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Testing the Orphanhood Method against Benchmark
Mortality Rates in South Africa Since 1996

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A dissertation submitted to the faculty of Commerce of the
University of Cape Town in partial fulfilment of the requirements
for the Degree of Master of Philosophy in Demography

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PLAGIARISM DECLARATION

This research is my original work, produced with supervisory assistance from my supervisor. I have used the Harvard Convention for citation and referencing. Each contribution from the works of other people has been attributed and has been cited and referenced. This dissertation has not been submitted for any academic or examination purpose at any other university.

Andrew Magadzire

Date

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ABSTRACT

This study utilises the 1996 and 2001 Censuses, and the 2007 Community Survey to test the orphanhood method mortality estimates against consensus estimates of mortality produced using other methods. In all the two censuses and the survey there were questions on the survival status of the respondent's biological parents. The orphanhood method is widely used in developing countries where the vital registration is incomplete.

In countries where the data on survival of parents has been compared with other mortality estimates, it has been observed that the orphanhood method estimates are biased by adoption effect, selection effect and age exaggeration. In the late 1980s and early 1990s, the advent of HIV/AIDS has also biased estimates obtained from the orphanhood method. Non-independence of the mortality of children and their mothers, relationships between HIV infection and fertility, and changes in age-specific mortality result in biases which affect the accuracy of the method. These biases have been observed to have a net effect of underestimating mortality especially female mortality. An adjusted method has been proposed which reduces error, when working with data taken from populations with a significant HIV prevalence. This adjustment can be applied, but further research to identify revised adjustments would further improve the accuracy of the method.

The current research applies four variants of the orphanhood method, the regression variant, UN Manual's two-survey variant, Timaeus's synthetic cohort variant and the one allowing for HIV/AIDS proposed by Timaeus and Nunn.

The research compares the proportion with mother/father surviving, the conditional survival probabilities $\frac{l(25+n)}{l(25)}$ and $\frac{l(35+n)}{l(35)}$ for females and males respectively, the estimated mortality estimates of ${}_{35}q_{15}$, ${}_{45}q_{15}$ and ${}_{35}q_{30}$ with the estimates from the benchmark. The proportion with mother/father surviving is used together with the regression coefficients to obtain the conditional survival probabilities $\frac{l(25+n)}{l(25)}$ and $\frac{l(35+n)}{l(35)}$ for females and males respectively. The Brass General Standard is used to estimate alpha which is then used to convert the conditional probabilities of survival into specific mortality estimates such as ${}_{35}q_{15}$, ${}_{45}q_{15}$ and ${}_{35}q_{30}$.

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1. INTRODUCTION

1.1 Background

The orphanhood method is a widely used indirect method for estimating adult mortality. The technique involves respondents in a survey or census being asked about their age and sex, and the survival status of parents, of everyone in the household. The proportion by age with mother/father alive as reported for children approximates a conditional survival probability and can be used to estimate adult mortality, subject to the validity of certain assumption.

Brass and Hill (1973) originally proposed the “orphanhood” method, a simple technique for estimating adult mortality levels from information about the survival of children’s parents. Over the years since the orphanhood method was originally proposed the regression coefficients which are used to convert proportions with mother/father surviving into conditional survival probabilities have been improved by, for example Hill and Trussell (1977) and Timaeus (1992). An advantage of making use of data on survival of parents is that they can be collected through simple census or survey questions such as: “Is the child’s mother/father alive?” and “How old is the child”. The response to the first question requires a “yes” or a “no”, and the second a number which are simple to answer and do not take much space.

The orphanhood method is subject to number of key assumptions, namely that:

- The mortality of the children and that their parents are independent.
- Children do not report the survival of adoptive parents as the survival their biological parents. “The impact of this is known as adoption effect”
- The mortality of non-parents and that of those with no surviving children is similar to that of those with surviving children.
- The pattern of fertility and mortality in the population under examination is similar to those of models used for the calculation of conversion factors. That is that the standard life table used to convert the proportions surviving to conditional survival probabilities $\frac{l(25+n)}{l(25)}$ and $\frac{l(35+n)}{l(35)}$ for females and

males respectively, has a similar mortality pattern and level to the population under consideration.

In developing countries, a number of the above assumptions are violated. The adoption effect can be reduced by wording the question in such a way to make it clear that it refers to biological parents. Timaeus (1991b) suggested a way of avoiding the adoption effect by considering only the responses of children who are over 20 years of age. The use of two adjacent surveys avoids the cumulative effect of adoption on the estimates of the proportion of parents surviving by comparing the proportion of those aged $x + 5$ to $x + 10$ with mother surviving in the second survey to the proportion aged x to $x + 5$ in the first survey with surviving mothers. The synthetic cohort method reduces the adoption effect by chaining cohort changes or growth rates which transmits a large part of the age misreporting bias to older age groups.

There is also the bias introduced by changes in mortality. If mortality is declining the proportion of non-orphans reflects mortality conditions during the past not conditions prevailing at the time of the survey. At older ages, say the 45-49 age group for example some of the deaths of the parents may have occurred a long time ago and hence the mortality estimates obtained might be different from the present mortality experience. There is a way of tackling this problem by attempting to identify a point in time when the cohort survival is approximately the same as the period survival at that point in time (United Nations, 1983, Palloni *et al* 1984, Brass, 1975).

Another problem is that the survival status is known about more mothers than fathers in populations where labour migration is prevalent. In the case of missing fathers it may be easier in some situations to report that the father is dead than to explain the situation that the father and the mother are not living together or that the survival status of the father is unknown. This has the effect of overestimating adult male mortality.

HIV/AIDS also creates biases in the estimates of adult mortality using the orphanhood method. Survival of parents is no longer independent of the survival of their children due to vertical transmission of infection from mothers to their

children. Children born to HIV positive mothers may be infected by HIV at birth or through breast-feeding and are most likely to die within the first five years of life. This means that there are fewer children alive to report on the survival status of parents with higher mortality due to HIV. Fertility is reduced for longer periods of HIV infection and adoption increases which will affect the estimates of mortality produced using the orphanhood method. HIV/AIDS changes the mortality pattern thereby violating the assumption that mortality level will increase by age with a slow and constant decrease over time on which the coefficients used to estimate time location are based. Violation of the assumptions underlying the orphanhood method due to the HIV epidemic may render the estimates of conditional survival probabilities inaccurate and the standard life table used to convert them into mortality measures inappropriate.

1.2 Statement of Research Problem

The purpose of this study is to test how well the orphanhood method (one and two survey variants) and variations and adjustments to counter some of the violations of assumptions work in a developing country with a high level of HIV by comparing the estimates of survival or mortality with those of benchmark mortality rates¹ in the South African context from 1996 onwards.

1.3 Specific objectives

- To assess the reliability of adult mortality estimates from the orphanhood method using the 1996 and 2001 censuses, and the 2007 Community Survey data by comparing them with the benchmark mortality estimates .
- To examine the extent to which the 1996 and 2001 censuses and the 2007 Community Survey yields measures of adult mortality that are typical of South Africa by comparing the results with other benchmark estimates.

There are four chapters after the introduction. Chapter 2 reviews literature on the orphanhood method and gives a summary on the mortality rates in South Africa. Chapter 3 gives an outline of the orphanhood method. It also describes how the

¹ Benchmark mortality rates/estimates are a set of mortality estimates which is assumed to be the best but not necessarily completely accurate estimates of mortality.

benchmark estimates were derived. Chapter 4 presents the results and analysis. Chapter 5 discusses the results and the conclusions reached.

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2. LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature on the orphanhood method. Section 2.2 discusses the basic orphanhood method as it was initially developed by Brass. Section 2.3 details the two-survey method where there are data on two successive surveys. Section 2.4 looks at the assumptions which are made when applying the orphanhood method and how some of them are violated. Section 2.5 discusses allowance for the impact of HIV/AIDS and section 2.6 details mortality estimates in South Africa from other studies.

2.2 Basic Orphanhood method

The orphanhood method attempts to estimate adult mortality from survey and census data on the survivorship of parents. Only one question in a survey or census, “Is your mother/father alive?” is required to estimate female or male mortality respectively. Many years ago, Lotka (1975), suggested a procedure to make direct calculations of orphanhood from these data. Henry (1960) developed the theory further and practical analytic methods were subsequently developed by Brass in 1967 and are presented in Brass and Hill (1973). The method has been improved over the years by subsequent authors (Hill and Trussell, 1977; Timaeus, 1991c; Hill, 2000) as discussed in detail below.

Answers to the questions, about survival status of parents provide estimates of the proportion of children in various age groups with parents alive at the time of the survey. These proportions are then used to estimate survivorship (United Nations, 2002). To estimate adult female mortality, the proportions of persons, in five-year age groups that have living mothers are used. The age of the children is a measure of the period of the risk of dying to which the mothers have been exposed, since mothers must have been alive when their children were born. The average age of mothers is determined from the mean age of all mothers at the time of their children’s birth, which is usually calculated from data on births in the 12 months preceding the survey, on the assumption that the mean age at birth changes only slowly over time.

The estimation of adult male mortality uses the proportion of persons in five-year age groups with living fathers. Fathers are only certain to have been alive at the time of conception and thus will have survived an additional three quarters of a year to the time of birth. The average age of fathers at birth is determined from the mean age at childbearing for men which is usually obtained by adding the average age difference between spouses to the mean age at birth for their children for women.

Brass established an equation relating female probability of surviving from age 25 to age $25+n$ to the proportion of respondents in two contiguous five-year age groups whose mother were still alive at the time of the survey. The equation is of the form:

$$\frac{l(25+n)}{l(25)} = W(n)S(n-5) + (1-W(n))S(n),$$

where $S(n)$ is the proportion of respondents aged from n to $n+4$ with mother alive, and $W(n)$ is a weighting factor employed to make allowance from age patterns of fertility and mortality (United Nations, 1983). The weights $W(n)$ depend on n , the central point of the age groups being considered, and M , the mean age of mothers at the birth of their children.

Brass and Hill (1973) cited in United Nations (1983), estimate life-table survivorship from data on survival of fathers using the equation

$$\frac{l(b+n+2.5)}{l(b)} = W(n)S(n-5) + (1-W(n))S(n),$$

where b is set to 32.5 and 37.5, the choice depending on which is closest to the mean age of fathers at the birth of their children.

Hill and Trussell (1977), proposed an alternative estimation procedure based on the following equation for women:

$$\frac{l(25+n)}{l(25)} = a(n) + b(n)M + c(n)S(n-5),$$

where $a(n)$, $b(n)$ and $c(n)$ are coefficients estimated by using linear regression to fit the equation to data from 900 simulated cases derived using fertility schedules generated by the Coale-Trussell model. They generated a variety of mortality schedules applying the Brass's logit relational model to each of the four Coale-Demeny mortality patterns as standards (United Nations, 1983).

The estimation of male adult mortality from data on survivorship of fathers proceeds in the same way as for the mothers. Survival probabilities are conditional on reaching age 35, rather than age 25 because husbands tend to be older than their wives. Proportions with father surviving are taken from two successive age groups rather than a single age group as was the case with Brass's method (United Nations, 2002). The equation for fathers is given by:

$$\frac{l(35+n)}{l(35)} = a_0(n) + a_1(n)M + a_2(n)S(n-5) + a_3(n)S(n).$$

Timaeus (1992) revised the regression coefficients for both maternal and paternal orphanhood. The coefficients were estimated from simulated data created from relational logit model life-tables, based on Brass's General Standard, and fertility distributions generated applying the relational Gompertz model to Booth's standard female fertility schedule and the Paget and Timaeus's standard for males (Timaeus, 1992). These standards were developed from populations with high fertility.

The survival probabilities derived using the orphanhood method refers to different time periods. Surviving parents of children 5-9 years will have survived between 5 and 10 years, while those of children aged 45-49 years will have survived between 45 and 50 years before the survey. Thus the estimate, for example of $\frac{l_{35}}{l_{25}}$ for mothers from the 5-9 age group represents, on average, the cohort mortality risk during the 10 years prior to the survey whereas the estimate of $\frac{l_{75}}{l_{25}}$ from the 45-49 age group represents, on average, the cohort mortality risk over the 50 years before the survey. These differences in reference period mean that the proportion with surviving parents contains information about both the trend and level of mortality. If mortality has been declining over the years then the estimate of $\frac{l_{75}}{l_{25}}$ from the 45-49 age group will represent a higher average level of mortality than the estimate of $\frac{l_{35}}{l_{25}}$ from the 5-9 age group. In order to be able to interpret and exploit the trend information the estimates of $\frac{l_{25+n}}{l_{25}}$ are translated into a common statistic, for example, ${}_{35}q_{30}$. The trend information inherent in the data may

be exploited by deriving a relationship between cohort survival statistics $\frac{l_{25+n}}{l_{25}}$ and the corresponding period statistics at specific points prior to the census/survey. If mortality has been changing there is a time t , prior to the survey, such that the cohort survivorship estimates are equal to the corresponding period survivorship estimates at time t . This point in time is referred to as the “time location” of estimates (United Nations, 2002).

If mortality has been changing fairly linearly over time it is possible to calculate the time reference reasonably simply. Brass and Bamgboye (1981) presented a method for estimating this time location. If adult female mortality has a pattern similar to that given by Brass’s General Standard, the number of years before the survey to which each estimate derived from maternal orphanhood data refers, is given by $t(n)$:

$$t(n) = \frac{n(1.0 - u(n))}{2.0} \text{ where } u(n) = 0.3333 \ln({}_{10}S_{n-5}) + Z(M + n) + 0.0037(27 - M).$$

When data on paternal orphanhood is used then $t(n) = \frac{(n + 0.75)(1.0 - u(n))}{2.0}$

where $u(n) = 0.3333 \ln({}_{10}S_{n-5}) + Z(M + n) + 0.0037(27 - M + 0.75)$. The value of $Z(M + n)$ is obtained by interpolating linearly from pre-tabulated values (table 88 of United Nations (1983)).

Alternative regression coefficients for estimating male mortality as well a different set estimating female mortality were produced by Timaeus (1992). If the regression coefficients are to be used to estimate female mortality, the regression equation is

$$\frac{l_{f(25+n)}}{l_{f(25)}} = \beta_0(n) + \beta_1(n)M + \beta_2(n)S(n-5) \text{ and to estimate male mortality, the}$$

$$\text{regression equation is } \frac{l_{m(35+n)}}{l_{m(35)}} = \alpha_0(n) + \alpha_1(n)M + \alpha_2(n)S(n-5) + \alpha_3(n)S(n). \text{ When the}$$

Brass method was compared to the regression method using about 1 000 cases of simulated data, it was found that the Brass method worked as well or better than the regression method for n not exceeding 30 years, while the regression produces better results for higher values of n (United Nations, 1983; Timaeus, 1992).

2.3 Two Survey Method

If data on survival of parents are available from two censuses/surveys five or ten years apart, the synthetic cohort procedure proposed by Zlotnik and Hill (1981) can be applied to obtain estimates that refer to the intervening period (United Nations, 1983, 2002). Survivors of cohorts from the first survey can be identified at the second survey assuming that migration in the period between the surveys is negligible and there is no relationship between the mortality of parents and that of their children. Survivorship probabilities applicable to, for example, a five year inter-survey period can be estimated from the constructed proportion not orphaned for a hypothetical inter-survey cohort of respondents (United Nations, 1983).

Let $S_1(x,5)$ denote the proportion aged x to $x+5$ whose mother is alive at the first survey and $S_2(x,5)$ denote the same statistic for the second survey. The proportion aged 5-9 with surviving mother in a hypothetical cohort will be the average of

$S_1(5,5)$ and $S_2(5,5)$, that is $S^*(5,5) = \frac{[S_1(5,5) + S_2(5,5)]}{2}$. The proportion with

mother/father surviving in subsequent years in the hypothetical cohort will be given by

$S^*(x,5) = \left[\frac{S_2(x,5)}{S_1(x-5,5)} \right] \cdot S^*(x-5,5)$. The ratios $\left[\frac{S_2(x,5)}{S_1(x-5,5)} \right]$ represent the change in

proportion with mother surviving in the actual cohort aged x to $x+5$ at the first survey, and therefore reflect mortality conditions during the inter-survey period.

Timaeus (1986) noted that when the interval between the surveys/censuses is not exactly five or ten years apart an adaptation of the inter-survey survival method can be applied. The synthetic ratios will be computed as:

$R(x,5) = \frac{S(x+5,5)\exp(2.5r(x+5,5))}{S(x,5)\exp(2.5r(x,5))}$ where $S^*(x,5) = \frac{[S_1(x,5) + S_2(x,5)]}{2}$ and

$$r(x,5) = \frac{\ln \left[\frac{S_2(x,5)}{S_1(x,5)} \right]}{t},$$

where t is the length of the intercensal period. The proportion with surviving parents for the hypothetical cohort is then calculated by $S^*(x,5) = R(x-5,5)S^*(x-5,5)$.

