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Illustrative Analysis: Infant and Child Mortality in Colombia

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The World Fertility Survey (WFS) is an international research programme whose purpose is to assess the current state of human fertility throughout the world. This is being done principally through promoting and supporting nationally representative, internationally comparable, and scientifically designed and conducted sample surveys of fertility behaviours in as many countries as possible.

The WFS is being undertaken, with the collaboration of the United Nations, by the International Statistical Institute in cooperation with the International Union for the Scientific Study of Population. Financial support is provided principally by the United Nations Fund for Population Activities and the United States Agency for International Development. Substantial support is also provided by the U.K. Overseas Development Administration.

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Preface

One of the main concerns of the World Fertility Survey has been the analysis of the data collected by the participating countries. It was decided at the outset that, in order to obtain quickly some basic results on a comparable basis, each country would produce soon after the field work a 'First Country Report', consisting of a large number of cross-tabulations with a short accompanying text. Precise guidelines for the prepation of the tables were produced and made available to the participating countries.

It was also recognised, however, that at later stages many countries would wish to study in greater depth some of the topics covered in their first reports, or indeed new but related subjects, using more refined analytic techniques. In order to assist the countries at this stage a general 'Strategy for the Analysis of WFS Data' was outlined, a series of 'Technical Bulletins' was started, dealing with specific methodological issues arising in the analysis, and a list of 'Selected Topics for Further Analysis of WFS Data' was prepared, to serve as a basis for selecting research topics and assigning priorities.

It soon became evident that many of the participating countries would require assistance and more detailed guidelines for further analysis of their data. Acting upon a recommendation of its Programme Steering Committee, the WFS then launched the present series of 'Illustrative Analyses' of selected topics. The main purpose of the series is to illustrate the application of certain demographic and statistical techniques in the analysis of WFS data, thereby encouraging other researchers and other countries to undertake similar work.

In view of the potentially large number of research topics which could be undertaken, some selection was necessary. After consultation with the participating countries, 12 subjects which are believed to be of top priority and of considerable interest to the countries themselves were selected. The topics chosen for the series span the areas of fertility estimation, levels, trend and determinants, marital formation and dissolution, breastfeeding, sterilization, contraceptive use, fertility preferences, family structure, and infant and child mortality.

It was envisaged that each study would include a brief literature review summarizing important developments in the subject studied, a clear statement of the substantive and methodological approach adopted in the analysis, and a detailed illustration of the application of such an approach to the data from one of the participating countries, but with emphasis on the general applicability of the analysis. These studies have been conducted in close collaboration with the country concerned, where possible with the active participation of national staff.

It should perhaps be emphasised that the studies in the 'Illustrative Analyses' series are meant to be didactic examples rather than prescriptive models of research, and should therefore not be viewed as cookbook recipes to be followed indiscriminately. In many cases the investigators have had to choose a particular course of action from several possible, sometimes equally sound, approaches. In some instances this choice has been made more difficult by the fact that demographers or statisticians disagree among themselves as to the approach most appropriate for a particular problem. In the present series we have, quite intentionally, resisted the temptation to enter the ongoing debates on all such issues. Instead, and in view of the urgency with which countries require guidelines for analysis, an attempt has been made to present what we believe to be a basically sound approach to each problem, spelling out clearly its drawbacks and limitations.

In this difficult task the WFS has been aided by an *ad hoc* advisory committee established in consultation with the International Union for the Scientific Study of Population (IUSSP) and consisting of Ansley Coale (Chairman), Mercedes Concepcion, Gwendolyn Johnson-Ascádi and Henri Leridon, to whom we express our gratitude. Thanks are also due to the referees who have generously donated their time to review the manuscripts and to the consultants who have contributed to the series.

Many members of the WFS staff made valuable contributions to this project, which was co-ordinated by V. C. Chidambaram and Germán Rodríguez.

Sir Maurice Kendall
WFS Project Director

Acknowledgements

I wish to express my appreciation to the several persons, particularly in the WFS central staff, who made comments on the first draft of this document. In particular, I wish to thank Ken Hill, who made valuable suggestions to improve the manuscript, and Germán Rodríguez, who in addition contributed to the analysis of mortality by calendar periods controlling age of mother and had the difficult task of translating the manuscript into English.

1. Introduction

In this study we illustrate the application of direct and indirect methods for estimating infant and child mortality to data from the Colombian National Fertility Survey conducted in mid-1976 as part of the World Fertility Survey.

The study has two objectives: (1) to show how the data collected in the World Fertility Survey may be used to estimate infant and child mortality; and (2) to produce such estimates for Colombia, a country which — like many other developing countries — lacks satisfactory information on mortality.

This document is organised in six chapters, including this brief introduction. Chapter 2 provides some background material which will prepare the reader for subsequent chapters. It provides information on the data available, and points out some of their limitations — particularly regarding sample size — for a study of infant and child mortality. It also includes a discussion of the direct methods used to estimate infant and child mortality. It should be noted that the methods themselves are not original; what is unusual is their application to data from a country like Colombia, where the quality of the demographic data usually available does not permit applying direct methods. As we shall see, the data collected in the Colombian survey do not appear to be affected by serious errors.

Chapter 3 deals with the plausibility of mortality estimates derived from the available data and, more generally, with the study of possible deficiencies in the data, specially regarding the omission of children who have died.

Chapter 4 presents the results obtained using direct methods. It includes mortality estimates by 5-year periods, by cohorts of children born in a given period, and by age of mother, as well as estimates for several breakdowns of the population which lead to mortality differentials by sex, urban or rural residence, level of education of the mother, and regions within the country.

Chapter 5 considers the estimation of mortality by applying indirect techniques to data on children ever born and children dead by age of mother (in 5-year groups) at the time of the interview. The Colombian survey included an individual interview, which collected directly from each woman a birth history, and a household survey, where the information on mortality is limited to children ever born and children dead. The results of both interviews are quite similar. The indirect estimates are compared with those obtained from the individual survey using direct methods.

The document ends with a brief Chapter 6, where the more important conclusions of the study are noted.

2. Remarks on the Data and Methodology

Before considering mortality estimates we shall describe briefly the data available from the survey and the analysis procedures to be utilised.

2.1 THE DATA

The Colombian National Fertility Survey was conducted in 1976 jointly by the *Corporación Centro Regional de Población* (CCRP), a non-profit private institution devoted to research in population, and the *Departamento Administrativo Nacional de Estadística* (DANE), the state agency responsible for the collection, processing and publication of statistical data, with the collaboration of the Division of Information Systems of the Ministry of Health in the design and implementation of the sample.

The mortality to be measured is that experienced by the children reported by the women interviewed. The following are some basic statistics from the individual survey:

— The sample comprises 5378 women between the ages of 15 and 49;

— of these women, 3225 reported having had at least one child.

— The total number of children ever born to these women is 14432;

— of these children, there are 17 for whom the survival status at the time of the interview is unknown;

— thus, there are 14,415 children for whom the basic information required, survival status at the time of the survey (mid-1976), is known.

— The total number of deaths among these children is 1830, classified by age at death in the following groups, with numbers indicated in parentheses:

1 — less than 1 month	(560)
2 — between 1 and less than 3 months	(151)
3 — between 3 and less than 6 months	(183)
4 — between 6 months and less than a year	(255)
5 — between 1 and less than 2 years	(286)
6 — between 2 and less than 5 years	(254)
7 — between 5 and less than 10 years	(89)
8 — 10 years or more	(52)

— The groupings cannot be altered because the information on date of death or exact age at death was not recorded (unlike date of birth, which is available).

— Among the deaths there are 1149 to children less than a year old, and 629 to children aged between 1 and less than 10 years, making a total of 1778 deaths to children under 10 years of age.

Thus, we may study the mortality experienced between the ages of 0 and 10 years (a total of 1778 deaths), by 14,415 children observed from birth, with the degree of detail by age just noted.

The number of cases seems appropriate for measuring mortality in the first 10 years of life for the whole sample. However, the number of cases may not be sufficient to establish reliable measures of mortality for subgroups of the sample. In dealing with subgroups throughout this study we have used coarser age groups as the number of cases was reduced, in order to control sampling errors.

It is important to keep in mind the limitations imposed by the reduced number of cases in the analysis of data for subgroups. To emphasize this point we have generally indicated the number of cases on which the analysis is based, and occasionally have noted that the rates obtained are based on very few observations.

2.2 THE METHODS

Mortality may be measured by any of the usual life table functions. We may use (1) the annual mortality rate between ages x and $x+n$, denoted $_nm_x$; (2) the probability of dying between birth and age x, denoted $q(x)$, or (3) its complement, the probability that a newly born child will survive to age x, denoted $l(x) = 1\text{-}q(x)$. From these we may, of course, calculate the other functions which comprise a life table.

It is convenient to distinguish two types of direct methods for estimating mortality*: (1) those which measure the mortality of a cohort, that is, children born in the same period, which may be one or several years, and (2) those which measure mortality in a given calendar period, in our case a 5-year period.

In measuring the mortality of a *cohort* through a given age range, say 0 to 5 years, we consider two types of situations; one where all the children in the cohort could have lived through the interval studied, in our example 5 years, and another where some members of the cohort have not had time, as of the interview date, to live through the interval. In the first case the measurement of mortality is direct, as the ratio of deaths recorded in the period to the number of children in the cohort defines $q(x)$, in our example $q(5)$. In the second case we must consider the situation of living children who have not reached the age defining the upper bound of the interval studied, in our example children under 5 years of age as of 1976. In this case it is more convenient to calculate mortality rates by age $_nm_x$ and use these to derive $q(x)$. Appendix I explains the procedure followed in this case, which is the most common in our study.

In measuring the mortality of a *period*, say 1971-75, the life table functions that may be calculated directly are conditional probabilities of death, which may then be used to derive $q(x)$. Appendix II illustrates the procedure followed in this case.

*Indirect methods are considered in Chapter 5

3 Evaluation of the Quality of the Data

In this chapter we assess the quality of the available data. It is not possible to determine directly whether the data are free from errors, but we may examine whether the data lead to plausible estimates of mortality. We may explore, for example, if the data are affected by omission of dead children, or whether the information presents any extraneous characteristics.

As none of the tests is conclusive on its own, it is necessary to conduct several checks. The fact that through *several* analyses we persistently obtain results which indicate that the estimates derived from the data are plausible, leads us to conclude that the data are reliable.

We shall examine the following aspects:

(i) The age-pattern of mortality is plausible.

(ii) Infant mortality increases with age of mother at the time of the survey, as we would expect in a situation of declining mortality.

(iii) Infant mortality is higher among the children of women with lower education as compared with the children of women with higher education, within age-groups of women.

(iv) Infant mortality varies with the age of the mother at the time of birth of the child, as it is known to occur in populations for which reliable data are available.

(v) Mortality declines over time.

(vi) The sex ratio at birth is normal.

(vii) Male infant mortality is higher than female.

(viii) The age distribution of the sample of women is acceptable.

It may be noted that we have not included a rather obvious test, namely a comparison of mortality estimates derived from the survey with those derived from other sources such as vital registration. This is so because in Colombia there are no sources of data which may permit establishing the levels of mortality in early life with more precision than the present survey.

3.1 THE AGE-PATTERN OF MORTALITY IS PLAUSIBLE

We prove this claim by presenting a life table for the United States, both sexes, other races 1939-41, which shows a level and age pattern of mortality very similar to that obtained from the survey. The test is quite strict, as we have compared the values of the $l(x)$ function — that is the number of survivors at age x per 1000 live births — over the ages 0 to 10 with very fine subdivisions of age in the first year of life. As it may be argued that the quality of the basic information for "other races" in the United States around 1940 is of dubious value, we have also shown another mortality experience, this time limited to the first year of life, which corresponds to Scotland 1931-35 and also shows a strikingly similar level and pattern to that observed in the Colombian survey.

Table 3.1 shows the three life tables being compared. It appears almost unnecessary to note that the three life tables are very similar. Thus, the life table constructed from the survey data gives a plausible estimate of mortality.

Table 3.1. The Function $l(x)$ for (a) The Colombian Survey, (b) United States Total of "Other Races", 1939-1941, and (c) Scotland, 1931-35.

	$l(x)$		
x	Colombian Survey	U.S.A.[1] Other Races 1939-41	Scotland[2] 1931-35
0	1,000	1,000	1,000
1/12	961	961	962
3/12	951	945	951
6/12	938	927	938
1	919	907	918
2	898	888	
5	877	872	
10	867	861	

Sources:

[1] Thomas N. E. Greville, *'United States Life Tables and Actuarial Tables 1939-1941,* Bureau of the Census, Government Printing Office, Washington, 1946.

[2] Henri Bunle *'Le Mouvement de la population dans le Monde de 1906 a 1936'* Institut National d'Etudes Démographiques, Paris, 1854.

3.2 INFANT MORTALITY INCREASES WITH AGE OF MOTHER AT THE TIME OF THE SURVEY

One may suspect that women may omit children who have died, and that such omissions would increase with age of the woman. This type of error has been noted frequently in censuses and surveys.

On the other hand, if mortality has declined over time the proportion of children dead among women in the older ages should be higher than among younger women. However, one should not compare directly the proportions of children dead by age of mother, because such proportions reflect not only the level of mortality but also the longer exposure to the risk of death of the children of the older women. The comparison must be based on a measure of mortality which refers to a uniform period of exposure.

Table 3.2 presents two sets of estimates which are useful in detecting if the tendency to omit children who have died increases with age of mother at the time of the survey. The first set of estimates is based on a direct calculation of infant mortality based on data on births and infant deaths classified by age of mother in 1976 (see Appendix III). Note that infant mortality increases with age of mother except for the first two age groups, an exception which may be explained by the high mortality of children of very young mothers, as we shall see below. In general, however, infant mortality has been higher the older the mother is as of 1976 (and hence the earlier in time the child has been born). The plausibility of these results should be emphasized, as the data on child mortality by age of mother at the time of the survey will be used to illustrate the application of indirect estimation techniques in Chapter 5.

The second set of estimates is based on an indirect method proposed by Feeney (see Chapter 5). Unlike the previous estimates, the indirect estimates are not affected by possible errors in the dating of births or infant deaths. The results indicate that the infant mortality implied by the proportion of children dead by age of mother in 1976 increases as we go back in time. Hence, if there has been any error of omission as noted earlier in this section, this error is not of sufficient magnitude to hide a declining mortality trend.

