374	0.00405
25	953200	5706.5	4737.4	0.00599	0.00497	0.00548
30	763300	5958.9	4909.2	0.00781	0.00643	0.00712
35	597200	5687.5	4725.8	0.00952	0.00791	0.00872
40	485700	5963.1	5037.9	0.01228	0.01037	0.01132
45	408600	6100.6	5222.0	0.01493	0.01278	0.01386
50	328400	6689.3	5805.5	0.02037	0.01768	0.01902
55	257800	6160.7	5438.1	0.02390	0.02109	0.02250
60	183600	7269.0	6595.9	0.03959	0.03593	0.03776
65	124300	6571.4	7390.0	0.05287	0.05945	0.05616
70	78900	5607.1	5665.0	0.07107	0.07180	0.07143
75	47100	4742.9	4792.5	0.10070	0.10175	0.10122
80	22500	3028.6	3060.0	0.13460	0.13600	0.13530
85+	12100	2446.4	2471.3	0.20218	0.20424	0.20321
Total	11819200	102888.1	96196.1			

(1) Assuming TBVC deaths recorded
(2) Assuming TBVC deaths not recorded

Table 4.5: Ungraduated adult mortality rates: Males

Age(x)	Adjusted Population	Adjusted Deaths (1)	Adjusted Deaths (2)	$_5m_x$ (1)	$_5m_x$ (2)	$_5m_x$ Average
0	1989000	25100.0	23108.2			
5	1686700	1311.4	1210.0	0.00078	0.00072	0.00075
10	1449200	1082.6	1000.1	0.00075	0.00069	0.00072
15	1263200	1649.2	1506.3	0.00131	0.00119	0.00125
20	1115400	2352.3	2082.7	0.00211	0.00187	0.00199
25	981800	2667.4	2314.3	0.00272	0.00236	0.00254
30	791900	3165.2	2727.6	0.00400	0.00344	0.00372
35	626500	3109.1	2692.3	0.00496	0.00430	0.00463
40	522500	3512.9	3075.8	0.00672	0.00589	0.00630
45	449900	3752.3	3313.5	0.00834	0.00736	0.00785
50	368900	4381.1	3928.7	0.01188	0.01065	0.01126
55	300100	4242.4	3932.2	0.01414	0.01310	0.01362
60	229700	5802.3	5608.7	0.02526	0.02442	0.02484
65	169700	5720.5	5739.1	0.03371	0.03382	0.03376
70	122300	5850.0	5868.1	0.04783	0.04798	0.04791
75	79100	5984.1	6002.9	0.07565	0.07589	0.07577
80	44100	4802.3	4817.4	0.10890	0.10924	0.10907
85+	28000	4704.5	4718.8	0.16802	0.16853	0.16827
Total	12218000	89189.4	83646.7			

(1) Assuming TBVC deaths recorded
(2) Assuming TBVC deaths not recorded

Table 4.6: Ungraduated adult mortality rates: Females

Chapter 5

Infant and Child Mortality Rates for Blacks

This chapter is concerned with estimating childhood mortality. It begins with a report of the various attempts to estimate the infant and child mortality rates for the Black population around 1985. Each of the estimates is then examined in turn to see which estimates are likely to be more reliable. Based on this discussion the chapter concludes by deciding on the most likely estimates of male and female infant and child mortality rates.

5.1 Estimates

Estimates of infant mortality for the country as a whole, around 1985, range from a low of 62 per 1 000 for 1983-1987 (Rossouw and Hofmeyr 1990) to a high of 94-124 per 1 000 for the period 1981-1985 (Yach 1988). The various estimates are presented in Figure 5.1 below. In order to decide on the most reasonable estimate it is necessary to examine the methods used in deriving these rates and the quality of the data used.

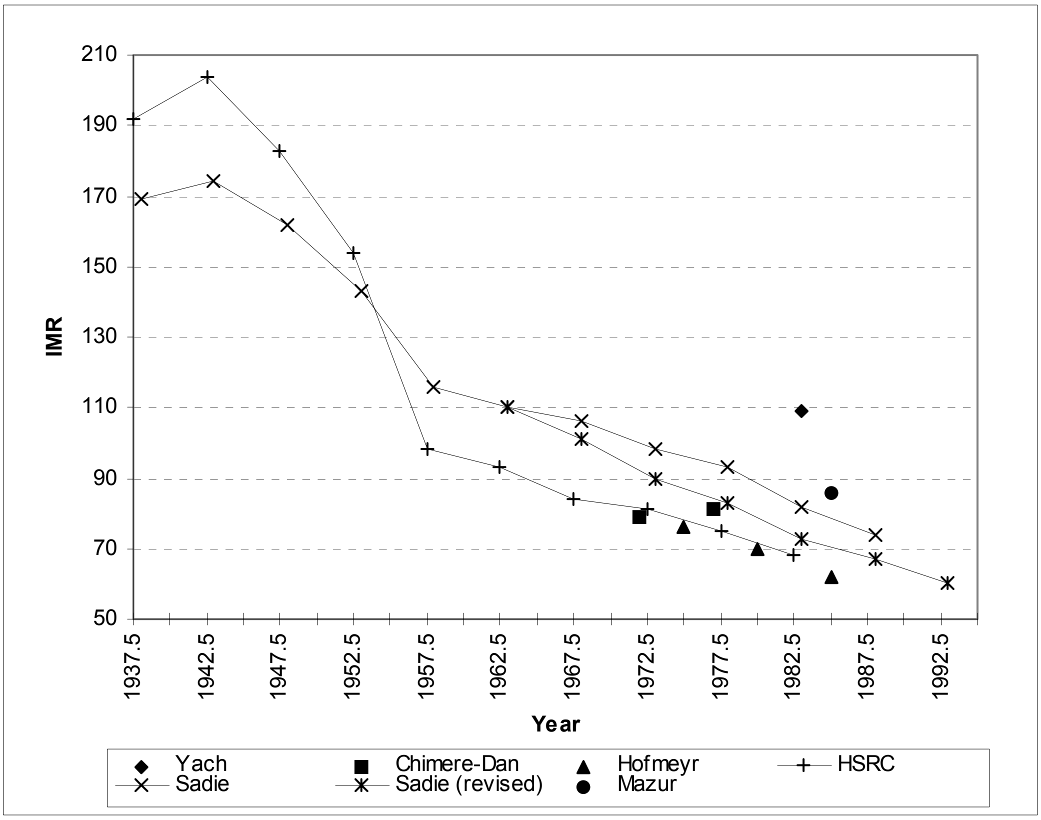

Figure 5.1: Various estimates of infant mortality rate

5.1.1 Estimates derived on the basis of IMRs in metropolitan areas

Yach (1988) collected information on the infant mortality rate (IMR), total population and total births for the period 1981 to 1985 inclusive from the Medical Officers of Health of the 10 largest metropolitan areas in the RSA. He then calculated a weighted IMR for the period using the number of births as the weighting factor (excluding all years/places with fewer than 500 births).

The minimum national IMR was estimated by first estimating the non-metropolitan IMR for the Coloureds. This was done by assuming that the national IMR (on the basis of the deaths under 1 year of age and births for the period as published by CSS) was a weighted average of the metropolitan and non-metropolitan IMRs weighting by the distribution of the population. The non-metropolitan IMR for Blacks was then derived by applying the ratio of the non-metropolitan IMR to the metropolitan IMR for Coloureds (namely 2.6) to the estimated metropolitan IMR for the black population group. The national IMR for blacks was then derived by taking a weighted average of these two estimates using the population distribution as weights.

A maximum estimate was derived by (arbitrarily) replacing the 2.6 multiple by 3 and repeating the exercise.

From these calculations he estimated that the IMR for the period 1981-85 lay in the range 94-124.

5.1.2 Estimates derived from a survey of births and survivors

Chimere-Dan (1993) applied the Trussell version of a Brass indirect technique (UN 1983) to estimate infant and childhood mortality rates (CMRs) from information gathered from an HSRC fertility survey carried out in 1982 (van Tonder 1985).

The coefficients used to derive the estimates of mortality and the time periods to which the rates applied were those based on the UN General Standard model life table (UN 1990).

Since the fertility survey was based on "ever-married" women (and the technique requires to be applied to all women) Chimere-Dan adjusted "the number of women and births and deaths" to be "more representative of the black population" but does not describe how this was done.

These rates appear in Table 5.1.

Year	IMR			CMR		
	Male	Female	Both	Male	Female	Both
1968	82	76	80	40	35	38
1971	76	66	71	34	27	31
1973	74	94	84*	35	49	42
1975	74	91	83	33	46	40
1977	97	88	92	52	44	48
1979	68	66	67	28	27	28

* misprinted in the original as 94.

Table 5.1: Chimere-Dan's rates (deaths per 1 000 births)

5.1.3 Estimates derived from the SADHS

Hofmeyr (Rossouw and Hofmeyr 1990) analysed data collected from the South African Demographic and Health Survey (SADHS) carried out from June 1987 to April 1989. Particulars were collected directly from the mother about, inter alia, the dates of birth, sex and age at death of each child. From these data the rates shown in Table 4.2 were estimated directly.

Period	IMR	${}_4q_1$	${}_5q_0$
1973-77	76	35	108
1978-82	70	31	98
1983-87	62	23	84

Sex	%	IMR	${}_4q_1$
Boy	50.4%	50	24
Girl	49.6%	40	23

Table 5.2: Hofmeyer's rates by period and sex

5.1.4 Estimates derived from the reconstruction of the age structure of the population at census dates (HSRC)

Mostert *et al* (1987) reconstructed the age distribution of the population at various census dates in the past. Briefly, this was achieved by first estimating a growth rate of 0,0208 p.a. from Sadie's (1970) reconstruction of the 1936 and 1946 census populations and on the basis of a life expectancy at birth of 40 years (Sadie 1973) choosing a female "West" model stable population.

They then redistributed the previous total population (for 1935) to this distribution and derived the male estimates by multiplying these figures by the masculinity ratios for level 9 West model life tables and assuming a masculinity ratios at birth of 1,02.

This basis population was projected using an "assumed" trend in the Total Fertility Rates (TFRs) on the basis of past censuses, known incidence of contraception, the 1960 fertility survey together with migration estimates from Mostert *et al* (1985), and assuming West mortality. These projections were then reconciled with the actual censuses.

The IMRs were those implied from the underlying models and are shown in Table 5.3.

Period	IMR		
	Male	Female	Combined
1970-75	89.2	73.4	81.4
1975-80	82.4	67.3	75.0
1980-85	75.8	60.3	67.6

Table 5.3: HSRC's rates (deaths per 1 000 births)

5.1.5 Estimates derived from population reconstruction and projection (Sadie)

Sadie (1988) first derived $P_B = {}_5N_0/B$ from forward and backward population projections, fertility surveys and comparisons with school registrations. He then derived the IMR from this by assuming "that the age distribution of child deaths (children under 5) as published by the Central Statistical Service (1982 to 1985), and representing partial data, would apply to the universe" (Sadie 1988, 44). He established a figure of 80% for $D_0/{}_5D_0$ for the period 1980-1985. Rates for other periods were estimated by noting that "international and South African experience indicates that this proportion increases over time as the value of P_B rises" and hence extrapolating on the basis of the proportions experienced by the Coloured population group.

These rates appear in Table 5.4.

In 1992 Sadie (CSS 1992c) amended his estimates to take into account the results of the SADHS. This he did by starting with his estimate of the IMR for 1960-65 and decreasing the rates in subsequent years "in accordance with the tempo of diminution conveyed by the SADHS and Mostert *et al* (1987) figures". This resulted in the revised IMRs shown in Table 5.4.

Period	IMR	P_B		Revised IMR
		Male	Female	
1975-80	89*	0.8830	0.8958	83
1980-85	82	0.8935	0.9020	73
1985-90	74	0.9039	0.9115	67

* misprinted in the original as 93.

Table 5.4: Sadie's rates

5.1.6 Estimates derived from the *Poverty* survey

Mazur (1995) analysed the data contained in the Project for Statistics on Living Standards and Development undertaken by the South African Labour and Development Research Unit (SALDRU) (1994). The survey contained data on retrospective pregnancies, child birth and child death from women 15-49 years of age.

From these data infant, child and under-five mortality were estimated based on the Trussell and Palloni-Heligman variations of the Brass method using the UN General Model Life Table (UN 1982).

From this Mazur estimated the Black IMR to be 86 (over the period 1980 to mid-1992 which has been plotted at 1985 for convenience since there was "no discernable decline in infant, child and under-five" mortality over the period) and ${}_4q_1$ of about 45.

5.1.7 Estimates derived from October Household Surveys

Nannan (1996) and Maphumulo (1995) analysed the data collected from the 1993 and 1994 October Household Surveys (carried out by the Central Statistical Services) respectively. The data gathered by the surveys comprised for each household details (including sex, whether still alive, age, age at death if died, and date of birth) of each child borne to the women aged between 15 and 49 in the household. From this Nannan estimated the IMR to be 13.9 and ${}_4q_1$ to be 11.7 per 1 000 while Maphumulo estimated, on the basis of the survey a year later, the IMR to be 11.

Various suggestions are offered by Nannan as to why the estimates are so poor. Needless to say figures of this order of magnitude are of little use in determining estimates for our purposes and will not be discussed further[20].

5.2 Discussion

Examining these estimates in turn.

5.2.1 On the basis of metropolitan IMRs

There are a number of problems with Yach's estimate.

Firstly, the range of the IMR is incorrect owing to a minor arithmetic error - the range using his method should have read 93-107.

Secondly, his estimate of 'national' Coloured IMR of 51.9 failed to take into account the effect of late registration of births (see, for example Sadie (1988, 32)) and a more accurate estimate would have been 56 (Sadie 1988, 36; CSS 1987e, 15-16).

Thirdly, although the estimate of the metropolitan IMR of 38.6 does not, in itself, seem unreasonable, an inspection of the wide differences between metropolitan areas, the fluctuations of IMR in some of the areas, and the poor recording of births must cast some doubt on the reasonableness of the estimate.

Fourthly, and most importantly, there is no evidence to support the assumption that the ratio of non-metropolitan IMR to the metropolitan IMR for Blacks is of the same order as, or indeed greater than, that for Coloureds. In fact, the higher the Black metropolitan IMR the more untenable such a proposition becomes.

[20] These estimates were considered to be too extreme (and unreliable) to include in Figure 5.1.

Finally, although the ratio of non-metropolitan to metropolitan IMRs calculated for the White, Coloured and Asian population groups represent a national picture, this is not the case for the Black population group. A substantial portion of the Black population group lived in the TBVC area and Yach's research gives no clue as to the IMR for this section of the population.

5.2.2 On the basis of the 1982 fertility survey

The pattern of rates which are presented by Chimere-Dan is highly implausible. Not only do the rates show wild fluctuations from one period to the next but on average the female IMR is higher than that for males. This could be the result of a number of problems with the research.

The first stems from weaknesses of the survey itself, for example, the masculinity ratio of children reported ‘ever born’ is 0.99 on average and ranges between 0.97 and 1.10 for the various age groups of the mother. (The ratio should be of the order of 1.02 (Sadie 1988; Mostert *et al* 1987.))

The second problem concerns, the adjustment made to the survey figures to take account of the fertility of all women in the population group. It is unclear what adjustment was made but this could contribute to some extent to the strange results obtained.

Thirdly, Chimere-Dan does not discuss the appropriateness of the UN model life table to the South African experience. As the results are quite sensitive to the model chosen and since there is evidence that most popularly used model life tables are not appropriate to South African conditions (Dorrington 1989, 177; Sadie 1988, 44) this is a drawback of the method.

As a matter of interest the same technique was applied to the same data but after adjusting the number of women in the age groups 15-29 to give parities consistent with fertility rates estimated by Sadie (1988, 48) and using the West model life table (for illustration purposes). The results are shown in Table 5.5.

	IMR (/1 000)		
Year	Males	Females	Both
1980	81	70	76
1978	87	74	81
1976	81	75	78
1974	81	72	76
1972	84	61	72
1969	88	61	79

Table 5.5: Rework of 1982 fertility data

Note that the female IMR is consistently below that of the males and that the estimates are much more consistent over time, albeit that there is still no evidence of improvement over time. However, it should be noted that since the survey only covered the four provinces (i.e. excluding the 10 formerly so-called homelands) a nondecreasing trend does not necessarily contradict a downward trend for the nation as a whole.

In the light of the above considerations it is felt that Chimere-Dan's estimates are not very useful in deciding on an IMR for the country as a whole.

5.2.3 On the basis of the SADHS

Rossouw and Hofmeyr point out that "the findings of the SADHS could be downwardly biased" (p.34). The reasons for this being both memory lapses (particularly as far as the 1970-74 estimates are concerned) and problems in getting respondents to talk about/recall infant or child deaths.

In addition an analysis of the results of the individual former 'homelands' (from the memorandums to the Directors and Secretaries of Health of the various former 'homelands', 1988 and 1989) do not inspire confidence, as Table 5.6 illustrates.

	IMR in Individual Regions	
	1978-82	1983-87
RSA (excl.)	65	60
Kwandebele	65	45
KaNgwane	45	45
Lebowa	65	60
Transkei	110	80
Ciskei	50	45
Bophuthatswana	70	40
Kwazulu	40	40
Gazankulu	45	45
Qwaqwa	85	45
Venda	n/a	n/a

Table 5.6: SADHS "homeland" infant mortality rates

Particularly troubling are:

1. In all but two surveys the IMR for 1983-87 in the former 'homelands' is lower than the remainder of the RSA.
2. There is a big difference between the former Transkei and the rest of the surveys.
3. The drop in IMR in some regions is unacceptably large between the two periods (e.g. the former Kwandebele, Bophuthastwana, Qwaqwa).

According to Rossouw (personal communication, 1992) "the national rate for the black population was calculated from births and deaths reported by mothers for the period 5-6 years preceding the survey from weighted data". However, it is difficult to imagine how the overall figure of 62 could have been derived from the above figures.

