# ESTIMATING ADULT FEMALE MORTALITY FROM REPORTS ON NUMBER OF CHILDREN SURVIVING

by Samuel H. Preston

Indirect estimates of mortality and fertility are frequently used to fill the informational gaps left by deficient vital registration in developing countries. The most successful of these techniques was originally developed by William Brass (see, for example, Brass et al., 1968). It converts survey or census reports by women on the number of their children ever born and surviving into estimates of child mortality. Largely because this technique has been so successful, the data required for implementing it are now routinely collected and widely available. The purpose of this note is to show how these data can also be used to estimate adult female mortality.

The basis of the adult estimation is the recognition that, in a closed population, the number of surviving children of women will equal the number of non-orphans in the population. Persons whose mothers have survived to report their existence in a survey are obviously not maternally orphaned. On the other hand, persons whose mothers have died will not be accounted for in women's reports. (Mothers may also have moved away from or into the population; therefore, the approach is strictly valid only in a population closed to migration.) In order to provide a reliable estimate of the number of orphans, the survey that produces estimates of surviving children must be nationally representative and must include reports of postreproductive women, although the large majority of surviving offspring in developing countries will belong to women still in their reproductive years.

Table 1 displays the number of reported surviving children and the fraction of the total population that they represent in various countries. The data are drawn from a large compendium of reports on children ever born and children surviving presented in the 1975 United Nations *Demographic Yearbook* (United Nations, 1976).[1] The table suggests that the approach has promise. Although there are some clear anomalies (especially Malaysia), the high mortality countries such as Nepal, Tanganyika, and Swaziland tend to be located at the lower end of the range in the estimated proportion of the population who are not orphaned.

### Procedure for converting a proportion non-orphaned into an estimate of mortality

In a closed population, the proportion of persons aged $a$ at time $t$ who are not maternally orphaned can be expressed as

$$M(x,t) = \int_{\alpha}^{\beta} F(a,\, t-x)\, {}_xP_a(t)\,da \qquad (1)$$

where

$M(x,t)$ = proportion of persons aged $x$ at time $t$ whose mother is living

$F(a, t-x)$ = proportion of births at time $t-x$ that occurred to mothers aged $a$

${}_xP_a(t)$ = probability of survival from age $a$ to age $a+x$ for cohort of women aged $a+x$ at time $t$

These quantities are shown on the Lexis diagram in Figure 1.

In a closed population this expression is exact, as long as the probability of offspring survival from birth to age $x$ is independent of maternal survival. This equation is the basis of a clever procedure developed by Hill and Brass (1974) to estimate adult mortality. A direct survey question on maternal survival can provide an estimate of the value of the left-hand side of the equation. If $F(a, t)$ can also be approximated from the survey, one can solve immediately for the set of ${}_xP_a$ functions in some model life table system that satisfies the equality. This procedure assumes that age-specific information is available on orphan-

**Table 1 Proportion non-orphans as inferred from comparison of number of surviving children reported by (surviving) mothers and total population size**