Table 3.2. Infant Mortality by Mother's Age in 1976. Direct and Indirect Estimates.

Age Groups	Direct Estimates			Indirect Estimates	
	Deaths Less Than 1 Year Old	Births	Infant Mortality	Proportion of Dead Children	Infant Mortality
i	*D*	*B*	1000 $q(1)$	D_i	1000 $q(1)$
15-19	25	237	121	.105	112
20-24	73	1,157	66	.087	70
25-29	124	2,052	62	.094	65
30-34	160	2,423	67	.101	63
35-39	233	2,911	80	.130	76
40-44	254	2,889	88	.145	78
45-49	280	2,746	102	.172	84

Source — Direct Estimates, Appendix III
— Indirect Estimates, Table 5.4.

3.3 INFANT MORTALITY IS HIGHER AMONG THE CHILDREN OF WOMEN WITH LOWER EDUCATION AS COMPARED WITH THOSE OF WOMEN WITH HIGHER EDUCATION, WITHIN AGE GROUPS OF WOMEN

One may suspect that even if there is no evidence of omission when the sample is considered as a whole, such evidence may appear if the analysis is restricted to women with a lower educational level, where one might expect a higher omission of dead children.

To explore this possibility we have established the level of mortality classifying the mothers simultaneously by age (as before, but using 10-year age groups) and level of education. The results are shown in Table 3.3. It may be noted that in all age groups, even among women 40-49 where the information might be more affected by omissions, the level of mortality is clearly higher in the subgroup of women with a lower educational level.

Table 3.3. Probability of Dying Before Age *x* ($q(x)$) for Children Born to Women Classified by Age and by Level of Education.

Age	Age of Women					
	20-29		30-39		40-49	
	Level of Education					
	0-2	3+	0-2	3+	0-2	3+
x	$q(z)$ o/oo					
1/2	58,4	38,1	73,1	48,0	77,8	65,6
1	80,6	50,7	91,6	58,3	103,1	84,3
2	106,1	65,6	118,7	70,4	130,2	105,9
5	133,8	78,2	149,7	82,3	157,3	122,6
10	142,0	90,3	159,8	87,7	168,5	133,8

In conclusion, there is no evidence of omission of children dead if we analyse the data for women with a low level of education.

3.4 INFANT MORTALITY VARIES WITH AGE OF THE MOTHER AT THE TIME OF BIRTH OF THE CHILD, AS IT IS KNOWN TO OCCUR IN POPULATIONS FOR WHICH RELIABLE DATA ARE AVAILABLE

The relationship between age of the mother at the time of birth of the child and subsequent infant mortality is as follows: relatively high infant mortality for very young mothers, say under 20, low infant mortality for mothers between 25 and 30 or 35 years old, and increasing infant mortality for older mothers.
The same pattern emerges from the survey data, as shown in Table 3.4. We present there the data classified in four categories of age of mother at the time of birth of the child, selected so as to have approximately the same number of recorded deaths in each category.

Table 3.4. Infant Mortality by Mother's Age at the Time of Birth of the Child

Age Group	Deaths Less Than 1 Year Old D	Births B	Infant Mortality $1000\,q(1)$
<20	290	2,926	100
20-24	347	4,650	76
25-29	247	3,531	71
30+	265	3,308	81
Total	1,149	14,415	81

Source: Table 4.5.

3.5 MORTALITY DECLINES OVER TIME

Table 3.5 shows that infant mortality has declined over time between 1956-60 and 1971-75. The indices shown correspond to the probability of dying in the first year of life. Even though the information available on mortality trends in Colombia is very deficient, the indication is that mortality has declined over time, as it has occurred in most countries in the period considered here. The data conform, once again, to our expectations.

Table 3.5. Infant Mortality by 5-Year Calendar Periods Between 1956-1960 and 1971-1975

5-Year Period	Infant Mortality (per 1,000)
1956-1960	99.3
1961-1965	78.2
1966-1970	67.9
1971-1975	66.2

Source: Table 4.9.

The results shown in Table 3.5 should be interpreted with caution. We have seen in the previous section that infant mortality depends on the age of the mother at the time of birth of the child. As we go back in time from 1975 to 1956 we are dealing with a progressively younger sample of women; in 1971 for example, we have only mothers aged under 45. As a result, the decline in mortality over time may be larger than the figures in Table 3.5 indicate, as we shall see in Section 4.6.

3.6 THE SEX RATIO AT BIRTH IS NORMAL

As may be noted from Table 3.6, the sex ratio of the births in the sample was somewhat high (above 107 males per 100 females) in 1941-59 and 1968-76, and somewhat low (103.7 per 100), in 1960-67, with an overall normal ratio of 106.2 for the whole period under study. There is no evidence that the reporting of births is more complete for one sex than the other, as has been found in other studies.

Table 3.6. Sex Ratios at Birth

Period of Birth	Births: Male	Births: Female	Sex Ratio
			o/o
1941-1959	1,775	1,653	107.4
1960-1967	2,518	2,429	103.7
1968-1976	3,139	2,918	107.6
1941-1976	7,432	7,000	106.2

3.7 INFANT MORTALITY IS HIGHER FOR MALES THAN FEMALES

It has frequently, almost universally, been observed that infant mortality is higher for males than for females. The results of the survey confirm this pattern, as it may be noted in Table 3.7.

Table 3.7 Infant Mortality by Sex for Different Cohorts

Period of Birth	Infant Mortality (per 1,000): Males	Infant Mortality (per 1,000): Females
1941-1959	119.5	94.5
1960-1967	80.9	76.2
1968-1976	74.0	59.3
Total	87.3	73.6

Source: Table 4.11

The ratio between male and female infant mortality rates is of the same order of magnitude in Colombia as in model life tables (West family of Coale-Demeny life tables, levels 15 or 17).

3.8 THE AGE DISTRIBUTION OF THE SAMPLE OF WOMEN IS ACCEPTABLE

We now consider whether the age distribution of the sample of women is comparable to what might be expected, as an additional check on the reliability and representativeness of the data.
In Table 3.8 we compare the age distribution of the 5,378 women the sample with the age distribution in two stable populations. Both models have the same structure, the model denoted "maximum" agrees with the observed number of women in the age group 15-19, which is apparently over-represented in the sample; the model denoted "minimum" agrees with the observed number of women in the age group 30-34, which is apparently under-represented. Figure 3.1 depicts these data.

Table 3.8 Age Distribution of the Female Population (a) Surveyed and (b) of 2 Model Populations

Age Group	Surveyed Population	Population of a Stable Model, Mortality of the Western Family, Level 13, of Coale-Demeny, Rate of Growth 3% Annually	
		Maximum	Minimum
15-19	1,423	1,423	1,029
20-24	1,051	1,190	861
25-29	842	994	719
30-34	599	828	599
35-39	579	681	493
40-44	476	564	408
45-49	408	454	328
Total	5,378	6,134	4,437

Source: Coale, A.J. and P. Demeny, *Regional Model Life Tables and Stable Populations,* Princeton University Press, Princeton, 1966.

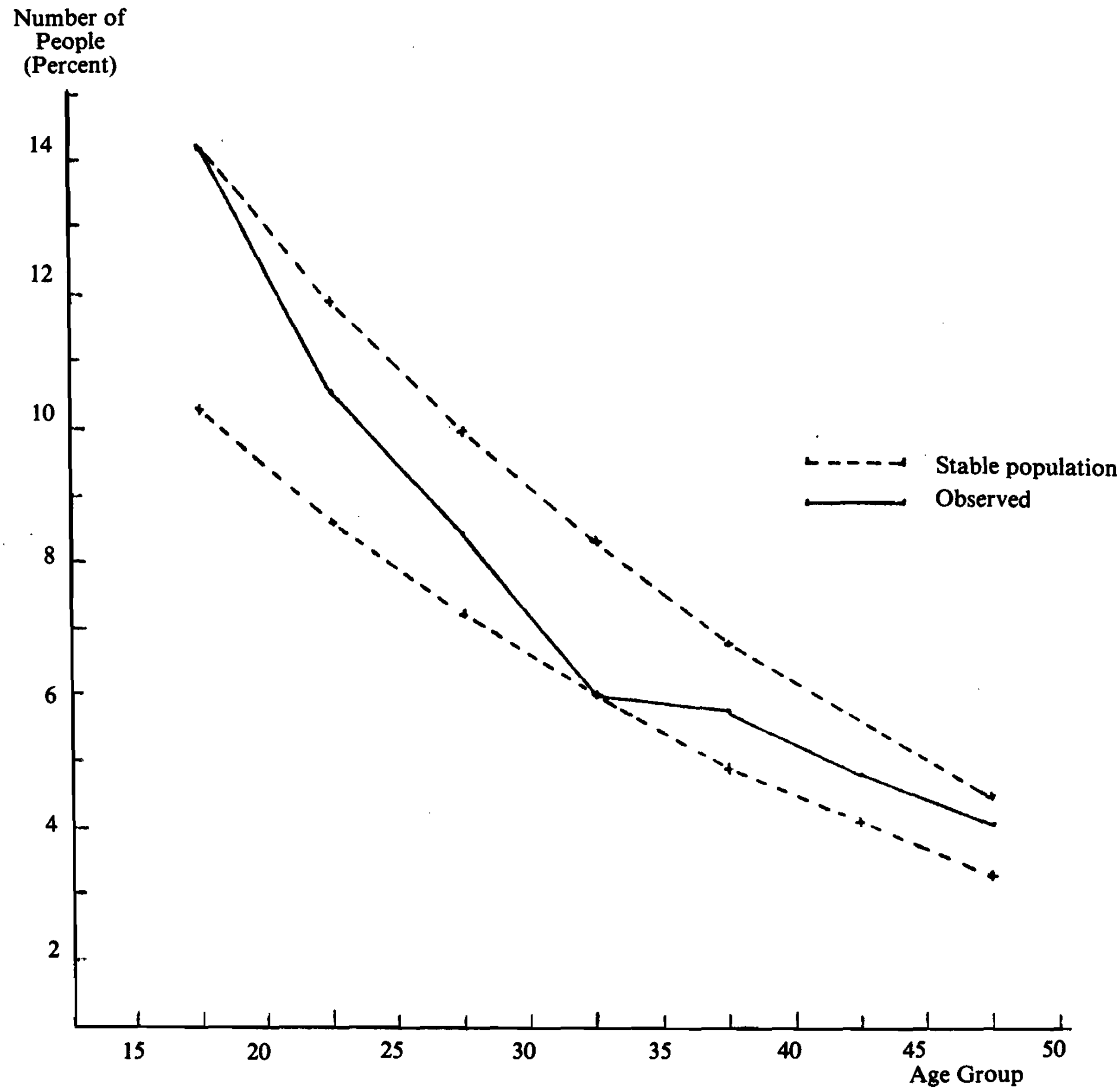


Figure 3.1 Age Distribution of the Female Population Between Ages 15 and 50, Observed and from Two Models

We may conclude that, except for the two age groups mentioned above, 15-19 and 30-34, the number of women in the remaining ages is distributed in a similar fashion to the model populations considered. The differences between the observed and expected numbers are not very important and do not invalidate the data in the sense of questioning their representativity.

In conclusion, the data collected in the survey appear to be of sufficient quality to study the mortality of the children reported by the respondents.

4 Direct Estimates of Mortality

In this chapter we present mortality estimates obtained by direct methods. We consider 10 different analyses including mortality estimates by birth cohort, age of mother, birth order, calendar periods, sex of child, and background characteristics of the mother such as type of place of residence, education and region. Although the list of topics is extensive it is by no means complete; we have selected those aspects which we consider of greater interest. We now consider each of these analyses in turn.

4.1 MORTALITY BETWEEN AGES 0 AND 10 BY BIRTH COHORTS

We shall present two analyses of mortality by birth cohort, that is for groups of children born in the same calendar period, dealing respectively with mortality between the ages of 0 and 10 (this section) and infant mortality (section 4.2).

For the purposes of the present analysis, we have considered only three cohorts: children born between 1941 and 1959, between 1960 and 1967, and between 1968 and 1976. These groupings have been selected so as to yield a sufficient number of deaths in each cohort; the 1,778 reported deaths to children under the age of 10 are thus divided into three approximately equal groups with about 600 deaths each.

Tables 4.1, 4.2 and 4.3 present the life tables calculated for each of these three cohorts. The results are compared in Figure 4.1, which shows the life table function $_nm_x$, and Figure 4.2 which shows the life table function $q(x)$.

Table 4.1: Life Table for Children Born Between 1941 and 1959

Age Group		Time Lived	Mortality Rate	Probability of Survival	Surviving	Dead
x	$x+n$	$_nE_x$	$_nm_x$	$_np_x$	$l(x)$	$q(x)$
0	1/2	278.4	.6034	.9509	1.0000	.0000
1/12	3/12	538.8	.0891	.9853	.9509	.0491
3/12	6/12	794.4	.0793	.9804	.9369	.0631
1/2	1	1550.8	.0574	.9717	.9186	.0814
1	2	3006.0	.0339	.9666	.8926	.1074
2	5	8743.5	.0093	.9726	.8628	.1372
5	10	14270.0	.0028	.9861	.8391	.1609
10	w				.8274	.1726

Total births: 3,425

Total deaths (less than 10 years): 591

Table 4.2 Life Table for Children Born Between 1960 and 1967

Age Group x	x+n	Time Lived $_nE_x$	Mortality Rate $_nm_x$	Probability of Surviving $_nP_x$	Surviving $l(x)$	Dead $q(x)$
0	1/12	403.2	.4886	.9601	1.0000	.0000
1/12	3/12	786.0	.0611	.9899	.9601	.0399
3/12	6/12	1165.3	.0532	.9868	.9504	.0496
1/2	1	2294.8	.0353	.9825	.9379	.0621
1	2	4500.5	.0216	.9787	.9214	.0786
2	5	13201.5	.0078	.9769	.9018	.0982
5	10	19525.0	.0020	.9901	.8810	.1190
10	w				.8723	.1277

Total births: 4,937

Total deaths (less than 10 years): 627

Table 4.3: Life Table for Children Born Between 1968 and 1976

Age Group x	x+n	Time Lived $_nE_x$	Mortality Rate $_nm_x$	Probability of Survival $_nP_x$	Surviving $l(x)$	Dead $q(x)$
0	1/12	495.3	.3937	.9677	1.0000	.0000
1/12	3/12	956.7	.0575	.9905	.9677	.0323
3/12	6/12	1381.4	.0420	.9896	.9585	.0415
1/2	1	2604.5	.0326	.9838	.9485	.0515
1	2	4618.5	.0188	.9813	.9332	.0668
2	5	9814.5	.0071	.9788	.9157	.0843
5	10	5802.5	.0017	.9914	.8963	.1037
10	w				.8886	.1114

Total births: 6053

Total deaths (less than 10 years): 560

Figure 4.1 shows that the risk of dying in each of the ages studied declines as we move from the oldest to the youngest cohort. Figure 4.2, which shows cumulative probabilities of dying up to each age (under 10), cannot but confirm these results. The cumulative effect of the decline in mortality observed at all ages is reflected in the probability $q(10)$ of dying before the age of 10, or its complement 1-$q(10)$, the probability of surviving up to age 10. A total of 8,274 out of every 10,000 children born between 1941 and 1959 reached the age of 10, compared with 8,723 out of every 10,000 born between 1960 and 1967, and 8,886 out of every 10,000 born between 1968 and 1976 (see tables 4.1-4.3).