The conclusion must be that the estimate of 62 for the period 1983-1987 must be treated with a great deal of caution and if used at all is likely to be an under-estimate of the true national rate.

5.2.4 On the basis of the HSRC's census reconstructions

Since there is little to choose between Hofmeyr's estimate and those of the HSRC one must also conclude that the HSRC's estimates are on the light side.

Part of the problem may be the fact that the technique they used to re-estimate the populations at the census dates was dependent on the West model life tables of Coale and Demeny (1966) which, as was pointed out earlier, does not provide a very useful fit to South African data.

5.2.5 On the basis of Sadie's population reconstruction

The logic of Sadie's derivation is as follows:
$P_B = {}_5N_0/B$ i.e. $(1-P_B) = {}_5D_0/B$ where ${}_5D_0$ represents the deaths between birth and the following census (i.e. $B - {}_5N_0$).

However, the $IMR = D_0/B$ which implies that the $IMR = \frac{D_0}{{}_5D_0}(1-P_B)$.

Now if we assume that $P_B \approx \frac{{}_5L_0}{5l_0}$ then $\frac{{}_5D_0}{B} \approx \frac{5l_0 - {}_5L_0}{5l_0}$

$$= \frac{1}{5l_0}\left(4.75d_0 + 3.6d_1 + 2.5d_2 + 1.5d_3 + 0.5d_4\right)$$

(assuming $L_0 \approx 0.25l_0 + 0.75l_1, L_1 \approx 0.4l_1 + 0.6l_2$ and $L_x \approx \frac{1}{2}(l_x + l_{x+1})$ for $x > 1$).

Now multiplying through by *B* and approximating $\frac{d_i}{l_0}B$ by D_i (where D_i are all the deaths during 1982-85 aged *i* last birthday at death) we get

$${}_5D_0 \approx \frac{1}{5}(4.75D_0 + 3.6D_1 + 2.5D_2 + 1.5D_3 + 0.5D_4).$$

However, Sadie approximated ${}_5D_0$ by $D_0 + 0.8D_1 + D_2 + D_3 + 0.2D_4$. The more accurate estimate results in values for $D_0/{}_5D_0$ of 85.3% for males and 85.5% for females. Since, in addition, the data for the years 1984 to 1986 gives an estimate of 84.5% it seems more reasonable to use 85% instead of 80%. This would give an estimated IMR of 83 per mille for 1985 which, bearing in mind that the ratio $D_0/{}_5D_0$ for the Coloured population group was only 88%, may be a little on the high side.

5.2.6 On the basis of the *Poverty* survey

Mazur (1992) discusses the shortcomings of the survey and the method used to estimate the IMR and CMR and concludes that his estimate of IMR is "either only slightly high (by 5-10 percent) or rather high (by at least 25 percent)" (p.31). However, it is interesting to note that estimates for the White, Coloured and Asian population groups were not published because they were "relatively high when compared to estimates obtained by other researchers in recent years". While this over-estimation may be partly (for Whites and perhaps Asians) due to inappropriateness of the model life table used (Mazur, p.31) this explanation is not so persuasive for the Coloured population. For the Coloured population, application of this method resulted in an IMR of about 58 (private communication with South African Medical Research Council) compared with the 51.13 for males and 45.41 for females in the South

African Life Tables (CSS 1987e) - an over-estimate of some 17%. If the IMR for Blacks is assumed to be over-estimated to the same extent (a somewhat heroic assumption admittedly) then the underlying IMR would be of the order of 73-74 per mille.

5.3 Conclusion

5.3.1 Infant Mortality Rate

In 1992 Bradshaw *et al* estimated the IMR to be 70.5. This was based on the assumption that in all likelihood the true estimate of IMR would probably be between the correction to Sadie's estimate described in section 5.2.5 and the SADHS estimate. In the end they chose a value slightly less than the average of the two figures (83 and 62 respectively). It is interesting to note that this estimate is entirely consistent with Sadie's 1993 re-estimate, in the light of the SADHS, and this is the estimate that will be used in this study.

5.3.2 Child Mortality Rate

The ratio of IMR to CMR for the SADHS's rates around 1985 is approximately 2.7. In the case of Sadie's rates the ratio ranged between 2.4 and 3.0 depending on assumptions[21] so 2.7 seems a reasonable assumption. If we apply this to the IMR suggested in section 5.2.7 we get a ${}_4q_1$ of about 26 per mille.

5.3.3 Sex specific rates

Sex specific rates derived by Mostert *et al* (1987), Hofmeyr (Rossouw and Hofmeyr 1990) and the rework of the 1982 fertility survey data all give a ratio of male to female IMR in the range 1.22 to 1.26. On the other hand Sadie's method produces a ratio of only 1.09 for the periods 1980 to 1990.

In the absence of any strong indication either way it again seems reasonable to choose a figure somewhere between the two estimates. Since the ratio of male to female IMR for the Coloured population group for similar levels of IMR is 1.15 this was chosen as a reasonable compromise, giving a male IMR of 75 and a female IMR of 65.

As far as the CMR is concerned, since the rate is relatively low and the evidence is that the difference between the sexes is not large, rates of 27 for males and 25 for females were chosen.

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[21] The ratio ranged from 2,4 (assuming that the $\mathrm{IMR} \approx 0.8(1 - P_B)$) to 3.0 (assuming that the $\mathrm{IMR} \approx 0.85(1 - P_B)$) using Sadie's assumption that ${}_5L_0 \approx 0.1 l_0 + 0.9 l_5$.

Chapter 6

The Full Life Tables for 1985

In this chapter the infant, childhood and adult mortality rates from Chapters 4 and 5 are combined and then graduated to produce a set of complete life tables for the Black population group circa 1985. This table is then combined in a weighted average with the White, Coloured and Asian South African Life Tables for 1984-86 to produce a set of complete national life tables circa 1985. The complete tables appear in Appendix 4.

6.1 Ungraduated abbreviated life tables

Ungraduated abbreviated life tables for Black lives were constructed by first converting the central rates of mortality estimated in Chapter 4 into initial rates of mortality[22]. These rates were then combined with the q_0 and ${}_4q_1$ estimated in Chapter 5 to produce the abbreviated life tables in Table 6.1.

Age	Males	Females
0	1.00000	1.00000
1	0.92500	0.93500
5	0.90003	0.91163
10	0.89660	0.90822
15	0.89292	0.90497
20	0.88497	0.89933
25	0.86721	0.89044
30	0.84378	0.87921
35	0.81427	0.86301
40	0.77953	0.84326
45	0.73661	0.81709
50	0.68729	0.78562
55	0.62488	0.74259
60	0.55834	0.69369
65	0.46202	0.61257
70	0.34826	0.51721
75	0.24272	0.40657
80	0.14468	0.27707
85	0.07154	0.15835
90	0.02334	0.06457

Table 6.1 Ungraduated abbreviated life tables for Black lives 1985

[22] Using ${}_5q_x = 5 \cdot {}_5m_x \big/ (1 + 2.5\,{}_5m_x)$.

6.2 The method of graduation

The next step in producing full life tables was to graduate these abbreviated life tables. The method chosen to do this was the four parameter model proposed by Ewbank, Gomez de Leon and Stoto (1983).

Briefly this method requires that we find parameters α, β, κ and λ which provide the best fit for the following equation:

$$Y_x = \alpha + \beta T(l_{x,s};\kappa,\lambda)$$

where $Y_x = \text{logit}(l_x) = \tfrac{1}{2}\ln\left(\dfrac{l_x}{1-l_x}\right)$ and $l_x = {}_xp_0$

and

$$T(p;\kappa,\lambda) = \begin{cases} \dfrac{\left(\dfrac{p}{1-p}\right)^{\kappa} - 1}{2\kappa} & \text{for } p \geq 0{,}5 \\[2ex] \dfrac{1 - \left(\dfrac{1-p}{p}\right)^{\lambda}}{2\lambda} & \text{for } p < 0{,}5 \end{cases}$$

and $l_{x,s}$ is the l_x from a standard life table.

However, to improve the fit the following adaptations were made to the method suggested by Ewbank *et al*.

1. After exploring a number of alternatives[23] it was found that significantly better fits could be produced by using an alternative to their suggested standard life table. In the case of male lives the best standard was found to be the Coloured male life table for 1979-81 (CSS 1985)[24]. The same life table was used for females with the exception that l_1 was increased to 0.945 (with the childhood mortality rates adjusted correspondingly[25]). This adjustment was required in order to ensure that the graduation produced a CMR that was consistent with that estimated in Chapter 5. (These standard life tables are reproduced in Appendix 4.)
2. The initial estimates of ↦ and ↕ were based on the "central ages" 55, 60 and 65 (as opposed to 45, 50 and 55 suggested by Ewbank *et al*) since the alternative standard table falls below 0.5 in this interval. This adjustment lead to better initial estimates.
3. Instead of using ordinary least squares to fit ↦ and ↕ in the iterations as suggested by Ewbank *et al*, weighted least squares was preferred, with the weights being set as the reciprocal of the mortality rate being estimated. This was done in order to allow for the fact that errors are far more significant when the rates are low. It was found that not only did weighted least squares

[23] For example SA Life Tables 1984-86 (CSS 1987e).

[24] The published table was extrapolated beyond age 82 using the Gompertz curve (i.e. $\mu_x = Bc^x$) fitted to the rates over earlier ages.

[25] This was achieved by making use of the relationship suggested by Brass (1975), namely, $\text{logit}(l_x) = \alpha + \beta\text{logit}(l_{x,s})$ with the parameters chosen to give the desired l_1 and l_5 values.

produce better fits but the fit after only one iteration was frequently good enough.

6.3 The results

6.3.1 Black lives 1984-1986

The fitted parameters and the full life tables for Black lives 1984-86 are presented in Appendix 4.

Figures 6.1 and 6.2 illustrate the difference between the rates based on each of the assumptions that TBVC deaths are and are not included in the recorded deaths (Cases 1 and 2 respectively). As can be seen from these figures the difference is not large and it seems quite reasonable to average the two in order to estimate the mortality rates.

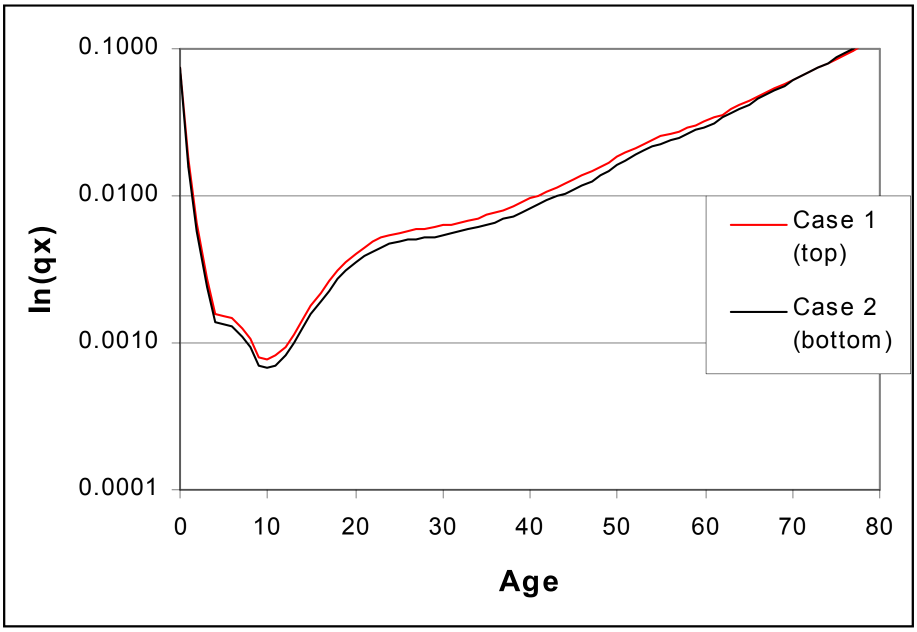


Figure 6.1 Mortality rates of Black male lives 1984-1986

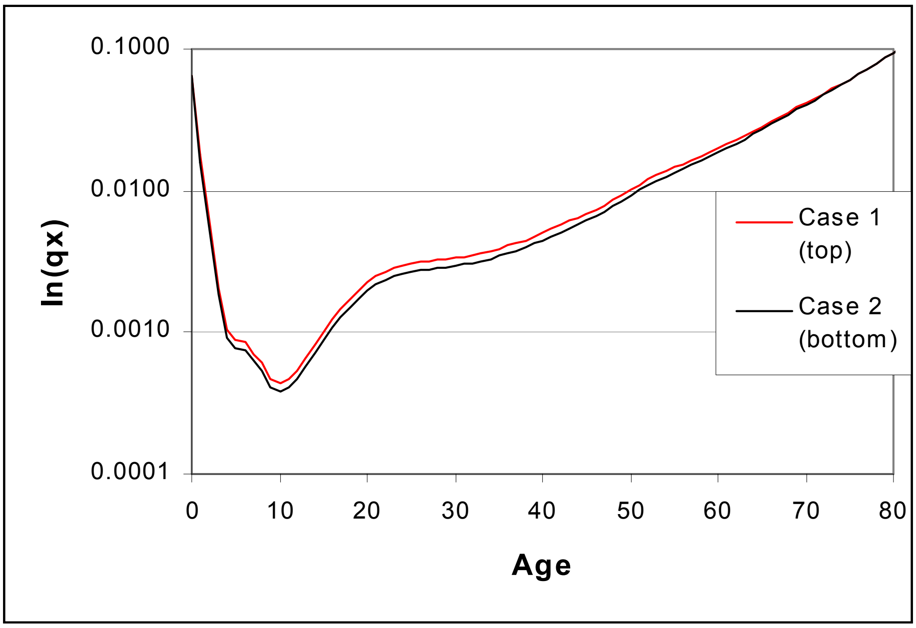


Figure 6.2 Mortality rates of Black female lives 1984-1986

In order to consider the reasonableness of the fit thus derived the graduated rates were compared with the observed rates (the average of the case 1 and case 2 rates scaled up by their respective undercounts). These comparisons appear in Figures 6.3 and 6.4.

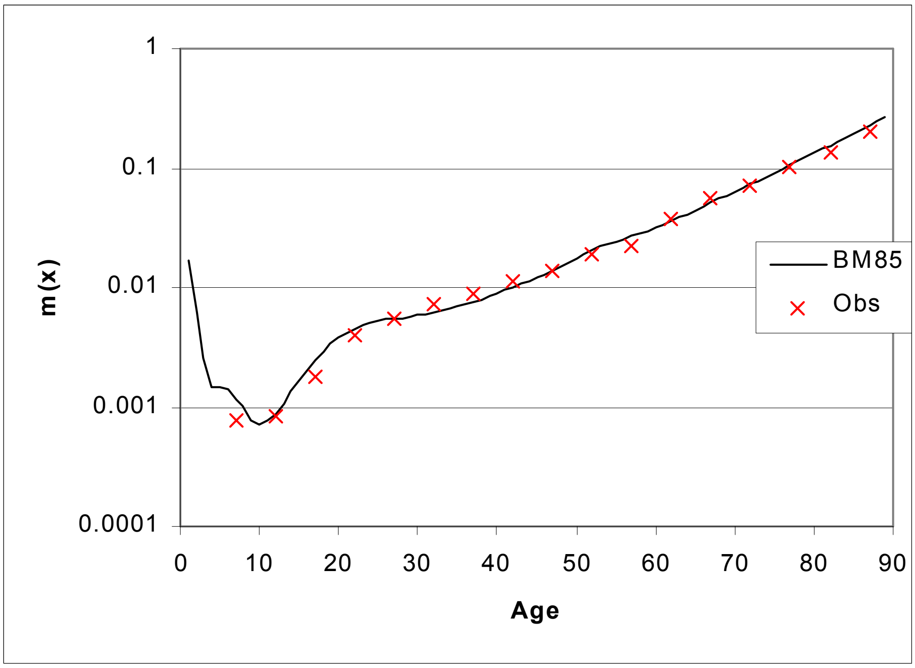


Figure 6.3 Comparison of graduated and observed: Black Males

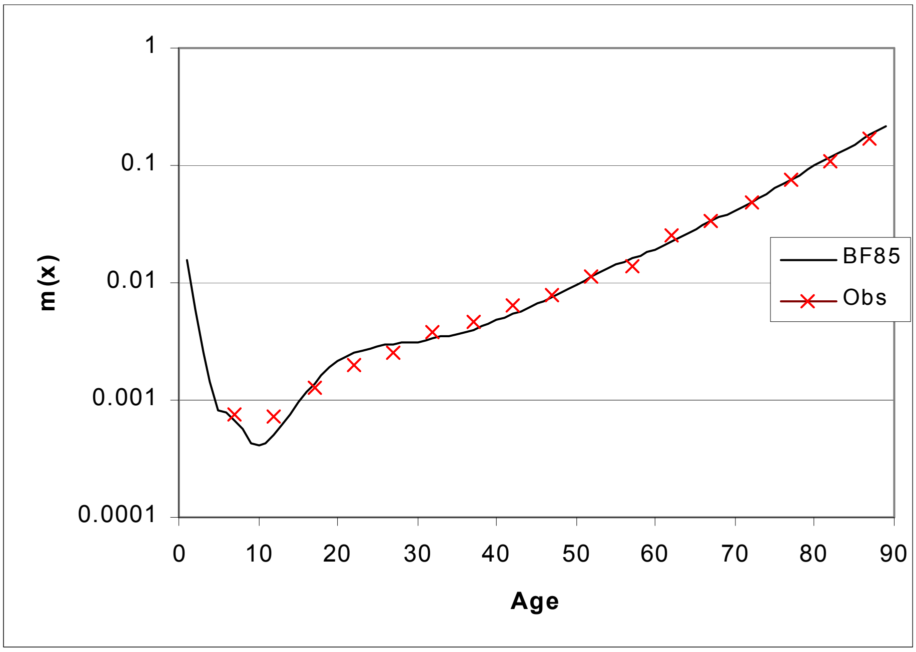


Figure 6.4 Comparison of graduated and observed: Black Females

These comparisons suggest that the graduated rates may underestimate mortality for both males and females in the age range 30-45. In addition the use of the Coloured Male life table as standard for the female graduation has lead to the slight overestimation of the rates in the 20-30 year ages for females. Apart from these shortcomings the graduations appear to be fairly reasonable.

