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IIASA Interim Report
January 1998

Noymer, A. (1998) Estimates of Under-five Mortality in Botswana and Namibia: Levels and Trends. IIASA Interim Report. IR-98-005 Copyright © 1998 by the author(s). http://pure.iiasa.ac.at/5641/

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INTERIM REPORT IR-98-005/January

Estimates of Under-five Mortality in Botswana and Namibia: Levels and Trends

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Contents

Abstract

Census data from 1991 from Botswana and Namibia were analyzed using the ‘children ever born technique’ to estimate child mortality. The method used is reviewed briefly, with emphasis on aspects not covered by the standard UN reference on mortality estimation, *Manual X*. The census data appear to be of very high quality for use with the children ever born technique. Between the mid-1970s and the early 1990s, both Botswana and Namibia experienced spectacular declines in under-five mortality ($_5q_0$) – estimates of $_5q_0$ during this time span dropped from greater than 150‰ to below 75‰ for both countries. Rural areas have higher mortality rates than urban areas, but both rural and urban areas experienced similar declines. Plausible reasons for the dramatic decline in mortality are discussed, and prospects for the future are assessed.

Keywords: *mortality estimation; under-five mortality; Botswana; Namibia.*

Acknowledgments

An earlier version of this paper was presented at the Botswana and Namibia Population Development and Environment (PDE) Task Force meeting held at IIASA in June 1997. This work began as part of my work as a Young Scientist Summer Program (YSSP) participant at IIASA, when I was on leave-of-absence from the Instituto Nacional de Estatística in Angola. Financial support for my YSSP participation was provided by the US National Science Foundation through the American Academy of Arts and Sciences. I acknowledge helpful comments from Riikka Raitis.

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Introduction

In many developing countries, vital registration data are incomplete. The severity of the under-reporting varies from country to country, and also varies over time within countries. Without reasonably complete vital registration, it is impossible to calculate the life table directly; doing so with partial data leads to severe biases. Mauritius is the only country from the World Health Organization's African region which lists mortality data in the most recent edition of the *World Health Statistics Annual* (WHO 1996). This could be due to lack of data collection, or lack of reporting to Geneva, or both.

The paucity of available data does not reflect a lack of need. For planning and for research, the current level of mortality, as well as its recent trend, are essential statistics. The ongoing work at IIASA on population, development, and environment in Botswana, Namibia, and Mozambique requires estimates of the demographic parameters of these three countries. This paper estimates under-five mortality (${}_5q_0$), using indirect demographic estimation techniques applied to the most recent census data from Botswana and Namibia (1991 for both countries). Under-five mortality (${}_5q_0$) is the probability that a child just born will die before his or her fifth birthday, assuming persistence of current levels of mortality. (Although this statistic is sometimes called a mortality 'rate', it is not a rate in the demographic sense [some quantity per unit of person-time], but it is a population average probability of death over a fixed age interval.)

Analyses such as the one here can provide estimates of mortality where direct measures (via a comprehensive vital registration system) do not exist. Another useful source of mortality estimates is data from the Demographic and Health Surveys[1] (DHS), an international program of surveys in developing countries; the DHS publish estimates of ${}_5q_0$ using methods similar to those contained in this paper. In both Botswana and Namibia, the trend found by the DHS is similar to the results presented here, but the levels are different.

This paper serves two purposes: first, estimates are provided which may be used in the present work at IIASA (as well as elsewhere); and second, an adaptation of the standard method is described in sufficient detail that compatible and comparable estimates may be produced for sub-national populations taken from the same censuses. An earlier version of the results was presented at the Botswana and Namibia Population Development and Environment (PDE) Task Force meeting held at IIASA in June 1997.

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[1] The Botswana DHS was called the 'Family Heath Survey' (see Lesetedi *et al*. 1989).

Materials and Methods

i. Overview

The source data are published census tables for Botswana and Namibia (Republic of Botswana n.d.; Republic of Namibia 1994a). The tables used are those on children ever born and children living, disaggregated by current age of mother (the raw data, as extracted from the census tables, are presented in Appendix A). Both national and rural/urban data were used.

The method used is the 'children ever born technique'[2] for estimating child mortality. The basic idea of the technique is that the probability of dying from birth to a given age (*i.e.* the life table ${}_nq_0$ value) is proportional to the fraction dead of the total births to mothers in a given age group. Older mothers have children who are, on average, older than the children of younger mothers, so data from older mothers produce mortality probabilities for a wider age range. For example, data from mothers aged 20-24 produce an estimate of ${}_2q_0$, whereas data from mothers aged 45-49 produce an estimate of ${}_{20}q_0$. The proportionality constants used in the analysis are derived from model stable populations and regression techniques; the constants used here are those of Trussell (United Nations 1983). The children ever born technique assumes that mortality is unchanging or falling monotonically, though it is relatively insensitive to short, sudden, changes in mortality.[3] The time locations of the various estimates are produced in a similar fashion.

The discussion of the data analysis in the following sub-section assumes some previous familiarity with demographic estimation. Reviewing all the minutiae of the method used and its assumptions would require more space than is warranted. The details of the technique are described in Chapter III of *Manual X* (United Nations 1983), and in references therein. Hill (1991) provides a more recent review of child mortality estimation methods. Understanding the results, presented in the following section, does not require reading this section.

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[2] This method is also known as the 'Brass technique', after its original developer, William Brass.

[3] 'Insensitive' is meant in *both* a positive and negative sense here. The technique will fail to pick up sudden changes in mortality (such as a 'spike' in time series data), even when such features exist. However, if the goal is to determine a long-term trend, exclusive of such mortality crises, then the methods can usually be used to provide robust estimates. Nevertheless, Garenne *et al.* (1996a,b) show that when departures from monotonic decline are too great, the children ever born technique performs badly compared to direct life table calculations based on birth histories.

ii. Data analysis

This sub-section discusses the steps of the data analysis. Particular attention is given to aspects of the work that differ from the ‘standard’ methods, which are described in great detail in Chapter III of *Manual X: Indirect Techniques for Demographic Estimation* (United Nations 1983).