| Country and year | Number of surviving children reported by mothers (1) | Size of population (2) | Proportion non-orphaned (1)/(2) |
|---|---|---|---|
| Bahrain, 1971 | 149,137 | 216,078 | .690 |
| Bangladesh, 1974 | 50,306,000 | 71,315,000 | .705 |
| Brazil, 1970 | 67,770,764 | 92,341,556 | .734 |
| Colombia, 1973 | 15,134,065 | 21,070,115 | .718 |
| Costa Rica, 1973 | 1,529,465 | 1,871,780 | .817 |
| Cuba, 1970 | 6,593,423 | 8,569,121 | .769 |
| Cyprus, 1973 | 502,961 | 631,778 | .796 |
| Dominican Republic, 1970 | 2,997,187 | 4,006,405 | .748 |
| Fiji, 1966 | 367,050 | 476,727 | .770 |
| Indonesia, 1971 | 82,316,386 | 118,367,850 | .695 |
| Iraq, 1965 | 4,915,451 | 8,047,415 | .611 |
| Kenya, 1969 | 8,243,495 | 10,942,705 | .753 |
| Malaysia, 1970 | 9,032,602 | 10,319,324 | (.875) |
| Nepal, 1971 | 6,994,094 | 11,555,983 | .605 |
| Philippines, 1970 | 26,910,007 | 36,684,486 | .734 |
| Seychelles, 1971 | 41,138 | 53,096 | .775 |
| Singapore, 1970 | 1,509,660 | 2,074,507 | .727 |
| Swaziland (African population), 1966 | 256,661 | 374,697 | .685 |
| Syria, 1970 | 4,910,369 | 6,304,685 | .779 |
| Tanganyika, 1967 | 8,166,049 | 11,958,654 | .682 |
| Turkey, 1970 | 25,622,419 | 35,666,549 | .718 |
| Western Samoa, 1966 | 105,096 | 146,627 | .717 |
| Zanzibar, 1967 | 243,480 | 354,815 | .686 |

PRINCIPAL SOURCE: United Nations, 1976.

1 The following classes of countries appearing in Table 52 of the U.N. Demographic Yearbook are excluded from Table 1: countries with populations less than 100,000; countries in which the number of women with "unknown" numbers of children surviving exceeded 5 percent of all women; more developed countries; and countries where the number of children surviving was estimated by the U.N. Statistical Office.

hood, contrary to the assumption made in the present procedure.

The proportion of the *total* population that is not orphaned may be found by weighting the above function by the age distribution of the population:

$$M = \int_0^{\infty} c(x) \int_{\alpha}^{\beta} F(a)\, {}_xP_a \, da\, dx \qquad (2)$$

where

$c(x)$ = proportion of the population that is aged $x$

and where we have dropped the index $t$ by assuming constancy of the $F(a)$ and ${}_xP_a$ functions. The ratio of reported children surviving to the total population gives a value for $M$. Converting to discrete notation, we have

$$M = \sum_{x=0}^{\infty} {}_5C_x \sum_{a=\alpha}^{\beta} {}_5f_a \frac{5\, \ell_{a+5+x}}{{}_5L_a} \qquad (3a)$$

$$= 5 \sum_{a=\alpha}^{\beta} \frac{{}_5f_a}{{}_5L_a} \sum_{x=0}^{\infty} {}_5C_x \; \ell_{a+5+x} \qquad (3b)$$

where

${}_5C_x$ = proportion of population between ages $x$ and $x$+5

${}_5f_a$ = proportion of births occurring to women aged $a$ to $a$+5

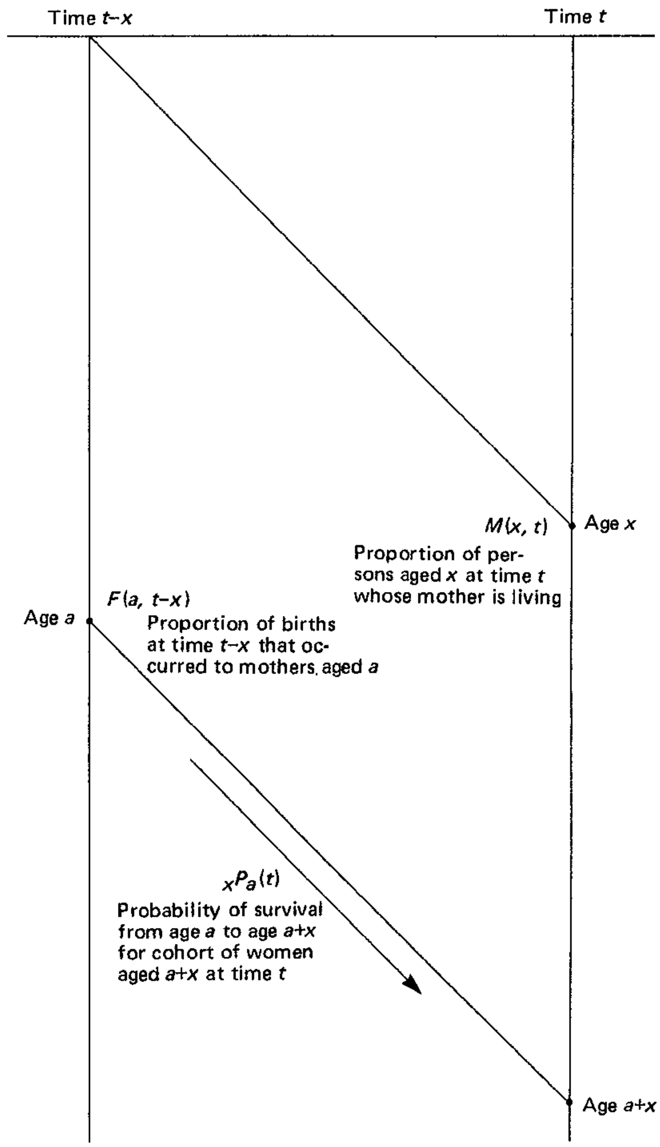
and the summation indices are understood to increase in steps of five.

