Child Survivorship Estimation: Methods and Data Analysis

The past 20 years have seen extensive elaboration, refinement, and application of the original Brass method for estimating infant and child mortality from child survivorship data. This experience has confirmed the overall usefulness of the methods beyond question, but it has also shown that their application is anything but routine.

It is never sufficient merely to calculate estimates from a single set of data. Estimates must be analyzed in relation to other relevant information before useful conclusions about the level and trend of mortality can be drawn. This data analysis, unlike the calculation of estimates, cannot be reduced to mechanical routine. It requires an ability that comes only with experience, the broader and more catholic the better.

This article aims to illustrate the importance of data analysis through a series of examples, including data for the Eastern Malaysian state of Sarawak, Mexico, Thailand, and Indonesia. Specific maneuvers include plotting completed parity distributions and "time-plotting" mean numbers of children ever born from successive censuses. A substantive conclusion of general interest is that data for older women are not so widely defective as generally supposed.

by Griffith Feeney

MORTALITY estimates based on child survivorship data will be with us for many decades to come. The only definitively superior source is a vital registration system that captures essentially all births and infant deaths. Such systems do not exist for much of the world's population—not in China, for example, nor in most countries in Asia or Africa, nor in many countries in Latin America—and their development will require efforts over many decades. Thus we will need to rely on child survivorship estimation and other indirect methods, as well as direct methods based on survey data, for the indefinite future.

The past two decades have seen extensive elaboration and refinement of the original Brass methods (Brass 1961; Brass et al. 1968). Indeed, the casual user is likely to be confused by and vexed at the variety of methods to choose from. We have also acquired an extraordinarily broad and varied experience with application. Although this experience has confirmed the overall usefulness of the methods beyond question, it has also shown that their use is anything but routine.

We have learned to distinguish between the various estimates generated in application and the conclusions that eventually result from analyzing these estimates. At best, we may conclude that a particular set of estimates represents the detailed level and trend of mortality. At worst, we may conclude that the data in question are so defective, or conceivably that particular circumstances so invalidate every available method, that no conclusions regarding the level and trend of mortality are possible. Most applications fall somewhere between these two extremes. In the nature of the situation, conclusions concern not only mortality in the population, but errors in the data and the validity of the various methods.

The necessity for data analysis emerges most clearly when different sets of data for the same population yield discrepant results,

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proving that at least some of the estimates are defective. How we proceed in such cases depends on the particular circumstances. Data analysis, unlike the calculation of estimates, is not reducible to mechanical routine. It benefits from knowledge of indefinite extent: knowledge of methods, of empirical patterns, of local context.

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It requires an ability that comes only with experience, the broader and more catholic the better. The only way to learn data analysis is to do it, to disregard methods as such and apply oneself to learning as much as possible about particular cases. The appropriate medium is thus the case study, in which the various possible maneuvers come to life as they are used to extract real conclusions from real data.

Proficiency in data analysis requires some understanding of the logic of the estimation procedures, an obvious point that has nonetheless been too often slighted in practice. No doubt this neglect is due partly to the difficulty of the methods and their profusion. Ironically, however, it is probably due also to Brass's ingenious "multiplier" method and the regression variants later introduced by Sullivan (1972) and Trussell (1975). The multiplier method is a wonderfully rapid and remarkably accurate computational shortcut that avoids the labor of direct solution of the estimation equations. An unfortunate side effect is the possibility of producing estimates without any understanding of the formal demographic structure of the data or the logic of the estimation procedure. Regression methods, unobjectionable in themselves, compound the danger by introducing a purely statistical procedure for computing multipliers.

This article aims to illustrate the importance of data analysis and to suggest several overlooked possibilities, through a series of examples. Beginning with a particularly intractable set of data for Sarawak, one of the two eastern states of Malaysia on the island of Borneo, I suggest how to move from a set of severely discrepant estimates to several reasonably defensible conclusions. I then discuss two simple graphical procedures for diagnosing data quality, illustrating them with applications to Sarawak, Mexico, and Thailand. The examples cannot be more than suggestive, for a thorough analysis of any one of the cases would require a paper to itself.

Nearly all work on child survivorship estimation to date has dealt with data classified by age of mother. Future work would probably do well to emphasize alternative

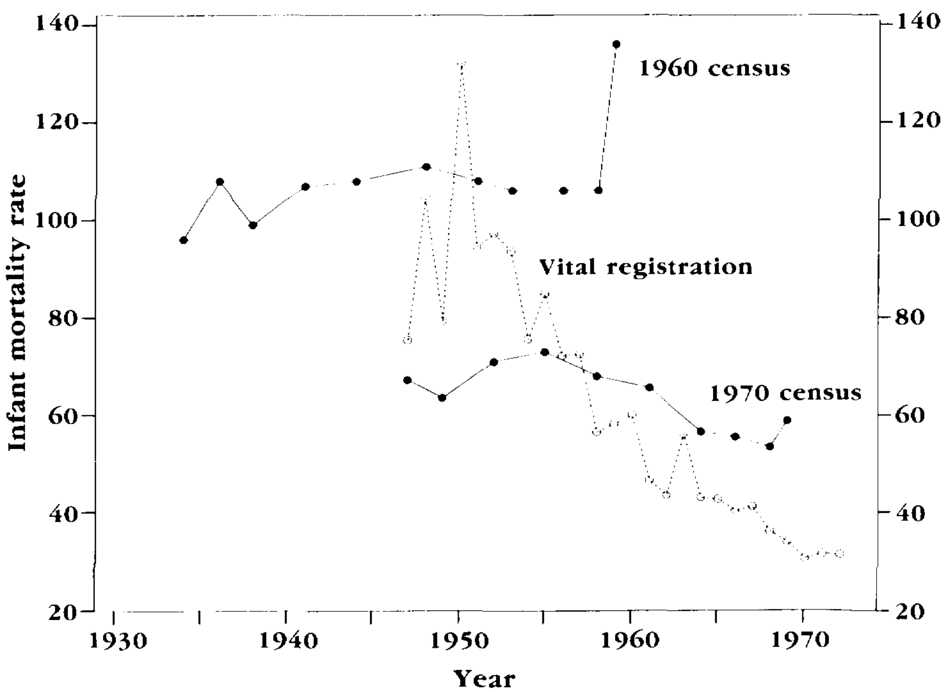

Figure 1. **Infant mortality rate estimates for Sarawak, East Malaysia, 1935–70**

Sources: Child survivorship estimates from 1960 and 1970 censuses: Table 1 of this article. Infant mortality rates from vital registration: United Nations, *Demographic Yearbook* (1953, 1967, 1975).

classifications, following Sullivan's early initiative with data classified by duration of marriage (1972). Of particular importance is the recent work of Fernandez Castilla (1989), which shows how to use child survivorship data to analyze mortality differentials by family size. The penultimate section of the current article presents a brief example comparing estimates for Indonesia based on data classified by age with estimates based on data classified by year of marriage.