The total female population and children ever born (broken down by the usual age groups, 15-19, 20-24, *etc.*) permit the calculation of average parities in these age groups. Data on mothers younger than 15 were available for Botswana but were ignored. One sign of data quality is that average parity should increase monotonically with age; this pattern was observed in both the Batswana and Namibian data. The proportion dead was calculated using children ever born, in conjunction with either children living or children dead, depending on which of these two complementary statistics were provided in the census table.

The ${}_nq_0$ (n = 1,2,3,5,10,15,20) estimates and their time locations were then calculated exactly as described in *Manual X*. An example of these calculations is provided in Appendix B; the effects of using different model life tables are discussed below (under §iii of Results and Discussion). The ${}_nq_0$ values each have a different time location, so in their raw form they are not as useful as they would be if they were all from the same life table. One could calculate an average date, and then analyze the resulting mortality pattern *as if* all the mortality probabilities came from a single life table for that average date. A more satisfactory approach, however, is to convert all the ${}_nq_0$ estimates to some common, comparable, measure – for example under-five mortality (${}_5q_0$) – and then analyze the resulting time series. The ${}_nq_0$ values were converted to ${}_5q_0$ values in the following manner.

Each measure of ${}_nq_0$ implies, *ceteris paribus*, some overall level of mortality. This overall measure of mortality, in turn, implies some level of ${}_5q_0$. To convert, for example, a ${}_2q_0$ value to a ${}_5q_0$ value, we must quantify the overall level of mortality implied by the ${}_2q_0$ value, and then convert this to a ${}_5q_0$ value. This approach was employed to generate a time series of comparable values.

The Brass two-parameter relational model life table system was used (Brass and Coale 1968). In this system the following relationship exists:

$$\text{logit}(l_x^{\text{fit}}) = \alpha + \beta\cdot\text{logit}(l_x^{\text{ref}}), \qquad \text{(eqn. 1)}$$

where l_x^{fit} is a fitted life table l_x value, and l_x^{ref} is from a reference life table. The logit transform is Berkson’s logit, *i.e.* $\text{logit}(l_x) = 0.5\log[(l_0 - l_x)/l_x]$. The α parameter controls the level of mortality in the fitted life table relative to the reference life table (with $\alpha = 0$ being the neutral value). The β parameter controls how the shape of the survival curve differs in the fitted life table, compared to the reference table (with $\beta = 1$ being the neutral value). Once α and β have been determined from available data, any l_x value may be imputed using α, β, and the reference table.

Our observed ${}_nq_0$ values are analogous to l_x^{fit} in eqn. 1.[4] The observed mortality level (l_x^{fit}) may be expressed as the transform of some reference mortality level. The reference table is chosen *a priori* to be relatively close to the expected pattern of mortality in the given population.[5] Once a reference life table is chosen, l_x^{ref} is known for all x, and so once α, β become known we can determine l_x^{fit} *for any x.* (More precisely, we can only determine the logit of l_x^{fit}, but taking the antilogit is simple.) So knowing α, β and having a reference life table enables the calculation of the l_x^{fit} we desire, even if α, β were derived from a single observation. This way, we can go from ${}_nq_0$ to ${}_5q_0$.

The problem is that for each point in time, we have only one ${}_nq_0$ value, because each of the seven ${}_nq_0$ estimates has a different time location. Since for any given time location, t, we have two unknowns (α_t, β_t), but only one data point (${}_nq_0$), there are infinitely many solutions to the problem of solving for α_t, β_t. The way out is to fix β_t at unity, and it becomes easy to solve for α_t (this makes the fairly innocuous assumption that the life table at time t has the same shape as the life table family that was used in the preceding analysis[6]). The α_t, β_t values are then plugged-in to eqn. 1, along with the ${}_5q_0$ value from the reference life table, to get a fitted ${}_5q_0$ value which has the time location t.

In summary, the six ${}_nq_0$ estimates where $n \neq 5$ are converted to ${}_5q_0$ estimates by use of the Brass logit relational model life table system, where β is fixed at unity, and six α_t values are calculated from the ${}_nq_0$ values and a reference life table. The α_t values are then used to calculate ${}_5q_0$, using a reference ${}_5q_0$ value and eqn. 1. The result is a series of seven estimates of under-five mortality, which span approximately 1-15 years before the date of the census.

In addition to under-five mortality, expectation of life is a statistic that is of interest. Each of the seven original ${}_nq_0$ estimates implies an expectation of life – one approach would be to use the parameters discussed above (*i.e.* α_t, β_t [=1]) to calculate not just under-five mortality but also an entire abridged life table, and thus have a series of seven values of $e^o(0)$. However, this approach leans very heavily on the data, and especially on assumptions. The time series of under-five mortality rates that was calculated is trustworthy within the limitations of the children ever born method, plus the limits of the assumption $\beta_t = 1$ that is used to convert everything from ${}_nq_0$ to ${}_5q_0$. On the other hand, calculating $e^o(0)$ based only on α_t would imply knowledge of mortality at many ages that we do not possess. The expectation of life at birth would be determined only by child mortality. All of the variation in our time series plot of $e^o(0)$ would be attributable to the variation seen in the ${}_5q_0$ series. The apparent gain in

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[4] Since $l_x = 1 - {}_xq_0$ (in a life table with a radix of unity), the mortality probabilities may be used just as easily as l_x values in eqn. 1.

[5] In practice, more than one reference table was tried, with little difference between them. This is discussed in more detail below.

[6] *Manual X* discusses choice of life table family (Trussell coefficients), and the sensitivity of the estimates with respect to this is discussed below. The reference table used in determining the ${}_5q_0$ values (see eqn. 1) is always from the same family as the Trussell coefficients used in the preceding analysis. The $e^o(0)$ level of the reference table is chosen to be close to the expected value of $e^o(0)$ (and does not vary for the seven estimates), but because the α_t controls changes in the level of mortality of the fitted table, the procedure is very robust to changes in the level of the reference table.

information would be greater than the actual gain. For this reason, only one $e^{o}(0)$ estimate was produced per data set, and it was assigned the average date.