The survivorship factor derives from observing that, taking persons currently aged $x$ to $x$+5 as concentrated at age $x$+2.5, the survivorship ratio applicable to the mothers who were aged $a$ to $a$+5 at birth is ${}_5L_{a+x+2.5} \div {}_5L_a$; and that ${}_5L_{a+x+2.5}$ may be approximated by $5\ell_{a+x+5}$.

The age distribution of the population and the age distribution of mothers at childbirth are assumed to be provided by the survey, as is the estimate of surviving children. Identifying the mortality level is then simply a matter of solving for the level of mortality in some model life table system that satisfies the equation. For a preliminary judgment about the level of mortality implied by the ratio of reported surviving children to total population, it is convenient to refer to model stable populations. The Appendix, prepared by Griffith Feeney, shows the proportion not maternally orphaned in stable populations at various levels of growth rates, life expectancies at birth, and mean ages of the fertility schedule. Clearly, the proportion non-orphaned rises with increases in growth rates and life expectancy; it falls as the mean age of the fertility schedule rises.

The main advantage of this approach vis-à-vis the orphanhood approach of Brass and Hill is one of availability and not of technique. It can be applied to data sets that are many times more numerous. The main technical disadvantage of the approach is that it yields only one estimated mortality level, and that level pertains to a very vaguely defined period. The mean length of observation of mother's mortality is simply equal to the mean age of the population, which in developing countries is often between 20 and 25 years. The mean time since mother's death thus may be around 10–12 years. The Hill-Brass approach, on the other hand, yields a series of age-specific survival estimates, one for each age group of reporting individuals. The periods of reference are more precisely defined, although they are not constant from age to age and the tendency for users to cast aside reports for younger persons makes the reference period somewhat more distant, on average, than in the present variant.

**Figure 1 Lexis diagram illustrating derivation of expression for proportion of persons alive at time $t$ who are not maternally orphaned**




Both techniques are subject to an adoption bias: the tendency for children (particularly young ones) of dead mothers to be ascribed to a living mother. The present technique may be somewhat less vulnerable to this problem in general if assignments are made more frequently by mothers themselves and less frequently by proxies. An additional source of error in the present approach works in the opposite direction: the tendency for mothers to fail to report living children. Undoubtedly in some populations this tendency will be so strong that no useful results can be obtained. In general, it seems more likely that the technique will overestimate than underestimate mortality.

### Application of the technique

The country chosen for experimental application of the technique is Bangladesh, where a very detailed demographic survey carried out in 1974 included a direct question on orphanhood (Bangladesh Census Commission, 1977). It also included the requisite tabulations on number of surviving children, age distribution of the population, and age distribution of mothers at childbirth.