The Sarawak data of 1960 and 1970

Sarawak provides an excellent example of the importance of comparing estimates from various sources and of the kind of analysis that is required when these estimates indicate problems with the data or the estimation procedure. Child survivorship data by five-year age groups of mother are available from the 1960 census, taken under British auspices, and from the 1970 census of Malaysia, Sarawak being one of the two eastern states of the country. Infant mortality rates are also available from vital registration data, though both birth and death registration is incomplete to an unknown but probably substantial degree.

Table 1. **Child survivorship data (by age) and infant mortality rate (IMR) estimates: Sarawak, censuses of 15 June 1960 and 25 August 1970**

Age	Women	CEB	CS	IMR	Time
1960 census					
15–19	34,700	8,630	7,420	136	59.1
20–24	28,808	38,630	33,303	106	57.6
25–29	29,372	83,460	70,457	106	55.7
30–34	23,699	94,424	78,467	106	53.5
35–39	20,957	99,273	80,893	108	50.8
40–44	18,399	91,467	72,598	111	47.7
45–49	13,369	66,477	51,805	108	44.4
50–54	12,403	56,611	42,891	107	41.2
55–59	6,812	30,648	22,969	99	38.5
60–64	7,618	31,470	22,172	108	36.0
65–69	3,692	14,996	10,510	96	34.0
1970 census					
15–19	46,619	8,911	8,371	58.8	69.4
20–24	36,614	50,801	47,218	53.4	67.9
25–29	29,806	85,444	78,318	55.5	66.0
30–34	24,830	100,832	91,470	56.6	63.8
35–39	23,421	116,918	103,392	65.6	61.1
40–44	19,652	101,352	88,066	68.0	58.1
45–49	16,119	83,998	70,974	73.0	54.8
50–54	14,860	70,131	58,347	71.0	51.8
55–59	9,329	42,910	35,625	63.6	49.1
60–64	9,122	37,384	29,929	67.3	46.7

Sources: 1960 census: *Sarawak: Report on the Census of Population Taken on 15 June 1960,* Table 16, p. 233, Women by addition of numbers of single and ever-married women. 1970 census: unpublished tabulations, Department of Statistics, Kuala Lumpur, Malaysia.

CEB—children ever born.

CS—children surviving.

Figure 1 shows infant mortality rates estimated from both censuses together with rates from vital registration. Table 1 presents the child survivorship data and estimates. The vital registration figures are from the United Nations *Demographic Yearbook* series. The estimates were obtained by direct solution of the estimation equations as described in Feeney (1980).

We see at once that the estimates from the two censuses and from vital registration are radically inconsistent. The 1960 census estimates show infant mortality approximately constant at slightly over 100 per thousand through the late 1950s. The 1970 census estimates show slightly declining mortality, but with a level during the 1950s of less than 70 per thousand, some 30 percent below the level indicated by the 1960 census. Both series of estimates turn up sharply just before the census date, behavior that may be safely attributed to the bias introduced by differential infant mortality by age of mother. The vital registration figures are much lower than the 1970 census estimates during the 1960s and between the 1960 and 1970 census estimates before 1958. They decline sharply over the period as a whole.

Either infant mortality was constant during these decades, or it was changing. Suppose that we knew that it was constant. What level would we infer from the data in Figure 1?

If the level were that indicated by the 1970 census, the 1960 census must have overstated proportions of deceased children by a factor of nearly two. Since the weakness of child survivorship data is a tendency for deceased children to be underreported, this conclusion is most improbable. We may with confidence rule out the possibility of constant mortality at the level of the 1970 census, a conclusion supported also by the relatively low level that would be so indicated.

If we knew that infant mortality rates were constant, then, we would take the level to be that indicated by the 1960 census, slightly over 100 per thousand. To defend this conclusion, however, we would have to explain both why the estimates from the 1970 census are so much lower and why the vital registration figures are declining if infant mortality was in fact constant. It is possible that the 1970 census did a poorer job than the 1960 census of securing information on deceased children. The census operations were carried out by different authorities, and therefore the default supposition that they were conducted similarly, and so should give similar results, does not apply. Nonetheless, in the absence of any particular reason to suppose a poorer census in 1970, we would be inclined to reject this conclusion. Although the decline in the registration values might be due to an increase in birth registration completeness or to a decline in the completeness of registration of infant deaths, the magnitudes necessary to achieve the result would be most implausible.

Since the supposition that infant mortality was constant leads to unsatisfactory conclusions, we explore the alternative, that mortality was changing. The vital registration series in Figure 1 shows year-to-year fluctuations that are probably real, as we do not expect registration completeness to vary erratically from one year to the next. These fluctuations cannot appear in the child survivorship estimates, however, because they are absent in the child survivorship data, which average survivorship over many cohorts.

To see this, consider the fundamental tautology

$$Q = \int c(x)q(x)dx \qquad (1)$$

where Q is the proportion of some group of children born before time t who are surviving at time t, $c(x)$ is the distribution of these children by time of birth, measured backward from time t, and $q(x)$ is the proportion of children born at time $t-x$ who die before time t. The shape of the function $c(x)$ for the children ever born to various age groups of women is shown in Brass et al. (1968: 110). Year-to-year fluctuations in mortality cannot be reflected in Q because the various cohorts represented, with the exception of those born just prior to time t, will all experience both years of high mortality and years of low mortality.

Information on these fluctuations is thus lost at the level of the data, independently of any particular estimation procedure. Although we can estimate trends, up or down, the estimated trends are necessarily smoothings of the underlying annual series if this series contains year-to-year fluctuations.

Both the vital registration series and the between-census comparison of the child survivorship estimates indicate a long-term decline in mortality. If this is in fact what happened, how do we explain the various discrepancies in the picture?

Suppose that the 1970 reports of child survivorship for women in the younger age groups are accurate, but that reports for the older age groups deteriorate progressively, with women in the oldest age groups failing to report close to half of their deceased children. This is qualitatively plausible, though the magnitude of the effect is severe. The corresponding correction of the 1970 estimates would rotate the plot upward from the right end of the series, bringing the estimates for the older age groups at the 1970 census into approximate correspondence with the estimates from the younger age groups at the 1960 census.

These corrected child survivorship estimates would lie well above the vital statistics values, but this could be explained by underregistration of infant deaths, relative to births, which we expect in any case. The vital registration values and the child survivorship estimates would indicate similar rates of decline in this case, a consistency that lends support to the interpretation.

If we were to conclude the analysis at this point, we would have reasonably sound indications for the following conclusions. (1) Infant mortality rates in Sarawak were declining during the 1950s and 1960s. (2) The level of mortality was 50–60 per thousand in the late 1960s and 100–110 per thousand in the late 1950s, indicating a rapid decline of about five deaths per thousand per year. (3) Deceased children were progressively underreported with increasing age of mothers in the 1970 census, nearly half of all deceased children being unreported by the oldest women. (4) Infant mortality rates based on vital registration are low by something like 50 percent, indicating this order of incompleteness of infant deaths relative to births.