To calculate the $e^{o}(0)$ estimate, the logits of the seven data points and the logits of the seven values in the reference life table were used as ordered pairs to calculate α and β via an ordinary least squares (OLS) regression (see eqn. 1). The fitted α and β values were used to calculate a fitted abridged life table, from which $e^{o}(0)$ was calculated.[7] This process uses all of the available data (still by no means ideal, because no estimates of adult mortality are included) to make an estimate of $e^{o}(0)$. However, the association of this estimate with the average date is for convenience only, and should not be taken literally. It would be more precise to say that the estimate of life expectancy is an average over the period spanned by the seven ${}_5q_0$ estimates.[8]

In conclusion, this sub-section dealt with how the mortality estimates were determined. Mostly, 'garden-variety' indirect estimation techniques were used exactly as is described in, for example, the UN's *Manual X* (1983). There was some departure from these well-documented methods, however. Specifically, a time series of comparable ${}_5q_0$ estimates was produced, in lieu of a series of ${}_5q_0$ estimates, which are not comparable. In order to provide a complete account of how the results were obtained, the modifications to the method were emphasized. Using *Manual X* and the description here, district-level (or other sub-national level) results can be calculated which are comparable with the national data presented in the following section.

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[7] No separation factors were used, and l_{105} was taken to be zero. The family of the reference table was the same as that used previously, and the level was chosen subjectively to be close to the expected level in the results (level 13 in the Coale-Demeny system was used). As discussed in fn. 6, the technique used is robust to changes in level of the reference life table. Because the raw data are for both sexes, a combined-sex reference table was constructed, by averaging the two sex-specific tables for level 13, assuming a female radix of 100000 and a male radix of 105000, in keeping with a sex ratio at birth of 1.05 males per female.

[8] An alternative approach to estimation of life expectancy would be to average the seven $e^{o}(0)$ values implied by the α_t, β_t values used earlier. This approach gives a somewhat more optimistic picture, but it was not employed here because $\beta_t = 1 \ \forall \ t$, so the method used is preferable in that it takes full advantage of the two-parameter logit system.

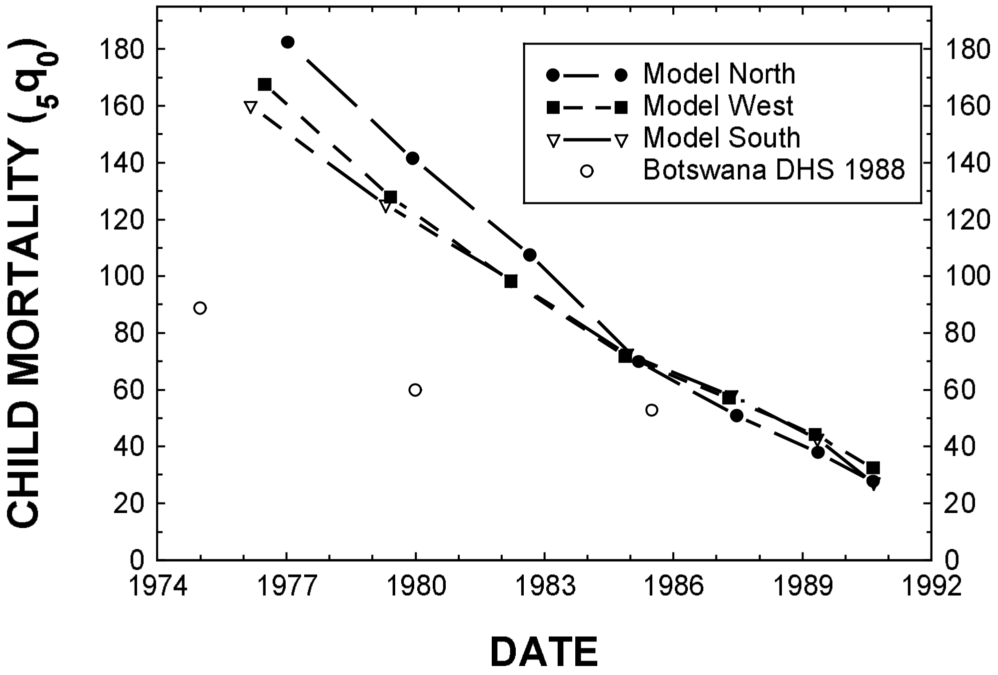
Results and Discussion

i. Botswana

The countrywide results for Botswana are plotted in Figure 1, along with under-five mortality estimates published in the Botswana DHS country report (Lesetedi *et al.* 1989). Three series are plotted: one each when the analysis assumed a North, South or West mortality pattern. The sensitivity of the estimates to the choice of the mortality pattern is discussed in §iii, below. The data used to make all of the Figures are presented in tabular form in Appendix C. The most striking feature of the under-five mortality trend is the strong decline from the mid-1970s to the early 1990s. Under-five mortality fell from about 180 per thousand around 1976 to 30 per thousand around 1990 – an incredible fall of, on average, 10 per thousand (absolute) per year. The exact estimates and time locations vary with the model life table used in the analysis.