A total of 50,306,167 children was reported as living by mothers in this survey (26.48 million males and 23.82 females), out of an estimated total population of 71,315,944 (Bangladesh Census Commission, 1977:24). Thus, the implied proportion non-orphaned was .705. Of the surviving children, only 10 percent (4.9 million) were accounted for by women aged 60 and above, and an additional 12 percent were accounted for by women aged 50–59. This approach implies that there were a larger number of maternal orphans than does the direct question on orphanhood, according to which .761 of the population had a living mother (Bangladesh Census Commission, 1977:33). It is not possible to trace the source of this sizeable discrepancy. It is worth noting, however, that the reported number of orphans from the direct question is almost certainly too low at ages 0–19, where more than half of the population is located. Converting the proportion orphaned at these ages into life expectancy estimates in the West model life table system produces estimates in the range of 55–60 years (Coale and Demeny, 1966). As indicated below, this range is probably ten years too high. Presumably the adoption bias is quite strong at these ages. On the other hand, the mothers' reports seem to indicate too many female orphans; only 69.3 percent of the female population appears in reports by mothers of surviving children, whereas 71.1 percent of the male population is accounted for in mothers' reports. There is thus a suggestion that surviving females are differentially omitted by mothers, such that an additional 1.2 percent of the total population should have been reported as non-orphaned.

Solving for the level of mortality in a model life table system that satisfies Equation (3) takes perhaps an hour. The easiest way to proceed is to replace ${}_5C_x$ by ${}_5N_x$ in (3b), giving an expression representing the estimated number of persons with a living mother (that is, the number of children reported as surviving by mothers). Taking $\alpha = 10$ and $\beta = 55$, this yields

$$5\frac{{}_5f_{10}}{{}_5L_{10}}[{}_5N_0\ell_{15} + {}_5N_5\ell_{20} + \ldots + {}_5N_{70}\ell_{85}]$$
$$+\ 5\frac{{}_5f_{15}}{{}_5L_{15}}[{}_5N_0\ell_{20} + {}_5N_5\ell_{25} + \ldots + {}_5N_{65}\ell_{85}]$$
$$\vdots$$
$$+\ 5\frac{{}_5f_{50}}{{}_5L_{50}}[{}_5N_0\ell_{55} + {}_5N_5\ell_{60} + \ldots + {}_5N_{30}\ell_{85}]. \quad (3c)$$

An illustration of the calculations required is shown in Table 2. Each entry in the last column may be interpreted as the estimated number of non-orphans whose mothers were aged $x$ to $x$+5 at their birth. In total, there should have been 51.03 million non-orphans if all mothers were exposed after childbirth to West model 11 mortality conditions. Repeating the calculation for West model 9 produces an estimated 49.15 million non-orphans. The recorded value (surviving children reported by mothers) of 50,306,167 thus lies between the predictions of the two levels. Interpolating between them, the implied life expectancy at age 25 is 37.1 and at birth it is 43.1 years. These are tolerable implications and they are consistent with the Brass *child* mortality analysis of the same data, in which the female $q(5)$ of .216 is associated in the West model life table system with a life expectancy at birth of 46.1 years (Bangladesh Census Commission, 1977: 165). The direct questions on orphanhood were converted into an estimated $\mathring{e}_{25}$ of 38.7 for females (p. 91). The direct question presumably produces a higher life expectancy estimate because it is based upon fewer orphans.

I suggested above that the mothers' reports were deficient in the number of surviving female children. So I repeated the estimation exercise using only male data. The resulting estimate of female life expectancy at birth in the West model life table system is 47.2 years and at 25 it is 39.0 years. These figures are somewhat closer to results based on the child mortality analysis and on analysis of direct reports on orphanhood. They are not necessarily any more plausible, however, since the orphanhood estimates refer to a period earlier than that of the childhood estimates, and mortality may have been declining.