It is difficult to say just how much confidence would attach to these results, and of course different degrees are appropriate to different conclusions. We would probably be fairly confident that infant mortality rates were in fact declining, that reporting of deceased children deteriorates with mothers' age, and that rates based on vital statistics are too low owing to underregistration. We would have less confidence in magnitudes. Nothing in our analysis thus far rules out the possibility that the child survivorship estimates for the younger age groups are too low, for example. Certainly we would not expect any magnitude to be accurate to better than plus or minus 10 percent, so that an infant mortality estimate of 55 per thousand means anywhere between 50 and 60 deaths per thousand. Greater precision may not be attainable with these data, and it certainly is not attainable without further analysis.

The modesty of these results should not be allowed to obscure how much progress we have made with a particularly intractable set of data. Indeed, the point of departure, the data plotted in Figure 1, reflects several fundamental results and decisions that have allowed us to go much further than we otherwise could have.

The first requisite is the ability to date the child survivorship estimates obtained from each age group of mothers. Without the ability to date, we lose the time dimension in Figure 1 and the possibility of comparing the child survivorship estimates either with themselves or with the vital statistics series. The problem of dating was taken up by Brass (1975: 57–59), but it was solved effectively only with work by Palloni (1977, 1979, 1980, 1981); Preston and Palloni (1978); Palloni and Heligman (1986); and myself (Feeney 1975a, 1976b, 1977, 1980, 1982), pursuing lines similar in intent though different in detail. Brass and Bamgboye (1981) have subsequently given an elegant new solution (see also Brass 1985).

We must also use the data for each age group to estimate a common statistic, for only in this way are comparisons possible. Equation (1) shows that to derive life table mortality statistics from child survivorship data we must first be able to estimate the time distribution of children ever born $c(x)$. Brass developed both the general procedure for doing this and the original implementation based on his fertility polynomial, results given a useful exposition by Retherford (1979). We may now attempt to solve equation (1) for the life table schedule $q(x)$. To obtain a solution, however, we must assume that $q(x)$ conforms to some known one-parameter model life table family, that is, that

$$q(x) = q_M(x;w) \qquad (2)$$

for some w, where $q_M(x;w)$ denotes $1-l_x$ in the model life table family identified by the parameter value w. Substituting (2) in (1) gives

$$Q = \int c(x) q_M(x;w) dx, \qquad (3)$$

which will have a unique solution for w on very weak assumptions about the form of the model schedules.

In solving equation (3) we are solving for the model life table parameter w, which determines a particular model life table and hence any particular statistic in this life table. The widespread use of Brass's multiplier method for the calculation of estimates has obscured this generality. The multiplier method provides a convenient way to solve equation (3), and there is no reason not to avail ourselves of it. In doing so, however, we should not forget that the resulting $q(x)$ values may be translated to estimates of the parameter w and hence to any life table statistic we choose.

The extent to which users of these methods have failed to execute this translation is remarkable, for without it the dating result is of little use. To know $q(1)$ at one time, $q(2)$ at some earlier time, $q(3)$ at some earlier time yet, and so on, tells us nothing about the trend of mortality. In some cases this failure may be due to ignorance, to rote application of the multiplier shortcut without understanding what it accomplishes. In other cases it reflects a misplaced fastidiousness having to do with the robustness of various life table statistics. Brass's $q(x)$ values are probably more robust than any other equally convenient statistics, and their translation to any common standard loses some of this robustness. The con-

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sistency checks allowed by translation to a common standard are so powerful, however, that one should not fail to make them.

The infant mortality rate is probably the least robust of any statistic we are likely to choose and should on this ground be avoided. If we do not use the infant mortality rate, however, we lose the comparison with the vital statistics series, for although infant mortality rates are readily available from vital registration data, $q(x)$ values are not.

Here again, the value of the comparison with the vital registration series is so great that it would be foolish not to make it. It is important because it provides evidence that is both independent of and different in kind from the child survivorship estimates and because the consistency of the rate of decline suggested by the vital statistics series and the between-census comparison of the child survivorship estimates provides important evidence for our rough but useful picture of rapidly declining infant mortality.

That child survivorship data for older women are frequently defective has led to an undue readiness to dismiss them altogether. There are many cases in which data for older women, though undoubtedly imperfect, provide useful information.

Finally, we would lose a good deal of the picture in Figure 1 if we failed to make estimates for older as well as younger age groups of women. Child survivorship data for older women are frequently defective, and this has lead to an undue readiness to dismiss them altogether. Sullivan (1972) provides an extreme example in giving multipliers only for women under age 30. I have argued elsewhere (Feeney 1987: 361) that this is a mistake, but the point bears repeating. There are many cases in which data for older women, though undoubtedly imperfect, provide useful information.

Estimates for Costa Rica based on data for women well over age 50 compare nearly as favorably with vital registration as data for young women (Feeney 1980: 124). Estimates for Peninsular Malaysia are too low for older women, but no more so than for younger women (Feeney 1980: 125). The problem here turns out to be the Chinese subpopulation, in which women of all ages greatly underreport deceased children. The same phenomenon is observed in South Korea (Cho and Feeney 1976).

The operative factor is probably a culturally-based reluctance to report deceased children. It is certainly not a matter of memory lapse. For the Malay and Indian subpopulations of Malaysia, the child survivorship estimates for older women compare just as favorably with vital statistics figures as the estimates for younger women. These are only a few of many cases that might be adduced.

The analysis of the Sarawak data given above is of course only a bare beginning. A thorough analysis could go much further in various directions. We would certainly want to examine the child survivorship data from the 1947 and 1980 censuses, including perhaps a look at more detailed "community group," (i.e., ethnic group) classifications.

A parallel analysis of mortality in Sabah, the other East Malaysian state, might prove instructive. The area studies literature could be reviewed for broad changes in social, economic, and public health conditions consistent (or not) with a rapid decline in infant and child mortality. A study of the administration of the vital registration system over the period in question would be useful to the assessment of the level and trend of underregistration, though this would probably require recourse to unpublished government documents and interviews with local officials.

Looking at completed parity distributions: Sarawak and Mexico

One way to carry the Sarawak analysis further is to scrutinize the data on children born and surviving for evidence of inferior reports for older women. The 1960 census tables give numbers of ever-married women by age (10–14, . . . , 40–44, 45+) and number of children ever born (0, 1, . . . , 9, 10+) cross-classified by literacy and two ethnic categories, "indigenous" or "Chinese." Figure 2 plots the distribution of women 40–44 in these four groups by the reported number of children ever born.