The DHS mortality estimates are consistently lower (see Figure 1), though the trend is in the same direction and therefore the differences between the present results and the DHS results are smaller for the more recent estimates. There is no clear explanation of why the DHS estimates are lower. The census data obviously have a

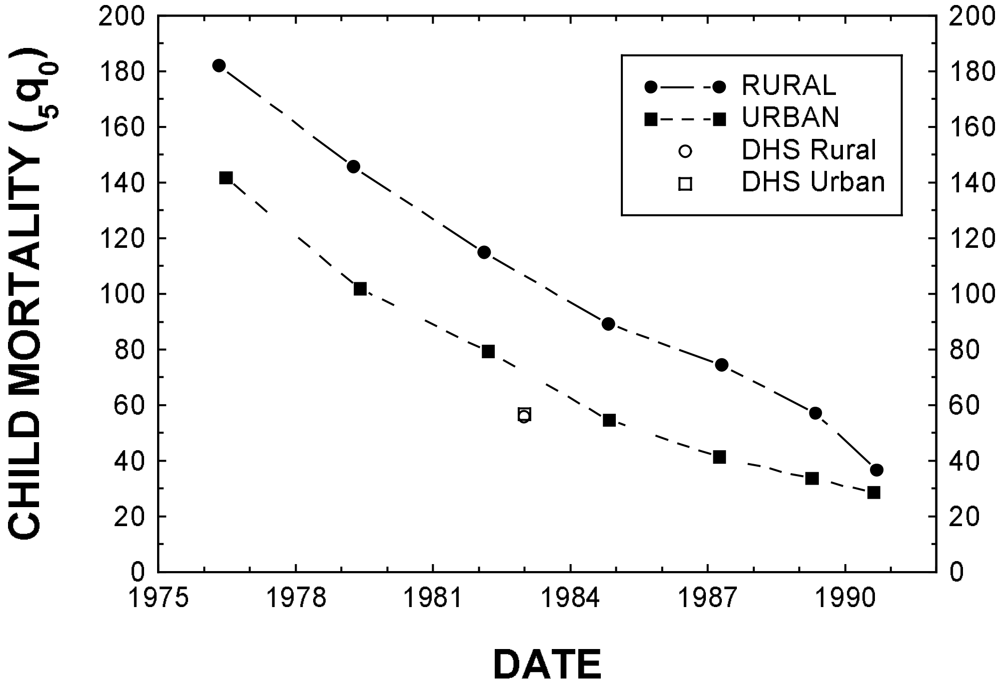
Figure 1: CHILD MORTALITY TREND: BOTSWANA



much larger sample size, but based on this fact alone it is not possible to place more faith in the present results over the DHS results; the DHS may have better quality data collection for the relevant questions. Whichever data series is more accurate, we can be sure that the long-term trend in under-five mortality in Botswana was downward between about 1975 and the early 1990s.

Figure 2 presents urban and rural mortality estimates for Botswana, when a West mortality pattern is used. It is not surprising that the rural estimates are consistently higher: rural areas have poorer access to health care, including vaccination programs; rural areas have poorer access to communication, including health care messages (about, for example, oral rehydration therapy); rural areas are less well served by infrastructure such as access to clean water and sanitation; and rural areas in developing countries tend to be poorer than urban areas, and income differentials can easily translate into nutritional differentials in developing countries. It is worth noting that the trend lines for the rural and urban series are nearly parallel, indicating that improvements in child health in rural areas were able to keep pace, in absolute terms, with similar improvements in urban areas. The recent estimates show that child mortality rates in rural and urban areas are converging, which is expected as rural areas catch-up to cities in terms of development. As with the country-wide estimates, the DHS rural and urban estimates of $_5q_0$ are lower than the estimates produced by the present study. It is somewhat surprising, however, that the DHS data show virtually no difference between rural and urban estimates of $_5q_0$.

Figure 2: URBAN / RURAL DIFFERENCES in CHILD MORTALITY in BOTSWANA



The life expectancy at birth for both sexes combined implied by the curves in Figure 1 (using the methods described above) varies between 54 and 60 years, depending on which model life table is used. There is an approximately 5-year difference in expectation of life at birth between rural and urban areas. These estimates are presented in tabular form in Appendix C.

The results of these analyses are based on aggregate data rather than registration of individual deaths; the mortality probabilities are indirect *estimates* rather than direct *measures* (the latter are ostensibly more reliable but are not infallible – either method is subject to biases, wide confidence intervals when sample sizes are small, *etc*.). However, unlike vital registration records of deaths recorded by cause, or other methods (such as case-control studies), the estimates here cannot be broken down by cause in any meaningful way. This makes it impossible to comment on the cause-specific components of the mortality decline using these data. From studies of cause-specific mortality in other settings (*e.g.* Preston 1976), we can infer that the observed mortality decline in Botswana is due to a combination of: improvements in hygiene and in nutrition; better access to health care (including oral rehydration therapy to treat the symptoms of diarrhea, and vaccinations for infants, children, and women of childbearing age); and increases in socioeconomic status during the study period (though the 1980s saw economic reversals in much of sub-Saharan Africa). The fact that we see urban/rural differentials is circumstantial evidence in support of this. Further consideration of the relative importance of economic gain *vs*. public health interventions, or of roles of synergy and antagony (*i.e.* 'negative synergy') in the effects of various interventions (vis-à-vis competing mortality risks) is beyond the scope of this paper.

It will be difficult for Botswana to maintain as dramatic a decline in under-five mortality. While there is no reason ${}_5q_0$ cannot continue to fall, even to levels seen in industrialized countries, the health advances that were responsible for (at least some of) the observed mortality declines are subject to diminishing returns to investment.[9] And while the HIV/AIDS epidemic is associated mostly with adult deaths, vertical transmission of HIV does result in pediatric AIDS deaths (see *e.g*. Nicoll *et al.* 1994), in addition to which, orphanhood and other social costs of the epidemic have deleterious indirect effects on child health.

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[9] For example, it is easier to go from zero vaccination coverage to 50% than it is to go from 50% to 100%.

ii. Namibia

Figure 3 presents the results of the countywide analysis for Namibia, along with similar estimates from the 1992 Namibia DHS (Katjiuanjo *et al.* 1993). As for Botswana, the results are plotted when a North, South, or West mortality pattern was used in the analysis (see §iii, below, for a discussion of the sensitivity of the estimates to choice of life table). The results in tabular form are presented in Appendix C. The trend in under-five mortality is a dramatic downturn, which is similar to that seen in Botswana but is all the more notable because the period was one of strife, as Namibia sought to gain independence from South Africa. For Namibia, the DHS estimates are a slightly better fit with the present results than was the case for Botswana. The DHS trend line is one of less rapid decline, but it starts from a lower estimate. The outcome is that for the mid-1980s, the present results are in excellent concordance with the DHS result,[10] whereas the DHS result for 1980 is more optimistic than the trend line of the present results, and the DHS result for 1990 is slightly more pessimistic than the trend line.