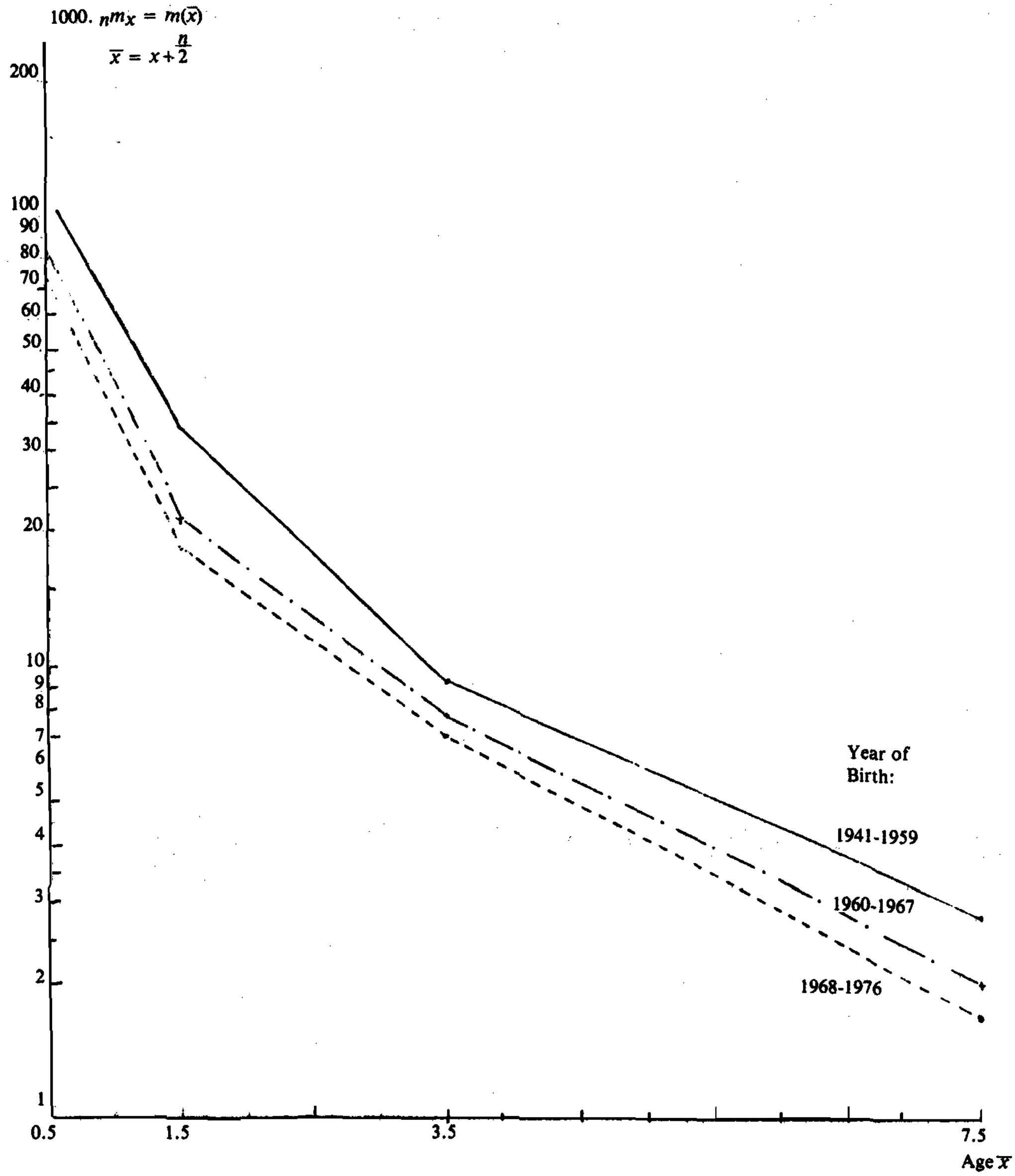


Figure 4.1 Mortality Rate $_nm_x$ Between 0 and 10 Years by Birth Cohorts

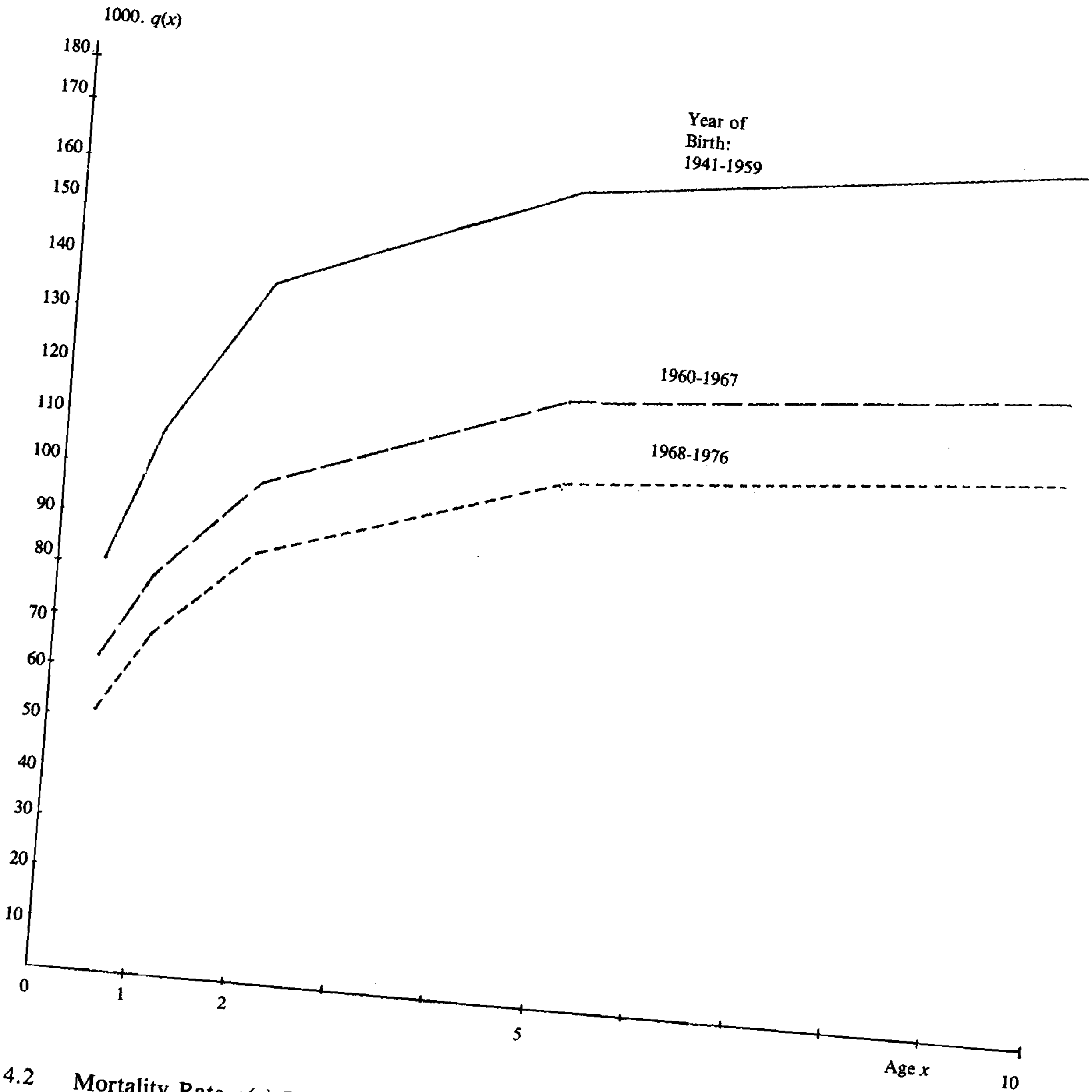


Figure 4.2 Mortality Rate $q(x)$ Between 0 and 10 Years by Birth Cohorts

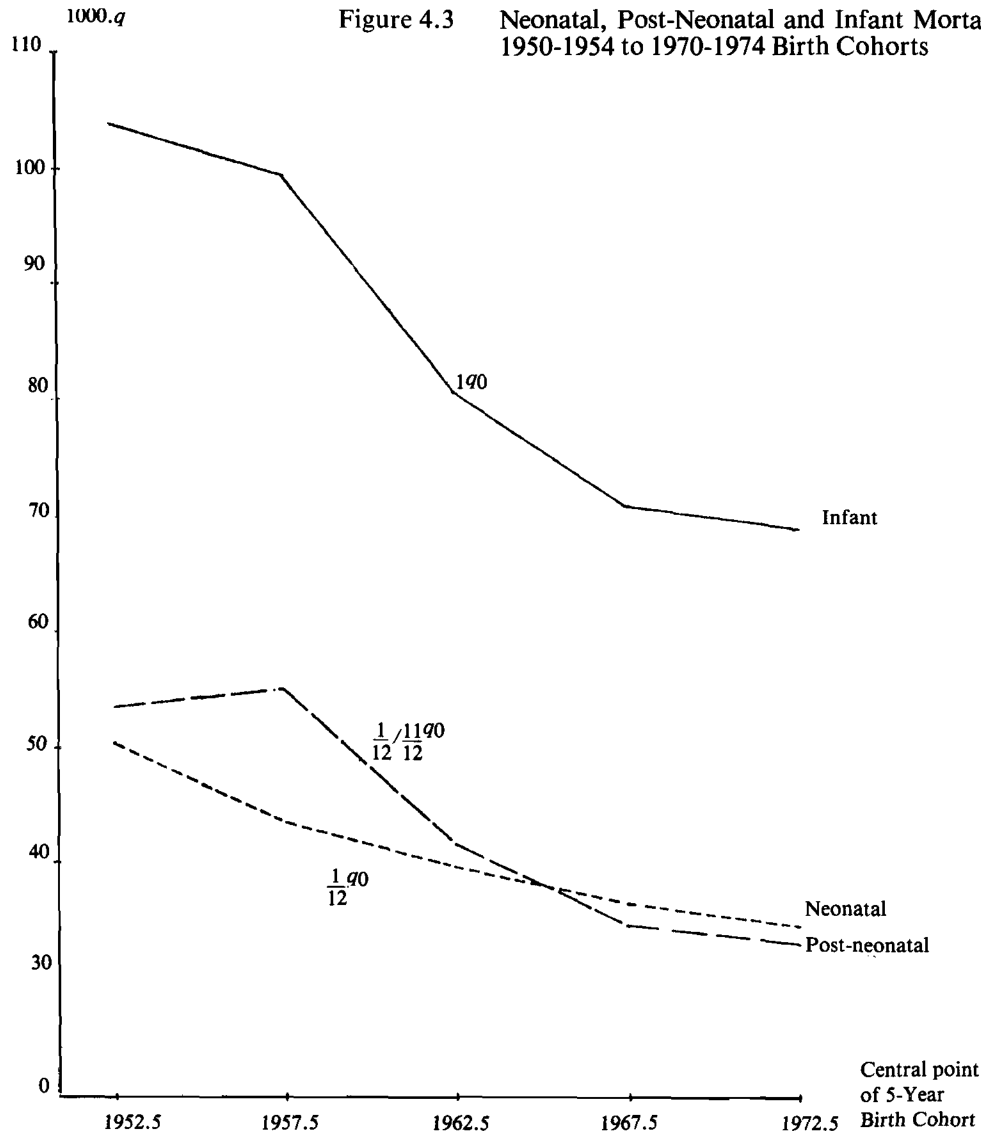
4.2 INFANT MORTALITY BY 5-YEAR COHORTS

We now consider infant mortality, subdivided into neonatal and post-neonatal components. The analysis is done for children born in each 5-year period between 1950-54 and 1970-74. Note that 1974 is the last year for which we have children who have reached age one.
Table 4.4 presents the basic data. For each 5-year cohort we show the total number of children born, the number who died in the first month (neonatal deaths) and between the age of 1 and 11 months (post-neonatal deaths), as well as the resulting neonatal, post-neonatal and infant mortality rates. Both the neonatal and post-neonatal rates are expressed per 1,000 live births, and their sum defines the infant mortality rate. These rates are depicted in Figure 4.3.

Table 4.4: Neonatal, Post-neonatal and Infant Mortality, by 5-year Birth Cohorts from 1950-1954 to 1970-1974

5-Year Birth Group	Births	Deaths: Less than 1 Month	Deaths: Between 1 and 11 Months	Mortality Rates (per 1000): Neonatal	Post-neonatal	Infant
1950-1954	1,047	53	56	50.6	53.5	104.1
1955-1959	1,976	86	109	43.5	55.2	98.7
1960-1964	2,935	114	123	38.8	41.9	80.7
1965-1969	3,480	127	121	36.5	34.8	71.3
1970-1974	3,493	122	116	34.9	33.2	68.1

Figure 4.3 Neonatal, Post-Neonatal and Infant Mortality, 1950-1954 to 1970-1974 Birth Cohorts



The neonatal and post-neonatal mortality rates are of approximately the same magnitude, and both have declined as we more from the older to the younger generations, with the decline in the post-neonatal mortality rate being somewhat more pronounced than the decline in the neonatal mortality rate, as one would expect given the level of mortality under consideration (post-neonatal mortality is more likely to decline than neonatal mortality)[1]

The infant mortality rate by 5-year cohorts, which combines the two components just considered, shows a clear decline as one moves from the 1950-54 birth cohort to the 1970-74 cohort. The decline is monotonic, and appears more pronounced among the older cohorts than among the younger ones.