We see at once that the shape of the parity distributions for the indigenous group is completely un-

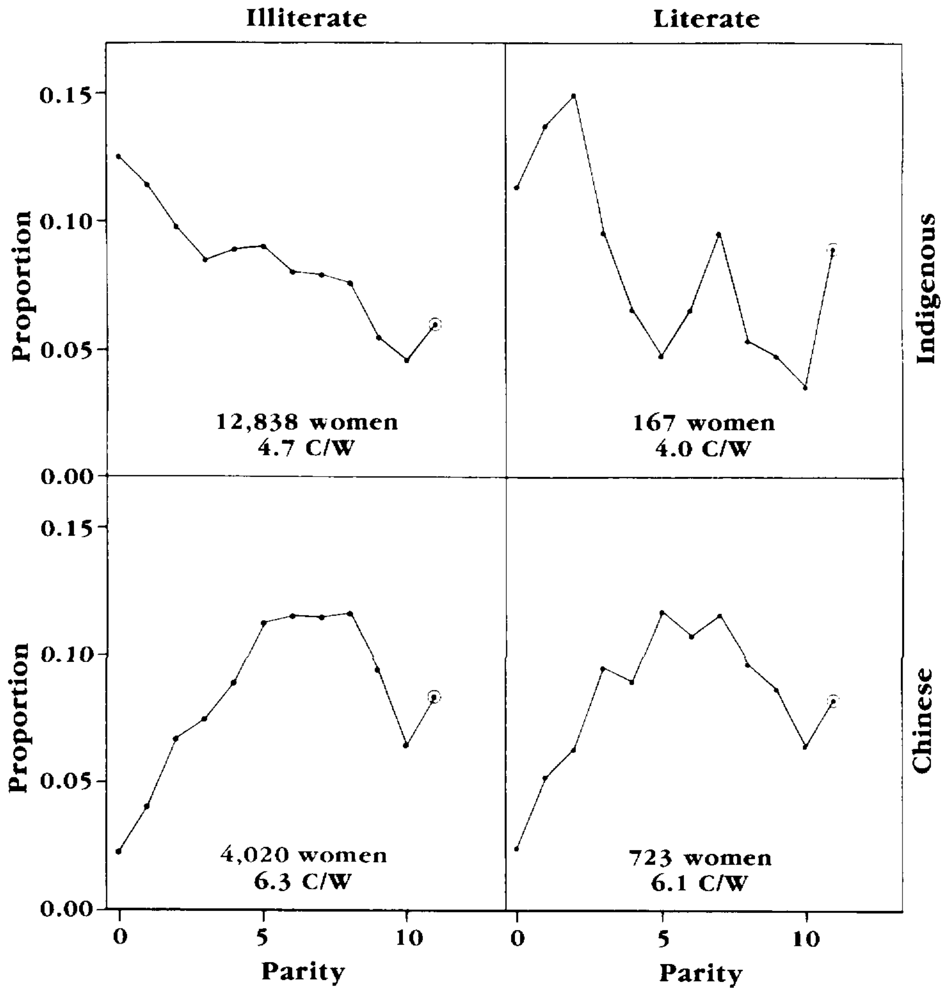


Figure 2. **Parity distributions for ever-married women aged 40–44, 1960 census of Sarawak, by literacy and "Indigenous" or "Chinese" ethnicity**

Source: Sarawak: Census of Population (1962).

reasonable, indicating serious deficiencies in the reporting of children ever born. Since indigenous women constitute some three quarters of the population, they dominate the whole. As a matter of pure logic, of course, inaccurate reporting of numbers of children ever born does not imply inaccurate figures on child survivorship, for if children ever born and surviving children are both underreported to the same extent, the calculated proportion of deceased children will be unaffected. Evidence of serious misreporting of children ever born nonetheless casts doubt on the reliability of the calculated proportions of deceased children. As far as it goes, then, the parity distributions in Figure 2 confirm the indirect inference of problems with data for older women drawn from Figure 1.

It is notable that the important variation in Figure 2 is between indigenous and Chinese women, with no obvious variation by literacy. Whatever is going wrong with the data for the indigenous women, it is evidently independent of literacy.

The distributions for the Chinese women do not show the obviously defective pattern of the indigenous women. Are the child survivorship data better for the Chinese subpopulation? A quick calculation shows that the median infant mortality rate estimate based on the 20–24 through 40–44 age groups is 26 per thousand. This is an unreasonably low value even if we assume that the Chinese are an exceptionally privileged minority.

Evidently numbers of children ever born are underreported by the omission of large numbers of deceased children despite the relatively plausible appearance of the parity distributions. Strong supporting evidence for this conclusion is afforded by case of the Chinese in Peninsular Malaysia.

A distribution of completed parity that looks unreasonable is a good indicator of reporting problems. A reasonable looking distribution is not an indicator of good reporting, however, because distributions by number of surviving children, which are what we would observe if no deceased children were reported, have a shape similar to distributions by number of children

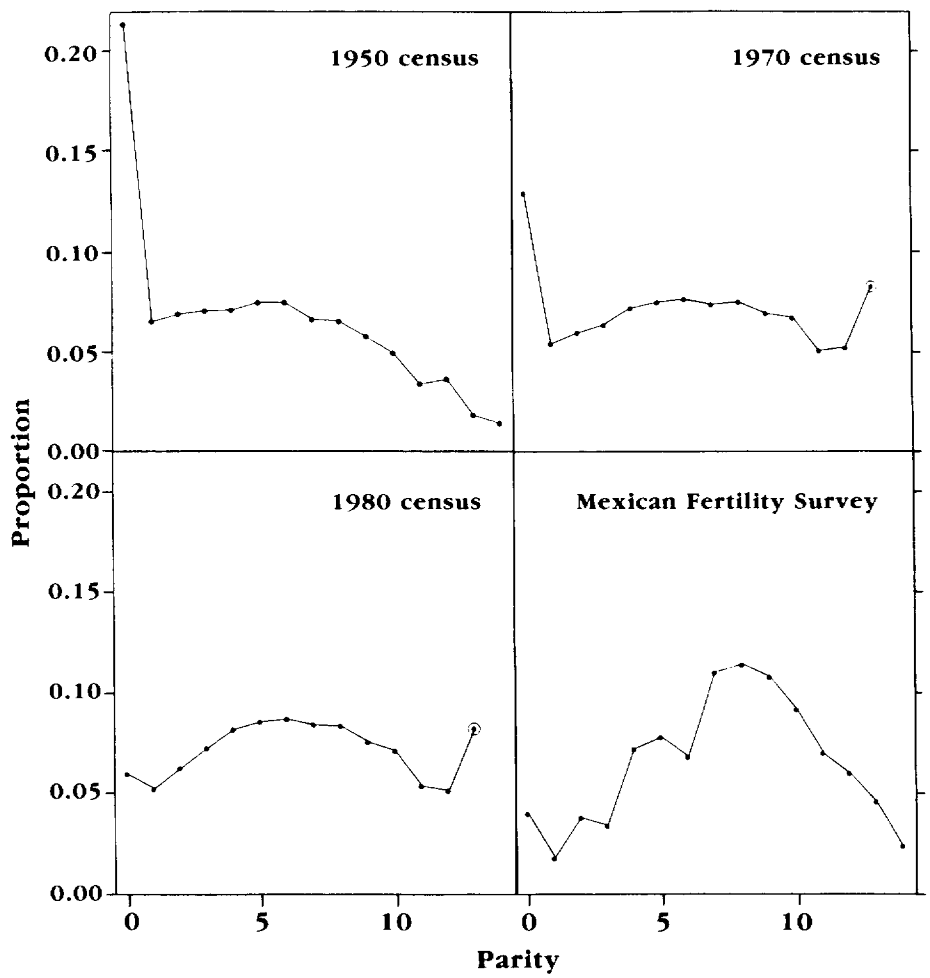


Figure 3. **Completed parity distributions for Mexico, from the censuses of 1950, 1970, and 1980 and from the Mexican Fertility Survey**