6.3.2 A national life table 1984-86

A national life table was produced by taking a weighted average of the Black life table (based on the average of the two cases) with the various South African life tables for 1984-1986 (CSS 1987e). The weights used were those derived from the HSRC population estimates (Mostert *et al* 1987 and van Tonder *et al* 1987) as these were the population estimates used to estimate the White, Coloured and Asian life tables (although any other estimates would have served equally well).

The resultant national full life tables appear in Appendix 4.

Chapter 7

National life tables: 1989-91 and beyond

From 1991, deaths in South Africa ceased to be recorded by race. Not only has this made it impossible to analyse mortality by population group[26] but in addition one cannot use the methods of the previous chapters to produce national life tables for 1989-91 and beyond. In this chapter we use the 1984-86 life tables to investigate the suitability of applying the Bennett and Horiuchi method to aggregate data in South Africa and suggest an alternative approach for producing national mortality rates over the next decade or so, while racial breakdowns are not known. This method is then used to produce a national life table for 1989-91.

7.1 Comparison of national life table based on aggregate data with the previous estimate for 1984-86

Figures 7.1 and 7.2 compare the rates derived by applying the Bennett and Horiuchi method to the aggregate national data[27] for 1984-86 and then graduating, with those derived in the previous chapter[28].

[26] Race is about to be re-introduced on the death certificate (on a self-classification basis).

[27] $\delta = -0{,}05\%$ for males and $\delta = -0{,}06\%$ for females and the percentages reported were 72% for males and 63% for females.

[28] Here the IMRs were taken to be 67 and 58 and the CMRs to be 24 and 22 for males and females respectively.

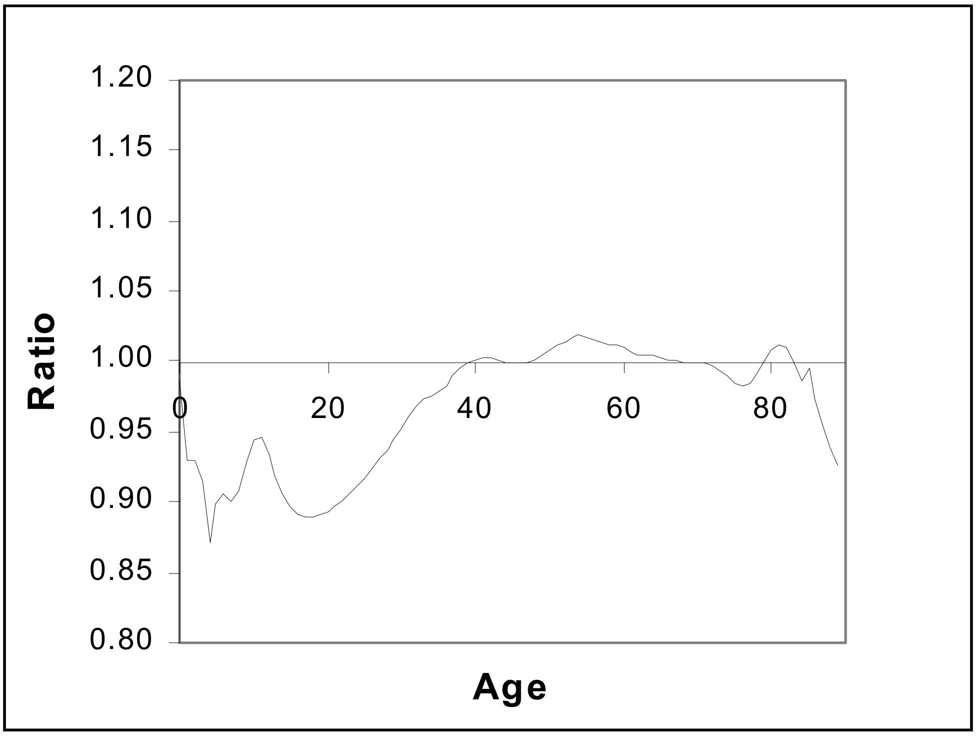


Figure 7.1 Ratio of national mortality rates: Males 1984-86

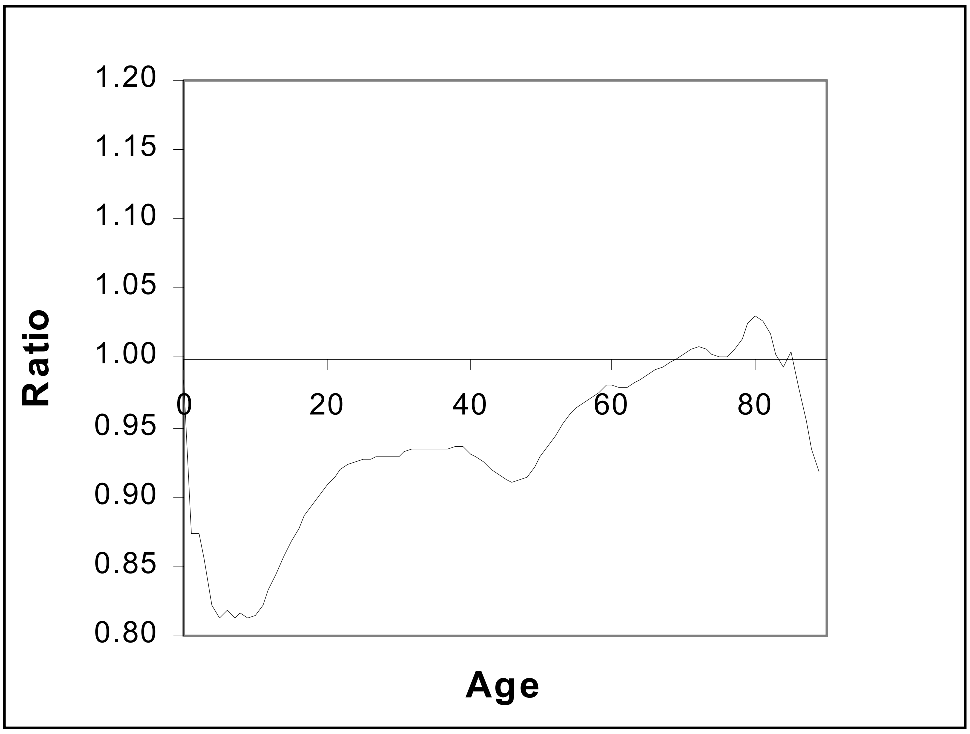


Figure 7.2 Ratio of national mortality rates: Females 1984-86

It is clear from these figures that a straight forward application of the Bennett and Horiuchi method significantly understates the rates below age 38 for males and 68 for females and overstates the rates for the older ages.

The reason for this is that the proportion of the population who were Black varies with age. This proportion, and hence the proportion of deaths arising out of the Black lives, is highest at the youngest ages. Since the percentage reported for Black and non-Black lives differ, this then leads to a violation of the assumption that, for the whole population, the percentage reported is constant with respect to age. In other words if one were to assume that the percentage of Black deaths that were reported was C^b (i.e. constant with respect to age) and the percentage of non-Black deaths that were reported was C^{-b} (i.e. also constant with respect to age[29]) then the percentage reported at age *x*, C_x, may be calculated using

$$C_x = p_x^b C^b + (1 - p_x^b) C^{-b} \qquad (7.1)$$

where p_x^b represents the proportion of all deaths which were classified as being Black.

In order to estimate C_x, the two scenarios were considered – one assuming that the TBVC deaths were recorded in the RSA (Case 1) and the other that the TBVC deaths were excluded (Case 2).

In the first case equation (7.1) was used estimating p_x^b by the proportion of expected Black deaths to the total expected deaths (on the basis of the mortality rates estimated in Chapter 6) and setting C^b to 56% for males and 44% for females, and C^{-b} to 100%.

In the second case equation (7.1) was expanded to $C_x = p_x^{b1} C^{b1} + p_x^{b2} C^{b2} + (1 - p_x^b) C^{-b}$ where p_x^{b1} represents the proportion of the total expected deaths which were Black RSA deaths, p_x^{b2} represents the proportion of the total expected deaths which were Black TBVC deaths (i.e. $p_x^{b1} + p_x^{b2} = p_x^b$) and C^{b1} and C^{b2} represent the proportion of the Black RSA and Black TBVC deaths respectively which were reported. In this case $C^{b2} = 0$ and C^{b1} was assumed to be 80% for males and 69% for females. p_x^b and C^{-b} were taken to be the same as in the first case.

These estimates of C_x together with p_x^b and p_x^{b1} as well as a linear regression fit to the average of the two estimates appear in Tables 7.1 and 7.2[30].

[29] Although there may be some variation between the White, Coloured and Asian race groups it is assumed that it unlikely to be significant for our purposes.
[30] It was decided to use the least squares linear fit to the average of the two estimates over the age range 15-84 to smooth the inconsistencies in the patterns, particularly over age range 0-14. (The R^2 was 0.91 and 0.97 for males and females respectively.)

Age (x)	Males				
	p_x^b	p_x^{b1}	C_x (case 1)	C_x (case 2)	Fitted C_x
0	92%	64%	59%	59%	66%
5	89%	61%	61%	60%	67%
10	86%	60%	62%	62%	67%
15	80%	60%	65%	68%	68%
20	80%	65%	65%	72%	68%
25	80%	68%	65%	74%	69%
30	80%	68%	65%	74%	69%
35	78%	65%	66%	75%	70%
40	76%	63%	66%	74%	70%
45	75%	61%	67%	74%	71%
50	73%	59%	68%	74%	71%
55	70%	55%	69%	74%	72%
60	65%	50%	72%	75%	72%
65	61%	42%	73%	73%	73%
70	58%	38%	74%	73%	73%
75	59%	38%	74%	72%	74%
80	59%	40%	74%	73%	74%
85	55%	37%	76%	75%	75%

Table 7.1 The proportion of deaths classified Black and the percentage of deaths reported: Males 1984-86

Age (x)	Females				
	p_x^b	p_x^{b1}	C_x (case 1)	C_x (case 2)	Fitted C_x
0	93%	64%	48%	52%	51%
5	85%	58%	53%	56%	52%
10	82%	57%	54%	57%	53%
15	85%	60%	52%	56%	54%
20	87%	62%	51%	56%	55%
25	86%	63%	52%	58%	56%
30	83%	62%	53%	59%	57%
35	79%	58%	56%	61%	57%
40	77%	56%	57%	62%	58%
45	75%	54%	58%	62%	59%
50	75%	53%	58%	62%	60%
55	73%	50%	59%	62%	61%
60	69%	46%	61%	62%	62%
65	67%	43%	62%	62%	63%
70	65%	41%	64%	63%	63%
75	64%	40%	64%	64%	64%
80	63%	41%	65%	65%	65%
85	55%	36%	69%	70%	66%

Table 7.2 The proportion of deaths classified Black and the percentage of deaths reported: Females 1984-86

Now obviously we can improve the estimated national mortality rates for this period by dividing the reported deaths by these percentages reported (which are lower than the percentage reported used earlier at the younger ages and higher at the older ages).

The impact of using age-group specific percentages reported is demonstrated in Figures 7.3 and 7.4 which reproduce Figures 7.1 and 7.2 but include the ratios of the rates which result from this "improvement"[31].

The improvement leads to better estimates below about age 65, particularly of the female rates, with the deviations above this age being confined, for the most part, within 5% of the underlying rate. The pattern of deviations is probably as much the result of a difference in shape between the standard and national life tables as it is errors in the estimation of the percentage reported.

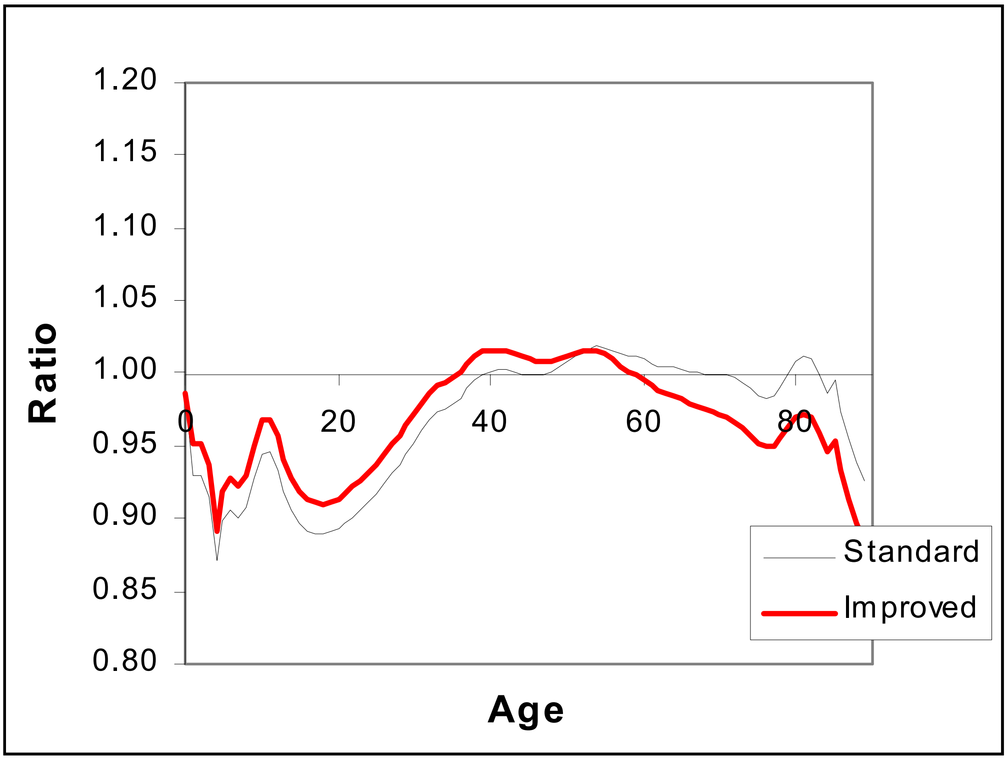


Figure 7.3 Ratio of national mortality rates: Males 1984-86

[31] Fitted percentages reported (as opposed to the actual percentages) were used in order to demonstrate the reasonableness of the approach.

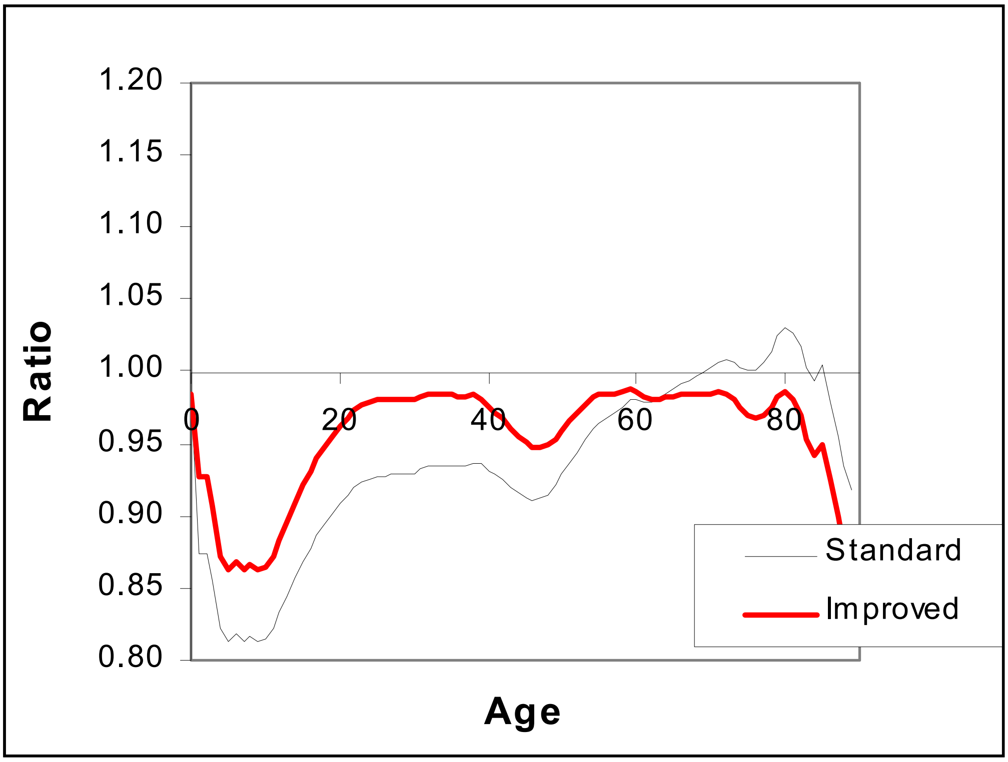


Figure 7.4 Ratio of national mortality rates: Females 1984-86

But what of future years? Well the pattern of the C_x s and their relationship to the p_x^b s suggest a method for estimating the C_x s in future years.

If we assume that the p_x^b s do not change very rapidly over time[32] we can see that the percentage reported at age x at some future date, C'_x, may be estimated as $C'_x = p_x^b(C^b + \varepsilon^b) + (1 - p_x^b)(C^{-b} + \varepsilon^{-b})$ where ε^b and ε^{-b} represent the change between the percentage reported at the specific future date and that for 1984-86 for the Black and non-Black populations respectively[33]. In other words $C'_x = C_x + p_x^b(\varepsilon^b - \varepsilon^{-b}) + \varepsilon^{-b}$.