Timaeus (1991b), extending earlier work, proposed a method which involves developing a synthetic cohort, based at age 20 from data on parental survival at two dates. This synthetic cohort represents the proportion of the adult population whose mothers or fathers would remain alive, at current levels of mortality, among those who had a living mother or father at exact age 20. The equations used to estimate parental orphanhood from age 20 is similar to those proposed for orphanhood since birth, but with different coefficients. For orphanhood from age 20 years, exposure is assumed to on average 20 years after the mean age of childbearing, M , and survivorship is estimated from a base of 45 years for females and 55 years for males. The equation for females is:

$$\frac{l(25+n)}{l(45)} = a(n) + b(n)M + c(n) \frac{S(n-5)(\tau)}{S(20,t)}, \text{ where } S(20) = \sqrt{{}_5S_{15}(t) {}_5S_{20}(t)}, \text{ and the}$$

equation for males can be estimated from orphanhood after age 20 as:

$$\frac{l_{(35+n)}}{l_{(55)}} = \alpha_0(n) + \alpha_1(n)M + \alpha_2(n) \frac{S(n-5)(\tau)}{S(20,t)} + \alpha_3(n) \frac{S(n)(\tau)}{S(20,t)}.$$

The synthetic cohort method based on age 20 is assumed to produce better results than methods using lifetime orphanhood because the approach avoids any errors in the data on children to be transmitted to the population aged 20 and above during the construction of the synthetic cohort. The weakness of this method, depending on the source of data, is that it is sensitive to difference in age reporting between the two surveys or the accuracy of retrospective reporting of dates of orphanhood (Timaeus (1991b)).

A major limitation of the two-survey approach is that measures of the cohorts' experience between the two surveys are very sensitive to differential reporting and sampling errors. Age reporting errors will mean that the age groups being compared at two dates are not fully equivalent (Zlotnik and Hill, 1981).

2.4 Assumptions of the orphanhood method

The orphanhood method relies on certain assumptions being met for it to produce plausible estimates. The assumptions are:

- (i) There is no substitution of foster parents for true parents in the responses.

- (ii) The patterns of fertility and mortality in the population under examination are similar to those of the models used for the calculation of the conversion coefficients.
- (iii) Mortality has been constant for some time before the survey.
- (iv) There is no correlation between the mortality of the parent and the number of offspring reporting on the same parent. Mortality of non-parents is the same as that of those with children, i.e., there is no selection bias.
- (v) The mortality of parents and that of their children is independent and there is no selection bias.

There is a problem in relating data on the death of parents to mortality levels due to the existence of a large number of selection factors. First, for an answer to a question pertaining to a specific person, that person must have had a child who can report on his or her death/survival. The mortality experience of a person who never had children cannot be taken into account. The second problem is the number of children that a person has had. The survival status of a person with 10 surviving children will potentially be reported on by 10 children while that of a person with one surviving child will only be reported once. Third, estimation is further complicated because the mortality of children also influence the data. If a person has had three children, all deceased, that person will not be represented, whereas another person who has had three children, all surviving, will appear three times in the data set (Brass, 1975; Blacker, 1977; Palloni, Massagli and Marcotte, 1984). These problems are complex because mortality among childless women might be higher than among other women, and the mortality of women with many children may be higher than that with few children. It is possible that biases introduced by these may be off-setting and that the net effect is not negligible (Palloni, Massagli and Marcotte, 1984). Suggestions have been made to include only data on the eldest surviving child to reduce the effect of selection but this has not worked because respondents may report that they are the eldest surviving child while in actual fact they are not (United Nations, 2002).

Brass (1975), notes that another source of error lies in the estimation of the value M , the mean age at birth of children. When this value is calculated from births in the past year the result may not be representative of the age distribution of mothers at the time of

birth, particularly for older children, born several years ago. However, this error is not significant. Even if M has changed over time, the possible range of change is not large enough to produce very different mortality estimates.

Another problem arises in relation to changes in mortality over time. Doubts can be cast about the applicability of the method to the proportions of orphans among older people, say aged 45-49. In such situations, some deaths of mothers/fathers must have taken place a long time ago. The mortality estimates obtained might be very different from the prevailing mortality (Hill and Trussell, 1977; United Nations, 2002). However, Brass (1975) argues that since mortality tends to increase with age at older ages many deaths of parents of persons aged 45-49 will have taken place in recent years. He further argues that in developing countries where mortality is both high and changing, the change is likely to be less dramatic at adult ages than for young people and infants.

For the young age groups, mortality estimates obtained using the orphanhood method are often lower relative to other age groups. This is due to the adoption effect. Timaeus (1986) notes that underreporting of orphanhood tend to be most common at the young ages, while the tendency to exaggerate age is thought to increase with the age of the respondent. Chaining cohort changes transmits a large part of this bias to older age groups (Timaeus, 1991b). In a number of applications in East Africa and elsewhere, the orphanhood method has yielded results that indicate rapid declines in mortality and inconsistencies between the estimates from successive enquiries. This appears to be caused by underreporting of orphanhood among those whose parents died when they were young.

By assuming that the mortality and likelihood of migration of respondents are not related to the mortality of parents, Timaeus (1991b) uses orphanhood data to create a synthetic cohort from age 20 to reduce the effect of the adoption bias. Extending earlier research, he presents separate series of regression coefficients for estimating female and male adult mortality from the proportion surviving according to the synthetic cohort from age 20 who had a living mother or father at the first survey. This approach is useful in dealing with one of the underlying problems of orphanhood, the “adoption effect”, but does not deal with some of the other problems of the method, such as the effects of the HIV/AIDS epidemic.

2.5 Allowing for HIV/AIDS

The HIV epidemic has increased the non-independence of mother's (and to lesser extent, father's) and their children's mortality significantly because of mother to child transmission of the virus. The HIV epidemic may also render the life table measures that the orphanhood provides, inaccurate because HIV changes the age pattern of mortality. Timaeus and Nunn (1997) worked with data with HIV prevalence and produced practical adjustment techniques to allow for the impact of HIV. They developed a correction for selection bias in reports of orphanhood and a revised procedure for estimating life table survivorship for use in populations with significant AIDS mortality.

Timaeus and Nunn (1997) modelled the effect of the HIV epidemic on maternal orphanhood, distinguishing infected (sero-positive) women, from uninfected (sero-negative) women. Women who were sero-positive a years ago have lower survival probability and lower fertility than other women. Timaeus and Nunn (1997) suggest that the proportion still alive of women who would have given birth a years ago in the absence of any impact of HIV infection on fertility is given by:

$$S(a) = \frac{N^+(a) + N^-(a) + N^i(a)}{\int_{\alpha}^{\beta} C^+(a, y) + C^-(a, y) dy}, \text{ where } N^+(a) \text{ is the number of living sero-positive}$$

women who would have given birth a years ago if fertility was the same as that of other women. $N^-(a)$ is the number of women who gave births a years ago at age y remaining alive and uninfected. $N^i(a)$ is the number of mothers who gave birth a years ago and have become infected since but remain alive. $C(a, y)$ is the number of children born a years before a demographic survey to women who were then aged y years.

If a proportion, h , of the children of sero-positive mothers have acquired the virus perinatally and it is assumed that, apart from vertical transmission, the mortality of orphans and non-orphans is the same, then the proportion of respondents aged a who report that their mothers are alive is given by

$$S^*(a) = \frac{(1-h)N^+ + N^-(a) + N^i(a)}{\int_{\alpha}^{\beta} (1-h)F(a, y)C^+(a, y) + C^-(a, y) dy} \text{ for } a \geq 5. \text{ } h \text{ is the proportion of the}$$

children of sero-positive mothers who have the virus transmitted to them perinatally. $F(a, y)$ is the age-specific ratio of the fertility of sero-positive to sero-negative women a years ago at age y . In this study, Timaeus and Nunn assume that $h = 25$ per cent but they also explore the effect of a vertical transmission rate of 35 per cent. In the end they suggest that ${}_5S_x$, the proportion of respondents in each five-year age group with living mothers, be calculated by interpolating between the point estimates for five yearly intervals assuming that births grew at a constant rate r , across each age group, that is:

$${}_5S_x = \frac{l(x)S(x) + e^{-2.5r} \frac{l(x) + l(x+5)}{2} \sqrt{S(x)S(x+5)} + e^{-5r} l(x+5)S(x+5)}{l(x) + e^{-2.5r} \frac{l(x) + l(x+5)}{2} + e^{-5r} l(x)}$$

Working with the data from Masaka district in Uganda Timaeus and Nunn (1997) found that one could expect small biases in reports on survival of mothers in populations affected by HIV/AIDS. The reason is that reduced fertility and vertical transmission are likely to select out more than half of the reported infected women. The bias in the reported proportion of respondents with living mothers increases with prevalence at a rate determined by F and H . The higher the vertical transmission, the lower the fertility of infected women and the greater the bias in reports on the survival of mothers. Assuming that the fertility of infected women is 20 per cent lower than other women and the vertical transmission rate is 25 per cent, Timaeus and Nunn (1997) produce the following simple equation for correcting for selection bias:

$${}_5S'_x = \frac{1 - 0.25P}{1 + 0.25P} {}_5S_x^* \approx (1 - 0.5P) {}_5S_x^*$$

where P is the sero-prevalence rate of women attending antenatal clinics aged 15-49 years and ${}_5S'_x$ is the adjusted proportion of mothers alive. To allow for the survival for more than five years of a significant proportion of mothers who were sero-positive when they gave birth, they suggest that the adjustment can be halved for respondents aged 5 to 9 so that ${}_5S'_5 = (1 - 0.25P) {}_5S_5^*$.

Timaeus and Nunn proposed further, that if a population-based estimate of sero-prevalence among women of childbearing age, P^* , is available, rather than one based on antenatal data, one must assume that the proportion of births to sero-positive

women aged y can be estimated from P^* , so that $C^+(a, y) = P^* \cdot C(a, y)$ and

$\frac{S(a)}{S^*(a)} = 1 - (1 - (1 - h)F)P^*$ with $F = 0.8$ and $h = 0.25$, the correction factor is:

$${}_5S'_x = (1 - 0.4P^*){}_5S_x^*.$$

Another source of bias in estimates of adult mortality derived using the orphanhood method for populations affected by HIV/AIDS lies in the regression equation used to convert proportions of respondents with living mothers into life table

probabilities $\frac{l(25+n)}{l(25)}$. These equations normally take the form, for females, of:

$$\frac{l(25+n)}{l(25)} = a(n) + b(n)M + c(n)S(n-5)$$

where M is the mean age at childbearing,

which allows for variations between populations in the ages over which mothers are exposed to the risk of dying. AIDS deaths are concentrated among young adults and thus the epidemic produces age patterns of mortality that differ from those in the mortality models used to estimate the coefficients of the coefficient equations (Timaeus and Nunn, 1997). Timaeus and Nunn produced provisional regression coefficients where the regression lines have lower intercepts and steeper slopes for respondents less than 25 years of age.

Although Timaeus and Nunn didn't suggest adjustment factors for the mortality of fathers, Timaeus and Jasseh (2004), estimated adult mortality from data on the orphanhood of children aged 5-14 years for a wide range of African countries. The data on maternal orphanhood were adjusted for biases arising from the reduced fertility of HIV-positive women. It was also adjusted for the mortality of vertically infected children on the basis of approximate expressions for these biases developed by Timaeus and Nunn (1997), the proportion of children aged 10-14 with living mothers was reduced by 47.5 per cent of the estimated prevalence of HIV infection in the population of women at the time of the children's birth. For children aged 5-9, they halved the adjustment. On the proportion of children with living fathers they reduced them by 60 per cent of those amounts of the mothers.

Variants of parental survival methods have been developed for use with data on survival of parents at times other than the time of the census or survey. Chackiel and Orellama (1985), proposed a supplementary question about the date of death of each parent who

has died. They found that this allows one to derive recent estimates of adult mortality from data on parental survival. A major problem with this variant is that respondents may not give accurate dates of death of parents who have died. Initial trials of the method in Bolivia, Costa Rica and Honduras yielded promising results but the method failed in Burundi (Timaues, 1991a). It is not yet clear if this method would work in Southern Africa where the level of literacy is low.

Timaues (1991a) refined a method of estimating adult mortality by survival of parents since first marriage. The reference period of the estimates is more recent than for overall parental survival, and any systematic bias due to adoption of young children should not affect data from first marriage onwards. The method also requires control for the ages of parents at the time of respondents' birth, and also a control for the distribution of respondents by age at marriage. This means that data for respondents under age 25 cannot be used because before this age most marriages will not have occurred (Hill, 2000).

Gakidou and King (2006), note that the DHS and the World Health Survey collect data for estimating adult mortality but current methods of using this information suffer from selection bias. Gakidou and King are concerned with the bias that mortality is not independent of size of family, i.e. the mortality being reported is that of the parents with surviving children and thus more likely to reflect the mortality of larger families. In the case of sisterhood data they developed an approach which avoids the assumption of independence of mortality among siblings which is corrected via weighting and requires extrapolation from observable patterns. Their method uses data on sibling survival to estimate adult mortality but they suggest that a similar method can be applied to data on survival of parents and other relatives.

2.6 Mortality Rates in South Africa

Adult mortality remains a neglected public health issue in Sub-Saharan Africa (Bradshaw and Timaues, 2006). This neglect is caused by a lack of empirical data about the levels of mortality experienced by these adults. Estimates of adult mortality by country have been produced by various international organisations. However, these rates should be used with caution. A number of studies have produced national estimates of South African mortality in recent years, for example, Udjo (1999) and most recently Dorrington,

Moultrie, Timaeus and Nannan (2004), Nannan, Timaeus, Bradshaw et al (2001), Hosegood, Vanneste and Timaeus (2004), Timaeus, Dorrington, Bradshaw et al (2001).

Mortality and morbidity trends in South Africa have been dominated by the HIV epidemic. There was a substantial increase in mortality of young adults during the 1990s and the new millennium. This has severely affected women aged 20 to 44 years and men in a wider age band (Bradshaw and Nannan, 2006). There is evidence of a reversal in the previously declining trend in adult mortality. A comparison of 1992-1993 with 1994-1995 shows that most of the increase in mortality is concentrated in the young adult (Tollman, Kahn, Garenne *et al.*, 1999). There has been a rapid increase in the number of deaths with marked changes in the age pattern of death distribution. AIDS and related diseases particularly Tuberculosis (TB) appears to be primarily responsible for the probable reversal in mortality especially in the rural areas of South Africa. A report from Stats SA based on the death notifications reflects the same rapid change in the age distribution of deaths. The increase in young adult deaths is most pronounced among young women (Bradshaw and Nannan, 2006).

In order to derive reliable mortality estimates, demographers require both suitable death and exposure (to the risk of dying) data. Mortality estimates may be derived directly by dividing the number of deaths by person-years of exposure. Direct estimation will only produce reliable estimates if both the population used to estimate exposure and the number of deaths reported for that population are accurate. In addition to vital registration, censuses and surveys provide demographers with important mortality data, particularly where vital registration is not complete (Bradshaw and Timaeus, 2006).

The use of surveys and retrospective survey questionnaires, both once-off and repeat visit surveys, may be key sources of mortality data (Timaeus, 1991b). In South Africa, Agincourt and Africa Centre for Health and Demographic Surveillance Sites are some of the sites where mortality research is done. At these sites repeat surveys are used to collect cohort mortality data over a period of time. Kahn, Garrene, Collinson, *et al* (2007), examine trends in age-specific mortality in a rural South African population from 1992 to 2003, a decade spanning major socio-political change and the emergence of the HIV/AIDS pandemic. When they compared age-specific mortality rates at the end of the surveillance period (2002-2003) with those of 1992-1993, they found

differential increases by age and sex. The increase in rates was greatest in the 20-34 age group in both males and females. Gender difference were also apparent; female rates increased greater than those for males in all age groups of younger adulthood (20-64) (Kahn, Garenne, Collinson *et al.*, 2007).

Estimates of both the level and shape of mortality in South Africa around 1985 and 1990 were derived by Dorrington, Bradshaw and Wegner (1999), using reported deaths and indirect mortality estimation techniques to correct for incomplete deaths data. Over the period 1998-2003 the reported number of adult death on the population register increased by 68 per cent. The authors point out that this represents a real increase of more than 40 per cent after allowing for both improvements in reporting and population growth (Bradshaw and Timaeus, 2006).

Applying the orphanhood method to data from the 1996 census, Udjo (1999), found that results of maternal orphanhood show that the proportions of male respondents reporting mother alive is higher than the corresponding proportion of female respondents. This is attributed to differential age misreporting. Males have a tendency to exaggerate their ages. The results from this study show a trend which is indicative of a sharp decline in female adult mortality. The trend in maternal orphanhood from the 1996 census applies several years before the census and this was before the impact of HIV and AIDS. Results from paternal orphanhood show that adult male mortality is high in South Africa (Udjo, 1999).

Dorrington, Timaeus, Moultrie et al (2004), produced provincial adult mortality rates for 1996 using the vital registration data in combination with the population data from the 1996 census and the completeness of the registration of child deaths. The completeness of child death was used to correct for under-reporting of the vital registration. One problem with the provincial adult mortality estimates produced is that some people who die in a province different from the one they reside according to the census are reported on the death certificate to be residents of the province in which the death occurred. This caused a numerator/denominator mismatch which produce bias in rates calculated by dividing deaths in the province by census based population estimates for that province.

A comparison of the death registration-based estimates for the 1980s, of adult mortality with those derived from the 1996 census orphanhood data for the same period showed some consistency (Dorrington, Timaeus, Moultrie *et al.*, 2004). The orphanhood data for men yielded estimates of the overall level of adult mortality across the country (South Africa), that were similar to those calculated from the vital registration. This was also true for women even though orphanhood estimates were a bit lower. These authors also noted that, like the death registration method estimates, those from the orphanhood method indicate that the differences in the male mortality between the provinces are much higher than the difference for females.