[1] See for example, Behm, Hugo, *Mortalidad infantil y Nivel de Vida*. Ediciones de la Universidad de Chile, Santiago, 1962.

4.3 INFANT MORTALITY BY AGE OF MOTHER AT THE TIME OF BIRTH OF THE CHILD

Just as in the previous section, we now expand on a brief analysis first presented in Chapter 3.

It is well known that infant mortality is associated with age of the mother at the time of birth of the child: infant mortality is very high when the mother is very young, reaches its lowest level for mothers around the ages of 25 and 30, and then increases steadily with age of mother.

Table 4.5 presents the results of the analysis. We consider four categories of age of mother at the time of birth of the child: under 20, 20-24, 25-29 and 30 or more. This grouping yields approximately the same number of infant deaths in each category (around 300). The table shows the life table functions $l(x)$ and $q(x)$ for subdivisions of the first year of life, as well as the number of births and infant deaths in each category. The function $q(x)$ is also depicted in Figure 4.4.

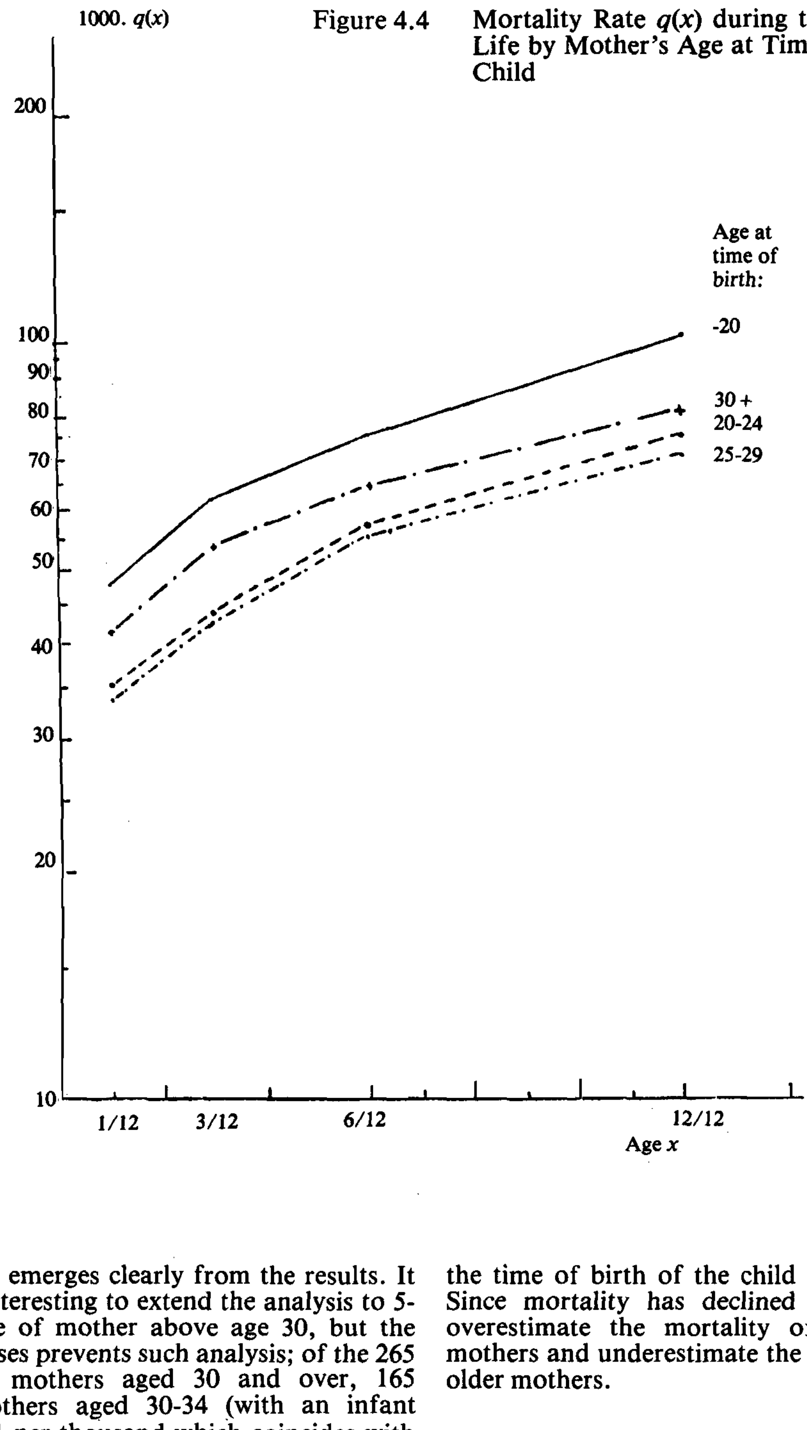
Table 4.5: Mortality during the First Year of Life by Mother's Age at the Time of Birth of the Child

Age of Children	Age of Mother at the Time of Birth of the Child							
	Less than 20		20-24		25-29		30 or More	
x	$l(x)$	$q(x)$	$l(x)$	$q(x)$	$l(x)$	$q(x)$	$l(x)$	$q(x)$
0	1.0000	.0000	1.0000	.0000	1.0000	.0000	1.0000	.0000
1/12	.9521	.0479	.9649	.0351	.9663	.0337	.9583	.0417
3/12	.9383	.0617	.9562	.0438	.9574	.0426	.9461	.0539
1/2	.9244	.0756	.9424	.0576	.9447	.0553	.9351	.0649
1	.8997	.1003	.9244	.0756	.9291	.0709	.9190	.0810
Births	2,926		4,650		3,351		3,308	
Deaths (<1)	290		347		247		265	

Total Births: 14,415

Total Deaths (<1): 1,149

Figure 4.4 Mortality Rate $q(x)$ during the First Year of Life by Mother's Age at Time of Birth of the Child



The expected trend emerges clearly from the results. It would have been interesting to extend the analysis to 5-year groups of age of mother above age 30, but the small number of cases prevents such analysis; of the 265 infant deaths for mothers aged 30 and over, 165 correspond to mothers aged 30-34 (with an infant mortality rate of 81 per thousand which coincides with the rate for the whole group) and only 100 correspond to older mothers. It is therefore prudent to analyse these data grouped in a single category, as done in Table 4.5.

In the analysis of these results it must be borne in mind that the sample is restricted to women aged 15 to 49 in 1976. Thus, children born to mothers aged 15 to 19 at the time of birth of the child may have been born at any time in the last thirty years. In contrast, children born to mothers aged 45 to 49 at the time of birth may only have been born in the last five years. Hence the results in Table 4.5 reflect not only the effect of age of mother at the time of birth of the child but also period effects. Since mortality has declined over time, the results overestimate the mortality of children of younger mothers and underestimate the mortality of children of older mothers.

4.4 INFANT MORTALITY BY BIRTH ORDER

Table 4.6 presents the life table functions $l(x)$ and $q(x)$ measuring mortality at four points in the first year of life, for children classified by birth order in three categories: first births, births of order 2 or 3, and births of order 4 or higher. Figure 4.5, depicting the function $q(x)$, shows clearly that first births have experienced a lower mortality than births of any other order. The other two groups considered, which together represent births of order 2 or higher, are similar to each other.

Table 4.6 Mortality during the First Year of Life by Birth Order

Age	Order					
	1		2-3		4 or More	
x	$l(x)$	$q(x)$	$l(x)$	$q(x)$	$l(x)$	$q(x)$
0	1.0000	.0000	1.0000	.0000	1.0000	.0000
1/12	.9634	.0366	.9604	.0396	.9605	.0395
3/12	.9562	.0438	.9471	.0529	.9503	.0497
1/2	.9441	.0559	.9334	.0666	.9375	.0625
1	.9290	.0710	.9140	.0860	.9183	.0817
Births	3,224		4,774		6,417	
Deaths (1)	226		405		518	

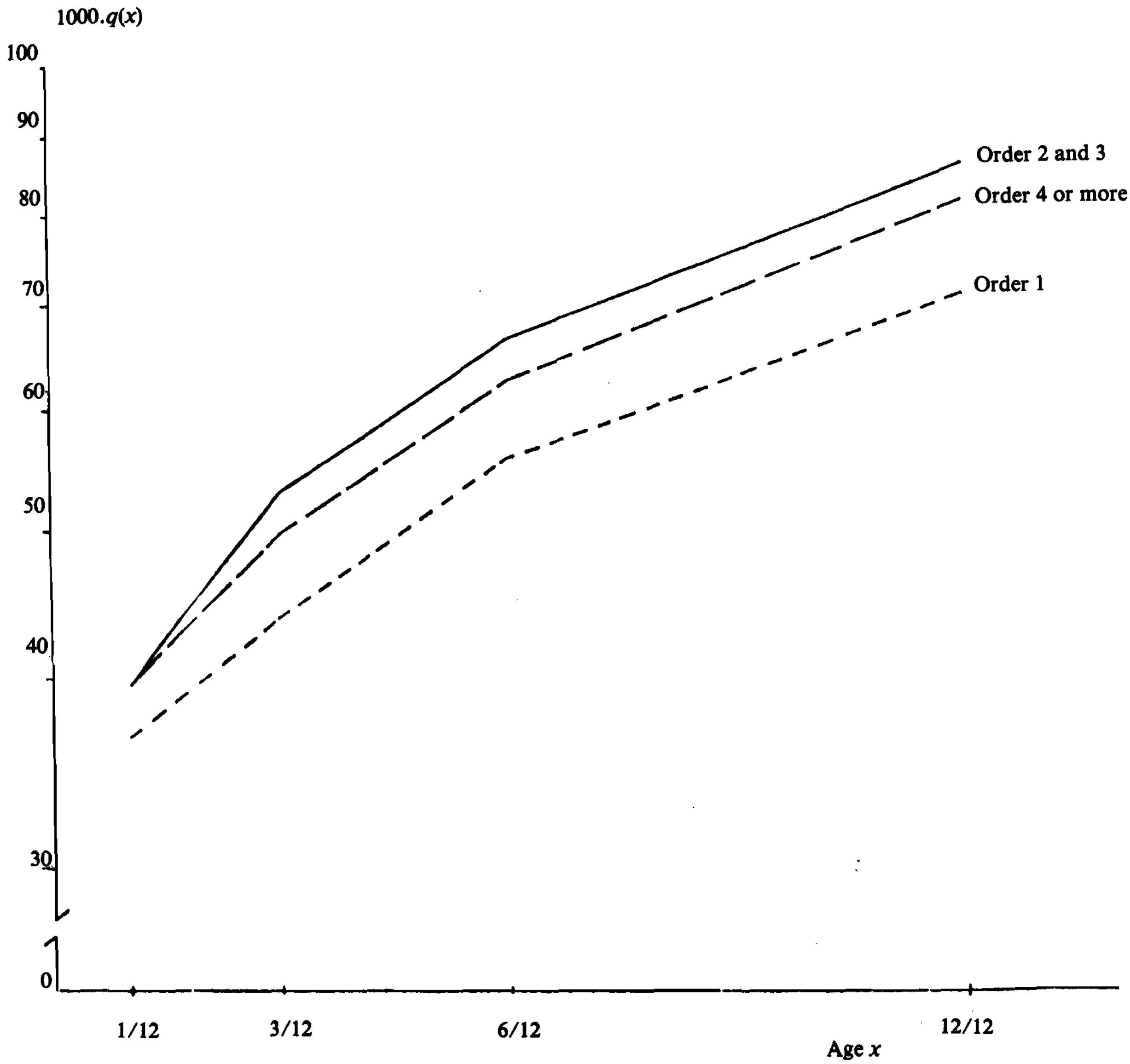


Figure 4.5 Mortality Rate $q(x)$ during the First Year of Life by Birth Order

Data on infant mortality by birth order are very scarce for developing countries. The experience from developed countries suggests that first births experience higher than average infant mortality. If that were the case in Colombia, the results of the survey could be indicating a selective omission of first births who died in infancy. Although we cannot rule out this possibility, we have found evidence from other countries which reflects lower than average infant mortality for first births. This evidence includes reasonably complete civil registration data from developed countries, namely Germany[1] and the United States[2], as well as data from developing countries including El Salvador[3] and Chile[4], which are consistent with our results for Colombia.

4.5 INFANT MORTALITY BY BIRTH ORDER AND AGE OF MOTHER AT TIME OF BIRTH OF THE CHILD

In studying infant mortality by age of mother at the time of birth of the child we found that infant mortality was very high among children born to very young mothers. When we studied infant mortality by birth order we found the lowest mortality among first births. As young women doubtlessly tend to have births of first order we face an apparent contradiction which deserves further analysis.

To investigate this aspect we cross-classified the data by birth order (1, 2-3, 4 +) and age of mother at the time of birth of the child (under 20, 20-24, 25-29, 30 +). Table 4.7 presents infant mortality estimates for each combination of categories of these variables. In some instances the number of observations is very small and consequently the resulting rate is subject to large sampling error. We have marked the two cases where the number of infant deaths reported is less than 20, to emphasize the unreliability of the estimates. The rates are also shown in Figure 4.6.

[1] "Mütter-und Sauglingssterblichkeit", Schriftenreihe des Bundesministers für Jugend, Familie und Gesundheit, Band 67, 1973.
[2] "A Study of infant mortality from linked records by age of mother, total birth order, and other variables". US Department of Health, Education and Welfare, 1960.
[3] "El Peso al nacer, la edad materna y el orden de nacimiento: tres importantes determinantes de la mortalidad infantil". Ruth R. Puffer and Carlos V. Serrano, Oficina Regional de la Organización Mundial de la Salud/Organización Panamericana de la Salud, 1975.
[4] "Mortalidad infantil en Chile. Tendencias, diferenciales y causas". Erica Taucher, Centro Latino-Americano de Demografia (CELADE), Santiago, 1979.