Now if we assume that there is some age, y, at which ${}_5\hat{N}_y / {}_5N_y$ is a reasonable estimate for C'_y, in practice y=65 appears to be a good choice[34], then provided that

[32] This is not an unreasonable assumption since at a particular age this proportion is a function of the proportion of the population which is Black and the mortality rate for Black lives relative to those of the non-Black lives and these factors are unlikely to change very rapidly over time (and may even change in compensating directions).

[33] Obviously if there is some way of more reliably estimating the p_x^b s at the new time point (such as applying the 1985 mortality rates to updated population estimates by race) then these should be used in preference.

[34] That is, old enough not to be too significantly influenced by the growth rate adjustment (δ) but young enough to avoid the complications of relative age misstatement at the older ages.

ε^{-b} is relatively small we can derive reasonably accurate estimates of C'_x using the following relationship: $C'_x = C_x + \left(\frac{C'_{65} - C_{65}}{p^b_{65}} \right) p^b_x$.

7.2 1990 national life table

The age specific estimates of completeness in Table 7.3 were estimated using the method outlined above.

Age (*x*)	Male % reported	Female % reported
0	57%	47%
5	58%	48%
10	59%	49%
15	60%	50%
20	60%	51%
25	61%	52%
30	61%	53%
35	62%	54%
40	63%	55%
45	63%	56%
50	64%	57%
55	65%	58%
60	66%	59%
65	67%	60%
70	67%	61%
75	68%	61%
80	68%	62%
85	69%	64%

Table 7.3 Percentages of deaths reported 1990

These percentages reported were then applied to the recorded deaths for the years 1989-91 and Sadie's estimate of the 1990 population to produce ungraduated central rates of mortality. These were then converted into initial rates of mortality and combined with estimates of IMR and CMR based on an extrapolation of the 1984-86 estimates using the trends in mortality implied by Sadie's (1988) survival probabilities[35]. The resulting abridged life tables were then graduated to produce full life tables for 1989-91[36]. These results appear in Appendix 5.

It is interesting to note that the percentage reported at age 65 appears to have fallen significantly over the five years since 1985 (by about 6% in the case of males and 4% in the case of females). It is presumed that this fall occurred mainly in the percentage of Black deaths which were reported.

[35] This gave IMRs of 0.058 and 0.049 and CMRs of 0.021 and 0.019 in the case of males and females respectively.

[36] For males a different standard table was used (CM85M) which produced a better fit. In this case the Coloured male life table for 1984-86 was used but setting l_1 to 0.95 (and adjusting, as before, the childhood mortality to ensure consistency between l_1 and l_5).

Chapter 8

Discussion and Conclusion

The conclusions that can be drawn from this study fall into two sections. The first concerns conclusions that arise from the various methods used and the various adaptations made to them. The second section covers conclusions about the results of this investigation. The chapter concludes with a brief review of some areas for future research.

8.1 Methods

8.1.1 Estimation of under-reporting

The first conclusion is to confirm the observation (Preston 1984) that the Brass and Preston and Coale methods give very similar results and that usually applying both provides little new information. However, as shown in this research, with a reasonably reliable estimate of the population, Brass's method has the advantage that it more easily facilitates the adjustment of deaths for known errors which cause known deviations from the expected pattern.

The use of the Bennett and Horiuchi method with reliable estimates of growth rates appears to be superior to either of the other two. However, this research has demonstrated that it is particularly important to ensure that the growth rates at the older ages are reasonable since the method appears to be particularly sensitive to an error in estimation of growth rates at these ages.

It was noted that when applying any of these methods to data for ages above 75 it is desirable to allow for the curvature within the five-year age group when estimating ${}_5N_x$ or N_x. Failure to do this in the case of the Brass method, if these points are to be used to derive the estimate of the percentage reported, will lead to an overestimate of the N_xs and hence to an underestimate of the extent of reporting. This is not often mentioned in texts describing this method, probably because these methods are usually applied to data requiring a much lower open interval. In the case of the other methods (despite such an adjustment being suggested by Bennett and Horiuchi (1984)) the adjustment does not appear to have much effect, particularly if the estimate is based on the median of the ${}_{10}\hat{N}_{x-5} / {}_{10}N_{x-5}$ ratios.

8.1.2 Graduation

The next set of conclusions concerns the adjustments to the method of graduation proposed by Ewbank *et al* . From these we can conclude the following:

1. Their general standard life table can be substantially improved upon - in the case of this research the Coloured male life tables seemed to provide a much better fit - although there may be a problem ensuring a good fit in the region of $p = 0.5$.
2. The method can also be improved upon (slightly) by using weighted least squares to fit the regression - in the case of this research the deviations were weighted by the inverse of the mortality rates to ensure a relatively better fit to the low mortality rates.
3. $T(p,\kappa,\lambda)$ where $p \geq 0.5$ fails to allow adequately for the range of shapes of the curve in the early age range. This was compensated for in this research by altering the standard so that it provided an acceptable estimate to ${}_4q_1$ (q_0 being replaced by an estimate derived by methods other than the graduation).

8.2 Results

8.2.1 Comparison with other tables - Blacks 1984-86

	By year of registration	By year of occurrence	BD&S (1)	Sadie 1985 (2)	HSRC 80-85 (3)	USCB 1985 (4)	West (level 16.8) (5)	Brass Afrstd (6)
q_0	0.075	0.075	0.073	0.072	0.072	0.068	0.089	0.051
${}_4q_1$	0.027	0.029	0.027	0.036	0.029	0.050	0.036	0.052
${}_{45}q_{15}$	0.386	0.406	0.428	0.342	0.291	0.328	0.319	0.319
${}_{20}q_{15}$	0.089	0.098	0.098	0.082	0.065	0.068	0.078	0.088
${}_{25}q_{35}$	0.326	0.342	0.366	0.283	0.242	0.279	0.261	0.254
e_0	56.1	55.1	54.8	57.1	59.2	56.8	56.1	56.4
e_{65}	11.5	11.4	11.4	13.4	14.2	12.0	11.7	11.2

Source: (1) BD&S - Bradshaw *et al* (1992)
(2) Sadie - Average derived from 1980-85 and 1985-90 survival probabilities using his (incorrect) assumptions (CSS 1992c)
(3) HSRC - Derived from the survival probabilities implied by their 1980 and 1985 population estimates (Mostert *et al* 1987)
(4) USCB - The US Bureau of the Census (Arriaga 1997)
(5) West - Coale and Demeny (1966)
(6) Brass Afrstd - Brass's African Standard from Brass (and others) (1968)

Table 8.1(a) Comparison: Black males 1984-86

	By year of registration	By year of occurrence	BD&S (1)	Sadie 1985 (2)	HSRC 80-85 (3)	USCB 1985 (4)	West (level 18.3) (5)	Brass Afrstd (6)
q_0	0.065	0.065	0.068	0.068	0.060	0.054	0.057	0.046
${}_4q_1$	0.025	0.026	0.028	0.033	0.024	0.049	0.024	0.038
${}_{45}q_{15}$	0.240	0.248	0.295	0.219	0.236	0.178	0.223	0.210
${}_{20}q_{15}$	0.050	0.052	0.050	0.031	0.056	0.030	0.054	0.057
${}_{25}q_{35}$	0.200	0.207	0.258	0.195	0.191	0.152	0.178	0.162
e_0	63.3	63.1	61.1	63.7	63.1	63.8	63.3	63.4
e_{65}	14.1	14.3	14.0	15.7	15.6	13.7	13.4	13.9

Source: (1) BD&S - Bradshaw *et al* (1992)
(2) Sadie - Average derived from 1980-85 and 1985-90 survival probabilities using his (incorrect) assumptions (CSS 1992c)
(3) HSRC - Derived from the survival probabilities implied by their 1980 and 1985 population estimates (Mostert *et al* 1987)
(4) USCB - The US Bureau of the Census (Arriaga 1997)
(5) West - Coale and Demeny (1966)
(6) Brass Afrstd - Brass's African Standard from Brass (and others) (1968)

Table 8.1(b) Comparison: Black females 1984-86

From Table 8.1 we can observe the following:

1. As this research is a refinement of that underlying the rates of Bradshaw *et al* not much is to be gained by comparing the two sets of rates in detail. However, it is interesting to note that the adult mortality in the current rates, particularly at the older ages is somewhat lower than for the previous estimates.
2. The rates derived from deaths by year of occurrence are higher than those based on deaths recorded by year reported. In the case of males they are about 10% higher in the 15 to 35 year age range and about 5% higher thereafter. In the case of females the rates are about 4% higher throughout. (The full life tables derived using the same methods as described in this thesis but based on deaths by year of occurrence have been included in Appendix 6.)
3. A comparison of the childhood mortality rates (${}_4q_1$) with Sadie's and particularly those of the US Bureau of the Census suggest that the rates produced by this research are too low. However, the ratio of the CMR to IMR is slightly more than 37% and inspection of the Coale and Demeny (1966) model life tables suggest that at this level of IMR the ratio is in the region of 40% for the "West" model, 60% for the "North" model and only 25% and 33% in the case of the "East" and "South" models respectively. (In the case of Sadie's rates the ratio is close to 50%[37] and in the case of the US Bureau of the Census rates it is above 70%.)
4. Sadie's rates appear to be too light - progressively with age (for example they are 8% lighter than the rates derived in this research in the 15-35 age range and 13% in the 35 to 60 age range for males).
5. Both the HSRC and the US Bureau of the Census estimates appear to be too light, the HSRC particularly in the case of males (25% lighter from age 15 upwards even though this is an estimate of mortality on average some two and a half years

[37] This is before correcting his estimate of IMR. After correcting the ratio is about 40%.

earlier) and the USBC particularly in the case of females (25% lighter in the 15 to 60 age group but similar thereafter).

8.2.2 Comparison with other tables - National 1984-86

	Males			Females			
	by year of registration	BD&S (1)	West (level 17.6) (2)	by year of registration	BD&S (1)	Udjo (3)	West (level 19.1) (2)
q_0	0.068	0.066	0.079	0.059	0.061	0.056	0.049
${}_4q_1$	0.024	0.024	0.031	0.022	0.024	0.041	0.018
${}_{45}q_{15}$	0.354	0.384	0.298	0.216	0.255	0.198	0.202
${}_{20}q_{15}$	0.080	0.087	0.070	0.043	0.043		0.046
${}_{25}q_{35}$	0.298	0.325	0.245	0.181	0.221		0.163
e_0	57.9	57.0	57.9	65.3	63.6	62.9	65.3
e_{65}	11.9	11.8	11.8	15.0	14.8		13.6

Source: (1) BD&S - Bradshaw *et al* (1992)
(2) West - Coale and Demeny (1966)
(3) Udjo - Udjo (1997)

Table 8.2 Comparison: National 1984-86

The interesting feature from Table 8.2 is the comparison of the female rates with those of Udjo (1997) derived from the 1995 October Household Survey[38]. From this comparison it would appear as if the estimates of the CMR derived from the OHS are too high while the adult mortality appears to be too low. In addition the estimate of life expectation at birth appears to be too low implying fairly high mortality at ages over 60.

[38] These rates were used to project an estimate of the 1996 population used to justify the order of magnitude of the 1996 preliminary census estimates (CSS 1997).

8.2.3 Comparison with other tables - National 1989-91

	Males					Females				
	By year of registration	USCB 1990 (1)	West (level 17.7) (2)	Timaeus 1990 (3)	Timaeus +Y(5) (3)	By year of registration	USCB 1990 (1)	West (level 19.6) (2)	Timaeus 1990 (3)	Timaeus +Y(5) (3)
q_0	0.058	0.058	0.078	0.070	0.052	0.049	0.047	0.045	0.063	0.049
${}_4q_1$	0.021	0.039	0.030	0.036	0.027	0.020	0.039	0.016	0.026	0.020
${}_{45}q_{15}$	0.374	0.316	0.295	0.336	0.274	0.220	0.174	0.190	0.221	0.181
${}_{20}q_{15}$	0.090	0.070	0.069	0.082	0.063	0.043	0.034	0.041	0.054	0.043
${}_{25}q_{35}$	0.312	0.265	0.243	0.274	0.225	0.185	0.146	0.155	0.176	0.144
e_0	58.1	58.9	58.1	56.3	60.5	66.2	66.2	66.4	62.9	66.5
e_{65}	12.0	12.6	11.8	10.9	11.5	15.1	15.2	13.8	14.5	14.5

Source: (1) USCB - The US Bureau of the Census (Arriaga 1997)
(2) West - Coale and Demeny (1966)
(3) Timaeus - Estimates of "Southern African" mortality (Timaeus 1997), +Y(5) refers to an adjustment proposed by the author to allow the actual mortality experienced below age five

Table 8.3 Comparison: National 1989-91

The comparison with the US Bureau of the Census rates shows similar features to those observed in Table 8.1, namely that their estimate of childhood mortality is too high while their estimate of adult mortality is too low. However, it is interesting to note that although this research was carried out completely independently of the US Bureau of the Census results, the estimates of IMR are virtually the same.

8.2.4 Males vs females

1. Female rates are in all instances lower than those of males at all ages however the level of difference is not consistent with that exhibited by the West model life tables (for example in Table 8.1 the male mortality lies between level 16 and 17 whereas the female mortality lies somewhere between levels 18 and 19). However, this difference both for Blacks and nationally is confirmed by the estimates of Sadie, the US Bureau of the Census and Timaeus.
2. Not only is there a difference in the level of mortality but the patterns of mortality appear to be somewhat different, with the female rates being, relatively, significantly lower in the adult ages. Timaeus (1997) also noted this difference.

8.2.5 Model life tables

1. Each of the tables produced in this research has been compared with the appropriate level of the West model life table since this model has been suggested by a number of demographers to model mortality in South Africa (e.g. Mostert *et al* (1987) and Timaeus (1997)). Timaeus found it to be preferable to the other Princeton tables - particularly the South which he chose to model mortality in "East", "Middle" and "West" Africa - since it "inflate(d)

the importance of adult mortality … and to a lesser extent also the diseases of infants as opposed to older children").

2. Although the West model exhibits the highest adult mortality of the four Princeton tables (UN 1983, 14-15) the above results demonstrate (and is confirmed by Timaeus) that the West model still understates the adult mortality. However, in the case of this research the difference appears to be significant (particularly in the case of males) and particularly above age 35, and in the case of males the West model appears to exaggerate ${}_5q_0$ (in the case of females it also tends to underestimate the IMR). Because of the weight of the Black population as a proportion of the national population similar patterns are found in the national rates. Thus the conclusion must be that none of the Princeton tables fit the South African mortality very well (but of the four the West probably provides the best fit)[39].

3. Brass's African standard, which was not specifically designed to fit Southern African mortality patterns (Brass 1966) was fitted to the Black 1984-86 mortality only. Once again the shape is very different with much too low infant mortality, too high child mortality, too low adult mortality (in the case of males above age 35 only).

4. Finally Timaeus constructed a number of life tables as his "best estimates of the actual life tables and prevailing life expectancy in sub-Saharan Africa and its main sub-regions in 1990" (one of which was "Southern" Africa which has been included in Table 8.3). He further suggested that they could be interpreted as "revised African regional and sub-regional standard model life tables" and to this end he fitted ↦ as a function of logit(l_5). Applying this adjustment to the l_5 from this research gives the results in the second column included in Table 8.3.

   Comparing these columns with the first we can see that for males Timaeus's standard, after taking into account logit(l_5), give significantly lower adult mortality (except at the extreme ages) while perhaps under-estimating infant mortality and overestimating child mortality. As far as females are concerned the IMR and CMR match those from this research but the adult mortality above age 35 is much lower.

   Thus if the rates determined in this research are a reflection of the underlying pattern of mortality in South Africa then this underlying pattern is not well represented by Timaeus's model table, or indeed by any of the other model life tables.

8.2.6 Trends in mortality

1. With exception of the rates below age five there has been no improvement in national mortality - in fact for males adult mortality appears to have deteriorated. However, before concluding that mortality is getting worse one should bear in mind that the national mortality is in effect a weighted average of the mortality of the various sub-populations (with that of the Blacks being significantly heavier than that of the other population groups) and that the

[39] It is interesting to note that in the case of the other population groups the West model tends to overstate adult mortality in all but the Coloured males (where it gives the same estimate), to overstate the IMR and in most cases the CMR as well.

proportion of the population which is Black at each age group is increasing. Thus it would seem that, with the exception of the childhood mortality, non-AIDS, national mortality in South Africa is probably not changing very rapidly.

2. AIDS may be expected to increase mortality significantly in the 15 to 60 year age range within the next 20 years. Figure 8.1 shows the mortality rates of Blacks projected by the ASSA model (Scenario 500, ASSA 1997). This projection may be slightly exaggerated since it is based on the assumption that non-AIDS mortality rates do not improve. However, it is entirely consistent with the quite startling suggestion made by Bradshaw *et al* (1992) that, left unchecked, male ${}_{45}q_{15}$ could reach 70% by the year 2000[40].

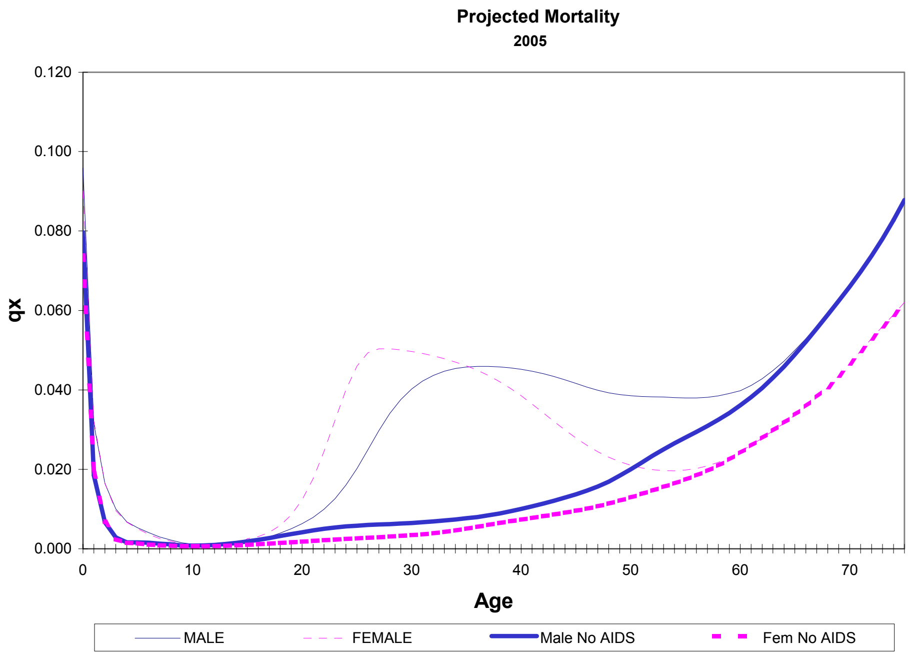


Figure 8.1 Projected mortality of Black lives in 2005, including AIDS

8.2.7 Areas of future research

This research has identified a number of areas requiring further research.