Figure 3: CHILD MORTALITY TREND: NAMIBIA

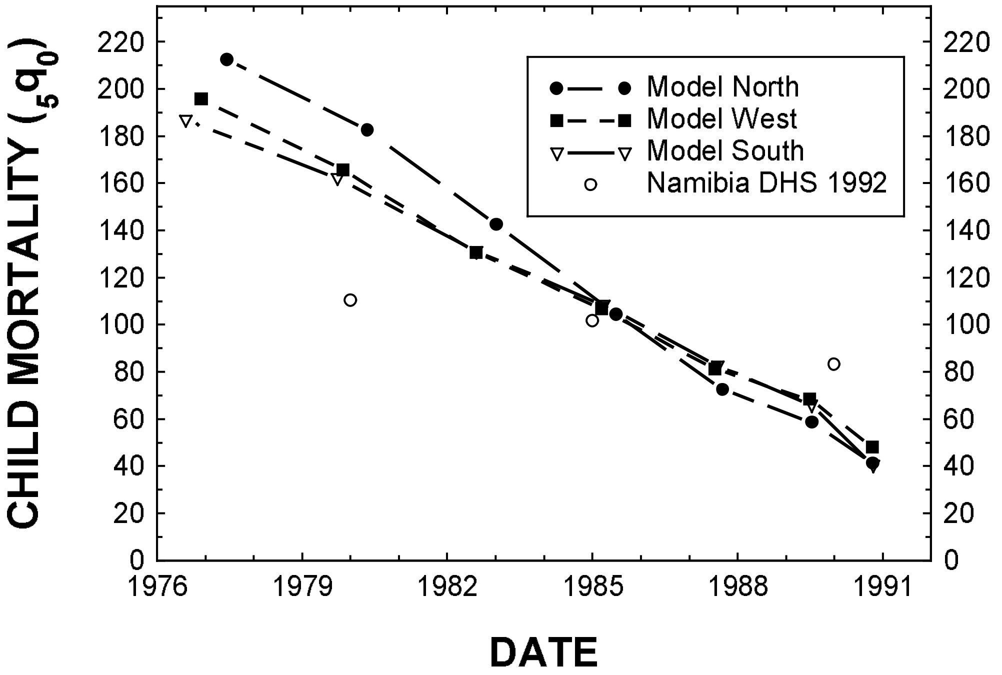

Figure 4 presents the urban and rural estimates of $_5q_0$, when a West mortality pattern is used in the analysis. As with Botswana, we see higher mortality in rural areas, with parallel trend lines indicating that mortality declines in rural areas kept pace (in absolute terms) with declines in urban areas; the narrowing of the gap in recent years indicates that rural areas have been able to catch-up somewhat. Also similar to Botswana, the DHS estimates show little difference in $_5q_0$ between rural and urban

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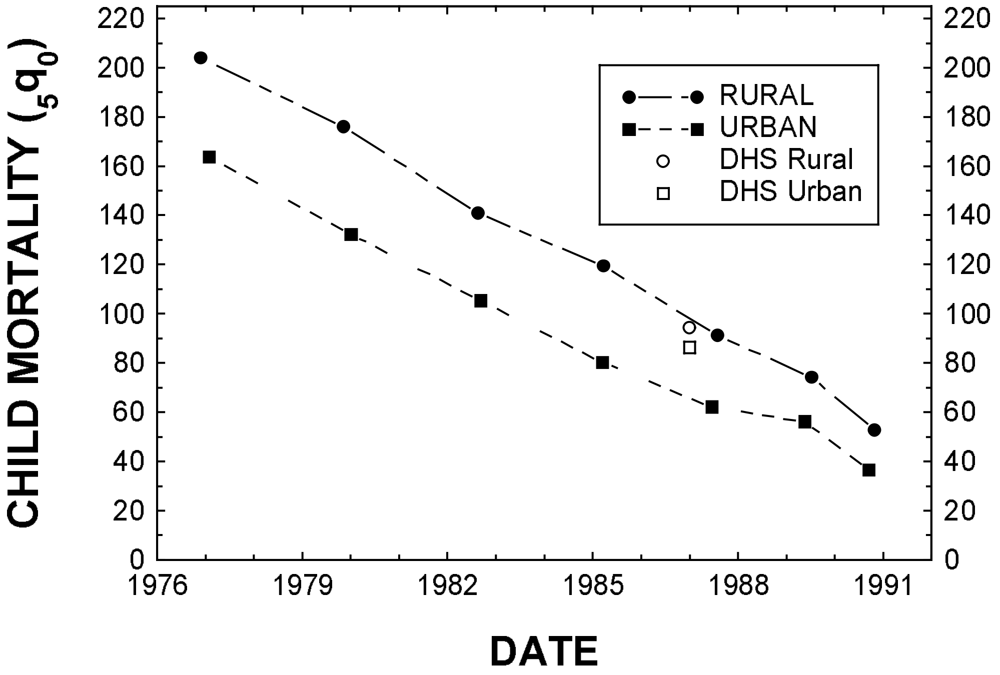
[10] Interestingly, at this date the results from this analysis also differ very little by life table family.

sectors, which is, again, surprising. The reasons discussed previously for the difference between rural and urban areas apply to Namibia as well.

The Republic of Namibia (1994b) published an estimate of 87 ‰ for ${}_5q_0$, based on the same census data. No exact time location was given (except "a short period before the census"), so it is hard to judge the concordance of this datum with the results reported here. Since we would expect the ${}_5q_0$ estimate to apply about five years before the census, the published ${}_5q_0$ value seems to agree well with the trend line in Figure 3. Hartmann (1994) published the same estimate, also without a time location. Hartmann also projects an infant mortality rate (${}_1q_0$) of 69 ‰ for 1994, which seems unduly pessimistic unless he is assuming the mortality situation worsened in Namibia between the late 1980s and 1994.