Estimates of the number of reported deaths together with the estimates of the population by population group, sex and age from each of the 1996 and 2001 censuses were used by Dorrington, Moultrie and Timaeus (2004) to estimate adult mortality. They use the general growth balance (GGB) method proposed by Hill (1987) to correct the census population for relative coverage and the synthetic extinct generations (SEG) method using these corrected estimates of the population to estimate mortality. The extinct generation method was used as a check on the estimates of under reporting of deaths derived from the GGB method. They produced mortality rates using vital registration data, 1996 and 2001 census data and compared them with those from other sources. They observed that mortality rates levelled off from the early to middle 1980s, but in the case of the African (hence South African) population, they appear to have increased rapidly since 1995. This is assumed to be the result of the impact of HIV/AIDS. These methods assume a closed population which could not be said about South Africa because migration, especially international migrations to/from South Africa, affect both enumerated populations and to a lesser extent deaths as well. Comparison of ${}_{15}q_{50}$ with that estimated using the orphanhood data showed a high degree of consistency between the estimates, with the weighted average of the population group-specific rates being close to the estimates of national mortality using the orphanhood data (Dorrington, Moultrie and Timaeus, 2004). However the white male (and to a lesser extent, white female) rates produced using the vital registration data appear to be higher than those produced using the orphanhood method.

Anderson and Philips (2004), in a report for Statistics South Africa on adult mortality (aged 15 – 64) between 1997 and 2004 based on death certificates, also note a dramatic

increase in the death rate. They attribute this largely to AIDS-related deaths. Young adults, especially women, have been particularly affected by HIV/AIDS. Between 1997 and 2004 the death rate for women aged 20 – 39 more than tripled and that for men 30 – 44 more than doubled. Although their estimates show a trend, magnitude and to some extent a pattern by age that is consistent with what might be expected due to the impact of HIV on mortality, the methodology they adopted is problematic because they used the mortality (non-AIDS + AIDS) from Spectrum to determine the completeness adjustment. Thus, adjusting registered deaths by these factors merely reproduces the Spectrum mortality.

Death rates and other mortality indices are both calculated directly using deaths and exposures and indirectly by the orphanhood method using data obtained by the Africa Centre Demographic Information System (ACDIS). Mortality in the study area rose sharply in the late 1990s and by the year 2000 the probability of a 15 year old dying before age 60 was 58 per cent for women and 75 per cent for men. AIDS with or without Tuberculosis is the leading cause of death in adulthood (Hosegood, Vanneste and Timaeus, 2004). The total observation period for each individual was calculated as the number of days that they had been observed as a member of an ACDIS registered household between 1 January 2000 and 31 December 2000. Information was also collected at the registration of each individual about the survival of his/her biological parents and if they were dead, about their date of death and age at death. These data were used by Hosegood, Vanneste and Timaeus to estimate adult mortality.

The probability of a 30 year old dying before reaching 65 (${}_{35}q_{30}$) calculated directly from the ACIDS death rates and those from ACDIS orphanhood-based estimates suggest that mortality of both men and women was much lower in the early 1990s than it was in the early 2000. The mortality might have been rising slowly in the late 1980s and early 1990s but rose sharply in the second half of the 1990s. Comparison of the ACDIS orphanhood based estimates with the 1996 census orphanhood based estimates further suggest that in the late 1980s and early 1990s, the mortality of men in the study area was similar to that of rural KZN in general. By 2000 the probability of dying between ages 15 and 60 was 58 per cent for women and 75 per cent for men. The sharp rise in adult mortality in the study population in the second half of the 1990s is in line with other

research suggesting that the HIV epidemic has reversed earlier mortality declines among the African population in South Africa (Hosegood, Vanneste and Timaeus, 2004).

2.7 ASSA2003 Model

The ASSA2003 AIDS and Demographic Model is a mathematical model developed by the Actuarial Society of South Africa. It was designed as a suite of several versions, the lite version models the population as a whole, the full version models each of the four population groups at national level and the provincial version produce results for each (Dorrington, Johnson and Budlender, 2005).

Dorrington, Johnson and Budlender (2005), noted that populations were re-estimated to be consistent with the 2001 census of adults aged 20+ and below age 20 the population has been constructed using the best estimates of fertility rates from censuses over the past 20 years. The model uses antenatal prevalence data from 2003 and mortality data for 2002/2003.

The model projects year by year changes in an initial population based on demographic, epidemiological and behavioural assumptions. The projections reflect changes between 1 July of one year and 30 June of the following calendar year. In the model “stock” numbers reflect the position at the middle of the year and “flow” numbers reflect the change from the middle of the year to middle of the following year.

ASSA2003 model models the population in three age groupings, young (up to 13 years), adult (14-59) and the old (60+). The adult group is divided into four risk groups (PRO, STD, RSK and NOT) separated by their level of risk of contracting HIV through heterosexual activity. It is assumed that most sexual activity occurs between partners in the same risk group. The ASSA model further assumes that members of the RSK group do not have sexual contact with members of the PRO group and members of the NOT do not have unprotected sexual contact with members of any of the other groups.

The model further assumes that a proportion of children born to HIV+ mothers are HIV+ at birth and a further proportion of non-HIV babies born to HIV+ mothers are infected through breast-feeding. It is also assumed that those who are HIV+ at birth will not survive to age 14 and there is no other source of infection before age 14.

The non-HIV probability of death and the probability of becoming infected are used in a multiple decrement life table. After 2001 mortality rates are projected to trend logistically to ultimate rates at a rate determined by a 'mortality improvement factor' using the following formula: $(a - b) \times (c^{(CurrYear - 2001)}) + b$, where a = the mortality rate in 2001, b = the ultimate mortality rate and c = the mortality improvement factor (Dorrington, Johnson and Budlender, 2005). In the absence of ARVs adults are assumed to progress through WHO's four Clinical stages before dying.

The parameters of the ASSA2003 model have been set by reference to studies of empirical evidence and where this was not possible, parameters are set within reasonable bounds to produce output comparable with observations of antenatal sero-prevalence levels and estimates of the true number of deaths based on the registered deaths corrected for under-registration. Model results are calibrated to match the results of the annual ANC surveys both in terms of overall level and by age (Dorrington, Johnson and Budlender, 2005).

3. METHODOLOGY

3.1 Background on data

This research uses data from the 1996 and 2001 Censuses 10% sample and the 2007 Community Survey (a nationally representative large scale survey). Census data for the years 1996 and 2001, and the Community Survey data for 2007 were downloaded from the Statistics South Africa website (Statistics South Africa, 2010²). The two censuses were both held on the 9-10 of October and the 2007 Community survey was held in February (the middle of February 2007 was taken as the reference date). They all included the questions on the survival of the person's biological parents.

Data for the two censuses is in the form of a 10 per cent data sample, which is a 10 per cent sample of all households and persons enumerated in the censuses. The 2007 Community Survey is a large scale survey to provide data on demographic and socio-economic issues at local, provincial and national level. The 2007 Community Survey enumerated 950 000 individuals and estimated a population of 48 million. The survey represents 2 per cent of the total population.

In the 1996 census 97 per cent of the respondents answered the question on the survival of their mothers while 95 per cent answered on the survival status of their fathers. In the 2001 census 99.9 per cent answered the question about the survival status of both their mothers and fathers. In the 2007 Community Survey 99.8 answered the question on the survival status of their mothers while 98.6 answered on the survival status of fathers. For the purpose of this research project the non-response and the missing were not included in the data analysis, which effectively assumes that the survival status of their parents is similar to those who have responded to the question on survival status of parents, because of the low level of non-respond.

² Statistics South Africa. 2010. *Interactive data*. <http://www.statssa.gov.za>. Accessed: 2 March 2010.

The orphanhood method adjusts the proportion of mothers and fathers alive to estimate $\frac{l_{(25+n)}}{l_{(25)}}$ and $\frac{l_{(35+n)}}{l_{(35)}}$ respectively, using models which seek to predict the departure of one from the other using age-specific fertility rates and model life tables. In situations where model life tables and age-specific fertility rates reflect actual experience reasonably and reported survival of mothers/fathers reflect survival of women and men in general, these factors are such that the method could be used to

approximate $\frac{l_{(25+n)}}{l_{(25)}}$ and $\frac{l_{(35+n)}}{l_{(35)}}$ for women and men in general. This may not be true in a

population with a high prevalence HIV epidemic which causes fertility and particularly mortality rates to change rapidly. In situations where HIV is widespread the mortality of the cohort of women aged 25 might increase far more rapidly in the years that follow than the mortality of women across a wider age range and might decrease after the age of peak HIV mortality has been passed. In addition, mortality as reported by children may not be a true reflection of the mortality of women of child-bearing age due to mother-to-child transmission and the relationship between HIV and fertility.

There are parental survival probabilities from the three surveys at the times of the surveys, namely: 1996.77, 2001.77 and 2007.13. Each survey produces estimates of $\frac{l_{(x+7.5)}}{l_{(x)}}$ to $\frac{l_{(x+47.5)}}{l_{(x)}}$ for both males and females, where x is the average age of parents at

birth for women and at conception for men. The estimates at the highest ages can probably be ignored for reasons of limited usefulness of knowing mortality that far back and the bias of age misreporting at highest ages. So the population with surviving mother/father from the orphanhood method are compared against the benchmark survival probabilities to see how well the orphanhood method works in South Africa.

The regressions then convert these into $\frac{l_{(35)}}{l_{(25)}}$ to $\frac{l_{(65)}}{l_{(25)}}$ for females and $\frac{l_{(45)}}{l_{(35)}}$ to $\frac{l_{(75)}}{l_{(35)}}$ for

males. These probabilities are then compared against the benchmark. In addition these sets of probabilities are converted into probabilities over more standard age range such as ${}_{35}q_{15}$, ${}_{35}q_{30}$ and ${}_{45}q_{15}$ which are then also compared against the benchmark.

3.2 Benchmark Mortality Rates

For the purpose of this project the benchmark mortality rates³ were derived in two periods. The first period was between 1950 and 1980 and the second period was between 1985 and 2007. We took the period between 1950 and 1980 because the proportion with mother/father surviving from the orphanhood method produces survival probabilities going back 40 to 50 years in time. The second period was taken between 1985 and 2007 because we used data from the ASSA2003 model which only projects from 1985.

3.2.1 Benchmark pre-1980

The estimates covering 1950 through to 1980 were derived as weighted averages of estimates of the United Nations Population Division, (United Nations, 2008) and Sadie, (1988). The UN Population Division estimates were approximated by projecting the population of South Africa for each year since 1950 using the EasyProj default assumptions and setting migration to zero. The underlying life table in each year were derived from the proportions surviving at each age. This approach was adopted because it is not clear which of the two estimates is the more correct. Sadie, (1988) provides survival ratios for Asian, Coloured and Black/African for the periods 1951-1956, and then in five-yearly intervals from 1955 to 1980. For the White population group estimates are provided for five-year periods starting from 1960-1965 through to 1975-1980. There are official SALT (South African Life Tables) for Whites, Coloureds and Indians (referred to as Asians) around each census, (i.e. 1946, 1951, 1961, etc) published as the abridged life tables by van Eerden and van Tonder (1975). We interpolate between the points of the abridged life tables by van Eerden and van Tonder, (1975) to estimate the survival ratios of the White population group for the period 1951-1956 and 1955-1960 which were missing from the Sadie, (1988).

Starting with Sadie's estimates the national survival ratios $p_B s$ (the probability of surviving from birth) and $p_x s$ (probability of surviving from age x to age $x+1$) were obtained by a weighted average of the published $p_B s$ and $p_x s$ for each population group using the numbers in the published estimates of population age group at the start

³ Benchmark mortality rates/estimates are a set of mortality estimates which is assumed to be the best, but not necessarily completely accurate estimates of mortality.

of each period as weights. The survival probability by age groups were taken from Sadie (1988), who gave them for 1951-1956, 1955-1960 through to 1975-1980 for each of the four population groups. Instead of using the number of births to weight p_B s we used the population number aged 0-4 in each population group given by Sadie since these estimates don't matter since the focus is on adult mortality.

The national survival ratios, P_x s were converted into ${}_5L_x$, and ${}_5L_0$ was obtained by multiplying the P_B s by 5. Thereafter ${}_5L_x$ was estimated by the following formula

${}_5L_{x+5} = P_x * {}_5L_x$ and this was calculated up to ${}_5L_{75}$. We set the open interval at age 85.

${}_5L_{80}$ and ${}_5L_{85}$ were calculated as ${}_5L_{80} = \frac{({}_5L_{75})^2}{{}_5L_{70}}$ and ${}_5L_{85} = \frac{({}_5L_{80})^2}{{}_5L_{75}}$ respectively. ${}_5L_x$ s

were then apportioned to L_x s using Beer's Ordinary Formula, a five term formula which divided ${}_5L_x$ into fifths (Shryock, Jacob and Associates, 1976). The central rate of

mortality m_x was then estimated as $m_{x+0.5} = \frac{2 * (L_x - L_{x+1})}{L_x + L_{x+1}} \approx \mu_{x+1}$.

The UN Population Division data was extracted by downloading the latest version of Spectrum and creating an EasyProj for South Africa. An approximation of the UN Population Division estimates was derived using EasyProj (United Nations, 2007), assuming that there was no migration. There was no HIV/AIDS before 1980 and the results are supposedly those underlying the UN population Division projections. We set migration to zero and output $P(x, t)$ for single ages and single years. The force of

mortality μ_{x+1} was estimated as $\mu_{x+1} = -\ln\left(\frac{P(x+1, t+1)}{P(x, t)}\right)$. These rates apply from the

middle of the year t to the middle of the year $t+1$ rather than year t .

Mortality estimates derived from Sadie and UN Population Division data sets were then averaged to obtain the benchmark mortality rates between 1957 and 1980. Interpolation was used to get the mortality rates in single years. The rates were smoothed at old ages by fitting a Gompertz curve to the average mortality rates from age 70 to age 80 to remove any oscillation due to the interpolation process.

3.2.2 Benchmark post 1980

After 1980 the benchmark mortality rates were derived by averaging estimates derived from ASSA2003lite version and UN Population Division abridged life tables. The UN Population Division abridged life tables for females and males were extracted for each of the periods 1985-1990, 1990-1995 to 2005-2010. The populations are projected from 1 July in the year t to 1 July in the year $t+5$, thus the mid-point of these 5 year periods is 1 January of year $t+3$ or exactly year $t+3$, i.e. 1988.0, 1993.0, 2003.0, etc.

The l_x s at individual ages were interpolated using Beer's Ordinary formula, a six term formula which minimises the fifth differences of the interpolated results (Shryock, Jacob and Associates, 1976). It also maintains the given values. For convenience it was assumed that l_x s were estimated for the years are centred on 1987.5, 1992.5 to 2007.5 for both males and females to be in line with estimates of the ASSA2003 model, since the difference will be somewhat trivial. From the l_x s at individual ages the survival probability p_x s were estimated and these were used to estimate the force of

$$\text{mortality, } \mu_{x+0.5} = \ln\left(\frac{1}{p_x}\right).$$

Full life tables for males and females were extracted directly from ASSA2003 lite model for the years centred on 1985 to 2008. The ASSA model projects l_x s from the middle of one year to the middle of the next, thus deaths over the year are centred at the start of the second year. The years which matched mortality estimates from the UN Population Division were used to estimate the force of mortality. Thus the estimates of l_x s centred on 1987.5, 1992.5 to 2007.5 were used to derive the survival probability p_x . These were then used to derive the force of mortality. Estimates of mortality derived from ASSA2003lite model and those derived from the UN Population Division data were then averaged to obtain the benchmark mortality rates for the years centred on 1987.5, 1992.5 to 2007.5. Interpolation was used to estimate mortality rates for single years linking 1980.5 to 1987.5 and again to estimate mortality rates in single years.

3.3 Conditional Survival probabilities (Benchmark)

The conditional survival probabilities for the benchmark were calculated for particular points in time as indicated by the time location from the orphanhood method. The benchmark force of mortality was converted to probabilities of survival using $p_x = \exp[-\mu_{x+0.5}]$. The p_x s were then used to determine the probability of

surviving in single ages for single years centred on 1982.5, 1983.5, and so on to 2007.5. Interpolation between the points was used to obtain the l_x s at a particular time location.

3.4 Proportion Surviving (Benchmark)

The proportion with mother/father surviving is a cohort measure of survival from the mean age of childbearing to the date of the census/survey. The mean age at childbearing was taken to be $M_f = 27$ (after rounding up $M_f = 26.86$) which was calculated from births in the last 12 months from the 2001 census. Six years were added to this mean age at childbearing to obtain $M_m = 33$ for males because men are on average 6 years older than their spouses. On the date of the survey respondents were on average 7.5, 12.5, 17.5 up to 47.5 years old. These average ages of respondents were subtracted from the date of the survey to obtain the year on which they were 27 years old for females or 33 years old for males, the mean age at childbearing. To obtain the proportion surviving on the date of the survey, $\mu_{x+t+0.5,t}$, the force of mortality in year t from the year of birth of child, was added diagonally starting from the mean age of childbearing n years before the survey to the date of the survey, where n is the average age of the respondents at the time of the survey. Then the proportion surviving was calculated as ${}_n P_{27} = \exp\left(-\sum_{t=0}^n \mu_{27+t,t}\right)$ for females and ${}_n P_{33} = \exp\left(-\sum_{t=0}^n \mu_{33+t,t}\right)$ for males.