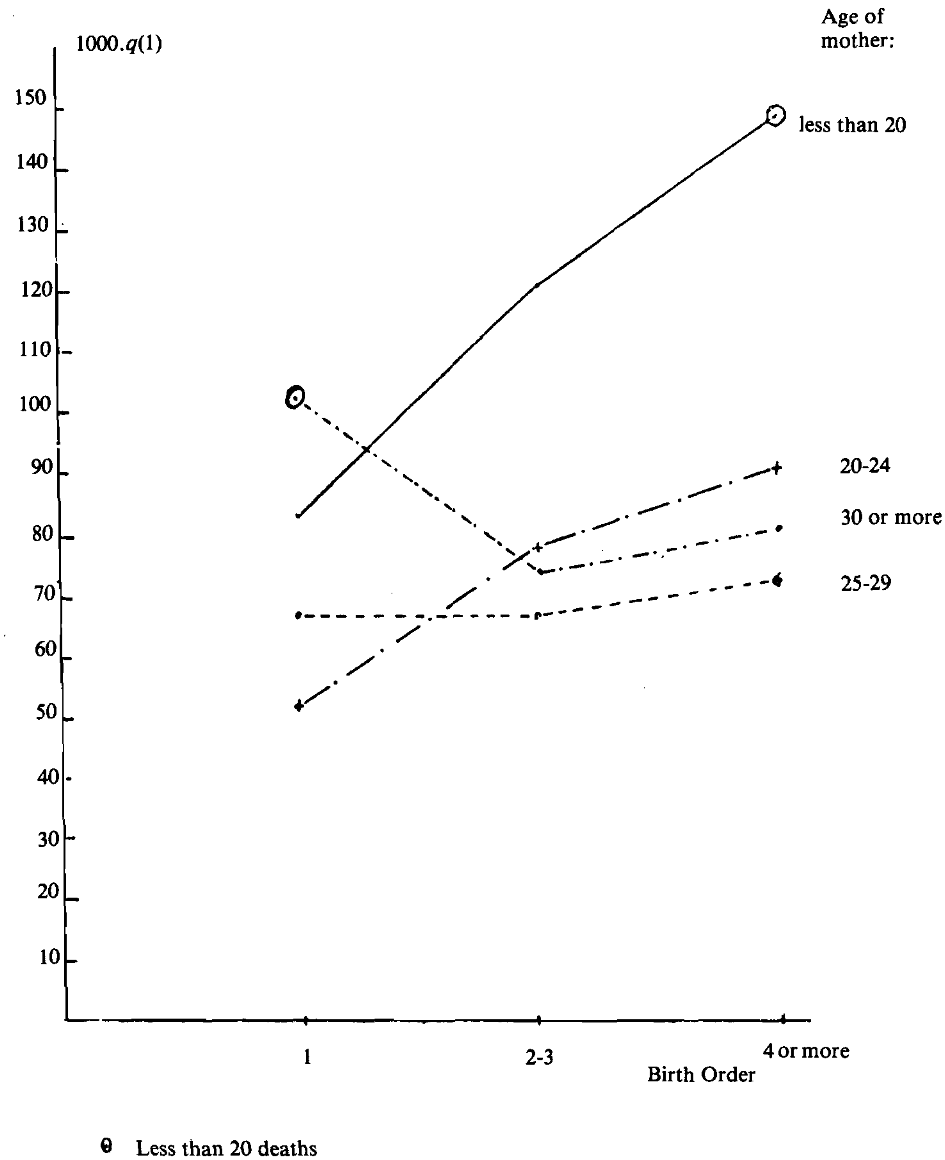
Table 4.7. Infant Mortality by Birth Order and by Age of Mother at Time of Birth of the Child

1000.$q(1)$

Age at Time of Birth	Order 1	Order 2-3	Order 4+	Total
20	83	121	149*	100
20-24	52	78	91	76
25-29	67	67	73	71
30+	102*	74	81	81
Total	71	86	82	81

*Less than 20 deaths

Figure 4.6: Infant Mortality by Birth Order and by Age of Mother at the Time of Birth of the Child



Before we examine these results it may be convenient to note that the analysis of infant mortality by age of mother at the time of birth of the child and birth order is confounded by period effects: the mortality experience of children of older mothers or of higher birth orders is more recent in time than the experience of children of younger mothers or lower birth orders.

Let us look first at the results by age of mother: infant mortality is high among children born to very young mothers (under 20) whatever the birth order, reaches the lowest values at ages 20-24 or 25-29 (more frequently at the latter ages), and increases again for children born to women age 30 or more, again whatever the birth order.

Let us now look at the results by birth order: first births have clearly the lowest mortality for age of mother under 20 and 20-24, the same mortality as births of order 2 or 3 for mothers age 25-29, and the highest mortality for mothers age 30 or more (although the last estimate is based on only 10 deaths and 100 births). If we compare the infant mortality rates for birth orders 2-3 with the rates for orders 4 and above we find that in all cases (one of them consisting of only 16 deaths and 109 births), infant mortality is higher for births of higher order, whatever the age of the mother. This pattern is clearly seen in Figure 4.6.

The analysis is facilitated if we consider the absolute number of births and deaths in each category, shown in Table 4.8.

Table 4.8 Births and Deaths in the First Year of Life, by Birth Order and by Age of Mother at the Time of Birth of the Child

Age of Mother at Time of Birth of the Child	Birth Order							
	Order 1		Order 2-3		Order 4+		Total	
	Births	Deaths	Births	Deaths	Births	Deaths	Births	Deaths
20	1,672	137	1,145	137	109	16	2,926	290
20-24	1,119	57	2,252	174	1,279	116	4,650	347
25-29	333	22	998	66	2,200	159	3,531	247
30+	100	10	379	28	2,829	227	3,308	265
Total	3,224	226	4,774	405	6,417	518	14,415	1,149

The low mortality of first births is explained because a large majority of first births occur at ages where there is a clear mortality differential by birth order, with first births experiencing lower mortality. Even though first births to women under 20 have an infant mortality rate somewhat higher than the average (83 rather than 81 per thousand), many first births occur to women age 20 to 29, which makes the overall infant mortality rate for first births lower than the average (71 for first births as compared to 81 for all births).

The analysis also reveals an important fact that explains the very high infant mortality for very young women (under 20); for these women the mortality experienced by births of order 2 and higher is very high: 121 per thousand for births of order 2 or 3 and 149 per thousand for births of order 4 and higher (even though the last value must be interpreted with caution as it is based on scant information: 16 deaths and 109 births).

Finally, the analysis of the data in Tables 4.7 and 4.8 reveals that the unclear pattern of mortality by birth order for births of orders above one is due to compositional differences by age. For example the incidence of births of order 2 or 3 in the age group under 20 is very high, and these children have a very high mortality. If we control this fact there emerges a clear trend of mortality increase with birth order, a result clearly documented in the Chilean study of Taucher[1].

4.6 MORTALITY BETWEEN BIRTH AND AGE 2 BY 5-YEAR CALENDAR PERIODS

Let us now consider mortality between the ages of 0 and 2, including subdivisions of the first year of life, by 5-year calendar periods between 1956-60 and 1971-75. The data are presented in Table 4.9 and Figure 4.7.

Table 4.9 Mortality Between 0 and 2 Years by 5-Year Calendar Periods from 1956-1960 to 1971-1975

	Life Span $(x, x+t)$				
x	0	1/12	3/12	1/2	1
$x+t$	1/12	3/12	6/12	1	2
	A. Deaths reported $({}_tD_x)$				
1956-1960	100.5	28.5	35.5	48.0	53.0
1961-1965	112.5	33.5	41.0	50.5	63.5
1966-1970	123.0	27.5	35.0	53.0	59.5
1971-1975	113.5	32.5	35.0	50.0	61.4
	B. Corresponding births $({}_tB_x)$				
1956-1960	2191.5	2168.5	2122.5	2035.0	1892.5
1961-1965	3073.0	3046.0	3012.0	2965.0	2829.5
1966-1970	3523.0	3521.5	3512.5	3493.5	3452.5
1971-1975	3481.5	3481.0	3505.0	3505.5	3518.0

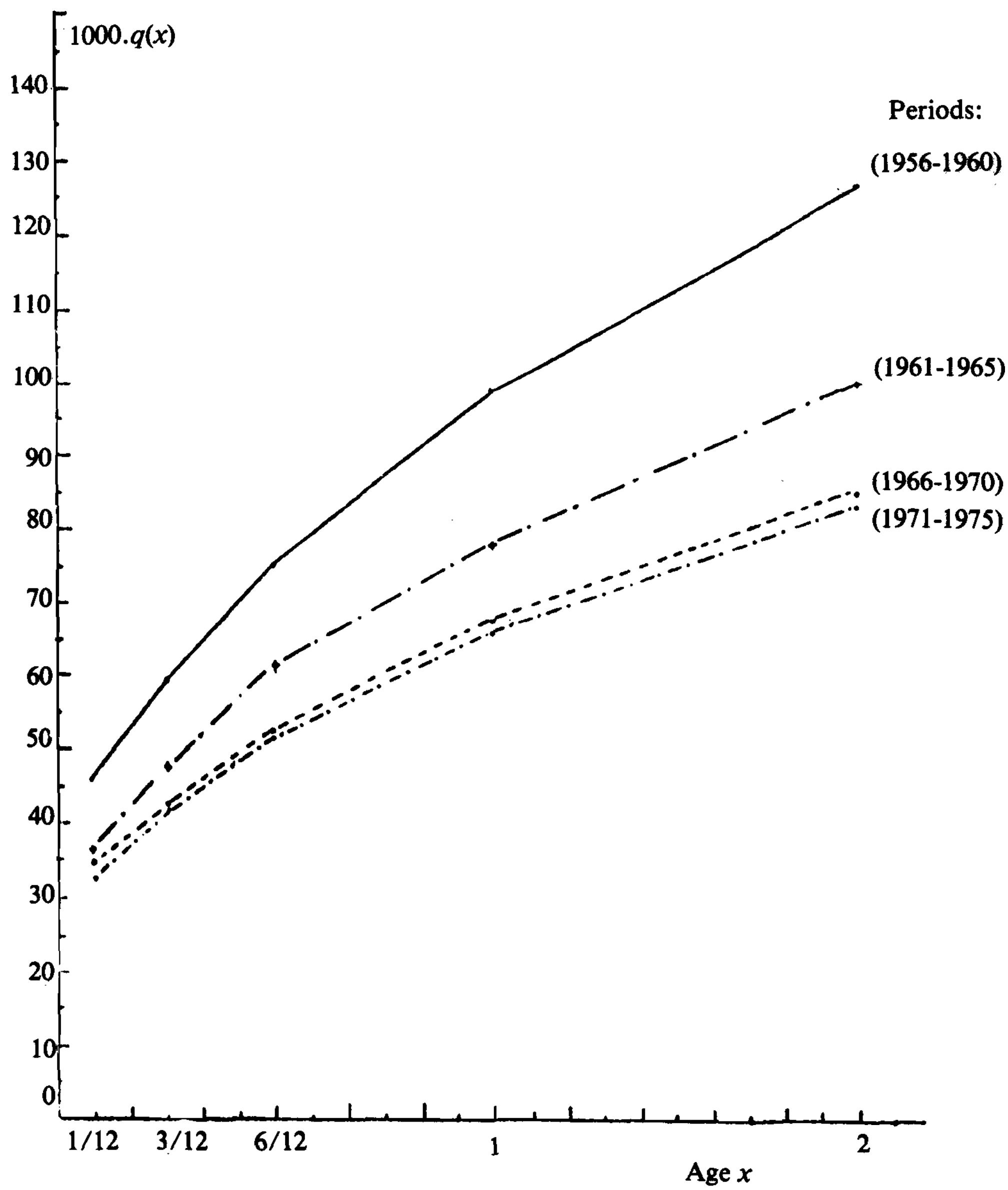
C. Deaths in the life table ($_td_x$, $0 = 1$)

1956-1960	.0459	.0131	.0167	.0236	.0280
1961-1965	.0366	.0100	.0136	.0170	.0224
1966-1970	.0349	.0078	.0100	.0152	.0172
1971-1975	.0326	.0093	.0100	.0143	.0175

D. Probability of dying between 0 and $x + t$ ($q(x + t)$)

1956-1960	.0459	.0590	.0757	.0993	.1273
1961-1965	.0366	.0476	.0612	.0782	.1006
1966-1970	.0349	.0427	.0527	.0679	.0851
1971-1975	.0326	.0419	.0519	.0662	.0837

Figure 4.7 Mortality Rate $q(x)$ Between 0 and 2 Years by Calendar Periods



The conclusion is clear: mortality has declined persistently. The decline over the first three quinquennia was more pronounced than over the last two, where the change is barely noticeable.

Since we know that child mortality depends on the age of the mother at the time of birth of the child, we must note that the mortality estimates by calendar period are affected by the fact that, as we go back in time, children born to older mothers are progressively less represented. Thus, while mortality estimates for years close to 1976 reflect the experience of children born to mothers age 15 to 49 at the time of birth of the child, the estimates for 5 years before reflect the experience of children born to mothers aged at most 45 at the time, and so on as we go back in time.

In order to establish the trend of mortality free of the compositional effect of age of mother we have calculated infant mortality rates within categories of age of mother at the time of birth of the child. We find that for children of women aged 20-24, 25-29 and 30-34 at the time of birth of the child, which constitute the bulk of the sample, infant mortality has clearly declined over time. The extent of the decline for these age groups exceeds 40 per cent and is larger than for the total sample.

The group of children to mothers aged under 20 shows a declining infant mortality up to 1966-70 and then an increase. This recent increase may well represent a real change: as fertility declines the group of women who have a child before age 20 tend to be more selected, that is, they tend to be of rural background and less educated.

The group of children born to mothers aged 35 and over at the time of birth of the child shows an increasing trend in mortality, but this effect is surely due to the age composition of this group: for the most recent period "35 and over" includes up to age 49, whereas for the previous five years it includes only up to age 44, and for the earlier five year period it includes only up to age 39. Thus, as we go back in time we are left with a younger group of mothers, whose children are therefore subject to a lower risk of dying.