Figure 4: URBAN / RURAL DIFFERENCES in CHILD MORTALITY in NAMIBIA



The life expectancy at birth for both sexes combined implied by the curves in Figure 3 (using the methods described above) varies between 55 and 61 years, depending on which model life table is used. There is an approximately 3-year difference in expectation of life at birth between rural and urban areas. These estimates are presented in tabular form in Appendix C.

The general reasons for decline in child mortality discussed with respect to Botswana hold true for Namibia as well. It is worth repeating, however, that the decline in child mortality in Namibia took place despite the Namibian war of independence. Like Botswana, and for the same reasons, Namibia will find it difficult to sustain as dramatic a decline in child mortality in the coming years. The differences between rural and urban areas remain higher in Namibia than in Botswana. Namibia may have success in the 1990s in reducing the gap in child mortality between rural and urban areas; Botswana's experience indicates that this is possible.

iii. The impact of choice of model life table

It is clear from Figures 1 and 3 that the results are (substantially) unchanged with the choice of family of life table.[11] It is reassuring that the observed trend holds no matter which life table family is used in the analysis. The results using model West and those using model South are practically indistinguishable. Model North, which has mortality more concentrated in youngest ages (compared to South and West, for similar values of $e^{o}(0)$), not surprisingly gives slightly higher estimates for most dates. For the same reason, North is more optimistic in the estimates of $e^{o}(0)$ (see Appendix C).

iv. A note on data quality

One thing that is striking about all of the results in this paper (both for Botswana and Namibia) is the apparent reliability of the most recent data points. All the estimates that were produced have been plotted in the Figures. Often in the children ever born method, the most recent points are considered to be unreliable, or are disregarded altogether. The most recent ${}_5q_0$ estimates arise from data of young mothers, who are themselves unrepresentative (and these mothers also have a high proportion of first births, which is an unrepresentative characteristic). These biases often result in the most recent one or two points being a clear departure from the trend established by the other five or six points (the departure is usually that these points are more pessimistic than the trend, but sometimes these points are, inexplicably, more optimistic). The usual practice is to excise these data points from the plot, which was not necessary here. It is possible that the apparent reliability of the most recent points is fortuitous – in other words, that the biases making these points overestimates are perfectly counteracted by unobserved biases acting in the opposite direction. All we can say is that, for whatever reason, these populations give results for the most recent points that are well in-line with the trend from the earlier points. All things being equal, the apparent reliability of these data points suggests very strongly that the data are of high quality (that is, that the data were well-collected and well-processed).

The consistency of the urban/rural results also suggests that the data are of high quality. The urban-rural differentials were in the expected direction, and the trend lines were parallel, which indicates (very plausibly) that, despite their worse situation, mortality in rural areas has been declining along with that in urban areas. It is worth noting that many women now living in urban areas may be migrants from rural areas, which can introduce biases. In spite of this, the urban/rural results (Figures 2 and 4) look very believable.

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[11] The 'North', 'South', and 'West' patterns ('families') of mortality we have been referring to without attribution are the Coale-Demeny model life tables (Coale and Demeny 1983). There is also a Coale-Demeny 'East' mortality pattern, but this seems never to be applied to African data. The North and South patterns are used most often in Africa, and the West pattern is taken to be a general one. Other systems of model life tables exist (published, for example, by the UN; by the OECD; and by William Brass), but *Manual X* lacks the appropriate coefficients for these tables.

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Appendix A: Census Table Data

The data are presented here just as they were extracted from the relevant census tables. In some cases, data on *children living* were taken from the census table and the *children dead* column was computed, while in other cases, the converse was true. Appendix B contains a sample worksheet.

I. Data from Botswana

i. Entire country

age group	total female population	total children ever born	children living
15-19	79413	14191	13530
20-24	62622	70212	66575
25-29	54440	123620	115739
30-34	44013	153751	142712
35-39	35741	164549	150094
40-44	25001	139007	123893
45-49	20496	123988	107532

Source: Table D6 (Republic of Botswana n.d., p. 289)

ii. Rural areas

age group	total female population	total children ever born	children living
15-19	38703	7556	7170
20-24	24467	32062	29936
25-29	22131	58619	53749
30-34	19006	75558	68794
35-39	16993	87153	78170
40-44	13543	81681	71502
45-49	12136	77946	66625

Source: Table D6-2 (Republic of Botswana n.d., p. 295)

iii. Urban areas

age group	total female population	total children ever born	children living
15-19	40710	6635	6360
20-24	38155	38150	36639
25-29	32309	65001	61990
30-34	25007	78193	73918
35-39	18748	77396	71924
40-44	11458	57326	52391
45-49	8360	46042	40907

Source: Table D6-1 (Republic of Botswana n.d., p. 292)

II. Data from Namibia

i. Entire country

age group	total female population	total children ever born	children living
15-19	84169	13521	12591
20-24	67264	69043	63569
25-29	57826	123795	112660
30-34	45625	160341	143268
35-39	34488	158561	140094
40-44	28058	155458	133538
45-49	22302	134725	113805

Source: Table F04 (Republic of Namibia 1994a, p. 934)

ii. Rural areas

age group	total female population	total children ever born	children living
15-19	62042	10002	9264
20-24	43656	47334	43290
25-29	35486	81203	73009
30-34	28560	109542	96519
35-39	22536	112933	98727
40-44	19825	119302	101409
45-49	16506	107088	89714