8.2.7.1 Improving death registration:

1. The first, and most obvious, is the need for research into the reasons for the under-reporting of deaths and the reason for the difference in the level of male and female under-reporting, and whether the TBVC deaths are being reported in the RSA. Such research would not only hopefully suggest ways of improving the recording of death data but would also provide a better understanding of the pattern of reported deaths.
2. Connected to the above it is necessary to investigate thoroughly the somewhat large discrepancy between deaths recorded in the death reports (i.e. deaths by year reported) and deaths by year of occurrence. If such research shows that deaths by

[40] In this regard it is interesting to note that the US Bureau of the Census estimate of Black mortality in 1990 shows ${}_{20}q_{15}$ some 13% higher for males and 27% higher for females than their 1985 estimates. This extra mortality they ascribe to AIDS deaths (although according to the ASSA scenario such a rapid increase in mortality is highly unlikely).

year of occurrence are the more reliable estimates (as might, on the face of it, be expected) then this will necessitate a re-estimation of the SALT (at least for 1984-86) and following that a re-estimation of the national 1984-86 and 1989-91 tables derived in this research.

8.2.7.2 Estimating infant and child mortality:

1. The method used in this research is dependent on reliable estimates of IMR and CMR and to a lesser extent the population. Thus if indirect methods are to be used to estimate population mortality in future (as seems likely at least for the foreseeable future) then it is going to be necessary to embark on research to try and improve on our estimates of infant and childhood mortality.

8.2.7.3 Improvements to the methods of estimation:

1. There is obviously a need to try and adapt the Bennett and Horiuchi method to allow for systematic differences in the percentage reported with respect to age which arise out of differences in the proportion the various sub-groups which experience different mortality rates (e.g. urban and rural, rich and poor, or in South Africa, race groups) are of the total population.
2. It could be very useful if one could create a life table (or life tables) which could be used to model the mortality of the population in South Africa. Such tables would be particularly useful in estimating mortality on a regional basis where it is not possible to assume a closed population (using methods such as that described by Courbage and Fargues (1979)). (Indeed with laxer immigration controls and registration together with "*de facto*" censuses in future it is likely that even at a national level one will no longer be able to assume that the population is closed which will increasingly render the methods used in this research useless.)

8.2.7.4 Monitoring the AIDS epidemic:

1. As has been indicated earlier, AIDS is likely to have a significant impact on mortality in future and reliably estimating the progression of the epidemic is a national priority. To date the models (Metropolitan Life[41], ASSA) have been calibrated on HIV prevalence mainly from annual antenatal clinic surveys. However, as the numbers of AIDS deaths become significant, reliable estimation of these could provide useful further collaboration of the model. However, with the current margin of error in the mortality rates it is unlikely that it would be before the year 2000 before meaningful results could be derived.

8.3 Overall conclusion

The overall conclusion must be that indirect demographic techniques can help considerably in estimating both the level and, to a certain extent, the shape of mortality in South Africa. However, given the low level of reporting and the distortions in the pattern of reporting due to urban/rural, racial and other inequalities in the society the results must be treated with some caution.

[41] The AIDS model devised by Metropolitan Life (Box 93, Cape Town 8000) is a propriety model first described in Doyle and Millar (1990).

From the results above one can probably safely say that with the exception of the infant and childhood mortality overall mortality did not improve in South Africa between 1985 and 1990. Given the spread of HIV it is probable that mortality has worsened in the 15 to 60 year age range since then. In addition one can also conclude that the shape of mortality in South Africa is significantly different from current model life tables. All of which suggests that it is going to be increasingly difficult to ascertain the level and shape of mortality in the country in the years to come unless the level of reporting improves markedly.

Appendix 1: Population 1980, 1985, 1990

A1.1 Quinquennial Estimates of Black Population

MALE							
	ENUMERATED(1) & (2)		HSRC's ESTIMATE(3)		Sadie's ESTIMATE(4)		
AGE	1980	1985	1980	1985	1980	1985	1990
0	1175850	1427164	1894899	2224096	1739500	2010400	2267900
5	1240225	1408114	1621301	1851598	1473700	1713200	1983400
10	1139450	1365284	1398201	1607199	1268900	1466100	1705700
15	937840	1082317	1207100	1384501	1122700	1260200	1457200
20	748533	914491	1021699	1189599	974100	1106600	1243400
25	609799	769642	815499	1003800	783300	953200	1084700
30	480958	598215	654800	799800	616800	763300	930400
35	390717	495217	538200	639901	508300	597200	738600
40	358964	407116	458900	522601	435600	485700	573400
45	294764	356308	377000	440900	358900	408600	458700
50	234715	265867	309701	356300	290200	328400	377300
55	169313	204372	246700	285399	216300	257800	295000
60	157168	171063	187899	218599	157300	183600	221800
65	114428	154243	133801	156900	101900	124300	147900
70	77248	91585	86099	101900	71200	74400	92500
75	48381	56501	47601	56800	50300	47100	50000
80	25489	27768	18200	22200	21400	27800	26400
85+	19413	23971	6600	8100	11400	13500	16100
TOT	8223255	9819238	11024200	12870193	10201800	11821485	13670400

FEMALE							
	ENUMERATED(1) & (2)		HSRC's ESTIMATE(3)		Sadie's ESTIMATE(4)		
AGE	1980	1985	1980	1985	1980	1985	1990
0	1199288	1439138	1887701	2214100	1711400	1989000	2241400
5	1243737	1414645	1620799	1849700	1468900	1686700	1964000
10	1160964	1395373	1398800	1607900	1268400	1449200	1681300
15	1046477	1197588	1209701	1386700	1121700	1263200	1443900
20	880440	1093225	1026500	1195200	990800	1115400	1256200
25	701310	902135	828600	1011200	801800	981800	1105900
30	560290	694281	668900	814200	637200	791900	971000
35	461573	569630	552600	655300	534800	626500	780100
40	415570	480480	471001	539300	464400	522500	613700
45	333705	401811	389701	456700	385000	449900	508000
50	274842	317024	324999	373800	317900	368900	432800
55	202050	250158	265499	306400	250500	300100	349800
60	225912	267607	209799	243200	194400	229700	276900
65	160828	217354	157300	183200	137300	169700	202300
70	113036	131369	108200	126800	119400	111200	139100
75	65358	79691	64900	76500	68800	87900	82800
80	44693	46726	27200	33000	37000	44100	56800
85+	35833	42034	11500	14000	24200	28000	33000
TOT	9125906	10940269	11223700	13087200	10533900	12215700	14139000

A1.2 Enumerated South African-born Black Population, 1985

MALES

AGE (x)	RSA[5]	TRANSKEI[6]	BOP.[7]	VENDA[8]	CISKEI[9]	SA	SA (x to x+4)
0	184997	50768	24111	8342	12864	281082	1427165
1	169094	45862	20383	6223	11803	253364	
2	194861	51376	24458	7442	12568	290705	
3	201400	56814	25453	7754	13224	304645	
4	197325	52918	25920	8004	13202	297369	
5	185102	53648	24247	7426	10864	281287	1408115
6	182817	52648	23676	7407	10847	277395	
7	190092	49050	23989	7920	11458	282510	
8	198103	50940	24337	7933	11357	292670	
9	186080	47422	22345	7520	10885	274252	
10	206303	50687	26311	7617	11663	302581	1365284
11	160892	37991	21240	6102	8934	235160	
12	206281	48632	26417	7282	10930	299542	
13	181609	42822	22089	6738	10047	263305	
14	183522	42028	22568	6616	9963	264697	
15	171125	34207	21388	6203	11004	243927	1082318
16	164649	32829	20826	5435	10643	234382	
17	141937	25499	18708	4617	9296	200057	
18	161549	25803	19446	4827	9763	221388	
19	136925	17598	16765	3783	7492	182563	
20	156733	17916	19294	3499	9349	206792	914491
21	142299	11243	16060	2838	6261	178702	
22	146437	10707	15716	2597	6517	181975	
23	143148	9063	15116	2309	5340	174976	
24	141354	9217	14216	2116	5144	172047	
25	152806	8602	14322	1886	4744	182359	769642
26	123563	7924	13041	1608	4167	150303	
27	122079	6895	11934	1500	3872	146279	
28	129777	8946	12824	1660	4624	157831	
29	110943	7158	10190	1294	3284	132870	
30	138587	10341	13631	1613	5028	169200	598215
31	81827	5079	8261	953	2585	98705	
32	110662	6758	10465	1386	3588	132859	
33	82083	4484	7615	1001	2567	97750	
34	82727	5500	7721	966	2788	99701	
35	108325	5860	8143	1288	3221	126838	495217
36	83973	5727	7875	1054	2755	101384	
37	65470	4389	6125	767	2099	78850	
38	85370	7006	8518	1136	3351	105381	
39	66856	5911	6432	801	2764	82764	
40	106962	9439	9914	1202	5348	132865	407116
41	46569	3795	4914	507	1732	57518	
42	73446	5397	6585	774	2827	89029	
43	55610	3895	4894	676	2028	67103	
44	50076	3750	4508	497	1772	60603	
45	92163	6864	6756	1102	2670	109555	356308

46	48417	5135	4624	656	1547	60379	
47	41150	4671	4711	544	1487	52563	
48	57940	7187	6026	787	2306	74247	
49	47223	5441	4522	703	1676	59565	
50	71919	8728	6206	904	2522	90279	265867
51	27524	3465	3131	344	953	35418	
52	45464	5112	4461	586	1705	57328	
53	31335	3693	2966	483	1174	39651	
54	33702	4308	3270	536	1375	43192	
55	42160	3956	4227	597	1019	51958	204372
56	34690	5296	3387	694	1196	45263	
57	22817	3492	2496	401	792	29998	
58	31557	5367	3397	430	1321	42073	
59	25710	4746	3005	512	1106	35079	
60	52454	7800	4364	939	1895	67452	171063
61	15077	3392	2154	312	789	21725	
62	20588	6047	3749	423	2097	32904	
63	18262	2850	1673	399	727	23911	
64	18652	3195	1856	392	977	25072	
65	38626	6544	2799	813	1360	50142	154243
66	16072	5303	2642	391	1152	25560	
67	21399	5866	1928	476	965	30634	
68	16655	6473	2465	548	1091	27231	
69	12646	4780	2077	470	703	20676	
70	28378	8072	3678	784	2245	43158	91585
71	10384	2020	1333	388	389	14513	
72	10475	2751	1749	399	684	16058	
73	6715	1700	1221	298	366	10300	
74	4045	1764	1055	253	439	7556	
75	13695	2543	1555	452	609	18854	56501
76	5709	2399	1296	209	446	10059	
77	3242	1334	837	114	287	5814	
78	6571	3005	1748	238	646	12208	
79	4973	1803	2208	181	402	9567	
80	10516	1319	1494	309	681	14318	28768
81	2202	320	373	98	192	3186	
82	3006	268	330	122	177	3903	
83	2485	175	224	127	122	3132	
84	3321	258	303	158	189	4228	
85	4376	474	406	161	174	5592	23971
86	1498	276	280	58	114	2226	
87	1300	293	210	47	80	1930	
88	971	213	219	30	79	1512	
89	1826	325	376	75	84	2687	
90	2742	425	405	82	144	3798	
91	449	76	96	15	21	657	
92	581	72	138	26	37	853	
93	268	55	66	11	20	420	
94	311	54	101	16	30	512	
95	852	86	130	43	38	1149	
96	669	71	109	32	32	912	
97	308	64	71	13	11	467	
98	862	84	135	29	28	1138	
				118		118	

FEMALES

AGE (x)	RSA[5]	TRANSKEI[6]	BOP. [7]	VENDA[8]	CISKEI[9]	SA	SA (x to x+4)
0	186598	51678	24459	8233	12682	283651	1439139
1	168512	46211	20655	6098	11637	253113	
2	195260	53278	25100	7278	12391	293308	
3	201798	58603	25562	7827	13038	306828	
4	199912	55262	26082	7968	13016	302239	
5	183059	53762	24140	7387	11236	279585	1414646
6	182080	53591	23412	7244	11218	277545	
7	189077	49257	24027	7807	11850	282018	
8	201128	52203	24985	7945	11746	298007	
9	187805	47837	22878	7713	11258	277491	
10	207332	50783	27481	7766	12115	305477	1395373
11	164624	39656	21792	6272	9281	241626	
12	206276	49985	27066	7326	11353	302006	
13	186955	44896	23404	6951	10437	272643	
14	188307	44892	23317	6756	10350	273621	
15	179942	38293	22043	6131	10834	257242	1197588
16	177890	38645	22401	5672	10478	255086	
17	153538	31804	20153	4936	9153	219584	
18	180335	36308	21979	5608	9612	253842	
19	152227	28713	19046	4472	7376	211834	
20	184734	38702	22988	5183	10715	262322	1093225
21	153054	26588	19070	4632	7176	210520	
22	157691	26720	18695	4992	7470	215568	
23	151492	24298	17687	4695	6121	204292	
24	149839	24135	16019	4634	5895	200523	
25	160953	25611	16738	4474	6110	213886	902135
26	128075	23355	14986	4053	5367	175836	
27	110886	18867	13619	3577	4987	151936	
28	164866	26096	15127	4124	5955	216168	
29	105476	19855	11784	2963	4230	144308	
30	162139	31594	15296	4531	6476	220036	694281
31	73899	13920	9256	2082	3329	102486	
32	116635	18560	12238	3529	4621	155582	
33	75584	11404	8768	2446	3307	101509	
34	84729	14350	9450	2548	3590	114668	
35	109976	16841	9373	3188	4428	143805	569630
36	87936	16212	9198	2851	3786	119983	
37	59115	11661	7047	1811	2885	82519	
38	94130	18667	9705	3192	4606	130300	
39	65347	14673	7045	2159	3800	93023	
40	124578	27142	11436	3647	7350	174153	480480
41	42459	9115	5601	1215	2380	60769	
42	77335	12959	7848	2165	3886	104193	
43	55028	9547	6148	1651	2788	75162	
44	48017	8983	5588	1179	2435	66202	
45	90761	16001	7166	2807	3234	119970	401811
46	48285	11623	5602	1625	1874	69009	
47	38093	10509	5726	1254	1801	57382	
48	61754	15469	6567	2246	2794	88829	
49	46816	11104	4878	1792	2030	66620	
50	86202	19036	7406	2810	3055	118509	317024

51	27124	6711	3840	892	1154	39722	
52	46296	9477	5304	1510	2066	64653	
53	30455	6747	3841	991	1423	43457	
54	35211	8038	4493	1275	1666	50683	
55	43579	7307	5559	1641	1808	59895	250158
56	36621	9841	4107	1806	2123	54498	
57	23241	5995	3209	1021	1406	34872	
58	37815	9223	4144	1827	2345	55354	
59	30168	8316	3635	1459	1962	45540	
60	77674	18263	6178	2783	3363	108262	267607
61	20395	6413	3104	874	1401	32187	
62	30104	12663	5413	1279	3721	53180	
63	24863	6451	2558	1089	1290	36251	
64	24329	7528	2996	1140	1734	37727	
65	50778	11641	4304	2545	1867	71135	217354
66	19248	7398	3895	1013	1580	33135	
67	27182	8293	2483	1119	1325	40402	
68	24689	10042	3699	1372	1497	41298	
69	19190	7092	2993	1145	965	31385	
70	40269	12585	5365	1666	3081	62966	131369
71	11814	2918	1970	663	533	17898	
72	14033	4423	2502	745	938	22641	
73	8588	2438	1867	445	502	13840	
74	8871	2614	1561	375	602	14024	
75	18190	3669	2385	887	892	26024	79691
76	7973	3287	1933	468	653	14314	
77	4231	1441	1238	252	421	7582	
78	9710	4384	2293	560	947	17894	
79	7729	2608	2561	390	589	13877	
80	18196	2613	2460	683	998	24950	46726
81	3545	599	545	183	282	5154	
82	4771	544	578	243	259	6394	
83	3479	385	365	174	178	4582	
84	4178	461	507	222	277	5646	
85	6916	865	664	352	256	9053	42034
86	2656	581	478	149	167	4030	
87	2034	514	331	115	117	3112	
88	1693	368	365	79	115	2621	
89	3092	628	491	203	124	4538	
90	5188	872	724	172	211	7167	
91	696	126	187	38	31	1078	
92	1136	155	257	60	54	1662	
93	557	96	137	33	30	852	
94	599	141	169	31	45	985	
95	1429	159	233	70	56	1947	
96	1248	147	199	52	46	1692	
97	563	109	135	28	16	852	
98	1643	175	276	58	41	2193	
				251		251	

A1.3 Estimates of National Population 1985, 1990 and 1995

	MALE(10)			FEMALE(10)		
AGE	1985	1990	1995	1985	1990	1995
0	2450660	2722070	2976540	2419070	2683770	2942630
5	2129130	2421180	2694420	2094270	2392120	2658560
10	1935010	2120400	2413020	1908540	2088040	2386070
15	1702090	1923120	2108690	1697550	1901920	2081590
20	1513890	1679160	1899150	1522690	1688470	1892940
25	1327550	1484580	1648850	1354760	1510840	1676510
30	1095910	1297710	1452930	1123600	1340920	1496740
35	900730	1064150	1260720	929910	1108230	1324440
40	742040	868710	1026090	775760	912620	1089510
45	625660	705450	830250	664790	755860	891260
50	503870	581480	660100	547880	640530	730530
55	401060	454900	529600	454200	519940	609980
60	300270	346770	397060	361410	419880	482680
65	215370	244400	288660	279130	320180	374130
70	142750	161300	186600	211220	232720	269010
75	84890	94854.19	108350	139870	160605.1	178210
80	41730	47660	53830	79250	92203.54	106680
85+	20820	24984	28590	49620	58580	68950
TOT	16133430	18242878	20563450	16613520	18827429	21260420

Source:

(1) 1980: De facto less foreign born, i.e. Tables A3 and A4 less the relevant figures from Tables C1 and C2, Mostert et al (1987).
(2) 1985: see A1.2.
(3) Tables H1 to H4, Mostert et al (1987).
(4) Appendix D2, Sadie (1988).
(5) Tables G5 and G6, Mostert et al (1987).
(6) Transkei (1987)*.
(7) Bophuthatswana (1987)*.
(8) Venda (1987).
(9) Ciskei (1986)*.
(10) Aggregation of various tables in Sadie (1988).