3.5 Calculation of ${}_{35}q_{15}$, ${}_{35}q_{30}$ and ${}_{45}q_{15}$

The probabilities of dying ${}_{35}q_{15}$, ${}_{35}q_{30}$ and ${}_{45}q_{15}$ were estimated by first calculating the level of mortality implied by the survival probabilities at each particular time location, alpha, assuming that beta is equal to one and Brass's General Standard, using the

$$\text{formula } \alpha = -0.5 * \ln \left[1 + \left(\frac{\frac{{}_n P_{25} - 1}{l_{s(25+n)}}}{1 - {}_n P_{25}} \right) \right] \text{ and}$$

$$\alpha = -0.5 * \ln \left[1 + \left(\frac{\frac{{}_n P_{35} - 1}{l_{s(35+n)}}}{1 - {}_n P_{35}} \right) \right] \text{ for females and males respectively, with } l_{s(25+n)} \text{ and}$$

$l_{s(25)}$ from the Brass General Standard. Estimates of ${}_{35}q_{15}$, ${}_{35}q_{30}$ and ${}_{45}q_{15}$ are then

$$\text{calculated as } {}_{35}q_{15} = 1 - \frac{1 + \exp(2 * (\alpha + \beta \gamma_s(15)))}{1 + \exp(2 * (\alpha + \beta \gamma_s(50)))}$$

$${}_{35}q_{30} = 1 - \frac{1 + \exp(2 * (\alpha + \beta \gamma_s(30)))}{1 + \exp(2 * (\alpha + \beta \gamma_s(65)))} \text{ and } {}_{45}q_{15} = 1 - \frac{1 + \exp(2 * (\alpha + \beta \gamma_s(15)))}{1 + \exp(2 * (\alpha + \beta \gamma_s(60)))}, \text{ where}$$

γ_s is logit of the standard and we assumed that $\beta = 1$ as was done by Dorrington *et al* (2004). Setting $\beta = 1$ is a reasonable assumption since it is rare to have data of sufficient quality to permit accurate estimation of both α and β . β is the more susceptible of the two parameters to age misstatement and the major interest is usually attached to knowing the "level" not the shape of mortality.

3.6 Allowing for HIV/AIDS

We have taken P , the HIV prevalence of women aged 15-49 from the ASSA 2003 version of the ASSA model. Timaeus and Nunn (1997) assume that the fertility ratio of HIV positive women to HIV negative women is 0.8 and that the perinatal vertical transmission rate is 0.25. However, these assumptions do not appear to apply to South Africa where the fertility ratio of HIV positive women to HIV negative women in South Africa is higher. This is because young HIV positive women have a higher fertility rate than young HIV negative women thus this offsets the fact that older HIV positive mother are less fertile than older HIV negative women. The ratio from ASSA exceeds 1 and in the absence of other data we have assumed the reduction in fertility for HIV-positive women to be $F = 1$ and vertical transmission rate is $h = 0.2$ taken from

ASSA2003. Substituting these assumptions into the expression $\frac{S(a)}{S^*(a)} = \frac{1 - hP}{1 + \frac{1 - F}{F}P}$ we

obtain ${}_5S_x' = (1 - 0.2P) {}_5S_x^*$, where $S(a)$ is the proportion still alive of women who would have given birth a years ago in the absence of HIV infection on fertility, $S^*(a)$ represents the proportion of respondents aged a who report that their mothers is still alive and P represents prevalence at the time of the children's birth (Timaeus and Nunn, 1997).

The correction factor was halved for children aged 5-9. The proportion of respondents aged 10-14 with mother alive is thus reduced by 20 per cent of the

estimated prevalence at the time the children were born and respondents aged 5–9 are reduced by 10 per cent of the estimated prevalence. The proportion of children in the 5–9 and 10–14 with father surviving was reduced by 60 per cent of the reduction in mothers surviving (Timaeus and Jasseh, 2004).

Using data from the Masaka DSS (Uganda), Timaeus and Nunn (1997) have suggested new sets of coefficients to correct for HIV/AIDS. These regression coefficients were used for the 5–9 and 10–14 when the prevalence of women 15 to 49 was significant enough to be at least 5 per cent. For the rest of the age groups we used coefficients suggested by Timaeus (1992). Calculations of mean age at childbearing and time location were similar to that of the regression variant.

University of Cape Town

4. RESULTS

4.1 Proportion with mother and father surviving

The orphanhood method depends on the survival of mothers or fathers, as reported by children of different age groups at the time of the survey. Table 4.1 below shows the proportions reporting mother or father surviving, according to the 1996 Census, 2001 Census and the 2007 Community Survey. The first thing one notices is that the proportions with father or mother surviving decline with each successive survey in each particular age group, which suggests that mortality must have risen over the period 1996-2007, and particularly, at least in young adults.

Table 4.1 Proportion with mother or father surviving in each age group by year of the census or survey

Age Group	Males			Females		
	1996	2001	2007	1996	2001	2007
5-9	0.9140	0.8953	0.8502	0.9791	0.9684	0.9379
10-14	0.8809	0.8541	0.7887	0.9706	0.9527	0.9018
15-19	0.8279	0.8021	0.7346	0.9523	0.9353	0.8810
20-24	0.7491	0.7282	0.6811	0.9178	0.9057	0.8633
25-29	0.6552	0.6293	0.6118	0.8680	0.8566	0.8371
30-34	0.5409	0.5229	0.5164	0.8006	0.7902	0.7858
35-39	0.4365	0.4030	0.4162	0.7209	0.7033	0.7053
40-44	0.3269	0.2989	0.2992	0.6196	0.6075	0.6038
45-49	0.2345	0.2056	0.2090	0.5089	0.4936	0.4988
50-54	0.1554	0.1313	0.1290	0.3878	0.3722	0.3804
Median	0.5981	0.5761	0.5641	0.8343	0.8234	0.8115

The proportions with mother or father surviving were compared with the cohort probability of surviving from m to $m + n$, ${}_n p_m$ from the benchmark estimates, where n is the average age of children at the time of the survey and m is the mean age at child bearing. The values of n are 7.5, 12.5... up to 47.5. The mean age at childbearing was calculated from the 2001 census as 26.86 years for females which was rounded up to get $m = 27$ years. Six years were added to this to get $m = 33$ years for males because males are on average 6 years older than their spouses. Figure 4.1 to Figure 4.3 below show that whereas the benchmark estimates, ${}_n p_m$, are very similar for females for 1996 and 2001 census and $n > 20$ for the 2007 survey, they are noticeably greater than the proportion

with father surviving. This shows that, in general, while the orphanhood method estimates the survival of women reasonably accurately it underestimates survival of adult males. Figure 4.3 shows a different picture altogether. Here the proportion with mother surviving from the orphanhood method is slightly greater than the benchmark, ${}_n P_m$, for the young respondents (from the most recent period, $n=7.5, 12.5$ and 17.5).

Figure 4.1 Proportion with mother/father surviving, 1996 Census

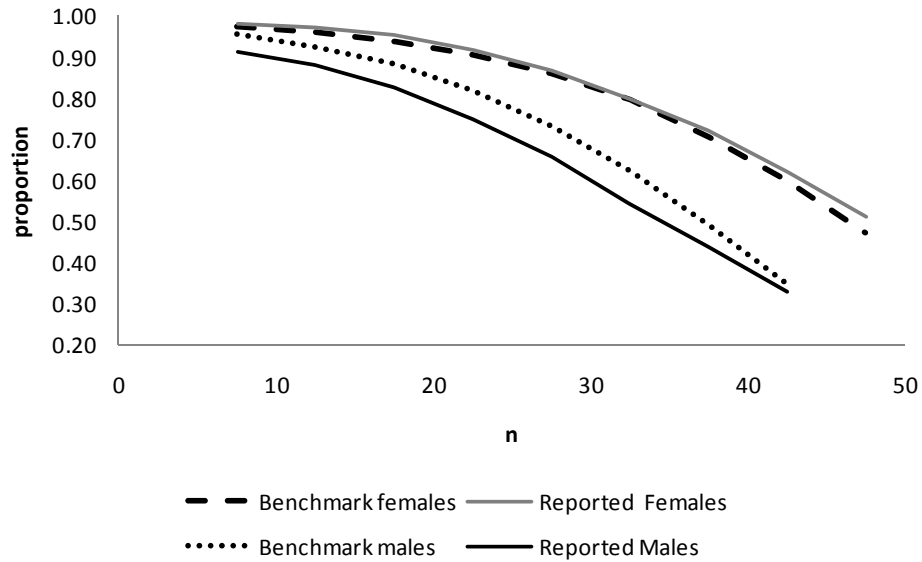
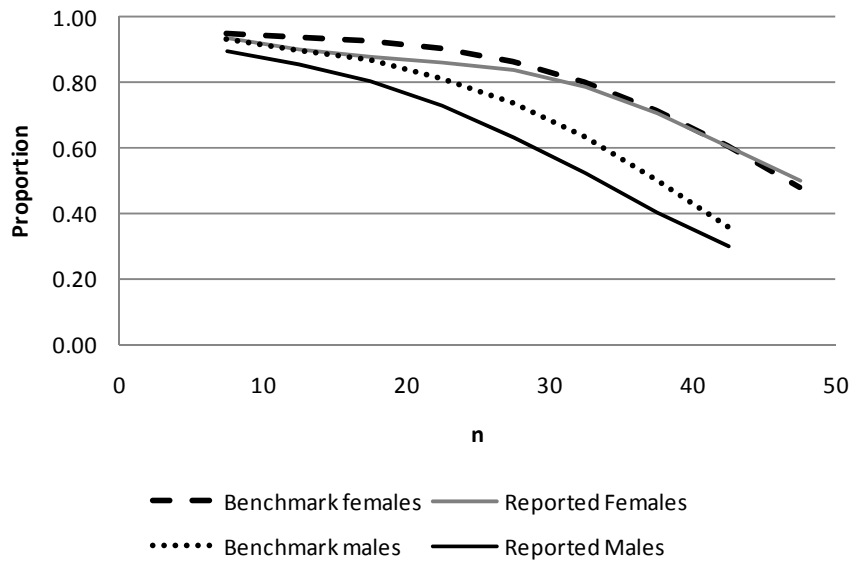


Figure 4.2 Proportion with mother/father surviving, 2001 Census



Between $n=27.5$ and $n=42.5$ the, ${}_n p_m$, obtained from the benchmark is slightly greater than the proportion with mother surviving from the orphanhood method. HIV/AIDS was only corrected for with the 2007 Community Survey data because that is only where the prevalence level of women at the time of birth of the child was significant (more than 5 per cent).

Figure 4.3 Proportion with mother/father surviving, 2007 Community Survey

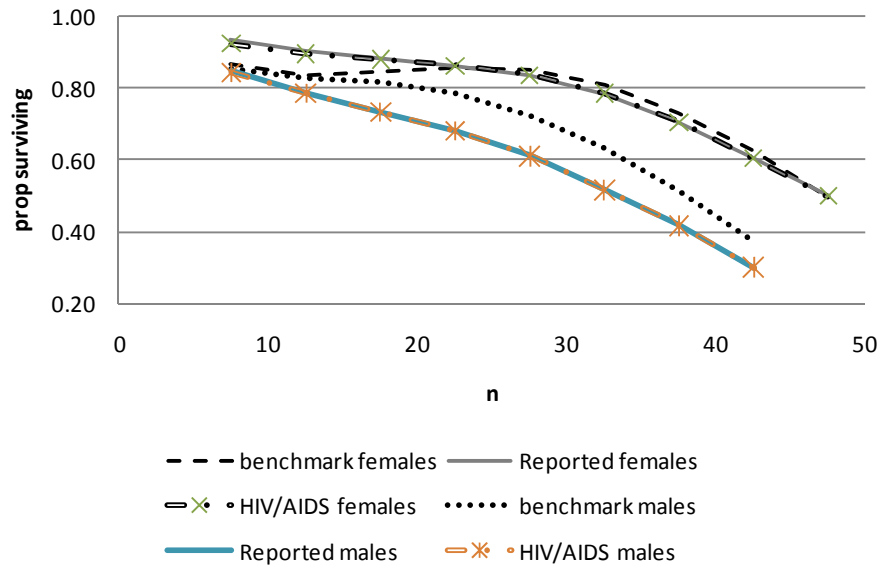
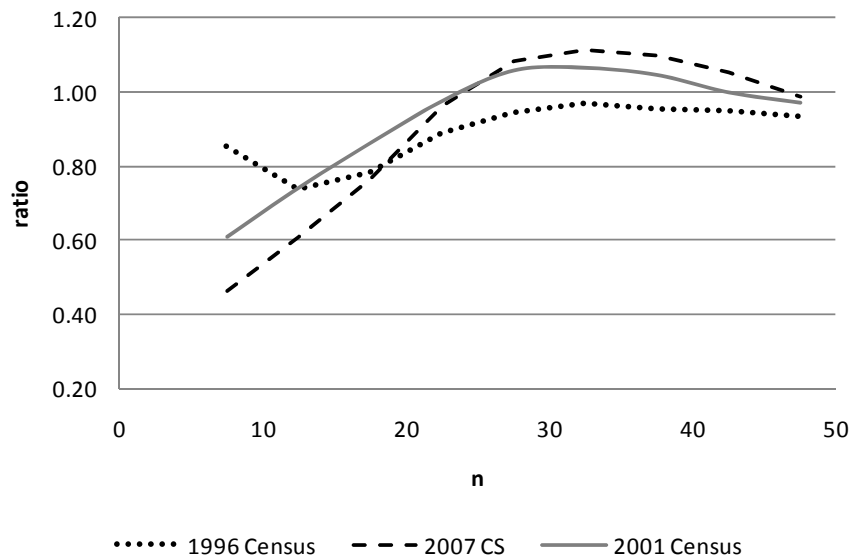


Figure 4.4 Ratio of estimated proportion with mother dead to the benchmark



As can be seen from Figure 4.3 the adjustment to the proportion surviving for the impact of HIV/AIDS appears to be inadequate although it has slightly improved the estimates. The proportion with mother surviving from the two variants is greater than ${}_n p_m$, estimated from the benchmark. After the age group 15-19, the proportion with mother survival almost equals ${}_n p_m$, from the benchmark.

Figure 4.5 Ratio of estimated proportion with father dead to the benchmark

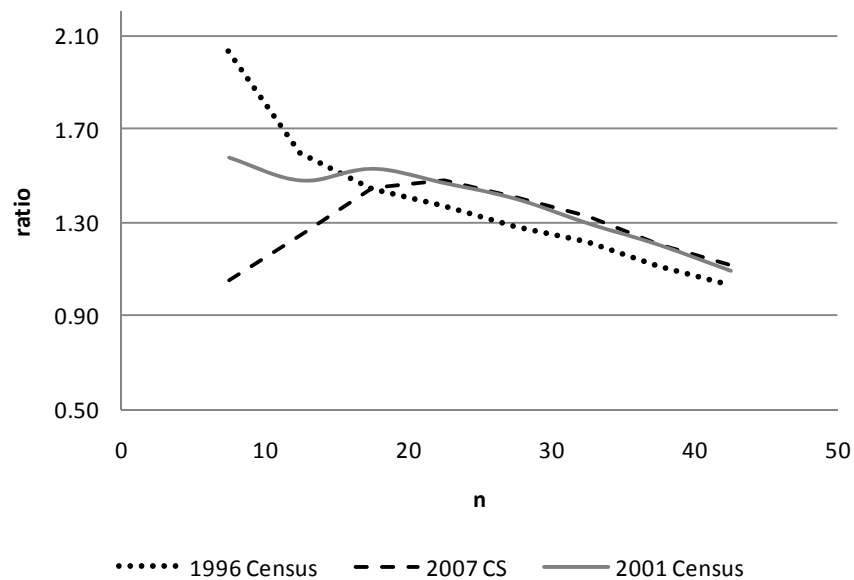


Figure 4.4 and Figure 4.5 show the ratio of the proportion with mother and father dead, $1-{}_n p_m$, to the benchmark respectively. From the 1996 data the ratio of the proportion with mother dead, $1-{}_n p_m$, to the benchmark is less than 1 for all ages. It is around 0.85 for $n = 7.5$ and it drops to around 0.75 for $n = 12.5$ before rising and levelling off to just below 1 for $n > 32.5$. Ratios of proportion with mother dead, $1-{}_n p_m$, estimated from the 2001 and 2007 data sets are less than 1 for $n < 27.5$ and they rose to above 1 after that before dropping to slightly below zero at the oldest age group. The ratios of the proportion with father dead, $1-{}_n p_m$ to the benchmark are greater than 1 for all ages in all the censuses and the Community survey. From the 1996 census, the ratio is two times greater than the benchmark for $n = 7.5$ and it drops with age to slightly above 1 for the oldest age group. In 2001 census the ratio also drops with age but not as fast as seen from the 1996 census. The 2007 Community Survey shows a different pattern

where the ratio is slightly above 1 for $n = 7.5$ and rose to a maximum of around 1.5 for $n = 22.5$ before following the same level and pattern with the 2001 census.

4.2 Conditional Survival Probabilities from age 25 (females) and 35 (males)

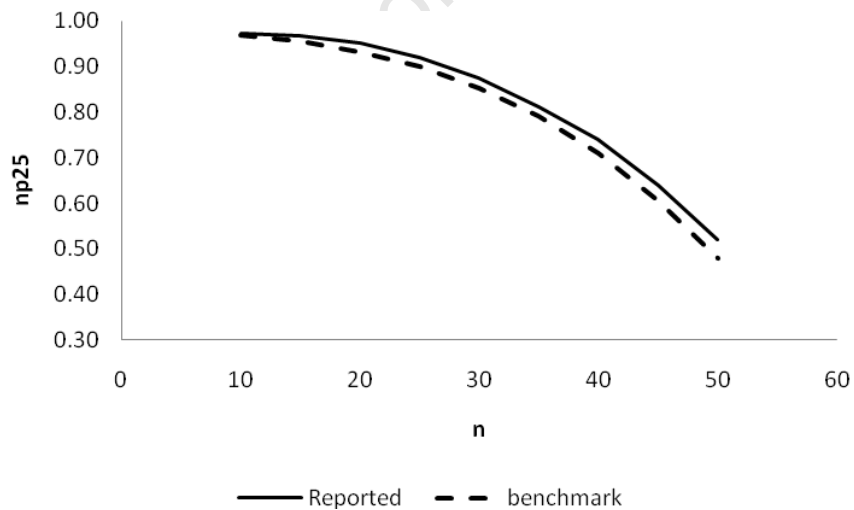
Data on orphanhood are converted to estimates of $\frac{l(25+n)}{l(25)}$ for females

and $\frac{l(35+n)}{l(35)}$ for males, representing the conditional survival probabilities where n can

take values 10, 15, 20... to 50 for females and up to 40 for males.