Sources: Mexican censuses of 1950, 1970, and 1980. Mexican Fertility Survey data from Lutz (n.d.).

ever born. Negative indications are useful, however, and looking at parity distributions may yield other insights, as the example of Mexico shows.

Children-ever-born data are available from the Mexican censuses of 1950 through 1980 and from the Mexican Fertility Survey. The distributions of women aged 45–49 by number of children ever born for the 1950, 1970, and 1980 censuses and for the survey are shown in Figure 3. The distribution for the 1960 census, not shown, is similar to that for the 1970 census.

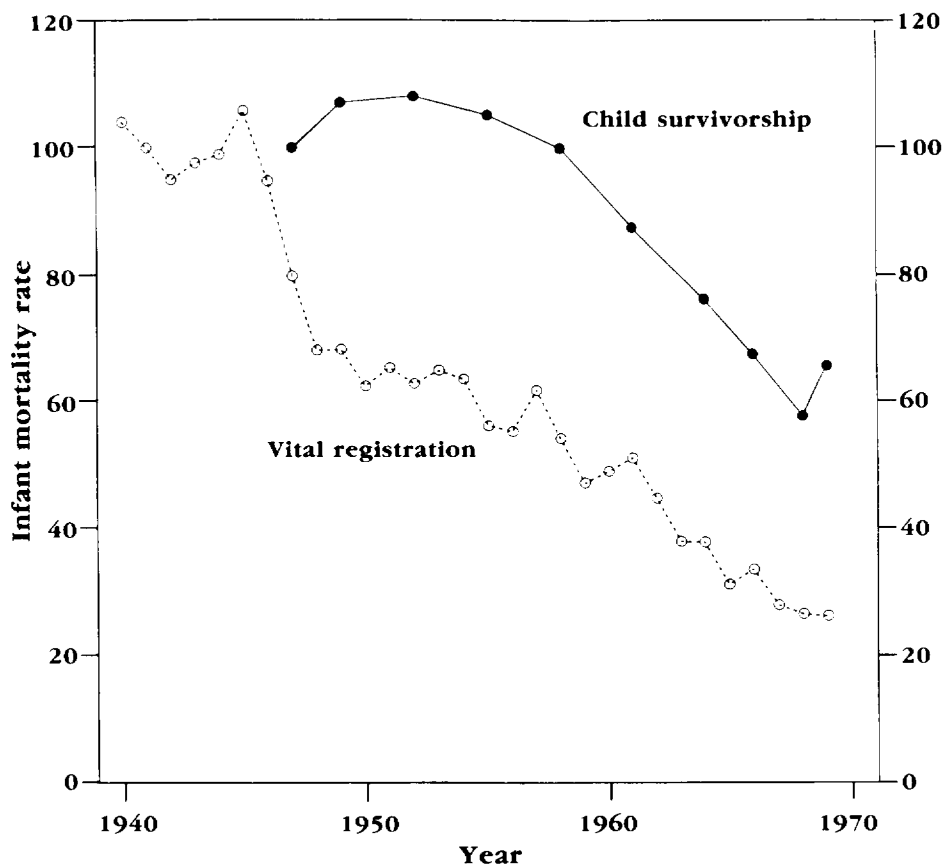
The distributions for 1950 and 1970 are highly atypical in two respects, the high proportions of women shown as childless, and the flatness of the rest of the distribution. The 1980 distribution shows a flatness only slightly less pronounced but a reasonable, though high, proportion childless.

These judgments obviously depend on familiarity with empirical patterns, which cannot be discussed even briefly here. Data are available in abundance in the 1981 United Nations *Demographic Yearbook* as well as in primary sources. Models should prove useful here as well, but the little work done thus far (Brass 1958) seems not to have been particularly useful in the analysis of such patterns.

Inspection of the census tables shows that those for 1950, 1960, and 1970 contain no entry for "children ever born not stated." The table for the 1980 census does include "children ever born not stated" entries, however, and indicates that 6.6 percent of women aged 45–49 did not report number of children ever born. If we add these women to those reporting no

Figure 4. **Infant mortality rates estimated from 1970 census child survivorship data and calculated from vital registration data: Thailand, 1940–70**

Sources: Child survivorship estimates: Table 2 in this article; registration values: United Nations, *Demographic Yearbook* (1953, 1967, 1975).



children ever born, 5.5 percent, we obtain 12.1 percent, slightly below the 14.7 percent reported as childless in the 1970 census. Grouping together women reporting zero children ever born and women not reporting children ever born in the 1980 census thus shows a pattern virtually identical to that of the earlier censuses, in which no "not stated" category is given.

We may safely conclude that the high childlessness indicated by the earlier censuses is spurious, reflecting the grouping of not stated and zero parity cases. Although similarly high rates of childlessness are observed elsewhere, they generally reflect a high incidence of either nonmarriage or sterility due to venereal disease, both conditions that would be unlikely to disappear in the decade between the 1970 and 1980 censuses.

The flatness of the distributions is not so readily interpreted but probably indicates some form of misreporting. Weak indirect evidence for this inference is provided by the tendency of the distributions to become less flat over time, which is consistent with improvements in reporting at each new census. Stronger and more direct evidence is provided by the distribution from the Mexican Fertility Survey (data from Lutz, n.d.: 44), which would be expected to improve on the census results in this respect. This distribution, shown in the lower right corner of Figure 3, is irregular owing to small numbers of women but shows a more typical shape than any of the census distributions.

Time plots of children-ever-born data: Thailand

Figure 4 shows child survivorship estimates from the 1970 census of Thailand (data from which are shown in Table 2) plotted together with vital registration figures. It is evident that the vital registration figures are much too low, so that the child survivorship estimates improve greatly on the registration data. The child survivorship estimates are themselves low, however, as shown by comparison with estimates from the 1974 Survey of Population Change (Knodel and Chamratrithirong 1978: 23). The apparent increase in mortality just before 1970 is due to the estimate from the 15–19 age group. The pattern is typical, and we can therefore disregard this estimate. The five preceding points, based on women of ages 20–45, rise rapidly as we move back in time, nearly doubling in a decade. Given the rapid rate of decline indicated, about five deaths per thousand per year, it is unlikely that reporting of deceased children for the oldest women in this age range is much inferior to the reporting of the youngest women, though the comparison with the Survey of Population Change data suggests that both groups are underreporting deceased children. The estimates for women over age 45 show a leveling off that may well be due to deteriorating reporting by those women.