* Data not published for individual ages was apportioned according to the RSA figures.

Appendix 2: Deaths (by year reported)

A2.1 Blacks (1984-86)

1984-1986				
AGE	MALE		FEMALE	
(x)		(x to x+4)		(x to x+4)
0	25685	35760	23763	33132
1	6227		5676	
2	2195		2147	
3	980		968	
4	673		578	
5	544	2179	415	1731
6	448		413	
7	427		334	
8	418		310	
9	342		259	
10	390	2021	271	1429
11	339		218	
12	440		298	
13	379		303	
14	473		339	
15	450	3923	343	2177
16	695		466	
17	786		386	
18	956		511	
19	1036		471	
20	1537	8123	663	3105
21	1395		543	
22	1695		604	
23	1721		639	
24	1775		656	
25	2362	9587	864	3521
26	1817		699	
27	1747		622	
28	1979		729	
29	1682		607	
30	3365	10011	1354	4178
31	1490		591	
32	1891		774	
33	1529		688	
34	1736		771	
35	2528	9555	1034	4104
36	1992		832	
37	1517		597	
38	1941		843	
39	1577		798	
40	3457	10018	1571	4637
41	1344		583	
42	1922		963	
43	1527		722	
44	1768		798	

45	3019	10249	1443	4953
46	1836		885	
47	1555		712	
48	2031		1003	
49	1808		910	
50	4137	11238	2088	5783
51	1613		787	
52	1965		1054	
53	1638		830	
54	1885		1024	
55	2500	10350	1319	5600
56	2260		1237	
57	1665		830	
58	1990		1066	
59	1935		1148	
60	5127	12212	3262	8017
61	1559		1031	
62	1651		1167	
63	1766		1151	
64	2109		1406	
65	3941	13213	2943	10102
66	2471		1800	
67	2704		1913	
68	2394		1920	
69	1703		1526	
70	4721	10205	3945	8715
71	1485		1186	
72	1493		1321	
73	1090		931	
74	1416		1332	
75	2013	5886	1823	5486
76	1216		1114	
77	666		651	
78	966		904	
79	1025		994	
80	2077	4821	2349	5288
81	578		652	
82	645		747	
83	725		728	
84	796		812	
85	761	3502	958	5772
86	387		515	
87	202		277	
88	185		287	
89	202		344	
90	497		812	
91	102		165	
92	92		157	
93	46		90	
94	85		144	
95	125		241	
96	99		203	
97	44		94	
98	146		309	
99+	529		1176	

Source: CSS Death reports.

A2.2 **Total** (average per annum 1984-86)

Age	White	Coloured	Asian	Black	Total
0	593	2488	223	11920	15223
5	75	157	26	726	984
10	106	137	26	674	943
15	275	385	60	1308	2027
20	515	714	117	2708	4053
25	446	709	105	3196	4456
30	444	638	110	3337	4529
35	536	639	147	3185	4507
40	690	679	181	3339	4889
45	902	793	234	3416	5346
50	1183	965	252	3746	6146
55	1681	975	318	3450	6423
60	2198	1071	296	4071	7636
65	2654	1051	291	4404	8400
70	2965	973	258	3402	7599
75	2711	651	165	1962	5489
80	1658	484	92	1607	3841
85+	1265	355	58	1167	2846
Total	20896	13864	2960	57618	95337

Table A2.1 Reported deaths 1984-86: Males

Age	White	Coloured	Asian	Black	Total
0	402	2152	178	11044	13776
5	54	111	24	577	766
10	55	92	15	476	638
15	113	162	30	726	1031
20	137	259	37	1035	1468
25	156	290	41	1174	1660
30	180	337	46	1393	1956
35	243	367	56	1368	2034
40	346	466	80	1546	2437
45	502	531	108	1651	2791
50	631	616	147	1928	3322
55	922	673	202	1867	3663
60	1335	748	232	2672	4988
65	1696	752	254	3367	6070
70	2259	818	202	2905	6184
75	2706	670	151	1829	5356
80	2313	588	95	1763	4759
85+	2975	623	93	1924	5615
Total	17025	10254	1991	39243	68513

TAble A2.2 Reported deaths 1984-86: Females

A2.3Total (average per annum 1989-91)

Age	Male	Female
0	12477	10994
5	952	705
10	889	628
15	2405	1025
20	4440	1552
25	5216	1849
30	5322	2125
35	5463	2366
40	5746	2633
45	5906	2881
50	6718	3833
55	6555	4246
60	7864	5568
65	7571	5646
70	7837	6934
75	6197	6167
80	4006	5331
85+	3253	6124
Total	98818	70607

Table A2.3 Reported deaths 1989-91

Appendix 3

Adjustment of the Black population estimates

A.3.1 Problems

Age	MALE 80-85	85-90	80-90	FEMALES 80-85	85-90	80-90
0	0.029	0.024	0.027	0.030	0.024	0.027
5	0.030	0.029	0.030	0.028	0.030	0.029
10	0.029	0.030	0.030	0.027	0.030	0.028
15	0.023	0.029	0.026	0.024	0.027	0.025
20	0.026	0.023	0.024	0.024	0.024	0.024
25	0.039	0.026	0.033	0.041	0.024	0.032
30	0.043	0.040	0.041	0.043	0.041	0.042
35	0.032	0.043	0.037	0.032	0.044	0.038
40	0.022	0.033	0.027	0.024	0.032	0.028
45	0.026	0.023	0.025	0.031	0.024	0.028
50	0.025	0.028	0.026	0.030	0.032	0.031
55	0.035	0.027	0.031	0.036	0.031	0.033
60	0.031	0.038	0.034	0.033	0.037	0.035
65	0.040	0.035	0.037	0.042	0.035	0.039
70	0.009	0.044	0.026	-0.014	0.045	0.015
75	-0.013	0.012	-0.001	0.049	-0.012	0.019
80	0.052	-0.010	0.021	0.035	0.051	0.043
85	0.034	0.035	0.035	0.029	0.033	0.031
TOTAL	0.029	0.029	0.029	0.030	0.029	0.029

Table A3.1 Age-group specific growth rates

Table A3.1 shows the age-group-specific growth rates for males and females for the periods 1980-85, 1985-90 and 1980-90. From these figures the following can be noted.

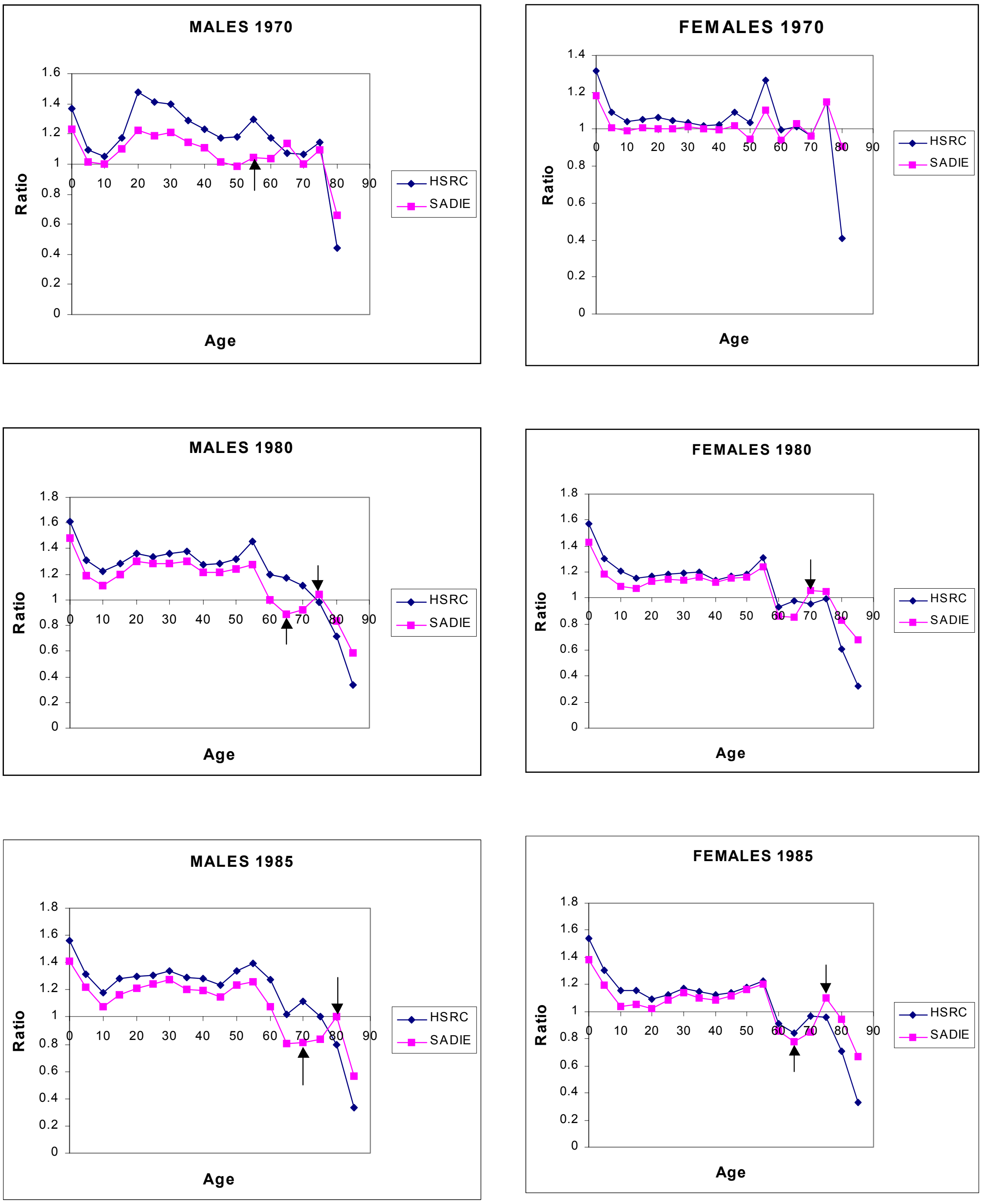
1. The 1980-90 growth rates are too low for the 75-79 year age group for males (-0.001) and the 70-74 and 75-79 year age groups for females (0.015 and 0.019 respectively).
2. More specifically for the 1980-85 period for males the growth rates in age groups 70-74 and 75-79 are too low (0.009 and –0.013 respectively) while those for the age groups on either side of these two appear to be on the high side (0.04 and 0.052). This pattern extends to the 1985-90 period (only advanced by one age group).
3. As far as the female lives are concerned the 70-74 year age group growth rate in the 1980-85 period is too low (-0.014) while those on

either side appear to be too high (0.042 and 0.049). This pattern extends to the 1985-90 period (only advanced by one age group).

4. One would expect age-group-specific growth rates for males and females to be similar. Although the male and female growth rates up to the 65-69 year age group are not entirely consistent one with the other there are no major differences between them. Above this age group there are some marked differences.

The Figures A3.1 to A3.6 compare the estimates of the population derived by the HSRC and Sadie with the censuses of South African born males and females in 1970, 1980 and 1985. From these figures the following can be noted.

1. It appears as if, for males, the cohort which was aged 80-84 in 1985 (and 75-79 in 1980 and 65-69 in 1970) has been consistently overestimated. The extent of this overestimate is, of course, unclear from these figures but an adjustment of 14% to 20% would not appear to be out of line.
2. There is also some evidence, although it is not as strong as for the above cohort, that the cohort which was aged 70-74 in 1985 may have been underestimated. This underestimate could be of the order of 5% to 10%.
3. As far as females are concerned the evidence, perhaps not as strong as for the males, suggests that the cohort which was aged 75-79 in 1985 may have been over-estimated by some 10%to 15% while the preceding cohort may have been underestimated by a similar amount.



Figures A3.1 to A3.6: Ratios of HSRC and Sadie Population Estimates to the Census

A.3.2 Adjustments

Thus in an effort to produce a consistent set of male and female age-group-specific growth rates of around 3% per annum the following adjustments were made to the population in 1985. The 80-84 year cohort for males was reduced by 19% while that of the 70-74 year age group was increased by 6%. For female lives the 75-79 year cohort was increased by 10% and the preceding age group reduced by 10%. These adjustments were carried through to the 1980 and 1990 estimates.

The only remaining inconsistency is the growth rate in the open interval and if we assume that the male growth in this interval should be equal to that of the female lives (which is consistent with the overall growth rate) and that the rate is consistent between 1980-85 and 1985-90 then this would imply that the number of lives in the open interval in 1985 should be reduced by 10%, but with no adjustment to the corresponding figures in either 1980 or 1990. (This implies slightly heavier mortality in this age group for these periods but the new survival probabilities are more consistent with one another than the previous survival probabilities.)

A.3.3 The Results

Table A3 and A3.3 show the adjusted populations and growth rates.

	POPULATION			GROWTH RATES		
AGE	80	85	90	80-85	85-90	80-90
0	1739500	2010400	2267900	0.029	0.024	0.027
5	1473700	1713200	1983400	0.030	0.029	0.030
10	1268900	1466100	1705700	0.029	0.030	0.030
15	1122700	1260200	1457200	0.023	0.029	0.026
20	974100	1106600	1243400	0.026	0.023	0.024
25	783300	953200	1084700	0.039	0.026	0.033
30	616800	763300	930400	0.043	0.040	0.041
35	508300	597200	738600	0.032	0.043	0.037
40	435600	485700	573400	0.022	0.033	0.027
45	358900	408600	458700	0.026	0.023	0.025
50	290200	328400	377300	0.025	0.028	0.026
55	216300	257800	295000	0.035	0.027	0.031
60	157300	183600	221800	0.031	0.038	0.034
65	108063	124300	147900	0.028	0.035	0.031
70	71200	78900	92500	0.021	0.032	0.026
75	40710	47100	53024	0.029	0.024	0.026
80	19600	22500	26400	0.028	0.032	0.030
85	10300	12100	14034	0.032	0.030	0.031
TOTAL	10195474	11819200	13671358	0.030	0.029	0.029

Table A3.2 Adjusted populations and growth rates: Males

AGE	POPULATION			GROWTH RATES		
	80	85	90	80-85	85-90	80-90
0	1711400	1989000	2241400	0.030	0.024	0.027
5	1468900	1686700	1964000	0.028	0.030	0.029
10	1268400	1449200	1681300	0.027	0.030	0.028
15	1121700	1263200	1443900	0.024	0.027	0.025
20	990800	1115400	1256200	0.024	0.024	0.024
25	801800	981800	1105900	0.041	0.024	0.032
30	637200	791900	971000	0.043	0.041	0.042
35	534800	626500	780100	0.032	0.044	0.038
40	464400	522500	613700	0.024	0.032	0.028
45	385000	449900	508000	0.031	0.024	0.028
50	317900	368900	432800	0.030	0.032	0.031
55	250500	300100	349800	0.036	0.031	0.033
60	194400	229700	276900	0.033	0.037	0.035
65	151005	169700	202300	0.023	0.035	0.029
70	107446	122300	139100	0.026	0.026	0.026
75	68800	79100	91065	0.028	0.028	0.028
80	37000	44100	51114	0.035	0.030	0.032
85	24200	28000	33000	0.029	0.033	0.031
TOTAL	10535652	12218000	14141579	0.030	0.029	0.029

Table A3.3 Adjusted populations and growth rates: Females

In total these adjustments amount to a decrease in the male population in 1985 of only 2 200 lives and an increase in the female population of only 2 300 lives.