A simple way to control the changing composition by age of mother over time is to consider only children whose mothers were under age 35 at the time they were born. Restricting the analysis to this group we find that the infant mortality rate for the four periods being considered was 99, 79, 68 and 62 per thousand, as shown in Table 4.10. The magnitude of the decline is thus 38 per cent, compared with only 33 per cent for all ages of mothers. This analysis provides a more refined estimate of the trend in infant mortality over time.

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[1] op. cit.

Table 4.10 Mortality Between 0 and 2 Years by 5-Year Calendar Periods from 1956-1960 to 1971-1975. Restricted to Women Aged Under 35 at the Time of Birth of the Child

	Life span $(x, x+t)$				
x	0	1/12	3/12	1/2	1
$x+t$	1/12	3/12	6/12	1	2
		A. Deaths reported $({}_tD_x)$			
1956-1960	100.5	28.5	35.5	48.0	53.0
1961-1965	106.5	27.5	41.0	49.0	62.0
1966-1970	106.0	24.5	31.0	44.5	51.0
1971-1975	93.0	25.0	24.5	42.0	46.0
		B. Corresponding births $({}_tB_x)$			
1956-1960	2191.5	2168.5	2122.5	2035.0	1892.5
1961-1965	2873.5	2857.5	2841.0	2822.5	2733.0
1966-1970	3023.0	3024.5	3022.0	3010.5	3001.5
1971-1975	2984.0	2988.5	3011.0	3013.0	3015.5
		C. Deaths in the life table $({}_td_x, l_0 = 1)$			
1956-1960	.0459	.0131	.0167	.0236	.0280
1961-1965	.0371	.0096	.0144	.0174	.0227
1966-1970	.0351	.0081	.0103	.0148	.0170
1971-1975	.03 12	.0084	.0081	.0139	.0153
		D. Probability of dying between 0 and $x+t$ $(q(x+t))$			
1956-1960	.0459	.0590	.0757	.0993	.1273
1961-1965	.0371	.0467	.0611	.0785	.1012
1966-1970	.0351	.0432	.0535	.0683	.0853
1971-1975	.0312	.0396	.0477	.0616	.0769

4.7 MORTALITY BY SEX

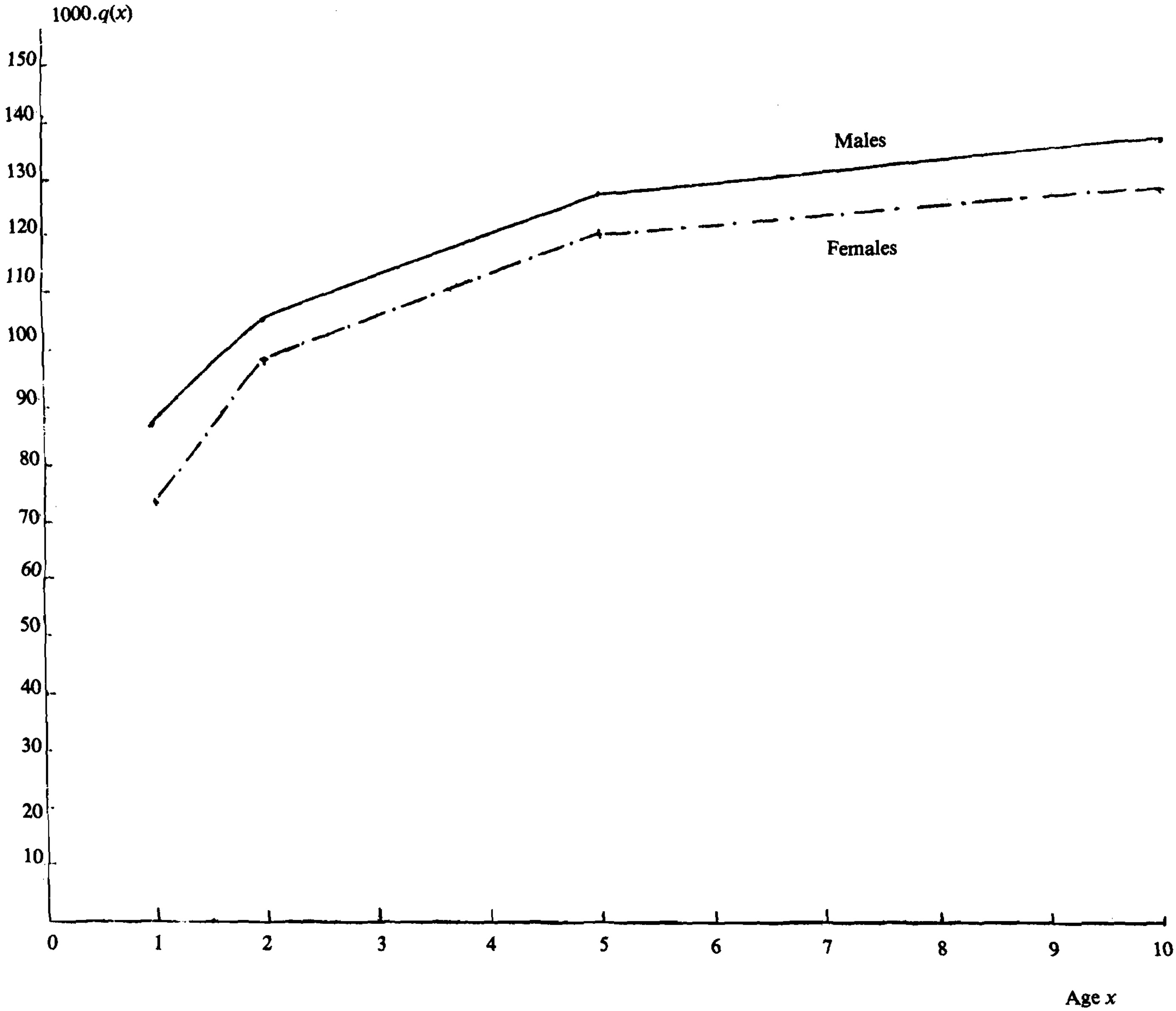
Table 4.11 presents child mortality between the ages of 0 and 10, measured by the life table functions $_nm_x$ and $q(x)$, separately for children of each sex. The analysis is done classifying the children in three cohorts by period of birth 1941-59, 1960-67 and 1968-76.

Table 4.11 Mortality by Birth Cohorts and by Sex

Age Groups		Born in the Period						Total	
		1941-1959		1960-1967		1968-1976			
$x,$	$x+n$	$_nm_x$	$q(x+n)$	$_nm_x$	$q(x+n)$	$_nm_x$	$q(x+n)$	$_nm_x$	$q(x+n)$
				Males					
0	1	.1310	.1195	.0861	.0809	.0806	.0740	.0946	.0873
1	2	.0279	.1437	.0184	.0976	.0170	.0895	.0202	.1055
2	5	.0109	.1713	.0068	.1159	.0070	.1085	.0080	.1268
5	10	.0030	.1837	.0023	.1261	.0017	.1159	.0025	.1376
				Females					
0	1	.1011	.0945	.0807	.0762	.0635	.0593	.0785	.0736
1	2	.0403	.1302	.0248	.0988	.0208	.0786	.0271	.0983
2	5	.0075	.1496	.0088	.1223	.0073	.0985	.0080	.1197
5	10	.0026	.1605	.0017	.1296	.0018	.1065	.0020	.1285

As noted earlier, we observe that infant mortality is systematically higher among males than among females. The cumulative probability $q(x)$ for the complete period 1941-76 also shows higher male infant and child mortality, as seen from Figure 4.8.

Figure 4.8 Mortality Rate $q(x)$ by Sex



The mortality rate for ages 1 to 2 years, however, shows the opposite pattern, namely higher female mortality. Between the ages of 2 and 10 there is no clear mortality differential by sex. These facts may be noted from Figure 4.9 for the total sample and Figure 4.10 for the three cohorts considered.

Figure 4.9 Mortality Rate ${}_nm_x$ by Sex

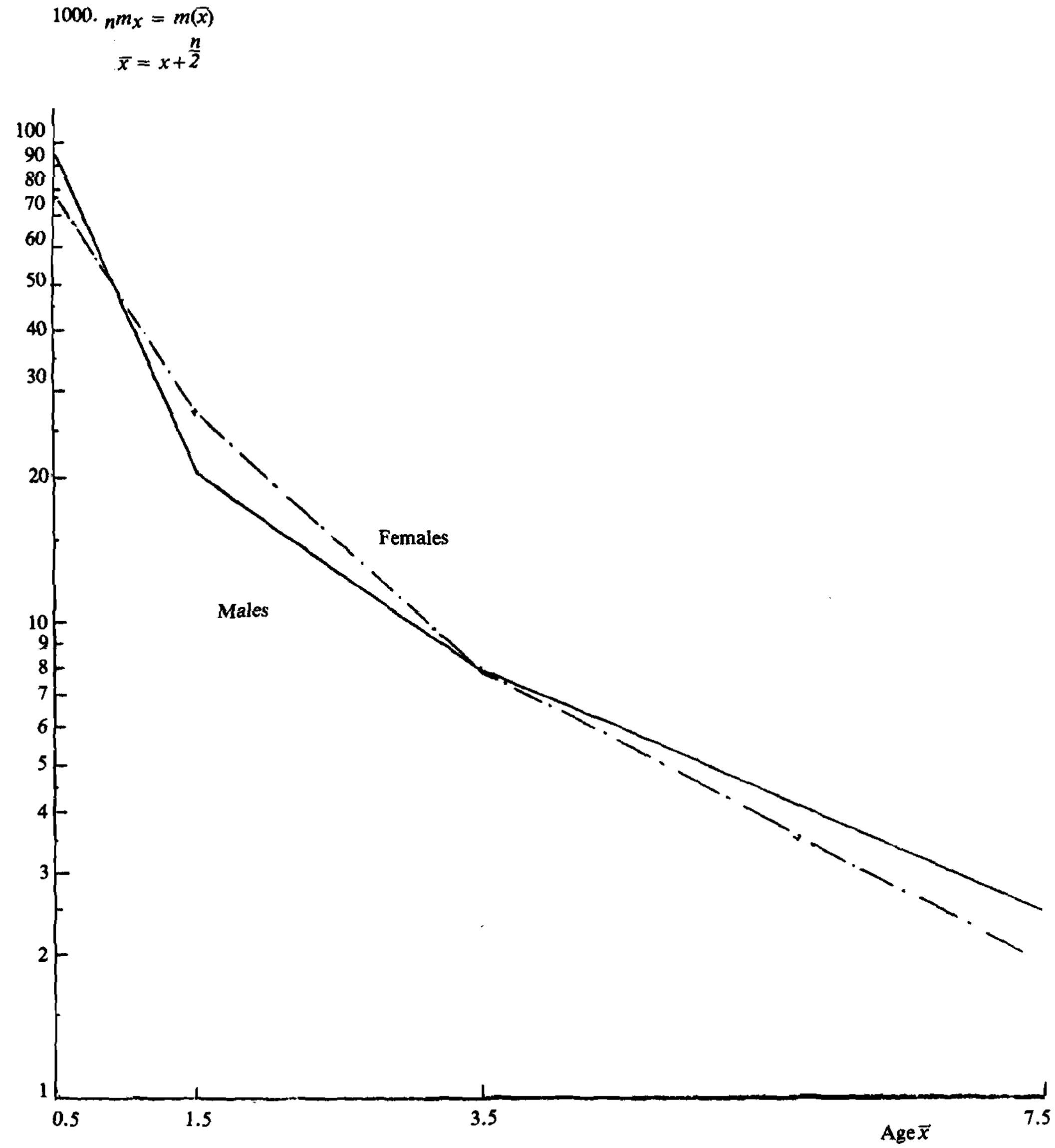
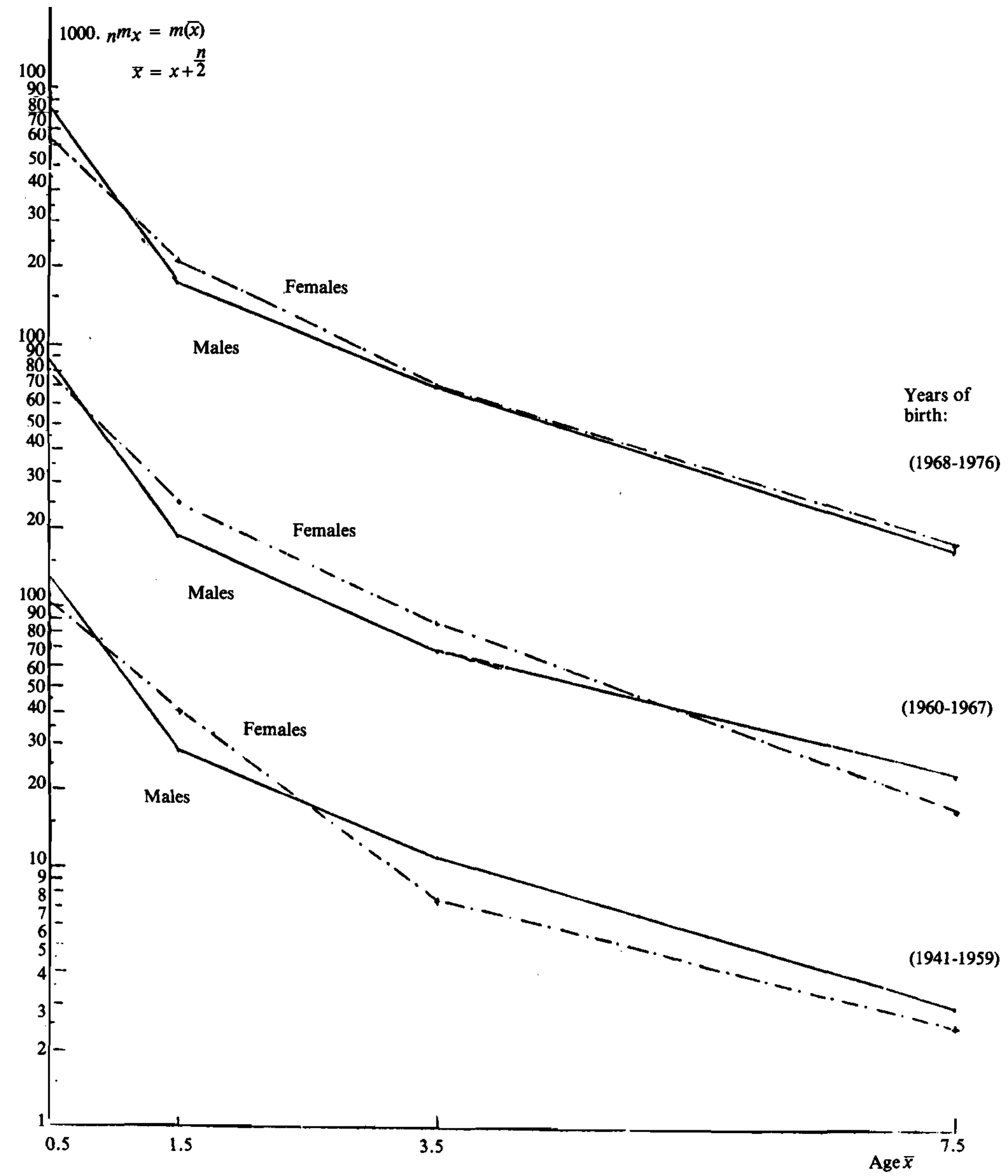


Figure 4.10 Mortality Rate ${}_nm_x$ by Birth Cohorts and by Sex



We have searched, among Latin American countries for which reliable life tables are available, for other instances where female mortality is higher than male mortality between the ages of 1 and 5 years, and we have found several cases shown in Table 4.12. We present the probabilities of dying between ages 0 and 1 and between ages 1 and 5 by sex, as well as the ratio between the male and female rates. It may be noted that in Guatemala (1971-72), Costa Rica (1972-74) and Mexico (1969-71) male mortality is higher than female in the first year of life, but the opposite holds for ages 1 to 5. Thus, in these countries we find a situation similar to that noted for Colombia; although it should be emphasized that in none of these countries the difference between male and female mortality between ages 1 and 5 is as large as that found in Colombia.