The technique described may function principally as a last resort for estimation purposes. Some populations in Africa, for example, have

**Table 2 Illustrative calculation of the number of persons not maternally orphaned, Bangladesh, 1974, based on Coale-Demeny West female model life table, level 11**

| $a$ (age) | ${}_5N_a$ (000) | $\ell_a$ | $\sum_{x=0}^{\infty} {}_5N_x \ell_{x+5+a}$ (000) | ${}_5L_a$ | ${}_5f_a$ | Number of non-orphans |
|---|---|---|---|---|---|---|
| 0 | 10,842 | n.a. | n.a. | n.a. | n.a. | n.a. |
| 5 | 12,384 | n.a. | n.a. | n.a. | n.a. | n.a. |
| 10 | 10,023 | n.a. | 430,589 | 37,243 | 0.003 | 173 |
| 15 | 6,337 | 7,369 | 405,068 | 36,321 | 0.142 | 7,918 |
| 20 | 5,301 | 7,160 | 377,252 | 35,154 | 0.272 | 14,595 |
| 25 | 5,184 | 6,902 | 347,729 | 33,812 | 0.249 | 12,804 |
| 30 | 4,117 | 6,622 | 316,508 | 32,353 | 0.164 | 8,022 |
| 35 | 3,844 | 6,319 | 283,880 | 30,787 | 0.105 | 4,841 |
| 40 | 3,203 | 5,996 | 249,872 | 29,139 | 0.042 | 1,801 |
| 45 | 2,503 | 5,659 | 214,359 | 27,397 | 0.017 | 665 |
| 50 | 2,265 | 5,299 | 177,396 | 25,388 | 0.006 | 210 |
| 55 | 1,401 | 4,856 | n.a. | n.a. | n.a. | n.a. |
| 60 | 1,574 | 4,324 | n.a. | n.a. | n.a. | n.a. |
| 65 | 764 | 3,634 | n.a. | n.a. | n.a. | n.a. |
| 70 | 798 | 2,833 | n.a. | n.a. | n.a. | n.a. |
| 75 | 311 | 1,931 | n.a. | n.a. | n.a. | n.a. |
| 80 | 266 | 1,072 | n.a. | n.a. | n.a. | n.a. |
| 85 | 193 | 250 | n.a. | n.a. | n.a. | n.a. |
| Not stated | 3 | n.a. | n.a. | n.a. | n.a. | n.a. |
| Total | 71,316 | n.a. | n.a. | n.a. | 1.000 | 51,029 |

NOTES: ${}_5N_x$ values from Bangladesh Census Commission, 1977, Table 1, page 24; value opposite age 85 is open-ended group; $\ell_x$ and ${}_5L_x$ values from Coale and Demeny, 1966:12. Only values necessary for the calculation are given here. Calculation of the sum-of-products term is expedited by writing the $\ell_x$ values on a strip of paper, which may be placed to the left of the ${}_5N_x$ column and moved up as the calculation proceeds. The first sum-of-products term is calculated as 10,842×7,369 + 12,384×7,160 + . . . + 798×250 = 430,588,925; the second is 10,842×7,160 + . . . + 764×250 = 405,068,474. The ${}_5f_a$ values are calculated from Bangladesh Census Commission, 1977, Table 12, page 41. The number of non-orphans is calculated, as indicated in Formula (3c) in the text, as

$$5\frac{{}_5f_a}{{}_5L_a}\sum_{x=0}^{\infty} {}_5N_x \ell_{x+5+a}$$

virtually no information on mortality other than responses to questions on children ever born and surviving. It seems useful to recognize that this information can support an estimate of adult mortality. In populations where more abundant materials are available, the technique may serve as a supplementary source with diagnostic power. If the technique gives an estimate of mortality that is clearly too high, the strong implication is that too few surviving children were reported by mothers, with obvious ramifications for the quality of fertility data. Where direct orphanhood responses are analyzed, it is at least sensible to check the volume of reported orphanhood against that which can be inferred from mothers' own identification of non-orphans and attempt to resolve any differences. □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## APPENDIX

by Griffith Feeney

In the model stable populations of Coale and Demeny (1966) the proportion of persons not maternally orphaned is determined by the expectation of life at birth $\mathring{e}_0$, the rate of increase $r$, and the mean age of the fertility schedule. The $\mathring{e}_0$ value determines the ${}_5L_a$ and $\ell_a$ values in Table 2, and $\mathring{e}_0$ and $r$ together determine the age distribution. The mean age of the fertility schedule determines a fertility schedule (Table XIII, p. 30) that may be applied to the age distribution to obtain the ${}_5f_a$ values in Table 2. Given ${}_5L_a$, $\ell_a$, and ${}_5f_a$, the computation described by Table 2 yields the proportion of persons not maternally orphaned.