Direct examination of the children-ever-born data for older women is illuminating. The parity distributions show no indication of faulty reporting; but as we have seen, this finding is inconclusive. Children-ever-born data were collected in the 1960 and 1980 censuses as well as in the 1970 census, however, and the time-plotting device introduced in Feeney (1988: 7.1.20) provides a useful test of the quality of data for older women.

In its simplest form, the technique consists of plotting the parity data for older women in any age group as though all children were born at exactly age 25. Mean number of children ever born to women aged 45–49, for example, is plotted at the time $t-(47.5-25)$, where t is the time of the census and 47.5 is the mid-point of the age group.

If women report children ever born completely, the plots from the three censuses will tend to coincide. Discrepancies will be due either to the dating procedure or to mortality selection effects. The dating procedure will work well for comparisons between censuses so long as period fertility does not fluctuate sharply during the period in question. Mortality selection effects come into play only in proportion to the extent of mortality between censuses, which does not become large until older ages. The analysis of children-ever-born data

Table 2. **Child survivorship data (by age) and IMR estimates: Thailand census of 1 April 1970**

Age	Women (000s)	CEB (000s)	CS (000s)	IMR	Time
15–19	1,864	245	230	65.6	69.2
20–24	1,262	1,367	1,268	57.6	67.9
25–29	1,085	2,795	2,521	67.5	66.1
30–34	1,040	4,175	3,671	76.2	63.9
35–39	930	4,932	4,199	87.4	61.4
40–44	741	4,547	3,718	99.8	58.4
45–49	577	3,651	2,886	105.0	55.1
50–54	465	2,910	2,222	107.9	51.9
55–59	379	2,318	1,718	106.9	49.0
60–64	301	1,761	1,284	99.8	46.6

Source: Unpublished tabulations, 1970 census, courtesy of the National Statistical Office, Thailand. Tabulations include never-married women and ever-married women reporting both number of children ever born and number of children surviving.

CEB—children ever born.

CS—children surviving.

Figure 5. **Time plot of mean number of children ever born, based on censuses of Thailand, 1960, 1970, and 1980**

Source: Table 3 in this article.

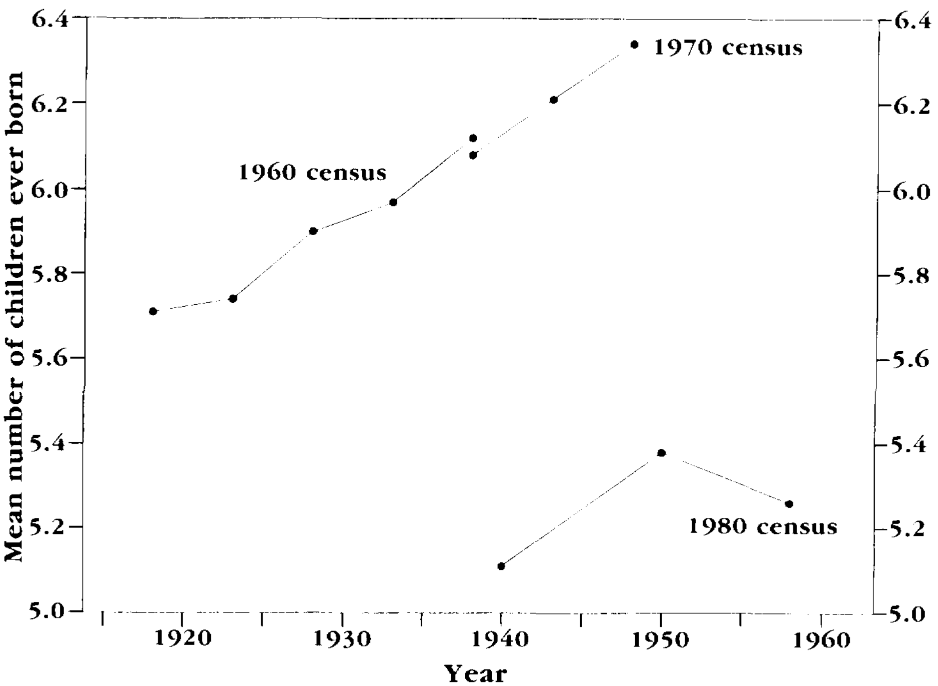


Table 3. **Mean number of children ever born to women of ages 45 and over, by age group: Thailand, Whole Kingdom, censuses of 25 April 1960, 1 April 1970, and 1 April 1980**

Age group	Mean CEB	Year
1960 census		
45–49	6.12	1938
50–54	5.97	1933
55–59	5.90	1928
60–64	5.74	1923
65–69	5.71	1918
1970 census		
45–49	6.34	1948
50–54	6.21	1943
55–59	6.08	1938
1980 census		
45–49	5.26	1958
50–59	5.38	1950
60–69	5.11	1940

Sources: Thailand Population Census: 1960, Whole Kingdom. Census date given in Preface. Mean number of children ever born from Table 14. *1970 Population & Housing Census: Whole Kingdom.* Census date given in Introduction. Mean number of children ever born from Table 7, p. 20. *1980 Population & Housing Census: Whole Kingdom.* Census date given on p. 29. Mean number of children ever born from Table 7, pp. 30–31.

CEB—children ever born.

from the Japanese censuses of 1950, 1960, and 1970 presented in Feeney (1990) suggests that, given low mortality, these discrepancies are very minor, no more than a few percent. Complete reporting by older women of children ever born will thus yield consistent time plots from successive censuses.

Figure 5 plots the mean number of children ever born to women over age 45 from the three Thai censuses (data shown in Table 3). The five points from the 1960 census are the mean numbers of children ever born to women in the age groups 45–49 through 65–69. The three points from the 1970 census are mean numbers of children ever born to women in the age groups 45–49 through 55–59. The 1980 census grouped data for women over age 50 into 10-year age groups; thus the rightmost point is for women 45–49, and the points to its left are for women 50–59 and 60–69. Since older age groups correspond to older cohorts, moving from younger to older age groups corresponds to moving back in time.

If we look at either the 1960 or the 1970 census alone, we see declining mean parity with increasing age of women, suggesting deteriorating reporting. When we put the data from the two censuses together, however, dating and plotting them, we find that they are very consistent, suggesting that the declines are due in fact to increasing fertility. The indication is that the period total fertility rate in Thailand rose from 5.7 children per woman around 1920 to 6.3 children per woman around 1950.