Table 4.12 Probability of Dying Between Ages 0 and 1 and Between 1 and 5, by Sex: Various Latin American Countries

Country	Probability of Dying Between Age 0 and 1			Probability of Dying Between Age 1 and 5		
	Males	Females	Ratio	Males	Females	Ratio
	(17	(2)	(1)/(2)	(3)	(4)	(3)/(4)
	(per 1000)		(per 100)	(per 1000)		(per 100)
Colombia (Survey)	87.3	73.6	118.6	43.3	49.8	86.9
Guatemala 1971-1972	108.7	91.9	118.3	86.6	93.4	92.7
Costa Rica 1972-1974	55.2	43.6	126.6	12.7	13.0	97.7
Mexico 1969-1971	72.2	60.6	119.1	33.5	34.5	97.1

Sources:
Costa Rica: Evaluación del Censo de 1973, Proyección de la Población por sexo y grupos de edades. 1950-2000. Dirección General de Estadística y Censos y CELADE. Costa Rica, junio 1976.
Guatemala: Juan Chackiel: Guatemala, Evaluación del Censo de 1973 y proyección de la población por sexo y edad 1950-2000. CELADE. Serie A N°1021, Costa Rica, febrero, 1976.
Mexico: Tablas abreviadas de mortalidad para ocho regiones de México, 1970, Evaluación y Análisis. Serie III. N°3, 1976. Dirección General de Estadística.

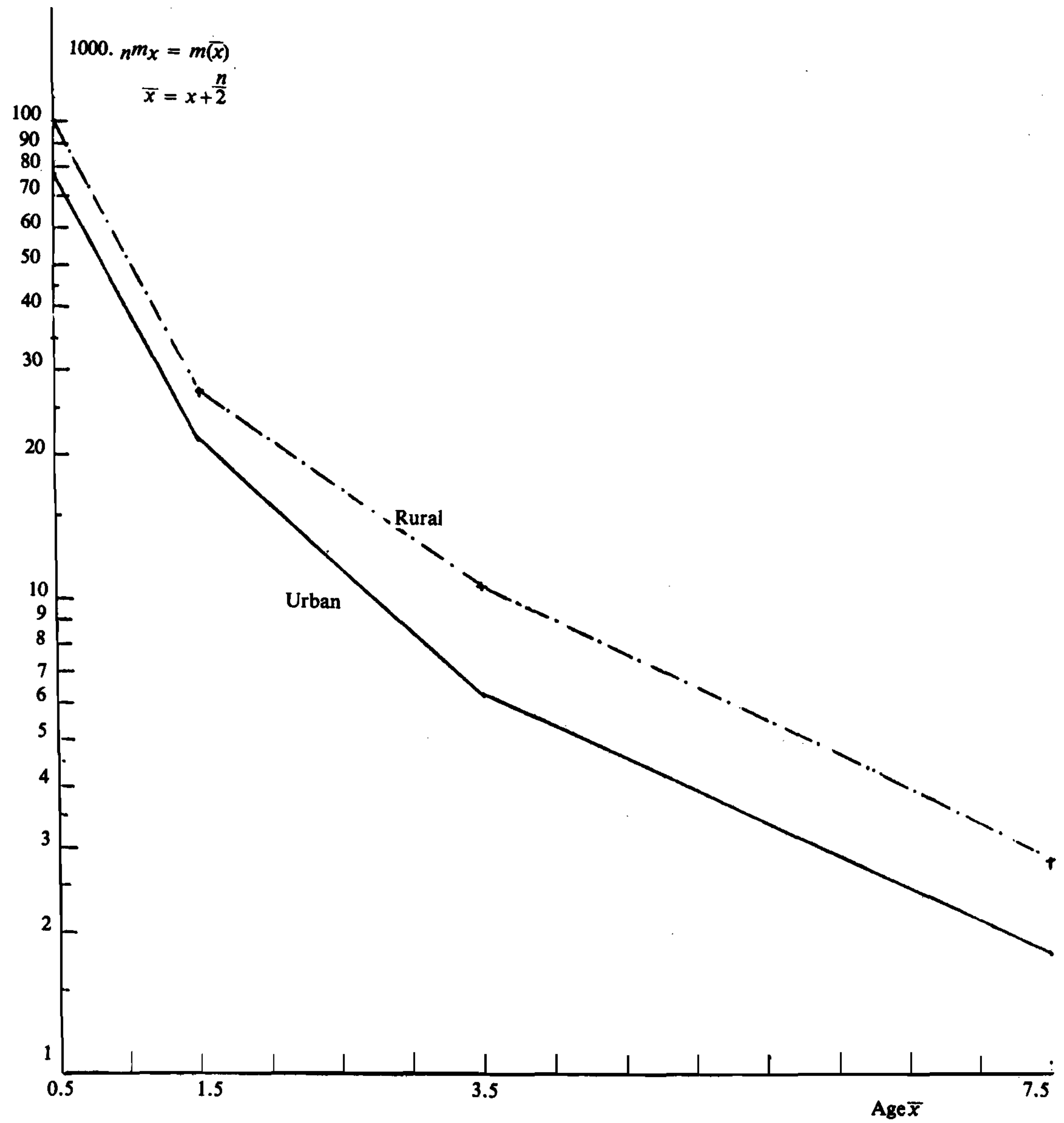
4.8 URBAN AND RURAL MORTALITY

Table 4.13 presents mortality tables for ages 0 to 10 and Figure 4.11 shows mortality rates for selected ages, by type of place or residence (urban or rural).

Table 4.13. Mortality by Type of Place of Residence: Urban and Rural

Age Groups		Urban		Rural	
x,	$x+n$	$_nm_x$	$q(x+n)$	$_nm_x$	$q(x+n)$
0	1	.0770	.0722	.0998	.0920
1	2	.0214	.0918	.0267	.1160
2	5	.0062	.1086	.0105	.1434
5	10	.0018	.1168	.0028	.1553

Figure 4.11 Mortality Rate ${}_nm_x$ by Type of Place of Residence



The mortality differential by type of place of residence emerges clearly: urban mortality is lower than rural mortality.

In the analysis of these results it should be noted that type of place of residence refers to the respondent's residence at the time of the survey. To the extent that there is migration the mortality experience of children may not correspond to the mother's current place of residence. If we assume that the prevailing direction of migration is from rural to urban areas, it follows that urban mortality may be inflated by the higher mortality of the children of migrant rural women. In other words, the urban-rural differential may be higher than indicated by the above results.

4.9 CHILD MORTALITY BY EDUCATIONAL LEVEL OF THE MOTHER

Table 4.14 shows mortality rates for selected ages and probabilities of dying between birth and age 10 for children classified by educational level of the mother in two categories: two years of schooling or less (including women with no education), and three years of schooling or more. The mortality rates are depicted in Figure 4.12.

Table 4.14. Mortality of Children by Mother's Level of Education

Age Groups		Mothers with 0-2 Years of Education		Mothers with 3 or More Years of Education	
$x,$	$x+n$	$_nm_x$	$q(x+n)$	$_nm_x$	$q(x+n)$
0	1	.1031	.0952	.0708	.0664
1	2	.0299	.1218	.0175	.0826
2	5	.0110	.1503	.0051	.0965
5	10	.0025	.1609	.0020	.1055

The expected pattern emerges clearly: the mortality of children of women with lower education is higher than the mortality of the off spring of mothers with higher schooling.

It should be noted here that level of education is not a fixed attribute but may increase through life, specially for very young women. Thus a woman may have had a lower educational level at the time her children were born than at the time of the survey. As in the case of the urban-rural differential, the educational differential may thus be higher than indicated in Table 4.14.

On the other hand, the level of education of the population has increased and infant mortality has declined over time. As a result women with low education in the sample will tend to be older than average, and their children, having been born earlier in time, will have been subject to a higher than average mortality risk. In other words, a declining trend in infant mortality combined with improving educational standards in the population may inflate educational differentials.

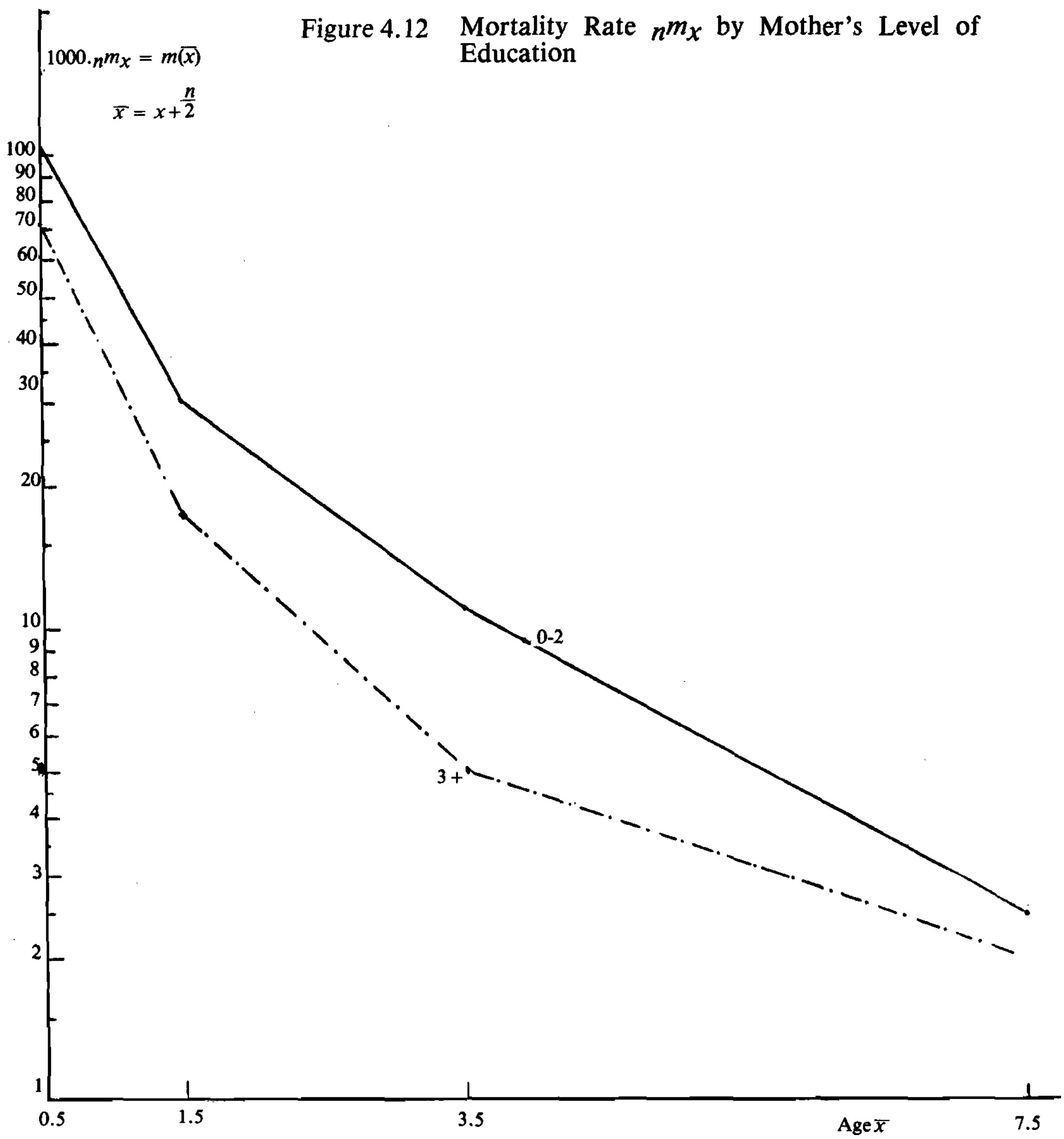


Figure 4.12 Mortality Rate $_nm_x$ by Mother's Level of Education

It would be possible to estimate infant mortality controlling the two variables discussed, namely level of education of mother and calendar period when the child was born. The effort is not justified, however, given that we are interested in verifying the existence of clear differences among large segments of the population rather than in measuring such differences precisely. The simpler objective is achieved with the more elementary analysis presented in Table 4.14.