On the basis of these adjusted populations the growth rates in the open intervals become:

Age (x)	*Male*	**Female**
65	2.90%	2.85%
75	2.80%	2.98%
85	3.10%	3.10%

Appendix 4: Full life tables

A4.1 Standard tables (l_x) used in the graduations

Age	Males (CM80)	Females (CM80F)	**Males** (CM85M)	Age	Males (CM80)	Females (CM80F)	**Males** (CM85M)
0	1.000000	1.000000	1.000000	45	0.728900	0.728900	0.772810
1	0.931318	0.945000	0.950000	46	0.718460	0.718460	0.763206
2	0.915182	0.918639	0.938558	47	0.707445	0.707445	0.752983
3	0.909392	0.910328	0.934925	48	0.695772	0.695772	0.742097
4	0.906923	0.907140	0.933463	49	0.683335	0.683335	0.730512
5	0.905532	0.905532	0.932005	50	0.670020	0.670020	0.718197
6	0.904165	0.904165	0.930988	51	0.655769	0.655770	0.705136
7	0.902850	0.902850	0.930035	52	0.640588	0.640588	0.691320
8	0.901748	0.901748	0.929108	53	0.624540	0.624540	0.676752
9	0.900792	0.900792	0.928325	54	0.607743	0.607744	0.661445
10	0.900075	0.900075	0.927856	55	0.590348	0.590348	0.645421
11	0.899396	0.899396	0.927481	56	0.572474	0.572474	0.628704
12	0.898674	0.898674	0.927081	57	0.554203	0.554204	0.611312
13	0.897835	0.897835	0.926555	58	0.535582	0.535582	0.593267
14	0.896809	0.896809	0.925816	59	0.516627	0.516627	0.574590
15	0.895533	0.895533	0.924792	60	0.497333	0.497333	0.555307
16	0.893951	0.893952	0.923429	61	0.477692	0.477692	0.535447
17	0.892015	0.892016	0.921688	62	0.457696	0.457696	0.515047
18	0.889687	0.889688	0.919546	63	0.437341	0.437341	0.494151
19	0.886944	0.886944	0.916995	64	0.416629	0.416629	0.472811
20	0.883776	0.883776	0.914043	65	0.395578	0.395578	0.451087
21	0.880196	0.880196	0.910708	66	0.374240	0.374241	0.428897
22	0.876233	0.876234	0.907023	67	0.352705	0.352705	0.406342
23	0.871935	0.871935	0.903029	68	0.331088	0.331089	0.383501
24	0.867358	0.867358	0.898768	69	0.309530	0.309530	0.360463
25	0.862563	0.862563	0.894291	70	0.288175	0.288175	0.337324
26	0.857604	0.857604	0.889645	71	0.267147	0.267147	0.314188
27	0.852525	0.852525	0.884880	72	0.246544	0.246545	0.291168
28	0.847352	0.847352	0.880039	73	0.226448	0.226448	0.268383
29	0.842117	0.842117	0.875132	74	0.206924	0.206924	0.245955
30	0.836789	0.836789	0.870209	75	0.188032	0.188032	0.224011
31	0.831349	0.831349	0.865278	76	0.169834	0.169834	0.202678
32	0.825777	0.825777	0.860322	77	0.152393	0.152393	0.182079
33	0.820055	0.820055	0.855301	78	0.135775	0.135775	0.162335
34	0.814163	0.814164	0.850154	79	0.120043	0.120043	0.143559
35	0.808083	0.808083	0.844802	80	0.105262	0.105262	0.125853
36	0.801786	0.801787	0.839183	81	0.091514	0.091514	0.109306
37	0.795240	0.795241	0.833251	82	0.078882	0.078882	0.093990
38	0.788403	0.788404	0.826981	83	0.067435	0.067435	0.079960
39	0.781227	0.781227	0.820366	84	0.057160	0.057160	0.067248
40	0.773660	0.773660	0.813410	85	0.047939	0.047939	0.055867
41	0.765660	0.765660	0.806109	86	0.039752	0.039752	0.045806
42	0.757197	0.757197	0.798441	87	0.032569	0.032569	0.037032
43	0.748253	0.748254	0.790369	88	0.026344	0.026344	0.029491
44	0.738822	0.738822	0.781846	89	0.021020	0.021020	0.023109

A4.2 The Parameters

Table		Standard	Number of iterations	Sum of squares (0-85)	α	β	κ	λ
BM85	Case 1	CM80	1	0.00041	0.0693	0.8618	0.0630	0.0512
	Case 2	CM80	3	0.00057	0.1376	0.8600	0.0012	0.0798
	Average	CM80	2	0.00040	0.1016	0.8654	0.0297	0.0646
BF85	Case 1	CM80F	3	0.00016	0.3799	0.7720	-0.0889	0.0483
	Case 2	CM80F	3	0.00014	0.4235	0.7795	-0.1523	0.0538
	Average	CM80F	3	0.00014	0.4014	0.7742	-0.1177	0.0525

A4.3 Black Life Tables 1984-86 (q_x)

Age	Males			Age	Females		
	Case 1	Case 2	Average		Case 1	Case 2	Average
0	0.0750	0.0750	0.0750	0	0.0650	0.0650	0.0650
1	0.0179	0.0160	0.0169	1	0.0164	0.0145	0.0155
2	0.0065	0.0057	0.0061	2	0.0061	0.0054	0.0058
3	0.0028	0.0024	0.0026	3	0.0027	0.0023	0.0025
4	0.0016	0.0014	0.0015	4	0.0015	0.0013	0.0014
5	0.0015	0.0013	0.0014	5	0.0009	0.0008	0.0008
6	0.0015	0.0013	0.0014	6	0.0008	0.0007	0.0008
7	0.0012	0.0011	0.0012	7	0.0007	0.0006	0.0007
8	0.0011	0.0009	0.0010	8	0.0006	0.0005	0.0006
9	0.0008	0.0007	0.0008	9	0.0005	0.0004	0.0004
10	0.0008	0.0007	0.0007	10	0.0004	0.0004	0.0004
11	0.0008	0.0007	0.0008	11	0.0005	0.0004	0.0004
12	0.0009	0.0008	0.0009	12	0.0005	0.0005	0.0005
13	0.0012	0.0010	0.0011	13	0.0007	0.0006	0.0006
14	0.0014	0.0013	0.0013	14	0.0008	0.0007	0.0008
15	0.0018	0.0016	0.0017	15	0.0010	0.0009	0.0009
16	0.0022	0.0019	0.0020	16	0.0012	0.0011	0.0012
17	0.0026	0.0023	0.0025	17	0.0015	0.0013	0.0014
18	0.0031	0.0027	0.0029	18	0.0017	0.0015	0.0016
19	0.0036	0.0031	0.0033	19	0.0020	0.0018	0.0019
20	0.0041	0.0035	0.0038	20	0.0022	0.0020	0.0021
21	0.0045	0.0039	0.0042	21	0.0025	0.0022	0.0023
22	0.0049	0.0042	0.0045	22	0.0027	0.0024	0.0025
23	0.0052	0.0045	0.0048	23	0.0028	0.0025	0.0027
24	0.0055	0.0047	0.0051	24	0.0030	0.0026	0.0028
25	0.0056	0.0049	0.0052	25	0.0031	0.0027	0.0029
26	0.0058	0.0050	0.0054	26	0.0031	0.0028	0.0030
27	0.0059	0.0051	0.0055	27	0.0032	0.0028	0.0030
28	0.0060	0.0052	0.0056	28	0.0032	0.0028	0.0030
29	0.0061	0.0053	0.0057	29	0.0033	0.0029	0.0031
30	0.0063	0.0054	0.0058	30	0.0034	0.0029	0.0032
31	0.0064	0.0055	0.0060	31	0.0034	0.0030	0.0032
32	0.0066	0.0057	0.0061	32	0.0035	0.0031	0.0033
33	0.0068	0.0059	0.0063	33	0.0036	0.0032	0.0034
34	0.0071	0.0061	0.0066	34	0.0038	0.0033	0.0035
35	0.0074	0.0063	0.0068	35	0.0039	0.0034	0.0037
36	0.0077	0.0066	0.0071	36	0.0041	0.0036	0.0038
37	0.0080	0.0069	0.0075	37	0.0043	0.0038	0.0040
38	0.0085	0.0073	0.0079	38	0.0045	0.0040	0.0042
39	0.0090	0.0077	0.0083	39	0.0048	0.0042	0.0045
40	0.0095	0.0082	0.0089	40	0.0051	0.0045	0.0048
41	0.0101	0.0087	0.0094	41	0.0054	0.0048	0.0051
42	0.0108	0.0093	0.0100	42	0.0057	0.0051	0.0054
43	0.0114	0.0099	0.0107	43	0.0061	0.0054	0.0058
44	0.0121	0.0105	0.0113	44	0.0065	0.0058	0.0061
45	0.0128	0.0111	0.0120	45	0.0069	0.0062	0.0065
46	0.0136	0.0119	0.0128	46	0.0073	0.0066	0.0070
47	0.0146	0.0127	0.0137	47	0.0079	0.0071	0.0075
48	0.0157	0.0137	0.0148	48	0.0085	0.0077	0.0081
49	0.0170	0.0149	0.0160	49	0.0093	0.0084	0.0089

50	0.0184	0.0162	0.0174	50	0.0101	0.0092	0.0097
51	0.0199	0.0176	0.0188	51	0.0110	0.0101	0.0105
52	0.0214	0.0190	0.0203	52	0.0120	0.0109	0.0115
53	0.0228	0.0203	0.0216	53	0.0129	0.0118	0.0123
54	0.0240	0.0216	0.0229	54	0.0137	0.0127	0.0132
55	0.0252	0.0227	0.0241	55	0.0146	0.0135	0.0141
56	0.0264	0.0239	0.0253	56	0.0155	0.0144	0.0149
57	0.0276	0.0251	0.0265	57	0.0164	0.0154	0.0159
58	0.0288	0.0264	0.0278	58	0.0174	0.0164	0.0169
59	0.0302	0.0279	0.0292	59	0.0185	0.0176	0.0180
60	0.0318	0.0296	0.0309	60	0.0197	0.0188	0.0192
61	0.0338	0.0316	0.0329	61	0.0210	0.0201	0.0205
62	0.0360	0.0338	0.0351	62	0.0226	0.0216	0.0220
63	0.0384	0.0362	0.0376	63	0.0243	0.0232	0.0237
64	0.0412	0.0390	0.0404	64	0.0262	0.0251	0.0256
65	0.0441	0.0421	0.0434	65	0.0283	0.0272	0.0277
66	0.0473	0.0453	0.0467	66	0.0306	0.0295	0.0300
67	0.0507	0.0489	0.0501	67	0.0330	0.0320	0.0325
68	0.0542	0.0526	0.0538	68	0.0357	0.0346	0.0351
69	0.0578	0.0564	0.0575	69	0.0385	0.0374	0.0379
70	0.0616	0.0605	0.0615	70	0.0414	0.0404	0.0409
71	0.0656	0.0649	0.0657	71	0.0447	0.0437	0.0442
72	0.0699	0.0696	0.0703	72	0.0482	0.0473	0.0477
73	0.0747	0.0748	0.0752	73	0.0521	0.0513	0.0517
74	0.0798	0.0805	0.0807	74	0.0564	0.0557	0.0561
75	0.0855	0.0868	0.0866	75	0.0612	0.0607	0.0610
76	0.0916	0.0937	0.0932	76	0.0666	0.0662	0.0664
77	0.0984	0.1012	0.1003	77	0.0725	0.0723	0.0724
78	0.1057	0.1095	0.1081	78	0.0791	0.0791	0.0791
79	0.1136	0.1185	0.1166	79	0.0863	0.0865	0.0865
80	0.1220	0.1280	0.1255	80	0.0940	0.0946	0.0944
81	0.1305	0.1377	0.1346	81	0.1020	0.1030	0.1027
82	0.1388	0.1475	0.1437	82	0.1102	0.1115	0.1110
83	0.1476	0.1577	0.1531	83	0.1187	0.1204	0.1198
84	0.1581	0.1700	0.1645	84	0.1289	0.1312	0.1303
85	0.1695	0.1831	0.1767	85	0.1400	0.1427	0.1417
86	0.1815	0.1973	0.1898	86	0.1518	0.1551	0.1538
87	0.1944	0.2124	0.2037	87	0.1644	0.1683	0.1668
88	0.2081	0.2286	0.2186	88	0.1778	0.1824	0.1807
89	0.2227	0.2459	0.2345	89	0.1921	0.1973	0.1954

A4.4 National Life Tables 1984-86 (q_x)

Age	Males	Females	Age	Males	Females
0	0.06788	0.05897	45	0.01046	0.00585
1	0.01510	0.01387	46	0.01120	0.00629
2	0.00542	0.00512	47	0.01204	0.00679
3	0.00235	0.00224	48	0.01302	0.00736
4	0.00139	0.00130	49	0.01415	0.00801
5	0.00133	0.00080	50	0.01541	0.00873
6	0.00126	0.00076	51	0.01673	0.00950
7	0.00107	0.00064	52	0.01808	0.01029
8	0.00092	0.00055	53	0.01939	0.01106
9	0.00067	0.00042	54	0.02065	0.01183
10	0.00063	0.00039	55	0.02191	0.01263
11	0.00067	0.00041	56	0.02322	0.01348
12	0.00078	0.00047	57	0.02460	0.01439
13	0.00097	0.00057	58	0.02606	0.01537
14	0.00123	0.00070	59	0.02760	0.01645
15	0.00154	0.00085	60	0.02937	0.01762
16	0.00189	0.00103	61	0.03138	0.01889
17	0.00228	0.00122	62	0.03359	0.02027
18	0.00269	0.00142	63	0.03600	0.02177
19	0.00310	0.00163	64	0.03867	0.02344
20	0.00350	0.00182	65	0.04161	0.02529
21	0.00386	0.00200	66	0.04478	0.02731
22	0.00417	0.00215	67	0.04811	0.02946
23	0.00443	0.00227	68	0.05158	0.03175
24	0.00462	0.00237	69	0.05517	0.03419
25	0.00476	0.00245	70	0.05889	0.03675
26	0.00486	0.00250	71	0.06285	0.03951
27	0.00492	0.00254	72	0.06719	0.04258
28	0.00496	0.00258	73	0.07202	0.04612
29	0.00503	0.00263	74	0.07738	0.05015
30	0.00511	0.00268	75	0.08325	0.05462
31	0.00522	0.00275	76	0.08945	0.05936
32	0.00534	0.00282	77	0.09584	0.06435
33	0.00549	0.00291	78	0.10229	0.06958
34	0.00568	0.00302	79	0.10881	0.07516
35	0.00589	0.00314	80	0.11566	0.08141
36	0.00614	0.00328	81	0.12310	0.08860
37	0.00641	0.00344	82	0.13095	0.09645
38	0.00673	0.00363	83	0.14022	0.10527
39	0.00712	0.00386	84	0.15190	0.11530
40	0.00759	0.00414	85	0.16078	0.12371
41	0.00809	0.00443	86	0.17521	0.13728
42	0.00863	0.00475	87	0.19072	0.15198
43	0.00921	0.00510	88	0.20689	0.16756
44	0.00982	0.00546	89	0.22326	0.18371

A4.5 Black life tables 1984-86 (based on deaths by year of occurrence)

Age	Males	Females	Age	Males	Females
0	0.0750	0.0650	45	0.0130	0.0068
1	0.0185	0.0160	46	0.0138	0.0073
2	0.0067	0.0060	47	0.0147	0.0078
3	0.0029	0.0026	48	0.0158	0.0085
4	0.0016	0.0015	49	0.0171	0.0092
5	0.0016	0.0009	50	0.0185	0.0101
6	0.0015	0.0008	51	0.0200	0.0110
7	0.0013	0.0007	52	0.0214	0.0119
8	0.0011	0.0006	53	0.0227	0.0128
9	0.0008	0.0005	54	0.0240	0.0137
10	0.0008	0.0004	55	0.0251	0.0146
11	0.0008	0.0005	56	0.0262	0.0155
12	0.0010	0.0005	57	0.0272	0.0164
13	0.0012	0.0006	58	0.0284	0.0174
14	0.0015	0.0008	59	0.0297	0.0186
15	0.0018	0.0010	60	0.0313	0.0198
16	0.0023	0.0012	61	0.0333	0.0211
17	0.0027	0.0014	62	0.0356	0.0226
18	0.0032	0.0017	63	0.0381	0.0243
19	0.0037	0.0020	64	0.0409	0.0262
20	0.0042	0.0022	65	0.0440	0.0282
21	0.0046	0.0024	66	0.0473	0.0305
22	0.0050	0.0026	67	0.0508	0.0329
23	0.0054	0.0028	68	0.0545	0.0354
24	0.0056	0.0029	69	0.0584	0.0381
25	0.0058	0.0030	70	0.0625	0.0410
26	0.0060	0.0031	71	0.0668	0.0441
27	0.0061	0.0031	72	0.0715	0.0475
28	0.0062	0.0032	73	0.0767	0.0512
29	0.0063	0.0032	74	0.0824	0.0553
30	0.0064	0.0033	75	0.0886	0.0598
31	0.0066	0.0034	76	0.0955	0.0649
32	0.0068	0.0035	77	0.1030	0.0705
33	0.0070	0.0036	78	0.1112	0.0766
34	0.0073	0.0037	79	0.1202	0.0834
35	0.0075	0.0038	80	0.1297	0.0905
36	0.0078	0.0040	81	0.1395	0.0980
37	0.0082	0.0042	82	0.1493	0.1054
38	0.0087	0.0044	83	0.1595	0.1133
39	0.0092	0.0047	84	0.1719	0.1227
40	0.0097	0.0050	85	0.1853	0.1327
41	0.0103	0.0053	86	0.1996	0.1434
42	0.0110	0.0057	87	0.2150	0.1549
43	0.0116	0.0060	88	0.2315	0.1670
44	0.0123	0.0064	89	0.2493	0.1798

Appendix 5: 1989-91 life tables

A5.1 The abridged ungraduated life table

Age	Males	Females
0	1.00000	1.00000
1	0.94200	0.95100
5	0.92222	0.93293
10	0.91910	0.93023
15	0.91584	0.92752
20	0.90633	0.92274
25	0.88673	0.91474
30	0.86151	0.90433
35	0.83319	0.89124
40	0.79945	0.87419
45	0.75838	0.85198
50	0.70989	0.82391
55	0.64857	0.78219
60	0.58028	0.72934
65	0.48826	0.65210
70	0.38666	0.56298
75	0.26863	0.44036
80	0.16441	0.32181
85	0.08707	0.20083
90	0.03193	0.08424