Source: Table F03 (Republic of Namibia 1994a, p. 923)

iii. Urban areas

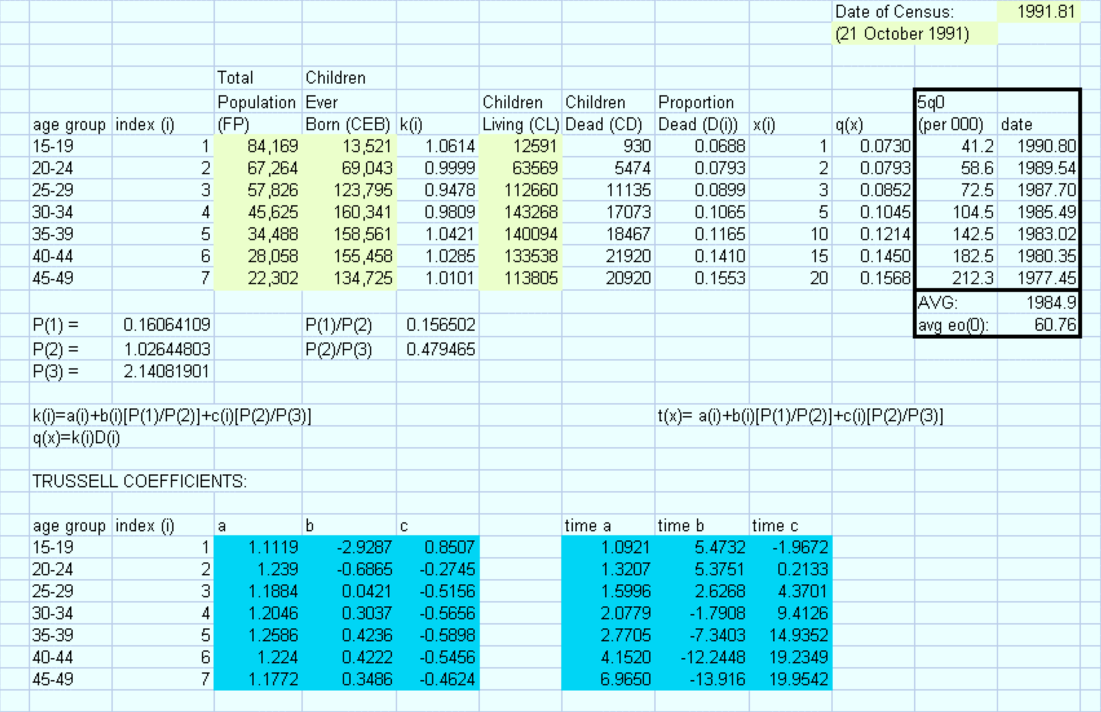
age group	total female population	total children ever born	children living
15-19	22127	3519	3327
20-24	23608	21709	20279
25-29	22340	42592	39651
30-34	17065	50799	46749
35-39	11952	45628	41367
40-44	8233	36156	32129
45-49	5796	27637	24091

Source: Table F04 (Republic of Namibia 1994a, p. 936)

Appendix B: A Sample Worksheet

Below is a sample worksheet used in the calculations. Panel 1 shows the main worksheet, where ${}_nq_0$ values [‘q(x)’] are calculated from the census data (a North mortality pattern is assumed here). Panel 2 shows the conversion of the ${}_nq_0$ values to ${}_5q_0$ values, the final results of which are also in the second rightmost column of panel 1. (The calculation of $e^{o}(0)$ is not shown.)

Panel 1:



Date of Census: 1991.81
(21 October 1991)

age group	index (i)	Total Population (FP)	Children Ever Born (CEB)	k(i)	Children Living (CL)	Children Dead (CD)	Proportion Dead (D(i))	x(i)	q(x)	5q0 (per 000)	date
15-19	1	84,169	13,521	1.0614	12591	930	0.0688	1	0.0730	41.2	1990.80
20-24	2	67,264	69,043	0.9999	63569	5474	0.0793	2	0.0793	58.6	1989.54
25-29	3	57,826	123,795	0.9478	112660	11135	0.0899	3	0.0852	72.5	1987.70
30-34	4	45,625	160,341	0.9809	143268	17073	0.1065	5	0.1045	104.5	1985.49
35-39	5	34,488	158,561	1.0421	140094	18467	0.1165	10	0.1214	142.5	1983.02
40-44	6	28,058	155,458	1.0285	133538	21920	0.1410	15	0.1450	182.5	1980.35
45-49	7	22,302	134,725	1.0101	113805	20920	0.1553	20	0.1568	212.3	1977.45
										AVG:	1984.9
P(1) =	0.16064109		P(1)/P(2)	0.156502						avg eo(0):	60.76
P(2) =	1.02644803		P(2)/P(3)	0.479465							
P(3) =	2.14081901										

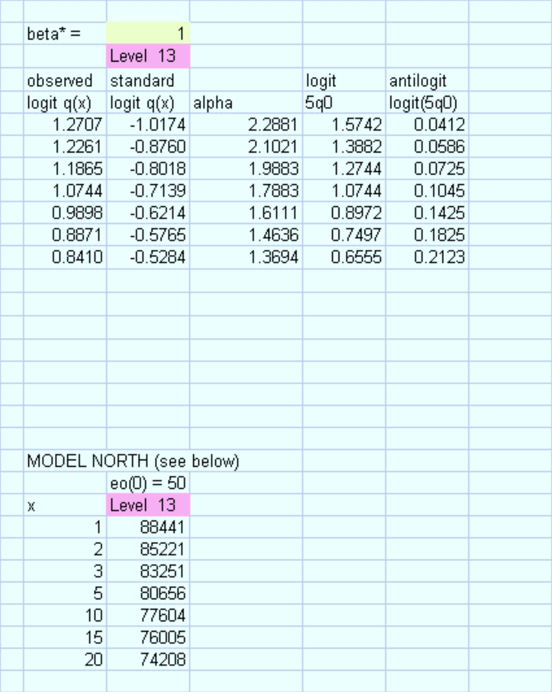
k(i)=a(i)+b(i)[P(1)/P(2)]+c(i)[P(2)/P(3)]　　t(x)= a(i)+b(i)[P(1)/P(2)]+c(i)[P(2)/P(3)]

q(x)=k(i)D(i)