Estimates of the conditional probabilities of survival from age 25 to age 25+ n for females in South Africa for the three surveys are shown in Figure 4.6 to Figure 4.8. The orphanhood results are compared with the equivalent benchmark estimates. From Figure 4.6, orphanhood estimates for women from 1996 census slightly overestimate conditional survival probabilities, less so at the shorter durations.

Figure 4.6 Estimated and benchmark conditional probabilities of surviving after age 25 for females, 1996 Census



Orphanhood estimates from the 2001 Census data set are different and noticeably less than the benchmark estimates when $n = 10$ and $n = 50$. For other values of n the probabilities are consistent with the benchmark estimates. For $n = 10$ and $n = 50$, conditional survival from age 25 was overestimated by the orphanhood method.

Figure 4.7 Estimated and benchmark conditional probabilities of surviving after age 25 for females, 2001 Census

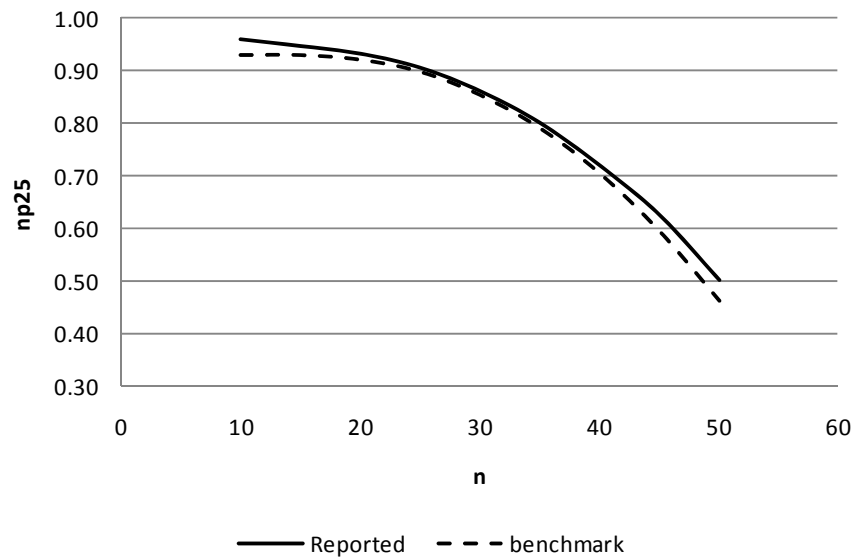
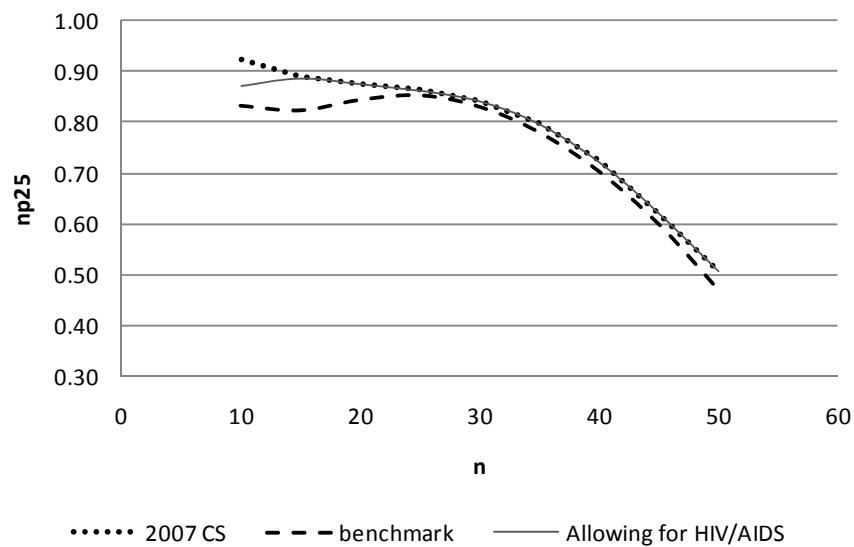


Figure 4.8 Estimated and benchmark conditional probabilities of surviving after age 25 for females, 2007 Community Survey

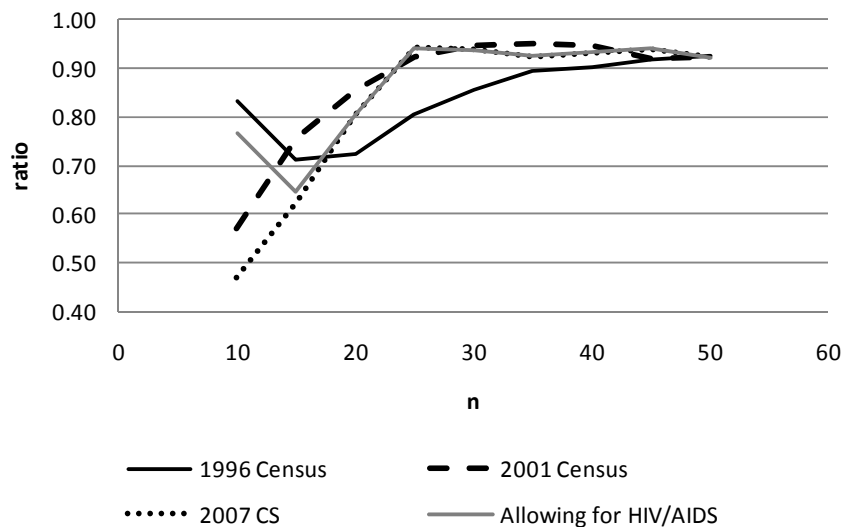


There are inconsistencies between the orphanhood estimates from the 2007 Community Survey and the benchmark estimates for $n = 10$, $n = 15$ and $n = 20$. The orphanhood estimates overestimates survival compared to the benchmark estimates. Between $n = 25$

and $n = 45$ there is consistency between the three sets of estimates. The ratios of orphanhood estimates to the benchmark estimates are presented in Table 4.2 (on page 44). In 1996 the ratio is almost equals to 1 for $n = 10$ after which it rises to about 1.08 when $n = 50$. For the 2001 Census the ratio is 1.03 when $n = 10$ and it drops down to 1.01 when $n = 20$ before levelling off and then rising again after $n = 40$ to 1.09 when $n = 50$. This pattern is repeated for the 2007 Community Survey where the ratio is 1.11 for $n=10$ and it falls to 1.01 for $n = 25$ and for $n = 30$ before rising to 1.09 for $n = 50$. Ratios of estimated conditional survival probabilities of dying to the benchmark estimates in Table 4.2 shows that the orphanhood method overestimates survival probabilities from age 25 for females.

Figure 4.9 shows the ratio of the estimated conditional probability of dying after age 25 for females to the benchmark for the three surveys. In all the surveys the ratios are less than 1 in all age groups. For the 2001 census and the 2007 Community Survey the ratios are less than 0.6 for $n = 10$ and they rose sharply to around 0.95 when $n = 20$ before they level off. The 1996 census produces a different picture altogether.

Figure 4.9 Ratio of estimated conditional probabilities of dying after age 25 for females, 1996-2007 to the benchmark estimates



The ratio is 0.83 for $n = 10$ and it drops to 0.71 for $n = 15$ and the rose gradually to maximum of 0.92 for $n \geq 45$. After allowing for HIV/AIDS in the 2007 Community Survey data set the ratios increased for n less or equals to 15 from 0.47 for the youngest

age to 0.77 after allowing for HIV/AIDS. This shows that allowing for HIV/AIDS improved the mortality estimates.

Figure 4.10 Estimated and benchmark conditional probabilities of surviving after age 35 for males, 1996 Census

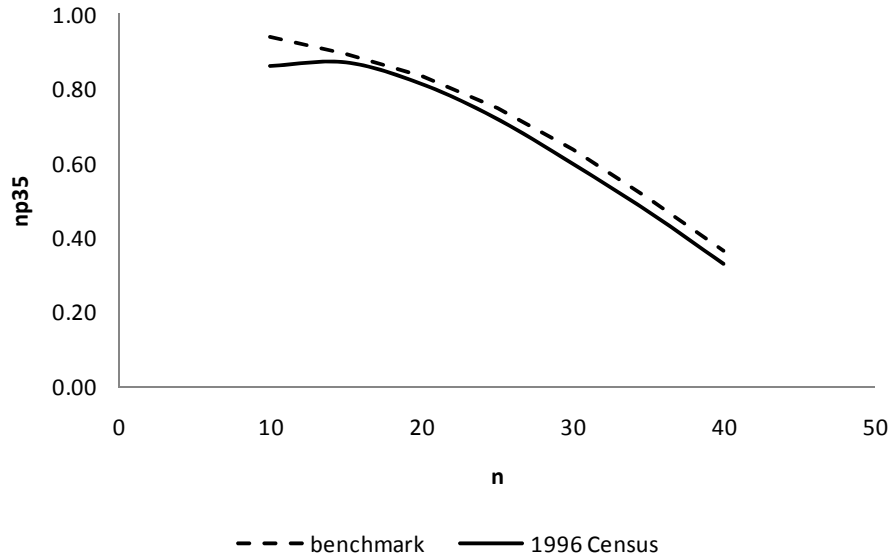


Figure 4.11 Estimated and benchmark conditional probabilities of surviving after age 35 for males, 2001 Census

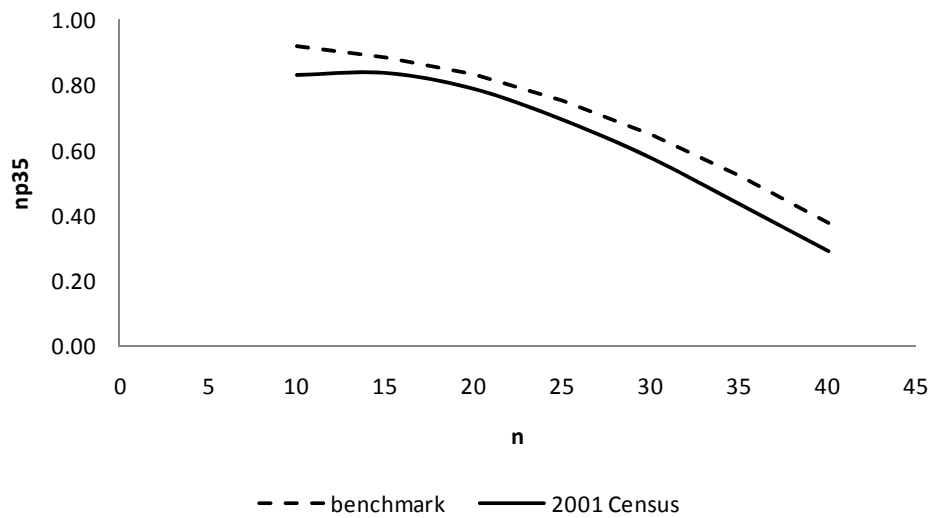


Figure 4.10 to Figure 4.12 show comparison between the estimated and the benchmark conditional probabilities of survival for males for the three surveys, 1996 and 2001 censuses, and the 2007 Community Survey. In all the three surveys the estimated conditional probabilities of survival are less than the benchmark conditional

probabilities of survival. The difference is more pronounced for n less or equals to 15 in all the three surveys. These three figures also show that the difference between the estimated conditional probabilities of survival increases with each successive survey. After allowing for the impact of HIV/AIDS (see Figure 4.12), there is a slight downward change in the estimated conditional probabilities of survival among the youngest respondents.

Figure 4.12 Estimated and benchmark conditional probabilities of surviving after age 35 for males, 2007 Community Survey

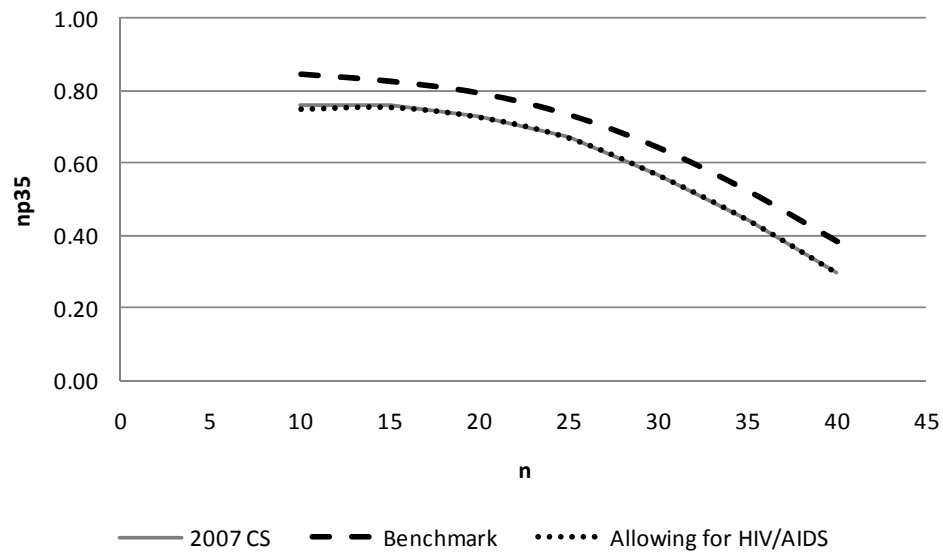


Table 4.2 also present the ratios of the estimated conditional probabilities of survival from age 35 for males to the benchmark conditional probabilities of survival for the three surveys. From the 1996 census, the ratio of the estimated conditional probabilities of survival from age 35 for males to the benchmark is 0.92 for $n = 10$ and it rose to a maximum of 0.98 for $n = 20$ before dropping gradually to 0.90 for $n = 40$. From the 2001 data set, there is a steep increase in the ratios from 0.92 for $n = 10$ to 0.95 for $n = 15$ and $n = 20$, and then a steep decrease to 0.76 for $n = 40$. The 2007 Community Survey shows ratios starting from 0.9 for $n = 10$ and this rose to 0.92 for $n = 15$ and $n = 20$ before dropping to 0.77 for $n = 40$. After adjusting for the impact of HIV/AIDS the difference in ratios appears when $n = 10$ and when $n = 15$. The ratios change from 0.9 to 0.89 and from 0.92 to 0.91 for $n = 10$ and $n = 15$ respectively.

Figure 4.13 Ratio of estimated conditional probabilities of dying after age 35 for males, 1996-2007 to the benchmark estimates

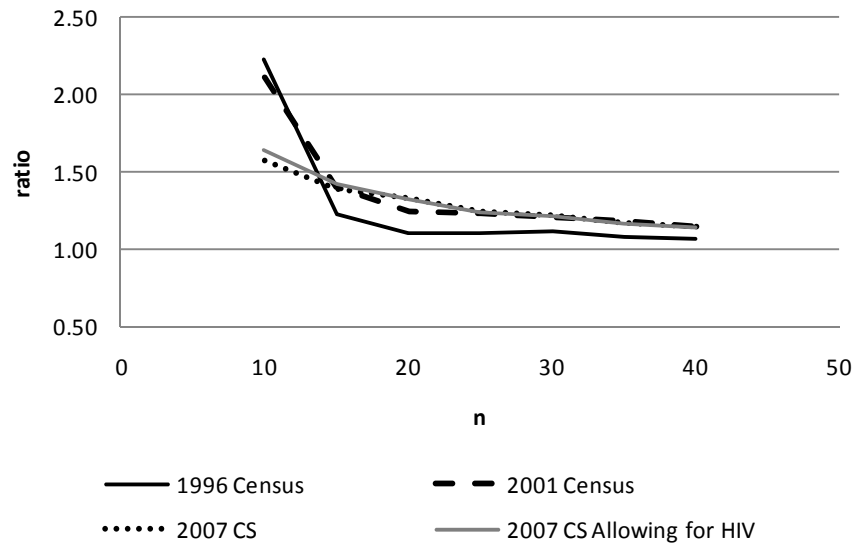


Table 4.2 Ratios of estimated conditional probabilities of dying to the benchmark estimates for females and males

n	Females				n	Males			
	1996	2001	2007	HIV		1996	2001	2007	HIV
10	1.01	1.03	1.11	1.05	10	0.92	0.90	0.90	0.89
15	1.01	1.02	1.08	1.08	15	0.97	0.95	0.92	0.91
20	1.02	1.01	1.04	1.04	20	0.98	0.95	0.92	0.92
25	1.02	1.01	1.01	1.01	25	0.96	0.92	0.91	0.91
30	1.03	1.01	1.01	1.01	30	0.94	0.89	0.88	0.88
35	1.03	1.01	1.02	1.02	35	0.93	0.83	0.85	0.85
40	1.04	1.02	1.03	1.03	40	0.90	0.76	0.77	0.77
45	1.05	1.05	1.04	1.04					
50	1.08	1.09	1.09	1.09					

Figure 4.13 shows the ratios of the estimated conditional probabilities of dying after age 35 for males to the benchmark estimates for the three surveys. In all the surveys the ratios are greater than 1 for all ages. From the 1996 and 2001 censuses the ratios are greater than 2 for $n = 10$ and they drop steeply for $n = 15$ before levelling off. The 2007 Community Survey shows a different picture where the ratio is about 1.6 and it drops at a slow pace with age. Figure 4.13 clearly shows that the orphanhood method overestimate adult male mortality especially information derived from the young respondents.