The data provide only an indication of the level and rate of increase of fertility during these decades, but the evidence that fertility was increasing is quite strong. Though certainly not definitive, the indication is valuable in that it refers to a period for which there are few alternative sources.

Mean parity for women aged 55–59 at the 1970 census is 0.04 children per woman below mean parity for the same cohort at the 1960 census, when they were ten years younger (Table 3). This may be due to increasing underreporting of children ever born with increasing age or to mortality selection, but in either case it is minor in relation to the overall increase in fertility indicated.

As striking as the consistency of the data from the 1960 and 1970 censuses is the inconsistency of the data from the 1980 census, which indicate a level of fertility fully one child per woman less than the earlier censuses. The inescapable conclusion is that something went seriously wrong with the children-ever-born question in the 1980 census.

We would expect the child survivorship data to be affected as well. The Institute for Population and Social Research (1985: 15–17) and Porapakkham (1986: 18–21) show that child survivorship estimates from the 1980 census fall below both those of the 1970 census and the Survey on Population Change results. The 1987 Demographic and Health Survey similarly estimates levels substantially above those estimated from the 1980 census child survivorship data (Chayovan et al. 1988: 90).

The analysis of Figure 5 thus yields three reasonably solid conclusions: (1) the children-ever-born data for the older women in the 1960 and 1970 censuses were evidently quite good; (2) fertility in Thailand was rising slowly during the first half of this century; and (3) something went seriously wrong with the 1980 children-ever-born data.

Child survivorship data other than by age: Indonesia

Although most child survivorship estimation to date has been done using data for women in standard five-year age groups, the principles expressed in equations (1–3) and the corresponding dating equations are general and yield estimates whenever it is possible to estimate the time distribution of children ever born $c(x)$. Sullivan (1972: 89) explored the use of data classified by duration of marriage. The time distribution of children ever born in this case may be estimated by a simple imitation of Brass's procedure for data classified by age (Feeney 1975b: 7–9). Sullivan's use of regression to compute multipliers does not require this estimation and so tends to obscure the logic of the estimation procedure.

Child survivorship data occur in other forms as well. The case in which the children-ever-born and surviving questions are addressed to women who have a birth during a given period is explored by Brass and Macrae (1984, 1985). A question on date of last live birth together with a question on the survivorship of this birth provides a particularly easy case, since the time distribution of children ever born is degenerate. Such data are available for several censuses and surveys in Indonesia (Das Varma 1983), though problems arise owing to nonreporting of year of last live birth, and perhaps also to a tendency to report year of birth of youngest surviving child rather than year of last live birth.

A question on the number of births in the year prior to a census or survey combined with a question on survivorship of these births provides a closely related alternative (Johnson 1982). Fertility surveys that include questions about birth histories generally obtain direct information on the survivorship at the time of the survey of the children recorded, whence we may compute child survivorship statistics for children born each year prior to the survey.

In this case also the time distribution of children ever born is degenerate. We simply match the proportion of surviving children Q with an appropriate $1-L_x$ value in a one-parameter model life table family to identify the estimated life table. An extension of this procedure, a variation of which is discussed below, makes it possible in principle to estimate annual trends of mortality without any assumption on the form of the trend (Macura 1982).

It seems both remarkable and unfortunate that Sullivan's initiative in estimating child survivorship with data classified by duration of marriage has not been more vigorously pursued.

In retrospect it seems both remarkable and unfortunate that Sullivan's 1972 initiative with data classified by duration of marriage has not been more vigorously pursued. One important advantage of using child survivorship by marriage duration seems not to have been clearly recognized at the time. Age-based estimates for young age groups are seriously biased by differential infant and child mortality by age of mother. This bias usually renders data for the 15–19 age group useless for mortality estimation, but the bias for the 20–24 age group can be serious as well, as indicated by Sullivan and Wilson (1982) in the case of Indonesia, and more generally by Fernandez Castilla (1989).

Since estimates from these age groups refer to the several years immediately preceding the census or survey, we are left without estimates for recent years, often the period we are most interested in. One possibility, explored in the case of Bangladesh by Ewbank (1982) and systematically developed in Fernandez Castilla (1989), is to correct for the bias by using additional information or models. Another is to classify women by duration of marriage, aggregating women of all ages who marry during a given time period, which may be expected to reduce the bias by attenuating the concentration of very young women in low-duration groups.

The recommended tabulation for child survivorship data by age of marriage is, for women reporting both children ever born and children surviving, the number of women classified by completed years of marriage and the number of children ever born and surviving to women in each of these duration groups. The restriction of the tabulation to women reporting both children ever born and children surviving eliminates biases due to differential nonresponses to the two questions (Feeney 1976a).

If the census or survey obtains date, rather than duration, of marriage, it may be desirable to replace the duration-of-marriage classification by year of marriage. This would yield the same result if the census or survey were conducted at year's end. Otherwise it will require some adjustment in the $q_M(x;w)$ values in equation (3) to allow for nonsurvival during the year in which the census or survey is taken.

Table 4 illustrates the corresponding estimation procedure with data from the 1976 Indonesia Fertility Survey. The upper panel shows a set of estimated time distributions of children ever born and the resulting estimates of infant mortality, the lower panel the basic data tabulated from the survey. The time distributions of children ever born were computed by means of a simple graphical smoothing of the mean number of children ever born (MCEB) values, assuming constant fertility. They are intended to be illustrative only. The infant mortality estimates were obtained by direct solution of the estimation equation (3) using tabular values of $q_M(x;w)$ from the Brass General model life table family.

Taking the median of the five estimates gives an estimated infant

Table 4. **Illustrative calculation of infant mortality rate estimates using child survivorship data classified by year of first marriage: Indonesia Fertility Survey, 1976**

Year of first marriage	Estimated time distributions of CEB						Estimated IMR
	1970	1971	1972	1973	1974	1975	
1974	0	0	0	0	40	60	141
1973	0	0	0	25	37	38	98
1972	0	0	18	27	27	28	106
1971	0	14	22	22	22	20	113
1970	12	18	29	18	17	16	101

Data

Year	Women	CEB	CS	MCEB	PDC
1974	319.3	212.7	186.4	0.666	0.124
1973	323.7	251.3	225.9	0.776	0.101
1972	361.9	404.3	355.3	1.117	0.121
1971	321.4	443.0	381.4	1.378	0.139
1970	345.7	574.4	498.6	1.662	0.132

Source: 1976 Indonesia Fertility Survey.
CEB—children ever born.
IMR—infant mortality rate.
CS—children surviving.
MCEB—mean number of children ever born.
PDC—proportion of deceased children.

mortality rate of 106 infant deaths per thousand births. This may be compared with the two kinds of estimates presented by Sullivan and Wilson (1982), based on the same source. On the one hand, estimation from survivorship of children ever born to women aged 20–24 gives values of 116, 134, 119, and 125 per thousand, respectively, using the Coale–Demeny North, East, South, and West model life table families (Sullivan and Wilson 1982: 5). On the other hand, direct calculation from the birth history data yields a value of 94 per thousand for the period 1971–74. Sullivan and Wilson show that the high mortality estimated for children of women aged 20–24 is due to a high proportion (nearly three quarters) of those children being born to mothers under age 20 and relatively high mortality risks for those children. (Sullivan and Wilson 1982: 11).