Table A1 shows proportions not orphaned in the West model for various values of $\mathring{e}_0$, $r$, and the mean age of the fertility schedule. The female rather than the total age distribution was used, a computational simplification that has no significant effect on the results. The model values used in the computation were not taken from the Coale-Demeny book; rather, they were computed, following the procedure described in Chapter 2 of the book, using several APL functions, in which language the computation was carried out.

Table A1 shows the range of values of proportions non-orphaned to be expected in various populations. The range is consistent with the range of empirical values in Table 1. The value for Malaysia is an outlier in Table 1 and suspect on that account. Examination of the values in Table A1 leaves little doubt that it is seriously in error.

The table also shows the rate at which proportions non-orphaned change with changes in $\mathring{e}_0$, $r$, and the mean age of fertility schedule. This indicates the sensitivity of estimates yielded by the Preston procedure to errors in proportions of non-orphans

It is worth noting that the values in the table are reasonably linear. The proportions in Panel 1 may be represented by $0.455 + 0.00267\mathring{e}_0 + 6.14r$ with a median error of only 0.002. The worst error is for $\mathring{e}_0 = 70$ and $r = 0.01$, for which the value given by the linear approximation exceeds the table value by 0.009. The expression $0.430 + 0.00239\mathring{e}_0 + 6.6r$ works equally well for Panel 2, with a median error of 0.002 and a worst error, shared by three entries, of −0.010. It should be noted, however, that a difference of this magnitude in the proportion not orphaned may correspond to a change of nearly five years in $\mathring{e}_0$.

**Table A1 Proportions of persons not maternally orphaned in Coale-Demeny West female model stable population**

| Expectation of life at birth: $\mathring{e}_0$ | Rate of increase: $r$ 0.010 | 0.015 | 0.020 | 0.025 | 0.030 |
|---|---|---|---|---|---|
| Panel 1: Mean age of fertility schedule = 27 years | | | | | |
| 40 | 0.626 | 0.658 | 0.687 | 0.713 | 0.738 |
| 45 | 0.638 | 0.672 | 0.701 | 0.728 | 0.754 |
| 50 | 0.650 | 0.684 | 0.716 | 0.743 | 0.769 |
| 55 | 0.662 | 0.695 | 0.728 | 0.757 | 0.782 |
| 60 | 0.673 | 0.708 | 0.741 | 0.770 | 0.796 |
| 65 | 0.684 | 0.720 | 0.755 | 0.785 | 0.811 |
| 70 | 0.696 | 0.733 | 0.768 | 0.800 | 0.827 |
| 75 | 0.708 | 0.748 | 0.783 | 0.814 | 0.842 |
| Panel 2: Mean age of fertility schedule = 31 years | | | | | |
| 40 | 0.596 | 0.628 | 0.659 | 0.687 | 0.713 |
| 45 | 0.606 | 0.641 | 0.672 | 0.701 | 0.728 |
| 50 | 0.617 | 0.651 | 0.685 | 0.715 | 0.742 |
| 55 | 0.625 | 0.662 | 0.696 | 0.727 | 0.755 |
| 60 | 0.634 | 0.672 | 0.707 | 0.740 | 0.768 |
| 65 | 0.644 | 0.683 | 0.720 | 0.752 | 0.782 |
| 70 | 0.653 | 0.694 | 0.732 | 0.765 | 0.795 |
| 75 | 0.665 | 0.707 | 0.745 | 0.781 | 0.812 |

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