Conditional probabilities of dying from age 25 for females and age 35 for males were calculated from the conditional survival probabilities. These conditional probabilities of dying from the orphanhood method were compared against the benchmark conditional probabilities of dying as shown in figure 4.14 and figure 4.15. Mostly there is a high degree of consistency between the estimates for big values of n , for both females and males. However, for male rates produced using the orphanhood method appear to be higher than the benchmark rates and for female rates produced using orphanhood method appear to be lower than the benchmark rates.

For $n= 10, 15, 20$ and 25 there are inconsistencies between the estimates with male orphanhood estimates greater than the benchmark and female orphanhood estimates less than the benchmark estimates. Female orphanhood estimates are affected by the adoption effect, where as male orphanhood estimates are less affected by HIV but are affected in the opposite direction by absent fathers reported as dead. A difference between the two sets of estimates is clearly noticeable from the 2001 and 2007 surveys for females for smaller values of n . This is because the orphanhood estimates underestimate the impact of HIV/AIDS which affected women of childbearing age especially young adults. Table 4.3 and 4.4 present conditional probabilities of dying from age 25 for females and from age 35 for males, respectively. From these, we see that the rates meet the expectations in terms of the ranking by gender. The probability of dying for males is generally higher than that of females. For females the probability of dying from age 25 to a particular age is greater from the benchmark than the orphanhood for all surveys. For males the orphanhood estimate is higher than the benchmark estimate.

Figure 4.14 Estimated and benchmark conditional probabilities of dying after age 25 for females (log scale)

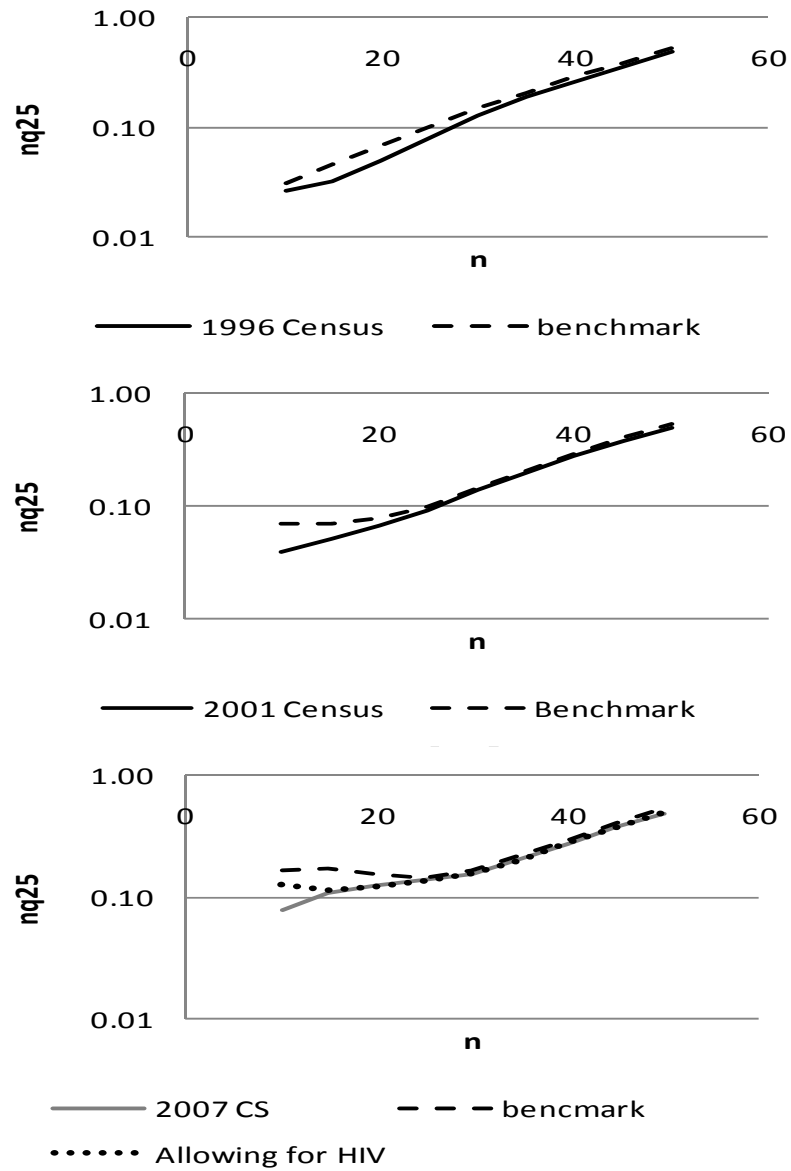


Figure 4.15 Estimated and benchmark conditional probabilities of dying after age 35 for males (log scale)

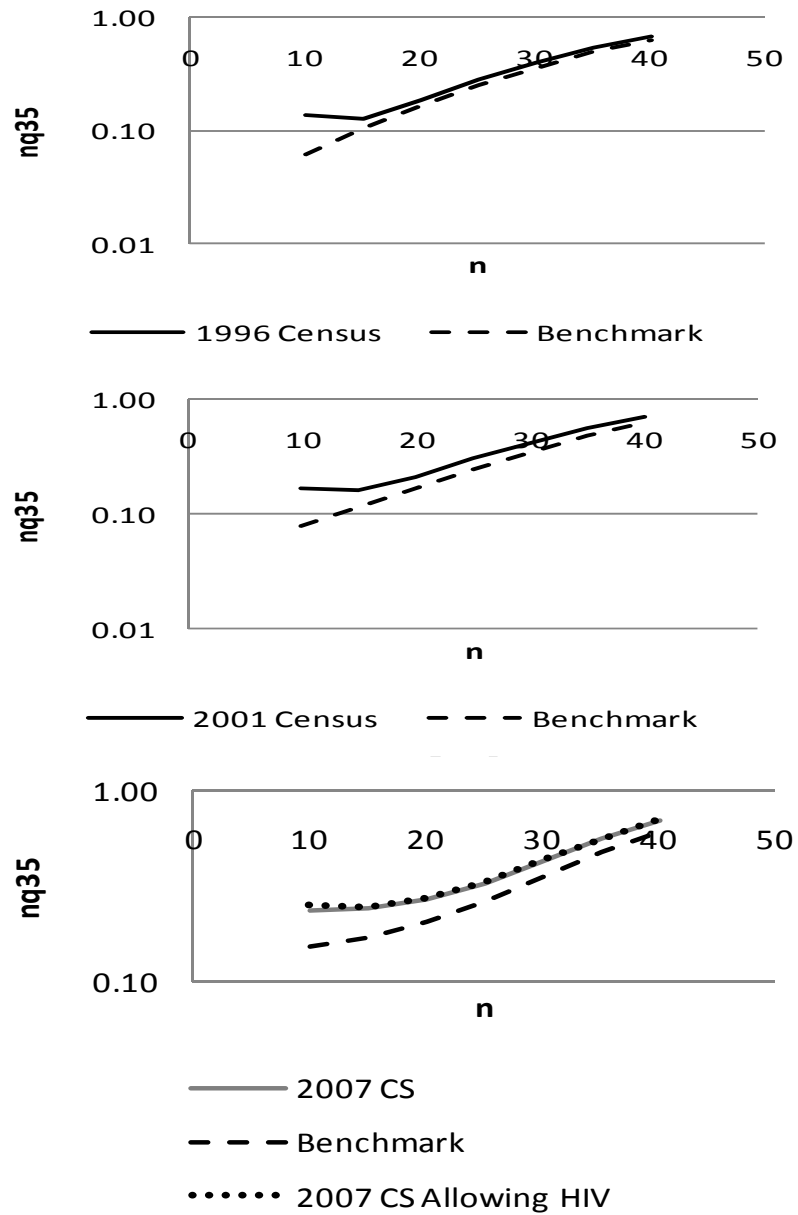


Table 4.3 Estimated and benchmark conditional probabilities of dying after age 25 for females

n	1996		2001		2007		
	Orphan	Benchmark	Orphan	Benchmark	Orphan	Benchmark	Allowing for HIV
10	0.0262	0.0315	0.0396	0.0693	0.0779	0.1661	0.1275
15	0.0326	0.0457	0.0524	0.0695	0.1091	0.1753	0.1128
20	0.0491	0.0679	0.0670	0.0783	0.1242	0.1544	0.1244
25	0.0812	0.1009	0.0936	0.1013	0.1371	0.1456	0.1371
30	0.1264	0.1481	0.1380	0.1457	0.1580	0.1685	0.1580
35	0.1878	0.2097	0.1985	0.2092	0.2031	0.2196	0.2031
40	0.2608	0.2896	0.2798	0.2956	0.2776	0.2976	0.2776
45	0.3604	0.3923	0.3740	0.4064	0.3782	0.4027	0.3782
50	0.4803	0.5198	0.4982	0.5395	0.4922	0.5334	0.4922

Table 4.4 Estimated and benchmark conditional probabilities of dying after age 35 for males

n	1996		2001		2007		
	Orphan	Benchmark	Orphan	Benchmark	Orphan	Benchmark	Allowing for HIV
10	0.1390	0.0624	0.1682	0.0795	0.2392	0.1523	0.2498
15	0.1293	0.1061	0.1621	0.1157	0.2403	0.1723	0.2449
20	0.1870	0.1690	0.2113	0.1708	0.2724	0.2053	0.2724
25	0.2811	0.2538	0.3061	0.2496	0.3301	0.2656	0.3301
30	0.4022	0.3619	0.4238	0.3503	0.4332	0.3569	0.4332
35	0.5309	0.4936	0.5662	0.4776	0.5570	0.4769	0.5570
40	0.6728	0.6345	0.7102	0.6209	0.7043	0.6177	0.7043

4.3 Comparison of ${}_{35}q_{15}$, ${}_{35}q_{30}$ and ${}_{45}q_{15}$

Figure 4.16 to Figure 4.21 show the comparison of the ${}_{35}q_{15}$, ${}_{35}q_{30}$ and ${}_{45}q_{15}$ for the three surveys with the benchmark estimates for both females and males. It is clear for both females and males that mortality is increasing with time. This is consistent with the HIV/AIDS epidemic which has affected Southern Africa as a region. The three surveys give a clear pattern of mortality in South Africa since the early 1980s to around 2005.

The pattern of the probabilities of dying, ${}_{35}q_{15}$, ${}_{35}q_{30}$ and ${}_{45}q_{15}$, for males from the orphanhood method are consistent with the benchmark estimates although the level of mortality estimates from the orphanhood method is higher than the benchmark rates in all the surveys as shown in Figures 4.17, 4.19 and 4.21. This can be attributed to absent

fathers being reported as dead. From the 2007 Community Survey, all the estimates of ${}_{35}q_{15}$, ${}_{35}q_{30}$ and ${}_{45}q_{15}$ for males level off in the most recent period before the survey. This is not consistent with the rising trend in mortality which has been witnessed. This information has been derived from youngest respondents. It is also clear that estimates derived after allowing for the impact of HIV/AIDS are slightly higher than estimates derived without allowing for the impact of the epidemic. For the 1996 and 2001 Censuses and the 2007 Community Survey the difference between the benchmark and the orphanhood method estimates of ${}_{35}q_{30}$ for males is much bigger.

Estimates of ${}_{35}q_{15}$, ${}_{35}q_{30}$ and ${}_{45}q_{15}$ for females in Figure 4.16, Figure 4.18 and Figure 4.20 are generally consistent with the benchmark mortality estimates. The probability of dying between ages 15 and 50 years from the orphanhood method are slightly lower than those from the benchmark. This is also consistent with what is expected especially at young (<20) ages because of the adoption effect where respondents report the survival of their adoptive mothers as that of the biological mothers. Before 1985, estimates from older children for 1996 census, between 1988 and 1995 from the 2001 census, and estimates between 1994 and 2000 from 2007 Community Survey, are equal to the benchmark estimates of ${}_{35}q_{15}$. The benchmark estimates show a levelling off of the probability of dying in the 1980s and early 1990s with the probability of dying between age 15 and 60 years increasing thereafter. There is also a clear pattern from the estimates of ${}_{35}q_{30}$ for females in the three surveys linking them together as evidenced in Figure 4.18. For both females and males the adjustment for HIV/AIDS has slightly improved the estimates of adult mortality.

Figure 4.16 Comparison of 35q15 estimated using the orphanhood with the benchmark, females

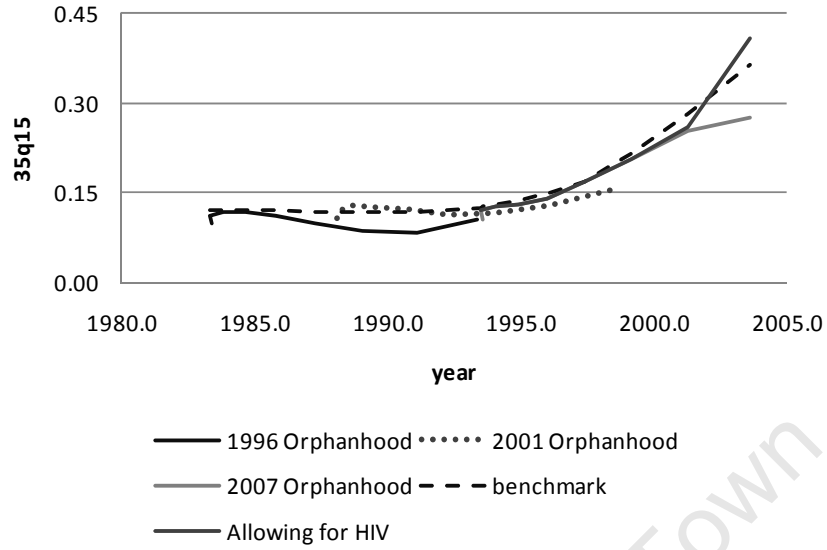


Figure 4.17 Comparison of 35q15 estimated using the orphanhood with the benchmark, males

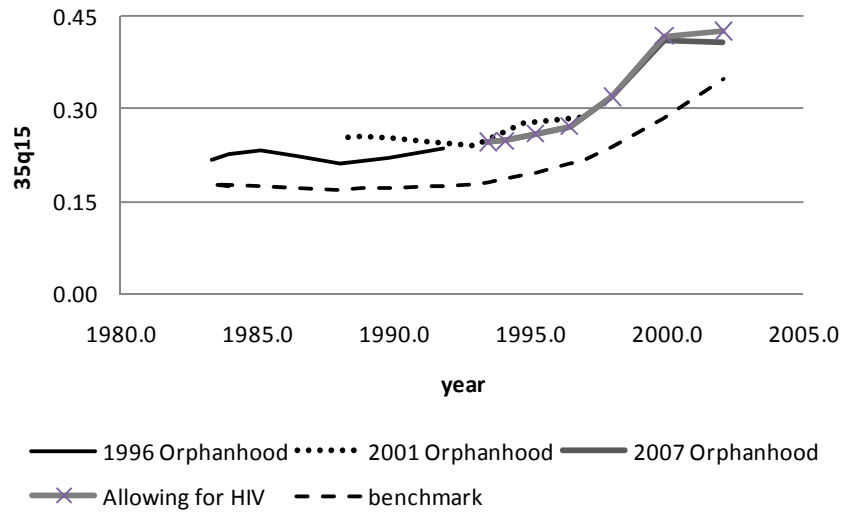


Figure 4.18 Comparison of 35q30 estimated using the orphanhood method with the benchmark, females

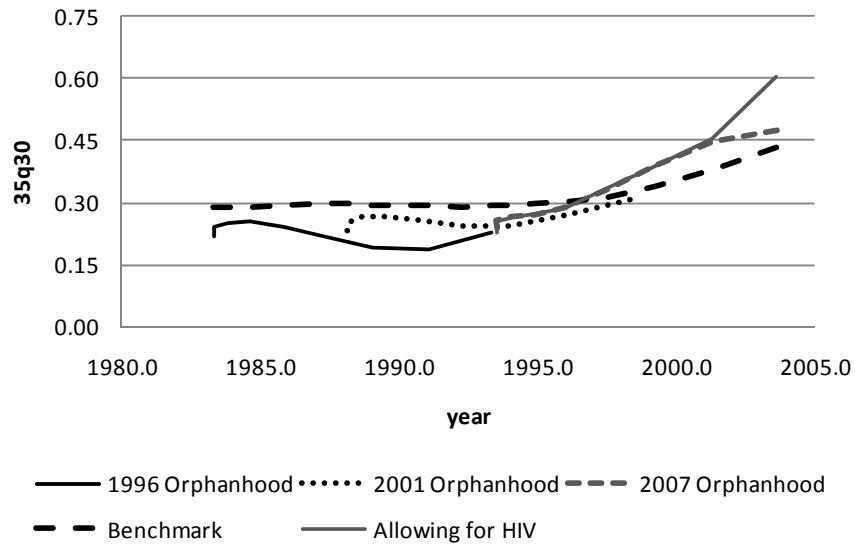


Figure 4.19 Comparison of 35q30 estimated using orphanhood method with benchmark, males

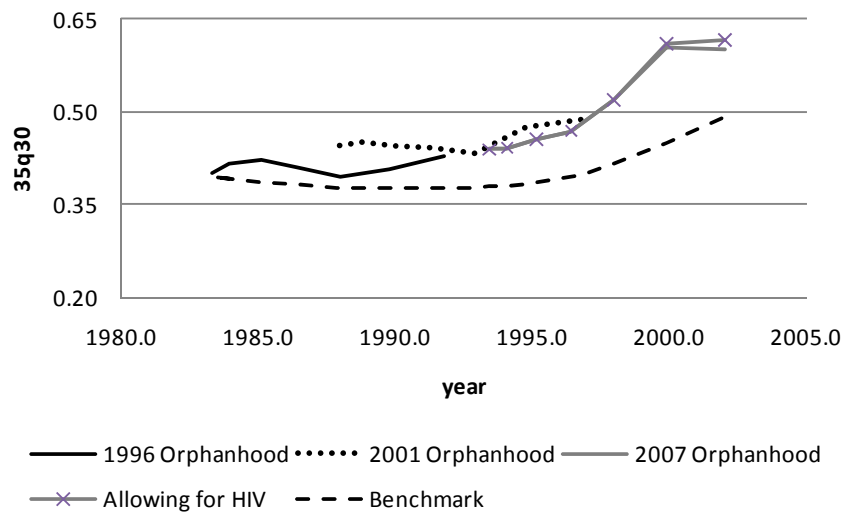


Figure 4.20 Comparison of 45q15 estimated using the orphanhood method with the benchmark, females