A5.2 The Parameters

Table		Standard	Number of iterations	Sum of squares (0-85)	α	β	κ	λ
NM85		CM80	2	0.00037	0.1790	0.9060	-0.0270	0.0193
NF85		CM80F	3	0.00062	0.4998	0.8003	-0.1902	0.0105
NM85I		CM80	2	0.00039	0.1758	0.8906	-0.0098	0.0117
NF85I		CM80F	3	0.00048	0.4839	0.7841	-0.1546	-0.0023
NM90		CM85M	1	0.00029	0.0543	0.8429	0.0591	0.0590
NF90		CM80F	3	0.00012	0.4877	0.8340	-0.1148	-0.0261

A5.3 National Life Tables 1989-91 (q_x)

Age	Males (CM80M)	Females (CM80)	Age	Males (CM80M)	Females (CM80)
0	0.05800	0.04900	45	0.01162	0.00583
1	0.01348	0.01251	46	0.01243	0.00625
2	0.00429	0.00474	47	0.01331	0.00674
3	0.00173	0.00206	48	0.01426	0.00733
4	0.00172	0.00117	49	0.01527	0.00803
5	0.00120	0.00069	50	0.01633	0.00881
6	0.00113	0.00066	51	0.01744	0.00965
7	0.00110	0.00055	52	0.01859	0.01052
8	0.00092	0.00048	53	0.01977	0.01140
9	0.00055	0.00036	54	0.02098	0.01225
10	0.00044	0.00034	55	0.02222	0.01311
11	0.00047	0.00036	56	0.02351	0.01399
12	0.00062	0.00042	57	0.02485	0.01494
13	0.00087	0.00051	58	0.02625	0.01597
14	0.00121	0.00064	59	0.02771	0.01713
15	0.00161	0.00079	60	0.02926	0.01831
16	0.00205	0.00096	61	0.03088	0.01955
17	0.00252	0.00116	62	0.03259	0.02095
18	0.00300	0.00136	63	0.03463	0.02252
19	0.00347	0.00157	64	0.03690	0.02427
20	0.00392	0.00177	65	0.03960	0.02619
21	0.00433	0.00196	66	0.04246	0.02828
22	0.00469	0.00212	67	0.04556	0.03051
23	0.00500	0.00225	68	0.04892	0.03286
24	0.00526	0.00236	69	0.05257	0.03532
25	0.00545	0.00244	70	0.05652	0.03793
26	0.00559	0.00250	71	0.06081	0.04073
27	0.00568	0.00255	72	0.06548	0.04377
28	0.00576	0.00259	73	0.07054	0.04710
29	0.00578	0.00264	74	0.07604	0.05077
30	0.00579	0.00270	75	0.08202	0.05481
31	0.00583	0.00278	76	0.08850	0.05925
32	0.00591	0.00286	77	0.09555	0.06412
33	0.00606	0.00296	78	0.10319	0.06945
34	0.00630	0.00307	79	0.11147	0.07524
35	0.00663	0.00319	80	0.12044	0.08135
36	0.00700	0.00333	81	0.13014	0.08758
37	0.00741	0.00351	82	0.14063	0.09374
38	0.00784	0.00371	83	0.15195	0.10012
39	0.00826	0.00394	84	0.16416	0.10776
40	0.00868	0.00420	85	0.17730	0.11584
41	0.00915	0.00449	86	0.19143	0.12435
42	0.00965	0.00479	87	0.20662	0.13327
43	0.01023	0.00512	88	0.22291	0.14258
44	0.01089	0.00546	89	0.24039	0.15225

Appendix 6: Copies of spreadsheets (unadjusted data)

A6.1 **Brass** (Black males 1984-86)

X	5NX	5DX	NX	NX+	DX+	dx+	bx+	%under-reported
								54.9%
0	2010400	11920		11821400	57617.33			LINE
5	1713200	726.3333	372360	9811000	45697.33	0.004658	0.037953	0.037784
10	1466100	673.6667	317930	8097800	44971	0.005553	0.039261	0.039416
15	1260200	1307.667	272630	6631700	44297.33	0.00668	0.04111	0.041467
20	1106600	2707.667	236680	5371500	42989.67	0.008003	0.044062	0.043877
25	953200	3195.667	205980	4264900	40282	0.009445	0.048297	0.046503
30	763300	3337	171650	3311700	37086.33	0.011199	0.051831	0.049697
35	597200	3185	136050	2548400	33749.33	0.013243	0.053386	0.053421
40	485700	3339.333	108290	1951200	30564.33	0.015664	0.055499	0.05783
45	408600	3416.333	89430	1465500	27225	0.018577	0.061024	0.063135
50	328400	3746	73700	1056900	23808.67	0.022527	0.069732	0.070328
55	257800	3450	58620	728500	20062.67	0.02754	0.080467	0.079458
60	183600	4070.667	44140	470700	16612.67	0.035294	0.093775	0.093579
65	124300	4404.333	30790	287100	12542	0.043685	0.107245	0.108862
70	74400	3401.667	19870	162800	8137.667	0.049986	0.122052	0.120337
75	47100	1962	12150	88400	4736	0.053575	0.137443	0.126873
80	27800	1607	7296.563	41300	2774	0.067167	0.176672	0.151628
85	9800	579	3338.542	13500	1167	0.086444	0.247299	0.186737
	3700	588		3700	588	0.15		0.302486
	11821400	57617.33						Regression
Correcting for curvature in N75							a=	0.029302
(x)	mu(x)	c=	1.1				b=	1.821231
		r=	0.029302					
75	0.061254	0.913423	1	0.956712	10.26511			
76	0.06738	0.907845	0.913423	0.871335				
77	0.074118	0.901749	0.829247	0.788509				
78	0.08153	0.89509	0.747772	0.708548				
79	0.089683	0.887822	0.669323	0.631781				
80	0.098651	0.879895	0.59424	0.558554				
81	0.108516	0.871258	0.522869	0.489211				
82	0.119368	0.861854	0.455553	0.424087				
83	0.131304	0.851628	0.39262	0.363493				
84	0.144435	0.840518	0.334366	0.307704				
			0.281041					

Correcting for curvature in N80

(x)	mu(x)	c=	1.1		
		r=	0.029302		
80	0.124659	0.857305	1	0.928653	11.2624
81	0.137125	0.846685	0.857305	0.791586	
82	0.150838	0.835154	0.725867	0.666039	
83	0.165922	0.822651	0.606211	0.552455	
84	0.182514	0.809114	0.4987	0.451103	
85	0.200765	0.794481	0.403505	0.362041	
86	0.220842	0.778689	0.320577	0.285103	
87	0.242926	0.761681	0.24963	0.219884	
88	0.267219	0.743401	0.190138	0.165744	
89	0.29394	0.723799	0.141349	0.121829	
			0.102308		

A6.2 Preston and Coale (Black males 1984-86)

			median=	54.7	GRO RAT =	0.0294				D(10+) =	44971.33			D(10+) =	44971.33			D(10+) =	44971.33		
	MALES		avedev=	0.378835						D(45+) =	27225.33	%REPORT =	56.70467	D(45+) =	27225.33	%REPORT =	54.82716	D(45+) =	27225.33	%REPORT =	54.61423
	TOTAL			A=65		A=75		A=85		Z(65+) =	11.49854		0.63991	Z(75+) =	6.784271		0.505528	Z(85+) =	3.485841		0.710179
AGE	POP	DEATHS	AGE	RAT(X)	CUMRAT(X)	RAT(X)	CUMRAT(X)	RAT(X)	CUMRAT(X)	N(X)	5N(X)	CUMN5(X)	CUMPOPN(X)	N(X)	5N(X)	CUMN5(X)	CUMPOPN(X)	N(X)	5N(X)	CUMN5(X)	CUMPOPN(X)
0	2010400	11920	0		56.5		55.0		55.1	253732	1154257	6514819	11534300	248000	1127553	6456473	11733000	248622	1130452	6509334	11807900
5	1713200	726.3333	5	57.0	56.3	55.6	54.8	55.8	54.9	207970	967088	5360562	9523900	203021	944035	5328919	9722600	203559	946537	5378882	9797500
10	1466100	673.6667	10	56.6	56.2	55.2	54.7	55.4	54.8	178865	831629	4393474	7810700	174592	811727	4384885	8009400	175056	813887	4432345	8084300
15	1260200	1307.667	15	56.7	56.1	55.3	54.6	55.5	54.7	153787	713338	3561845	6344600	150099	696157	3573157	6543300	150499	698022	3618458	6618200
20	1106600	2707.667	20	55.8	56.0	54.4	54.5	54.6	54.5	131548	606494	2848507	5084400	128364	591661	2877000	5283100	128710	593271	2920436	5358000
25	953200	3195.667	25	54.2	56.4	52.9	54.7	53.0	54.7	111049	509870	2242013	3977800	108300	497065	2285339	4176500	108599	498455	2327165	4251400
30	763300	3337	30	54.5	57.3	53.1	55.5	53.2	55.4	92899	424993	1732143	3024600	90526	413939	1788274	3223300	90783	415139	1828710	3298200
35	597200	3185	35	57.1	57.8	55.6	55.9	55.7	55.8	77098	351744	1307150	2261300	75050	342201	1374335	2460000	75272	343237	1413572	2534900
40	485700	3339.333	40	59.1	57.4	57.5	55.4	57.7	55.2	63599	288504	955406	1664100	61831	280265	1032133	1862800	62023	281160	1070334	1937700
45	408600	3416.333	45	58.4	56.6	56.6	54.6	56.8	54.4	51802	233371	666902	1178400	50275	226259	751868	1377100	50441	227031	789175	1452000
50	328400	3746	50	56.7	56.3	54.9	54.3	55.1	53.9	41546	184831	433530	769800	40228	178691	525609	968500	40371	179358	562144	1043400
55	257800	3450	55	55.9	56.3	53.9	54.2	54.2	53.5	32386	142848	248699	441400	31248	137548	346918	640100	31372	138123	382786	715000
60	183600	4070.667	60	56.3	57.7	54.1	54.8	54.3	53.5	24753	105851	105851	183600	23771	101275	209370	382300	23878	101772	244663	457200
65	124300	4404.333	65			54.9	54.4	55.2	52.2	17587				16739	67744	108095	198700	16831	68173	142891	273600
70	74400	3401.667	70			54.4	54.2	54.8	50.0					10359	40351	40351	74400	10438	40721	74719	149300
75	47100	1962	75					52.2	45.4					5782				5850	22695	33998	74900
80	27800	1607	80					45.4	40.7									3228	11302	11302	27800
85	13500	1167.333	85															1293			
TOT	11821400	57617.67																			
			MEAN	56.5	56.7	54.9	54.8	55.1	54.7												
			MEAN(5-65)	56.5	56.7	54.9	54.8	55.1	54.6												
			MEAN(20-65)	56.4	56.9	54.8	54.9	55.0	54.6												

A6.3 Bennett and Horiuchi (Black males 1984-86, A=85)

delta =	-0.0017		eA =	4.9			
%REPORT =	52.2	0.822834			Xi =	0.12	
Median =	52.9	0.327789					

AGE	POP85	DEATHS	5rx	5rx + delta	RAT(X)	CUMRAT(X)	N(X)	5N(X)	5rx + delta	mu(x)		adj5N(X)	CUMN5(X)	CUMPOPN(X)
0	2010400	11920	0.026526	0.024826		52.6	229030.7	1050308	0.024826	0.008316	0.069297	1050308	6216846	11807900
5	1713200	726.3333	0.029704	0.028004	52.1	52.7	191092.5	891350.2	0.028004	0.000596	0.004969	891350.2	5166538	9797500
10	1466100	673.6667	0.029583	0.027883	52.3	52.9	165447.6	771842.5	0.027883	0.000639	0.005322	771842.5	4275188	8084300
15	1260200	1307.667	0.026078	0.024378	53.0	52.9	143289.4	672263.5	0.024378	0.001423	0.011856	672263.5	3503346	6618200
20	1106600	2707.667	0.024409	0.022709	53.2	52.8	125616	587976.4	0.022709	0.003369	0.028072	587976.4	2831082	5358000
25	953200	3195.667	0.032554	0.030854	52.9	52.8	109574.6	501314.7	0.030854	0.004672	0.038936	501314.7	2243106	4251400
30	763300	3337	0.041107	0.039407	52.9	52.8	90951.3	406532.8	0.039407	0.006033	0.050274	406532.8	1741791	3298200
35	597200	3185	0.037368	0.035668	53.5	52.7	71661.83	321762.1	0.035668	0.007271	0.060588	321762.1	1335258	2534900
40	485700	3339.333	0.027486	0.025786	53.7	52.3	57043.01	260137.5	0.025786	0.009411	0.078423	260137.5	1013496	1937700
45	408600	3416.333	0.024535	0.022835	53.1	51.9	47012	214311.7	0.022835	0.011686	0.097382	214311.7	753358.4	1452000
50	328400	3746	0.026247	0.024547	52.6	51.7	38712.67	173577.3	0.024547	0.015848	0.132067	173577.3	539046.7	1043400
55	257800	3450	0.031031	0.029331	52.7	51.1	30718.25	135100.5	0.029331	0.018801	0.156676	135100.5	365469.4	715000
60	183600	4070.667	0.034362	0.032662	52.9	50.4	23321.97	98446.17	0.032662	0.030648	0.255403	98446.17	230368.9	457200
65	124300	4404.333	0.037254	0.035554	52.6	48.2	16056.5	63631.58	0.035554	0.052262	0.435513	63631.58	131922.7	273600
70	74400	3401.667	0.026172	0.024472	50.3	45.7	9396.131	36257.33	0.024472	0.071138	0.592818	36257.33	68291.15	149300
75	47100	1962	-0.0006	-0.0023	46.9	42.8	5106.803	20749.73	-0.0023	0.07022	0.585166	20862.28	32033.81	74900
80	27800	1607	0.020997	0.019297	42.8	40.2	3193.089	11397.65	0.019297	0.109858	0.915484	11171.53	11171.53	27800
85	13500	1167.333	0.034521	0.032821			1365.971		0.032821					
TOT	11821400	57617.67												
				MEAN	52.9	52.3								
				MEAN(5-65)	52.9	52.2								
				MEAN(20-65)	53.1	52.0								

A6.4 **Ewbank, Gomez de Leon and Stoto** (Black males 1984-86)

Age	lx	lxs	Yx	Yxs	tx	kx		T'x	Y'x	l'x	(lx-l'x)^2	t'x	k'x		T"x	Y"x	l"x	(lx-l"x)^2
		CM80																
0	1	1								1							1	
1	0.9250	0.93132	1.2562	1.3036	1.3648	0.0330		1.3727	1.2767	0.9278	0.00001	1.3487	0.0243		1.3553	1.2745	0.9275	0.00001
5	0.9000	0.905532	1.0988	1.1301	1.1776	0.0344		1.1818	1.1138	0.9027	0.00001	1.1643	0.0247		1.1689	1.1131	0.9026	0.00001
10	0.8966	0.900075	1.0800	1.0990	1.1553	0.0433		1.1479	1.0848	0.8975	0.00000	1.1423	0.0333		1.1356	1.0844	0.8974	0.00000
15	0.8929	0.895533	1.0605	1.0743	1.1321	0.0466		1.1209	1.0618	0.8932	0.00000	1.1194	0.0363		1.1092	1.0615	0.8931	0.00000
20	0.8850	0.883776	1.0202	1.0143		k=	0.0393	1.0559	1.0062	0.8821	0.00001		k=	0.0297	1.0455	1.0064	0.8821	0.00001
25	0.8672	0.862563	0.9383	0.9184				0.9523	0.9179	0.8624	0.00002				0.9438	0.9184	0.8626	0.00002
30	0.8438	0.836789	0.8433	0.8173				0.8441	0.8255	0.8390	0.00002				0.8374	0.8263	0.8392	0.00002
35	0.8143	0.808083	0.7390	0.7188				0.7395	0.7362	0.8134	0.00000				0.7343	0.7371	0.8137	0.00000
40	0.7795	0.77366	0.6315	0.6145				0.6296	0.6424	0.7833	0.00001				0.6259	0.6432	0.7835	0.00002
45	0.7366	0.7289	0.5142	0.4945				0.5043	0.5354	0.7448	0.00007				0.5018	0.5359	0.7449	0.00007
50	0.6873	0.67002	0.3937	0.3541				0.3591	0.4115	0.6949	0.00006				0.3579	0.4113	0.6948	0.00006
55	0.6249	0.590348	0.2552	0.1827				0.1840	0.2621	0.6281	0.00001				0.1837	0.2605	0.6274	0.00001
60	0.5583	0.497333	0.1172	-0.0053				-0.0053	0.1005	0.5501	0.00007				-0.0053	0.0969	0.5483	0.00010
65	0.4620	0.395578	-0.0761	-0.2120	-0.2195	0.1647		-0.2156	-0.0790	0.4606	0.00000	-0.2122	0.0056		-0.2149	-0.0844	0.4579	0.00002
70	0.3483	0.288175	-0.3134	-0.4521	-0.5016	0.2347		-0.4687	-0.2950	0.3566	0.00007	-0.4902	0.1805		-0.4656	-0.3014	0.3537	0.00003
75	0.2427	0.188032	-0.5689	-0.7314	-0.8055	0.1318		-0.7754	-0.5568	0.2472	0.00002	-0.7896	0.1035		-0.7671	-0.5623	0.2451	0.00001
80	0.144682	0.10525	-0.8885	-1.0701	-1.1855	0.0937		-1.1660	-0.8902	0.1443	0.00000	-1.1640	0.0762		-1.1476	-0.8916	0.1439	0.00000
85	0.071543	0.048	-1.2816	-1.4937	-1.6530	0.0645		-1.6849	-1.3331	0.0650	0.00004	-1.6246	0.0530		-1.6476	-1.3243	0.0661	0.00003
	0.02334					l=	0.0791						l=	0.0646				
			α=	0.1084				α=	0.1050						α=	0.1016		
	SS=	0.00040	β=	0.8409				β=	0.8535	SS=	0.00042				β=	0.8654	SS=	0.00040

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