The indirect IMR estimate of 106 per thousand from Table 4 lies well below the various indirect estimates based on child survivorship data classified by age, but also significantly above the value given by direct calculation from the birth history data. The first comparison suggests that the classification by year or duration of first marriage substantially reduces the bias due to differential mortality by age of mother. The second comparison suggests that it does not entirely eliminate it. Although it is possible that the directly calculated value is too low on account of misreporting of ages at death, some residual bias in the indirect estimates based on data by year or duration of marriage is to be expected. Children ever born to women recently married will include disproportionate numbers of children of younger women and of low birth orders. The use of child survivorship data classified by duration or year of first marriage substantially reduces the bias due to differential mortality by age of mother but does not eliminate it.

Data of the form shown in Table 4 may be used to estimate mortality for each year prior to the census or survey without any assumption about mortality change other than that the period life table each year conforms to a given model life table family. The idea is due to Macura (1982).

Assume data classified by completed years of marriage, and let Q_i denote the proportion of deceased children among all children born to women with i completed years of marriage. Then

$$Q_0 = q_M(1;w_1)$$

$$Q_1 = q_M(1;w_1,w_2)c_1(1) + q_M(2;w_1,w_2)c_1(2)$$

$$Q_2 = q_M(1;w_1,w_2,w_3)c_2(1) + q_M(2;w_1,w_2,w_3)c_2(2) + q_M(3;w_1,w_2,w_3)c_2(3)$$

and so on, where $\{c_i(x)\colon x=1,2,\ldots\}$ denotes the time distribution of children ever born to women with i completed years' duration of marriage and $q_M(x;w_1,w_2,\ldots)$ is the proportion of children born in the xth year prior to time t who die before time t if w_i is the level of mortality level in the ith year prior to time t. The $c_i(x)$ may be estimated as in the above example, with appropriate refinements. Solving the first equation yields an estimate of w_1, the level of mortality in the year prior to the survey. This may be entered in the second equation, which may then be solved for w_2, and so on. The data in Table 4 represent too few cases to apply this more demanding procedure.

Conclusion

The four examples presented here exemplify several lessons for the estimation of infant and child mortality from child survivorship data. First and most important is the importance of analyzing the mortality estimates that result from applying whichever method is used. It is never sufficient merely to calculate estimates from a single set of data, for there are numerous examples in which doing so gives disastrously bad results. Estimates must always be analyzed in relation to other relevant information before we can proceed to conclusions about the level and trend of mortality. In those rare cases where no other information is available, conclusions will necessarily be weak. If there was ever an Age of Innocence in these endeavors, we have emerged from it.

The Sarawak and Mexico examples both show the value of plotting and scrutinizing completed parity distributions. Despite the utter simplicity of this proceeding, it yields important conclusions in both cases, suggesting that it ought to be done routinely. That it is not now done routinely is suggested by its not being mentioned in the United Nations *Manual X: Indirect Techniques for Demographic Estimation,* with its explicitly pedagogical intent, as well as by the absence of examples in the literature.

The Mexico example shows also the importance of not restricting attention too narrowly to the data immediately at hand. The completed parity distributions from the 1970 census look suspicious, but it is only after comparing them with the distributions from the 1950, 1960, and 1980 censuses and those from the Mexican Fertility Survey that conclusions become clear.

A blunder that could have been avoided by executing this elementary maneuver appeared some years ago in a paper presenting a mathematical model for parity distributions "characterized by high fertility combined with high zero parity" (Golbeck 1981). The application was to the 1970 Mexican census, and the model fits the (faulty) data very well.

The widely observed tendency for the mean number of children ever born to decline with increasing age for older women is generally believed to indicate deteriorating completeness of reporting. Although this is no doubt true in some cases, perhaps even in most cases, the analysis of the Thai data from the 1960, 1970, and 1980 censuses suggests that the presumption should be revised. Data for older women remain suspect, but they should not be dismissed out of hand. When children-ever-born data are available for two or more censuses, there is much to be learned by time-plotting them. Nor does this conclusion apply only to populations with exceptionally good data. Japanese children-ever-born data for older women appear to be excellent (Feeney 1990); but data for Kenya, though obviously erroneous, suggest important conclusions for which there is little alternative evidence (Feeney 1988).

Data producers should take care not to discard the children-ever-born information for older women in tabulation. We cannot look at children-ever-born data for older women in India, for example, because the relevant age classification ends with a 50+ open-ended age group. The same applies to Mexico, and there are many other cases in which the open-ended age group is lower than it should be. This is a great pity, given the vast expense at which census and survey data are collected and the vanishingly small marginal cost of slightly more detailed tabulations. It should hardly be necessary to add that data should not be discarded in tabulation on the mere suspicion that it may prove to be faulty.

The final lesson, illustrated by the Indonesian example, concerns the exploration of alternatives to the almost universal tabulation of child survivorship data by age of mother. While there may be little call to add to the arsenal of methods now available for data classified by age, the field is wide open for the development and application of methods for alternative classifications.

An obvious first step would be to pick up where Sullivan left off with data classified by duration of marriage. For those more interested in substantive than methodological investigations, the important results of Fernandez Castilla (1989) allow the estimation of mortality by family size by suitable tabulation of information contained in scores of population censuses for countries the world over.

Child survivorship data will be providing important evidence on levels and trends of mortality for much of the world's population well into the next century. Although we have made significant advances in learning to extract useful information from this data, we can learn to do better in the future what we have already done well in the past.

The distinction between methods and data analysis is important because learning a method is so much simpler and easier than becoming proficient in its use. Learning a method is a matter of acquiring a clearly defined locus of demographic and mathematical knowledge, knowledge that may be mastered completely with sufficient study. Data analysis is an ability cultivated by experience, with each engagement an opportunity to broaden one's knowledge and sharpen one's acumen. When studying methods, there is generally a single and unambiguously correct answer to every question that arises. When analyzing data, significant conclusions are usually judgments on which even the most experienced analysts may differ to some degree.

Perhaps for these reasons, research and pedagogy seem to have favored the development and understanding of technique over knowledge and experience of application. Or have we simply been in the grip of a long swing of intellectual fashion? However this may be, data analysis merits more attention than it has received. We will certainly benefit from the continuing development of new methods, and they should be welcomed. Viewing the demographic enterprise as a whole, however, we may benefit even more by learning better how to use the methods we ready have.

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[1960 Census of Mexico] Numbers of women aged 12 and over by age and number of children born alive given in Table 37.

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