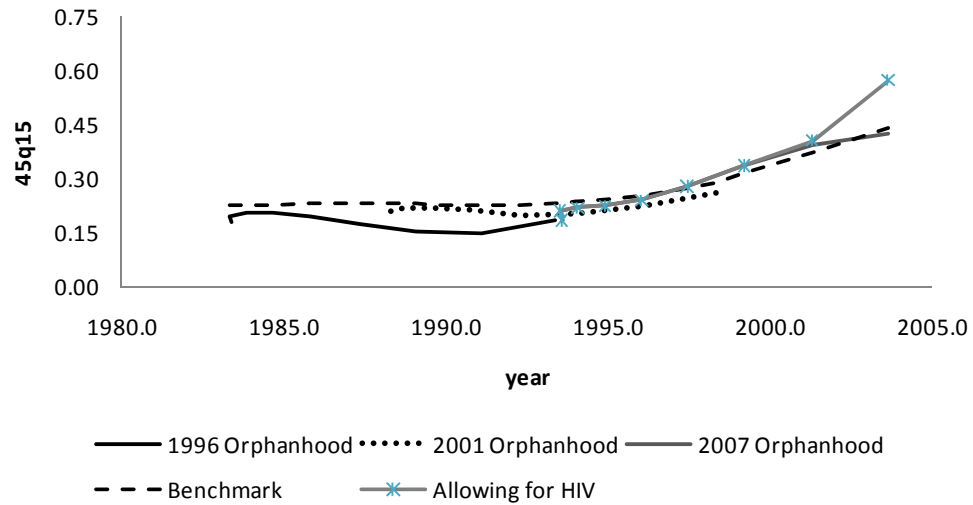
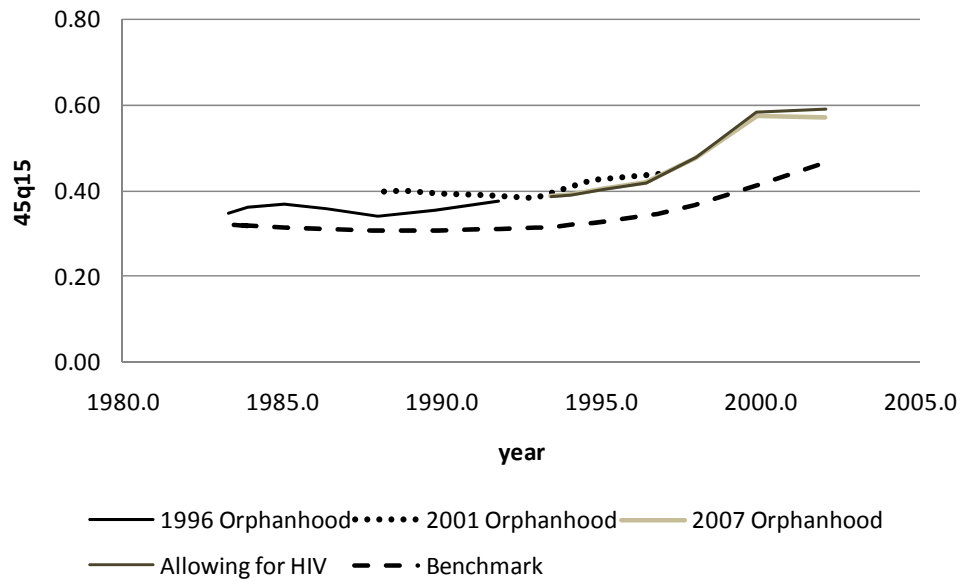


Figure 4.21 Comparison of 45q15 estimated using the orphanhood method with the benchmark, males



4.4 Synthetic Cohort Estimates of Maternal and Paternal Orphanhood

Figure 4.22 show the comparison of the probability of dying between age 15 and 60 derived using Timaeus's Synthetic Cohort approach and UN Manual Synthetic Cohort

approach for females with the benchmark. The synthetic cohort estimates for females from the two approaches show that the probability of a 15 year old dying before reaching 60 between 1996 and 2001 censuses was 28 per cent from Timaeus's approach and 27 per cent from UN Manual approach. Between 2001 census and 2007 CS the probability of dying between age 15 and 60 for females is estimated to be 30 per cent from Timaeus's approach and 43 per cent from the UN Manual approach. Between 1996 and 2001 censuses the two approaches produced estimates which are consistent though they are slightly lower than the benchmark. Between the 2001 census and the 2007 CS estimate of ${}_{45}q_{15}$ for females derived using the UN Manual approach are consistent with the benchmark estimates of ${}_{45}q_{15}$ but the estimate produced by Timaeus's approach is too low.

Figure 4.23 shows the comparison of the probability of a 15 year old dying before reaching 60 for males using Timaeus's Synthetic Cohort approach and the UN Manual approach with the benchmark estimates. The estimate of ${}_{45}q_{15}$ for males produced using Timaeus's approach between 1996 and 2001 censuses is 58 per cent. This rose to 63 percent between 2001 census and 2007 CS. These estimates are greater than the benchmark estimates of ${}_{45}q_{15}$. Estimates of ${}_{45}q_{15}$ for males produced using the UN Manual two-survey method are too low for the two inter-survey periods. Between the 1996 and 2001 censuses and between the 2001 census and the 2007 CS the probability of dying between age 15 and 60 are 19 percent and 16 per cent respectively. This is too low in a country experiencing HIV/AIDS epidemic like South Africa.

The method in UN Manual produced better estimates than Timaeus's method in the two periods, especially during the 2001-2007 period. While the estimates from the Timaeus method for females are very close to the benchmark, those for males lie above the benchmark. The reason for this is probably that the Timaeus's method removes most of the adoption effect, leaving, in the case of males, nothing to counterbalance the bias caused by absent fathers being reported as having died.

Figure 4.22 Comparison of 45q15 estimated using synthetic cohort with the benchmark, females

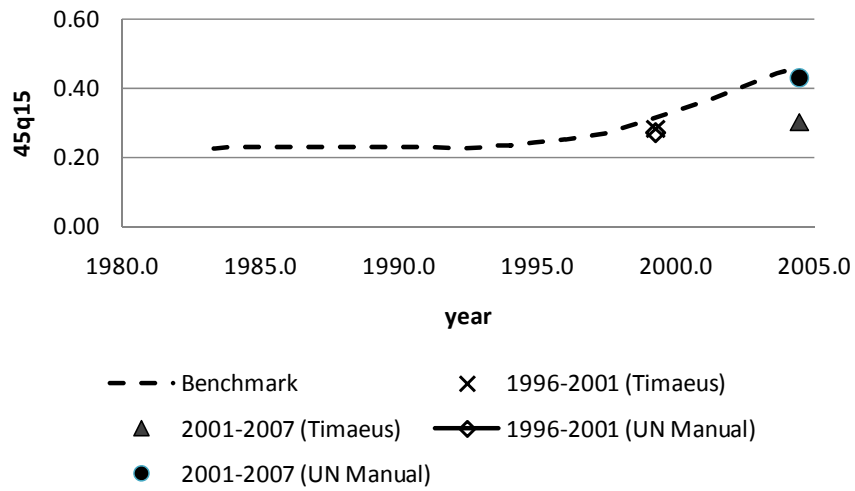
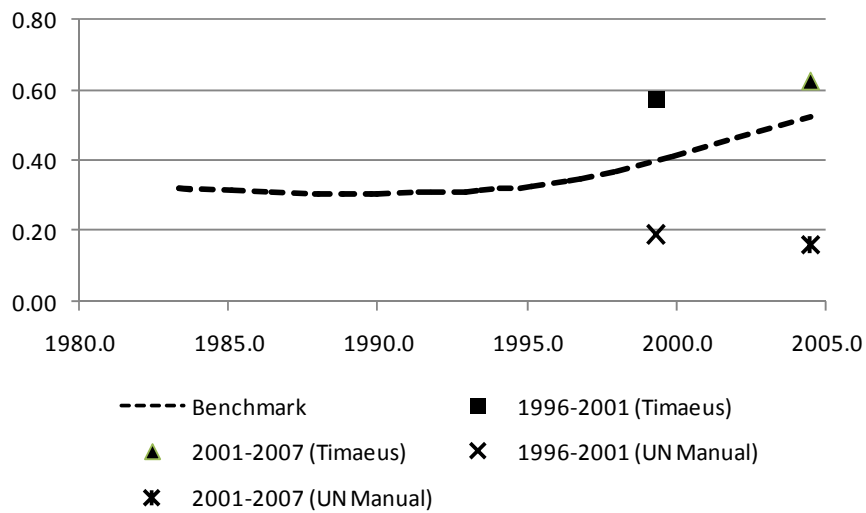


Figure 4.23 Comparison of 45q15 estimated using synthetic cohort with the benchmark, males



5. DISCUSSION

5.1 Introduction

The knowledge of levels and trends of adult mortality in African countries like South Africa is restricted by the incomplete coverage of the vital registration system. It is therefore imperative that existing data are utilized fully to understand the levels and trends of adult mortality in order to monitor the impact of the AIDS epidemic on adult mortality as well as design appropriate policies and programmatic interventions. The orphanhood method and other indirect methods have some advantages over direct methods of estimating mortality. One is that the information used is based on respondents' lifetime experience and thus, fairly precise estimates of the proportions of respondents with living parents (or other relatives) can be obtained even from surveys of moderate size. Furthermore, knowing the general functionality of this method, information on interesting aspects of mortality can be collected quite easily and at a moderate cost by including a few simple questions into existing or planned survey programs. Information about the level and trend of mortality differentials is often sufficient to provide a basis for forecasting and the allocation of resources (Luy, 2009).

The objective of this study was to test how well the orphanhood method (and some of its variants) works, particularly in a changing HIV/AIDS environment. This was done by creating a benchmark set of mortality rates which is the best estimate of the true mortality. The benchmark mortality estimates were derived by averaging estimates obtained from Sadie (1988) and UN Population Division (underlying the Spectrum model), before 1980 and averaging estimates from ASSA2003 version and UN Population Division, after 1985. The orphanhood method was applied to data from the 1996 and 2001 censuses, and the 2007 Community Survey.

Timaeus and Jasseh (2004) pointed out that estimates of adult mortality based on the survivorship of kin (mainly parents and siblings) reported by censuses and surveys are generally lower than model outputs. They are often viewed as much less reliable, although orphanhood data and siblings histories seem to provide consistent estimates (Timaeus and Jasseh, 2004). This research shows that, in the case of South Africa, the

orphanhood method can produce estimates of adult mortality which can be taken as minimum estimates for females and maximum estimates for males. The orphanhood method slightly underestimates the true female mortality and overestimates true male mortality. These slight variations from the benchmark mortality rates are probably caused by violations of the major assumptions of the method. It is crucial to assess the strength and weaknesses of the data used as well as the degree of accuracy provided by the indirect methods based on orphanhood.

In general, estimates of female mortality seem to produce better fits than estimates of male mortality for all the years and approaches. One of the reasons for this could be that more is known by respondents about maternal survival than for paternal survival.

5.2 Proportion with mother/father surviving

The results from the three surveys show that the proportion with mother surviving derived from the orphanhood method are fairly consistent with the cohort survival ratios ${}_n p_x$ derived from the benchmark estimates. From the 1996 census data the proportion with mother surviving from the orphanhood method matches the ${}_n p_x$ for all the other age groups save for the two oldest age groups where it is above the benchmark estimates. This deviation at older ages could be explained by age misreporting at older ages, or it could be because at oldest ages the ${}_n p_x$ refers to cohort survival almost fifty years before the survey. The proportions with mother surviving from the 2001 census data show evidence of slight over-estimation of survival among the youngest age groups, the 5-9 and the 10-14. This could be due to the adoption effect as young children report on the survival of non-biological parents. From the 2007 Community Survey data the proportion with mother surviving is greater than the ${}_n p_x$ from the benchmark for the three youngest age groups. The orphanhood method overestimates maternal survival by almost 8 per cent. The main reason for this is that the orphanhood method failed to capture the effect of HIV/AIDS which has also violated the assumption that there is no adoption effect. It is most likely that respondents from these age groups reported the survival of their adoptive parents as their biological parents' survival. At older ages, the estimated ${}_n p_x$ from the benchmark cohort survival is greater than the proportion with mother surviving. This could be due to age misreporting in the 2007 Community Survey.

Generally in all the three surveys the proportion with father surviving is less than ${}_n p_x$ estimated from cohort survival from the benchmark. Results from the 1996 census shows a deviation from earlier work by Hosegood *et al* (2004) where they found that orphanhood estimates of ${}_{35} q_{30}$ were lower than the ACDIS direct estimates. One of the reasons could be that the benchmark under estimate male mortality or did not capture the effect of HIV/AIDS in the early stages of the epidemic. It might be that more is known about the survival status of mothers than fathers in the South African population where labour migration is prevalent. There are a lot of missing fathers and it might have been easier in some situations to say the father was dead than to explain the situation that the father and the mother are not staying together or the survival status of the father is unknown. This could be one of the reasons why the proportion with father surviving is less than the cohort survival ${}_n p_x$ in all the surveys. The results of the proportion with father surviving also shows evidence of the adoption effect at young ages as the ratio of the proportion surviving over the benchmark cohort survival is almost 1 in all the three surveys. At older ages this ratio is also closer to 1 probably because of age misreporting.

The comparison of proportion with mother/father alive with the cohort survival ${}_n p_x$ shows that the terms mother/father are used loosely to denote not only the person's biological parents but also foster parents and older relatives acting in "loco parentis" (Blacker, 2004). This confusion leads to underreporting of orphanhood by respondents who lost their parents at young ages but whose replies describe their foster parents or step-parents. The adoption effect is more pronounced among the young ages whose adoptive parents are more likely to be alive. As people become older, the chance that their adoptive as well as their biological parent is dead increases.

Apart from the adoption effect found especially using the 2007 Community Survey, other data quality problems might be at stake, such as the selective migration of orphans or age heaping at ages ending in 0 or 5. This heaping will tend to move some children upward or downward in age and cause a slight underestimation or over estimation of mortality. This may lead to over or underestimation of mortality when the proportion with father or mother surviving is converted into conditional probabilities of survival.

5.3 Conditional Survival Probabilities from age 25 (females) and 35 (males)

The orphanhood method makes use of regression coefficients to convert the proportion with mother/father surviving into conditional survival probabilities from age 25 (females) and 35 (males). The coefficients are applicable only to 5-year age bands in period format.

Results show that from the 1996 census the probability of survival from age 25 to age $25+n$ for females has the same pattern as the benchmark although the level is slightly higher for all the age groups except the youngest age group. In the 2001 census data set there is evidence of the adoption effect among the youngest respondents as the orphanhood overestimate the conditional probability of survival from age 25 to age 35. For large values of n , $n = 45$ and $n = 50$ there are inconsistencies for females which may be due to age reporting errors. By 2001, South Africa was experiencing the HIV/AIDS epidemic and this might have accounted for the difference between conditional survival probabilities for $n = 10$ and $n = 15$ estimated from the orphanhood method and the benchmark estimates.

The estimated conditional probabilities of survival from the 2007 Community Survey data show that the orphanhood method underestimates female mortality especially for $n = 10, 15$ and 20 . The 2007 Community Survey data set shows that the orphanhood method is biased by the impact of HIV/AIDS. The benchmark rates show that HIV/AIDS has affected the conditional probabilities of surviving from age 25 to ages 35, 40 and 45, the most sexually active female age groups. The HIV/AIDS epidemic reduce fertility among HIV positive women which in turn affect the number of potential respondents who would report on the survival of parents particularly survival of mothers. The assumption that there is independence between the mortality of mothers and that of their children was violated as children were likely to die within five years of life due to vertical transmission. This has left no one to report on the survival status of mothers as both the mother and the child are likely to die from the epidemic. This relationship will result in underreporting of the mothers' deaths if the reporting is done by their children, as is the case in the orphanhood method. The probabilities of survival estimated from the orphanhood method using 2007 Community Survey data set show evidence of the adoption effect. As more and more mothers die from the

epidemic leaving their children in the care of grandparents (as seen from the ratios of estimated conditional probabilities of survival for values of $n = 45$ and $n = 50$ for females) and other surviving elder relatives.

After allowing for the effect of HIV/AIDS on fertility and adjusting for vertical transmission using the method for adjusting for selection biases brought by HIV/AIDS suggested by Timaeus and Nunn (1997) there is a drop in the conditional probability of survival from age 25 to age 35. This method involves reducing the reported survival, and the use of revised coefficients by Timaeus and Nunn (1997). This is because the adjustments were only done for the information given by those who are aged 5-9 and 10-14 where prevalence was significant enough (more than 5%) at the time of birth of the children. The method of adjustment proposed to Timaeus and Nunn (1997) results in under-estimating the survival for the youngest reporting age groups but is within 5% of the correct rate of survival for other groups.