TRUSSELL COEFFICIENTS:

age group	index (i)	a	b	c		time a	time b	time c
15-19	1	1.1119	-2.9287	0.8507		1.0921	5.4732	-1.9672
20-24	2	1.239	-0.6865	-0.2745		1.3207	5.3751	0.2133
25-29	3	1.1884	0.0421	-0.5156		1.5996	2.6268	4.3701
30-34	4	1.2046	0.3037	-0.5656		2.0779	-1.7908	9.4126
35-39	5	1.2586	0.4236	-0.5898		2.7705	-7.3403	14.9352
40-44	6	1.224	0.4222	-0.5456		4.1520	-12.2448	19.2349
45-49	7	1.1772	0.3486	-0.4624		6.9650	-13.916	19.9542

Panel 2:



beta* = 1
Level 13

observed logit q(x)	standard logit q(x)	alpha	logit 5q0	antilogit logit(5q0)
1.2707	-1.0174	2.2881	1.5742	0.0412
1.2261	-0.8760	2.1021	1.3882	0.0586
1.1865	-0.8018	1.9883	1.2744	0.0725
1.0744	-0.7139	1.7883	1.0744	0.1045
0.9898	-0.6214	1.6111	0.8972	0.1425
0.8871	-0.5765	1.4636	0.7497	0.1825
0.8410	-0.5284	1.3694	0.6555	0.2123

MODEL NORTH (see below)

	eo(0) = 50
x	Level 13
1	88441
2	85221
3	83251
5	80656
10	77604
15	76005
20	74208

Appendix C: Results in Tabular Form

This appendix presents, in tabular form, all of the data plotted in Figures 1,2,3,4. It also contains estimates of life expectancy.

I. Botswana

i. Analysis using model West and DHS results

DATE	**$_5q_0$ (‰)**	**Source**
1975.00	88.6	1988 DHS
1976.50	167.5	this analysis
1979.43	127.9	this analysis
1980.00	59.8	1988 DHS
1982.23	98.2	this analysis
1984.88	71.7	this analysis
1985.50	52.7	1988 DHS
1987.29	57.0	this analysis
1989.30	44.2	this analysis
1990.64	32.4	this analysis

i(a). Analysis using model West and DHS result (rural data)

DATE	**$_5q_0$ (‰)**	**Source**
1976.33	181.9	this analysis
1979.27	145.6	this analysis
1982.13	114.7	this analysis
1983.00	55.6	1988 DHS
1984.84	89.1	this analysis
1987.31	74.3	this analysis
1989.36	57.0	this analysis
1990.7	36.5	this analysis

i(b). Analysis using model West and DHS result (urban data)

DATE	$_5q_0$ (‰)	Source
1976.48	141.6	this analysis
1979.41	101.7	this analysis
1982.21	79.2	this analysis
1983.00	56.7	1988 DHS
1984.85	54.6	this analysis
1987.26	41.3	this analysis
1989.28	33.6	this analysis
1990.63	28.5	this analysis

ii. Analysis using model South

DATE	$_5q_0$ (‰)	Source
1976.16	159.9	this analysis
1979.31	125.1	this analysis
1982.22	98.7	this analysis
1984.93	72.6	this analysis
1987.35	57.9	this analysis
1989.35	42.6	this analysis
1990.66	27.2	this analysis

iii. Analysis using model North

DATE	$_5q_0$ (‰)	Source
1977.04	182.3	this analysis
1979.94	141.3	this analysis
1982.67	107.4	this analysis
1985.20	69.9	this analysis
1987.47	50.8	this analysis
1989.36	37.8	this analysis
1990.65	27.7	this analysis

iv. Estimates of complete expectation of life at birth [$e^{o}(0)$]

MODEL USED	**DATE**	**$e^{o}(0)$**	**Source**
West	1984.3	55.2	this analysis
South	1984.3	60.8	this analysis
North	1984.6	61.3	this analysis
Rural (West)	1984.3	54.0	this analysis
Urban (West)	1984.3	59.3	this analysis

II. Namibia

i. Analysis using model West and DHS results

DATE	**$_5q_0$ (‰)**	**Source**
1976.91	195.6	this analysis
1979.85	165.7	this analysis
1980.00	110.3	1992 DHS
1982.60	130.5	this analysis
1985.00	101.6	1992 DHS
1985.19	106.9	this analysis
1987.53	81.1	this analysis
1989.49	68.3	this analysis
1990.00	83.2	1992 DHS
1990.79	48.1	this analysis

i(a). Analysis using model West and DHS result (rural data)

DATE	$_5q_0$ (‰)	Source
1976.91	203.9	this analysis
1979.86	175.9	this analysis
1982.63	140.8	this analysis
1985.23	119.4	this analysis
1987.00	94.2	1992 DHS
1987.58	91.2	this analysis
1989.53	74.1	this analysis
1990.83	52.5	this analysis

i(b). Analysis using model West and DHS result (urban data)

DATE	$_5q_0$ (‰)	Source
1977.08	163.6	this analysis
1980.01	132.2	this analysis
1982.69	105.3	this analysis
1985.20	80.2	this analysis
1987.00	86.3	1992 DHS
1987.47	62.1	this analysis
1989.39	56.1	this analysis
1990.71	36.4	this analysis

ii. Analysis using model South

DATE	$_5q_0$ (‰)	Source
1976.59	186.8	this analysis
1979.73	162.1	this analysis
1982.60	131.1	this analysis
1985.24	108.2	this analysis
1987.59	82.5	this analysis
1989.53	66.0	this analysis
1990.81	40.4	this analysis

iii. Analysis using model North

DATE	**$_5q_0$ (‰)**	**Source**
1977.45	212.3	this analysis
1980.35	182.5	this analysis
1983.02	142.5	this analysis
1985.49	104.5	this analysis
1987.70	72.5	this analysis
1989.54	58.6	this analysis
1990.80	41.2	this analysis

iv. Estimates of complete expectation of life at birth [$e^{o}(0)$]

MODEL USED	**DATE**	**$e^{o}(0)$**	**Source**
West	1984.6	55.3	this analysis
South	1984.6	59.9	this analysis
North	1984.9	60.8	this analysis
Rural (West)	1984.7	54.9	this analysis
Urban (West)	1984.7	58.0	this analysis