The difference between the estimated conditional survival probabilities and the benchmark estimates are due to the fact that the coefficients given by Timaeus and Nunn (1997) are for ages below 30 and have been derived from data in a population (Masaka district in Uganda) with a lower prevalence of HIV than is being experienced in South Africa. Timaeus and Nunn warn that the coefficients they give are provisional and based entirely on data from Masaka district. The purpose of examining outcomes using these revised coefficients is to determine whether they reduce the error. Timaeus and Nunn (1997) state that their adjustments for selection bias in the two youngest age groups will achieve less accurate outcomes if the median survival time of infected women is longer than that assumed in their research. Compared to the benchmark estimates of conditional survival from age 25 to age $25+n$, the method suggested by Timaeus and Nunn (1997) still overestimate conditional survival probabilities from age 25 to age $25+n$ when $n = 10$ and $n = 15$, although these estimates are less than those obtained using the regression method.

In the 1996 and 2001 censuses and the 2007 CS, the conditional probability of survival from age 35 to $35+n$ for males is less than that estimated from the benchmark. This implies that the orphanhood method overestimates adult male mortality. The difference is more pronounced for small values of n . One of the main reasons for the difference

for small values of n is that these estimates were derived from information given by children aged 5-9, 10-14 and 15-19 age groups. These age groups are likely to have fathers who are aged less than 45 years and who are absent and hence reported as dead rather than explaining the situation that their survival status is unknown.

5.4 Estimates of ${}_{45}q_{15}$

The choice of the standard to convert conditional probabilities of surviving into estimates of mortality is vital if one is to deduce a level of mortality over a particular age range especially if this age range includes young adults in a period of AIDS epidemic. The standard used should have the right shape to allow for an appropriate level of excess mortality due to HIV/AIDS (Dorrington, Moultrie and Timaeus, 2004). Our approach was to use as standard Brass's General Standard as suggested in earlier work by Dorrington, Moultrie and Timaeus (2004). We used the Brass's General Standard because we wanted to test the standard approach. One could choose to use the INDETH of the WHO life tables as standard to see what impact it will have on the results. This question was ignored in this research.

The results show that in the 1996 and 2001 censuses and the 2007 CS, the broad index of ${}_{45}q_{15}$ for both females and males increases with time which is consistent with the benchmark and what is expected in populations with increasing HIV prevalence. The two censuses and the survey give a clear pattern of adult mortality in South Africa since the early 1980s to the mid-2000s. The shape of the estimates of ${}_{45}q_{15}$ over time for males is consistent with the benchmark estimates in the 1996 and 2001 censuses but the level of the orphanhood estimates is higher than the benchmark estimates. As was observed earlier, the orphanhood method overestimates mortality of fathers due to absent fathers reported as dead rather than their statuses reported as unknown. Results of ${}_{45}q_{15}$ from the 2007 Community Survey show a levelling off during the most recent period before the survey. This is not consistent with rising mortality experienced in South Africa in recent years. While one would not expect ${}_{45}q_{15}$ to rise without limit the slowdown could also be due to data errors. After allowing for the impact of HIV/AIDS using the method of adjusting for selection bias brought about by HIV/AIDS (Timaeus and Nunn, 1997), the estimates of ${}_{45}q_{15}$ obtained were higher than those obtained from

the regression variant, showing that Timaeus Nunn's method overestimate adult male mortality.

Timaeus's two-survey approach uses synthetic cohort data based on 20 years of age while the UN Manual is based on lifetime orphanhood. The synthetic cohort based on age 20 is expected to produce better results than synthetic cohort on lifetime orphanhood because the approach prevents any errors in the data on children being transmitted to the population aged 20 and above during the construction of the synthetic cohort.

The UN Manual two-survey approach slightly underestimates female adult mortality compared to Timaeus's synthetic cohort approach and the benchmark. Timaeus's synthetic cohort approach improved female adult mortality estimates both between 1996 and 2001 censuses and between 2001 census and 2007 Community Survey. This is because Timaeus's synthetic cohort approach reduces the effect of adoption by chaining cohort changes which transmit a large part of this bias to older age groups.

The UN Manual two-survey approach failed to produce reliable estimates of adult male mortality. Estimates produced by this method are too low for a country like South Africa experiencing HIV/AIDS epidemic. The two-survey method is affected by differential age reporting between the two-survey and this could be one of the reasons why these estimates of male adult mortality are not consistent with the benchmark estimates and those produced using Timaeus's synthetic cohort approach.

Timaeus's synthetic cohort approach produced adult male mortality rates which are greater than those produced from the benchmark between 1996 and 2001 censuses, and between 2001 census and 2007 CS. Timaeus's approach greatly improved female mortality estimates for the 1996-2001 period but did not do well for the 2001-2007 period. For male adult mortality, Timaeus's synthetic cohort method improved the estimates for both the 1996-2001 and the 2001-2007 periods. The male estimates are higher due to absent fathers but they are consistent with the benchmark estimates. Timaeus's approach may be useful in dealing with the problem of the adoption effect but does not deal with other problems such as the consequences of the HIV/AIDS epidemic and it is very sensitive to differences in the quality of age reporting between

inquiries. This could be the reason why the method didn't do well for the 2001-2007 periods for females.

Results show that estimates from the orphanhood method of the probability of dying between age 15 and 60 years for females are slightly lower than those from the benchmark estimates in the 1996 and 2001 censuses. These estimates are consistent with what is expected where data are affected by the adoption effect. Estimates from the 1996 census are linked to the 2001 census estimates giving clear pattern of mortality which is almost similar to the pattern portrayed by the benchmark pattern. The benchmark estimates of the probability of dying between age 15 and 60 years show a stalling in the 1980s which can be seen when the estimates obtained from the 1996 and 2001 censuses are joined together. Estimates obtained from the 1996 census data set applicable to periods nearer to 1996 are biased due to the adoption effect since these data were from young children who are more likely to report the survival of their adoptive mothers as it was of their biological mothers. This is also true for estimates from the 2001 census data set where estimates nearer to the census date are biased due to adoption effect. The estimates of ${}_{45}q_{15}$ for females from the orphanhood data derived using the 2007 Community Survey are quite different from what was obtained from the other two censuses in terms of pattern. Here the estimates of ${}_{45}q_{15}$ are greater than the benchmark estimates after 1998 which is not consistent with what is expected of populations suspected of having high prevalence of adoption. When HIV/AIDS was allowed for the difference between the benchmark and the estimates from the orphanhood method is wider. The difference is widens because the method by Timaeus and Nunn captures the effect of AIDS epidemic on adult mortality and thus cause increases the estimate.

Since no empirical gold standard exist to provide benchmark mortality rates allowing for the analysis adult mortality in South African population, there is no straight forward way to distinguish between the sources of biases such as survey misreporting, model overestimation and methodological assumptions. The assumptions used in projecting the ASSA model may affect the results obtained. Particularly noticeable is the selection effect of using the antenatal clinic surveys for the HIV prevalence. Women who visit antenatal clinics are expected to have higher levels of HIV prevalence than other women in the population. Another aspect of the ASSA model that may affect the

outcomes is the use of risk group. After allocation of the population to particular risk groups at a young age, there is no movement in the model between risk groups.

Simulated data might be useful for having a closer look at the level of mortality in areas where data are scarce. In developing countries simulation can be used to reproduce demographic dynamics of populations of fictitious individuals whose parental survival is recorded. Although the accuracy of simulated data depends on the assumptions they are based on, they can provide benchmarks of mortality rates on which comparisons could be made. The use of simulated data is an area which needs further research.

Typical problems with the orphanhood method are; a possible adoption effect; multi-reporting, selection effects regarding fathers and mothers if there is a relationship between parity and mortality, and regarding respondents if there is a relationship between parental and child mortality; and wrong age reports of the respondents. Another problem is the incorrect choice of theoretical fertility and mortality models underlying the different approaches used to convert the proportion of not-orphaned respondents into life table.

This study relates to the national population of South Africa. Further investigation could be extended to each of the four population groups in South Africa, White, Asian/Indian, Coloured and Black/African. These different population groups have different mean age at childbearing, levels of HIV prevalence and pattern of HIV spread. It is of interest to understand whether the differences in socio-economic and other factors associated with different mortality levels for adult South Africans apply for the different population groups. Applying the orphanhood method to each population group in South Africa will be greatly affected by the small sample size which is involved when population groups are considered rather than the national population.

The use of standard life tables to convert conditional probabilities of surviving $\frac{l(25+n)}{l(25)}$ and $\frac{l(35+n)}{l(35)}$ into other useful measures of mortality need further study. The age-specific mortality variations caused by HIV/AIDS should be reflected in any life table used to generate other measures of mortality. The shape of the mortality pattern changes over time as the epidemic progresses, and in future the impact of treatment and

intervention will mean that more people will survive for longer while infected by HIV/AIDS.

The regression coefficients were originally developed for use in populations with high fertility and this is not the case anymore for South Africa where fertility has been declining. In addition the mortality pattern in South Africa differs from those underlying the simulation used to produce the regression coefficients due to HIV/AIDS. New sets of regression coefficient need further research since we are experiencing an unusual age pattern of mortality in Southern Africa which renders the available regression coefficient to produce poor results.

The estimation of time location and reference period depend on the assumption that mortality increases with age which is now violated by the HIV/AIDS epidemic. Although the errors in estimating adult mortality introduced by errors in time location maybe small, HIV/AIDS does change the age pattern of mortality which affects the estimation of time reference so there is need for further investigation.

The methodology might allow research on mortality differentials by education, region and sub-groups of the population since census data do not have sample size limitations as in DHS and other household surveys. Further research could be done using Timaeus's Synthetic Cohort method to adjust the level for complete periods not just one time point between two dates because other indirect methods that give trend appear to be biased more severely than Timaeus's Synthetic Cohort method. One might explore whether one could compute/apply adjustment factors to shift, offset or adjust time trends from indirect estimates based on single surveys.

The research has demonstrated that using the responses of children about the survival of their parents would underestimate adult female mortality especially where the estimates are derived from data provided by young respondents, which can be attributed to the adoption effect. On the other hand, adult male mortality would be overestimated by the orphanhood method most probably due to absent fathers whose survival status is unknown and reported as dead. Estimates of female mortality from the orphanhood method should be taken as minimum estimates since they underestimate mortality and

those for males should be taken as maximum values since the orphanhood method over estimate adult male mortality.

Although most of the literature on orphanhood method focus on female mortality, for the purpose of this research project we didn't confine our research to female mortality because we wanted to test how orphanhood estimates of adult mortality are comparable to benchmark mortality estimates of both females and males.

Demographic trends have serious implications for social and health demands of a country. In most developing countries data are scarce and there is much uncertainty about adult mortality trends because of the lack of data. A range of indirect methods has been developed for mortality estimation in countries lacking adequate vital registration record. Information on orphanhood has been used as an estimator of adult mortality with plausible results. This research project has shown that while the orphanhood method slightly over estimate adult male mortality, adult female mortality is slightly under estimated, the method produce upper bounds for adult male mortality and lower bounds for adult female mortality. The over estimation of adult male mortality is due to absentee effect for paternal orphanhood while the under estimation of adult female mortality is due to adoption effect for maternal orphanhood.

In general this research has shown that the orphanhood method can be used to derive estimates of mortality rates that are consistent with other mortality estimates derived from conventional methods, in situations where there is insufficient data to estimate mortality directly. Violation of the "adoption effect" can be countered by applying the synthetic cohort method at age 20. Timaeus and Nunn's method deals with the effect of HIV/AIDS on the independence of mortality of parents and their children and hence greatly improved the estimates of mortality rates. Orphanhood female mortality estimates can be taken as lower bounds whereas orphanhood male mortality estimates can be taken as upper bounds since the orphanhood method slightly under estimate female mortality and over estimate male mortality. Timaeus's synthetic cohort method has proved to have performed better than all other variants of the orphanhood especially when used together with the method for allowing for HIV/AIDS. All the other variants produced good estimates and show that the orphanhood method can be used in situations where there is inadequate data.

Although neither direct questions in surveys nor indirect methods estimation can provide statistics on adult mortality that compare with those from an effective vital registration, it appears, at least for South Africa, that the orphanhood method (both the single survey and two-survey methods) produces plausible estimates of female mortality. However, in the case of males, the methods (both the single survey and two-survey methods) produce estimates that are higher than would be expected, although with plausible trend.

It is possible that this conclusion is a function of fact that non-HIV standard life table was used to convert the proportions surviving to a common mortality index, but this was not investigated in this research.

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APPENDIX

Table A.1 Estimated 35q15, 35q30 and 45q15 by time location, females

Time	orphanhood 1996			benchmark		
	35q15	35q30	45q15	35q15	35q30	45q15
1993.3	0.1039	0.2271	0.1835	0.1239	0.2923	0.2309
1991.1	0.0817	0.1852	0.1472	0.1183	0.2920	0.2276
1989.1	0.0844	0.1904	0.1516	0.1179	0.2948	0.2292
1987.3	0.0987	0.2175	0.1751	0.1182	0.2968	0.2306
1985.8	0.1106	0.2393	0.1943	0.1185	0.2921	0.2282
1984.6	0.1185	0.2531	0.2067	0.1187	0.2885	0.2263
1983.8	0.1168	0.2501	0.2040	0.1189	0.2860	0.2251
1983.3	0.1122	0.2420	0.1968	0.1190	0.2845	0.2243
1983.4	0.0997	0.2193	0.1767	0.1190	0.2846	0.2244
	orphanhood 2001			benchmark		
1998.3	0.1522	0.3089	0.2582	0.1918	0.3262	0.2910
1996.1	0.1288	0.2709	0.2229	0.1480	0.3031	0.2514
1994.0	0.1141	0.2455	0.1999	0.1285	0.2943	0.2348
1992.2	0.1138	0.2449	0.1994	0.1189	0.2907	0.2271
1990.8	0.1213	0.2579	0.2111	0.1180	0.2922	0.2276
1989.6	0.1261	0.2662	0.2186	0.1177	0.2937	0.2283
1988.7	0.1273	0.2682	0.2205	0.1181	0.2956	0.2298
1988.2	0.1183	0.2528	0.2064	0.1182	0.2964	0.2304
1988.1	0.1064	0.2317	0.1876	0.1182	0.2965	0.2304
	orphanhood 2007			benchmark		
2003.6	0.2758	0.4733	0.4248	0.3627	0.4319	0.4421
2001.3	0.2526	0.4464	0.3959	0.2821	0.3779	0.3707
1999.2	0.2066	0.3880	0.3355	0.2159	0.3403	0.3128
1997.4	0.1667	0.3313	0.2795	0.1693	0.3136	0.2705
1996.0	0.1397	0.2888	0.2394	0.1474	0.3028	0.2509
1994.9	0.1293	0.2717	0.2236	0.1358	0.2975	0.2410
1994.0	0.1261	0.2662	0.2186	0.1288	0.2945	0.2350
1993.5	0.1202	0.2561	0.2094	0.1249	0.2927	0.2317
1993.6	0.1041	0.2275	0.1839	0.1253	0.2929	0.2320

Table A.2 Estimated 35q15, 35q30 and 45q15 by time location, males

	orphanhood 1996			benchmark		
Time	35q15	35q30	45q15	35q15	35q30	45q15
1991.8	0.2373	0.4277	0.3762	0.1741	0.3753	0.3099
1989.8	0.2207	0.4067	0.3545	0.1705	0.3751	0.3074
1988.0	0.2116	0.3948	0.3423	0.1701	0.3773	0.3083
1986.4	0.2230	0.4097	0.3575	0.1708	0.3805	0.3104
1985.1	0.2329	0.4222	0.3705	0.1723	0.3842	0.3132
1983.9	0.2270	0.4149	0.3628	0.1736	0.3874	0.3157
1983.3	0.2168	0.4017	0.3493	0.1743	0.3891	0.3170
	orphanhood 2001			benchmark		
1996.8	0.2872	0.4859	0.4386	0.2157	0.3976	0.3463
1994.7	0.2767	0.4743	0.4259	0.1915	0.3833	0.3244
1992.9	0.2416	0.4330	0.3818	0.1777	0.3763	0.3125
1991.3	0.2474	0.4402	0.3893	0.1734	0.3754	0.3094
1989.9	0.2513	0.4449	0.3943	0.1707	0.3750	0.3075
1988.8	0.2565	0.4510	0.4008	0.1704	0.3765	0.3081
1987.9	0.2523	0.4460	0.3955	0.1700	0.3774	0.3082
	orphanhood 2007			benchmark		
2002.0	0.4084	0.6010	0.5723	0.3497	0.4904	0.4666
1999.9	0.4103	0.6026	0.5743	0.2857	0.4490	0.4116
1998.0	0.3195	0.5198	0.4766	0.2388	0.4150	0.3685
1996.4	0.2717	0.4686	0.4198	0.2100	0.3936	0.3408
1995.1	0.2596	0.4547	0.4047	0.1955	0.3854	0.3279
1994.1	0.2485	0.4415	0.3907	0.1859	0.3803	0.3195
1993.4	0.2463	0.4388	0.3878	0.1809	0.3778	0.3153
	orphanhood 2007 AIDS			benchmark		
2002.0	0.4264	0.6157	0.5904	0.3497	0.4904	0.4666
1999.9	0.4182	0.6090	0.5822	0.2857	0.4490	0.4116
1998.0	0.3196	0.5199	0.4767	0.2388	0.4150	0.3685
1996.4	0.2717	0.4686	0.4198	0.2100	0.3936	0.3408
1995.1	0.2596	0.4547	0.4047	0.1955	0.3854	0.3279
1994.1	0.2485	0.4415	0.3907	0.1859	0.3803	0.3195
1993.4	0.2463	0.4388	0.3878	0.1809	0.3778	0.3153