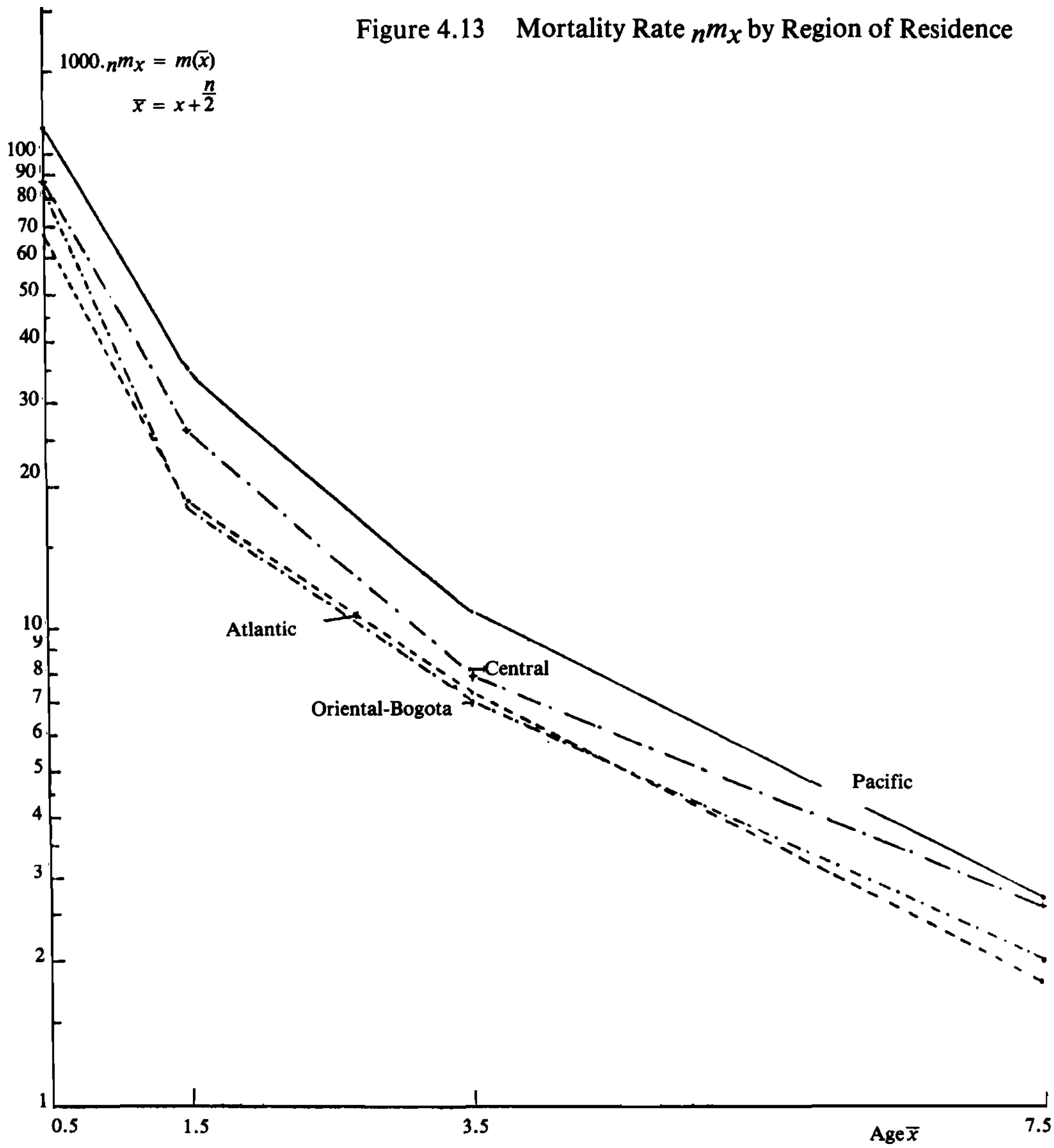
4.10 MORTALITY BY REGIONS

Finally, we examine mortality by regions. For this purpose the country is subdivided in four regions: Pacific, Central, Atlantic and Oriental-Bogota. It is not possible to study Bogota separately because of the small number of cases (1,353 births and 106 deaths).
The life table functions $_nm_x$ and $q(x)$ for the four regions are given in Table 4.15, while mortality rates for ages between 0 and 10 are shown in Figure 4.13.

Table 4.15 Mortality by Region of Residence

Age Group 1		Region							
		Pacific		Central		Atlantic		Oriental-Bogota	
x	$x+n$	$_nm_x$	$q(x+n)$	$_nm_x$	$q(x+n)$	$_nm_x$	$q(x+n)$	$_nm_x$	$q(x+n)$
0	1	.1143	.1044	.0876	.0816	.0674	.0638	.0827	.0769
1	2	.0350	.1352	.0261	.1052	.0184	.0808	.0180	.0934
2	5	.0109	.1629	.0079	.1262	.0073	.1007	.0069	.1120
5	10	.0027	.1741	.0026	.1374	.0018	.1087	.0020	.1207

Figure 4.13 Mortality Rate $_nm_x$ by Region of Residence



The highest mortality is found in the Pacific region, followed by the Central region and then the Atlantic and Oriental-Bogota, without appreciable differences between the last two in the age span 0-10 years, though Atlantic shows lower infant mortality than Oriental-Bogota.

One may doubt the fact that the Atlantic region should have the lowest mortality, as living conditions in that region are believed to be below the national average. We therefore analyzed in more detail the data by region, searching for possible deficiencies.

Table 4.16 shows the proportion of children dead by current age of the mother and by region. As we have noted before, these proportions should increase with age of the mother. We find the expected pattern in all regions except the Atlantic, where the proportion of children dead for women age 30-39 is lower than for women age 15-29. This irregularity may be due to poor quality of the data, perhaps omission of children dead in the group 30-39, or to the small number of observations.

Table 4.16 Number of Dead Children, Number of Births and Proportions of Children Dead, by Age of the Mothers and by Region of Residence

Age of Mothers	Region			
	Pacific	Central	Atlantic	Oriental-Bogota
		Number of dead children		
15-29	87	69	89	73
30-39	160	191	110	160
40-49	199	295	114	283
		Number of births		
15-29	662	886	912	986
30-39	1,007	1,552	1,264	1,511
40-49	1,040	1,814	832	1,949
		Proportion of children dead		
15-29	.131	.078	.098	.074
30-39	.159	.123	.087	.106
40-49	.191	.163	.137	.145

The same table presents the number of births and deaths reported in the survey classified by region. It may be noted that the Atlantic region shows the lowest number of deaths (only 313). It is not possible to determine whether mortality is actually lower or there has been omission of deaths in the data reported by women in this region.

This is the first instance in the analysis where we have presented a result which is believed to be affected by omission. This deficiency is confined to one particular region and cannot invalidate the results and conclusions presented earlier. It should be noted, however, that we have reserves regarding the conclusion that mortality is lowest in the Atlantic region and suspect that this conclusion is false.

It seems almost unnecessary to point out that region of residence refers to the mothers' residence at the time of the survey rather than the time their children were born and subject to the risk of mortality, and that the results are therefore affected by migration.

4.11 SUMMARY

We conclude this analysis with a summary table which lists the analyses that have been conducted, gives the number of categories used in each case and the ages considered, and provides reference to the tables and figures containing the results.

Analysis of Mortality By	Number of Categories	Ages Studied	Tables 4.	Figures 4.
1. Cohorts (0-10)	3	0-10	1,2,3	1,2
2. Cohorts (neonatal and post-neonatal)	5	0-1	4	3
3. Age of mother at birth of child	4	0-1	5	4
4. Birth order	3	0-1	6	5
5. Age of mother and birth order	12	0-1	7, 8	6
6. Calendar periods	4	0-2	9, 10	7
7. Cohorts and sex	8	0-10	11, 12	8, 9, 10
8. Urban and rural	2	0-10	13	11
9. Educational level	2	0-10	14	12
10. Region	4	0-10	15, 16	13

5 Indirect Methods for Estimating Mortality

The application of direct estimation techniques to the data from the Colombian survey has lead to mortality estimates which appear to be reliable and not affected by omission of dead children. Let us now take these estimates as correct and see how closely we can replicate the results by applying indirect estimation techniques to one of the items of information used before, namely the proportion of children dead by age of mother at the time of the survey. The exercise is of methodological interest: knowing beforehand the level of mortality that we are trying to estimate, we can assess the efficiency of the indirect techniques used. It also serves to illustrate the procedures that would be used to estimate mortality if the data required for direct estimation were not available.

5.1 THE DATA

Two sets of data on the proportion of children dead by age of mother are available: (a) information provided directly by the woman in the birth history section of the individual interview, or "individual data", and (b) information provided in the household survey, not necessarily by the mothers themselves, or "household data". The children reported in the individual survey (which covered 5,378 women) are also included in the household survey (which covered 12,914 women).

One may expect the individual data to be of better quality than the household data, as the information is always collected directly from the woman herself. The household data, on the other hand, are analogous to the data usually collected in censuses and surveys which do not go into a detailed study of fertility. In many developing countries mortality estimates are usually derived from information provided for all members of the household by a respondent who is not necessarily the mother of the children in question.

Table 5.1 shows the basic data used to derive indirect estimates of mortality. It may be noted that the household survey provides information on the survival status of 34,161 live births, of whom 4,423 had died. The corresponding figures for the individual survey are 14,415 live births and 1,830 deaths.

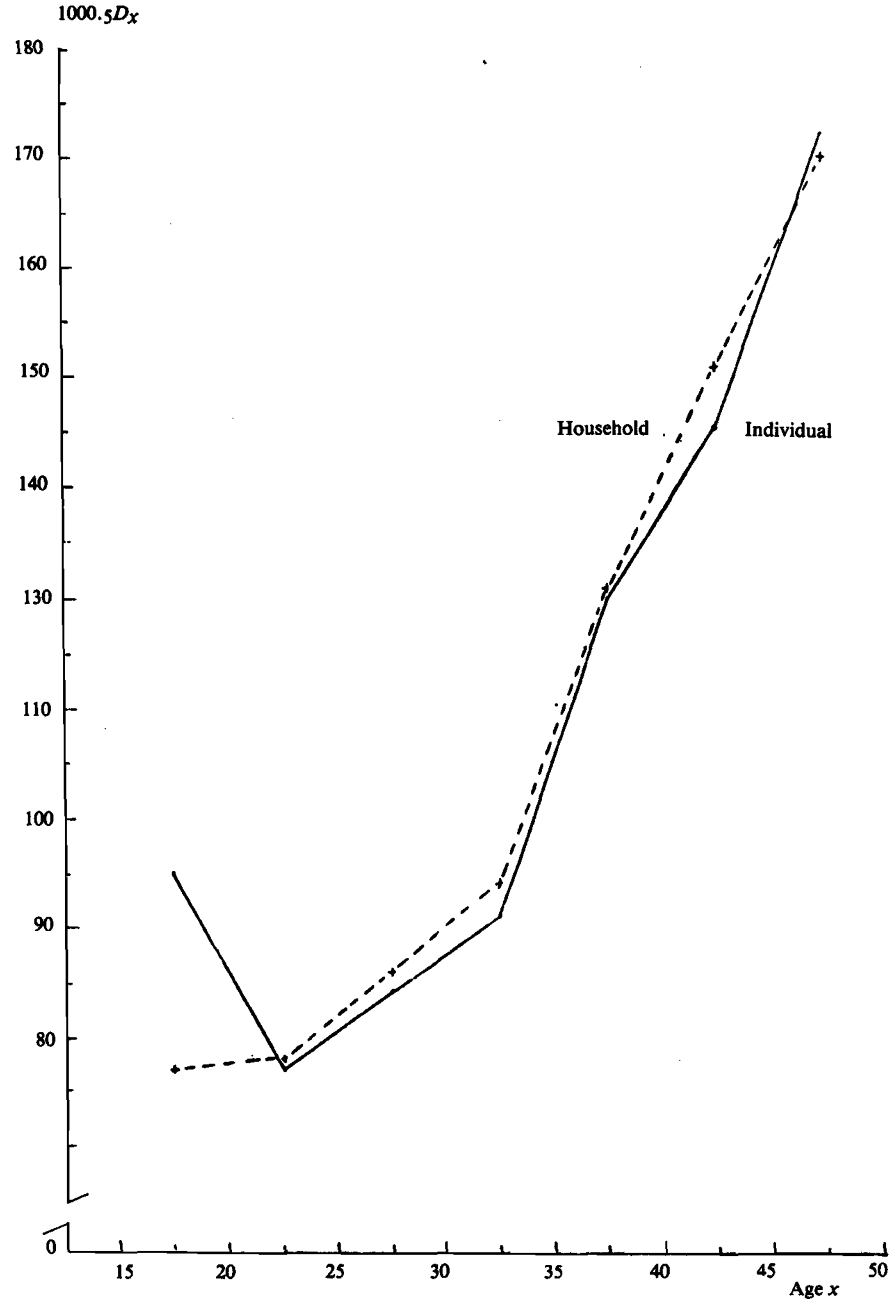
Table 5.1 Women, Children Ever Born, Children Who Have Died, Average Number of Children Ever-Born and the Proportion Who Have Died, by Age of Mother

Sub-script i	Age Groups	Women N_i	Children Ever Born C_i	Children Who Died CD_i	Average Number of Children Ever Born P_i	Proportion Dead/ Born D_i
			Household Survey			
1	15-19	3,294	497	43	.151	.087
2	20-24	2,576	2,707	238	1.051	.088
3	25-29	2,046	4,740	453	2,317	.096
4	30-34	1,399	5,275	551	3.771	.104
5	35-39	1,497	7,550	989	5.043	.131
6	40-44	1,087	6,760	1,024	6.219	.151
7	45-49	1,015	6,632	1,125	6.534	.170
Total		12,914	34,161	4,423	2.645	.129
			Individual Survey			
1	15-19	1,423	237	25	.167	.105
2	20-24	1,051	1,157	101	1.101	.087
3	25-29	842	2,052	192	2.437	.094
4	30-34	599	2,423	244	4.045	.101
5	35-39	579	2,911	377	5.028	.130
6	40-44	476	2,889	420	6.069	.145
7	45-49	408	2,746	471	6.730	.172
Total		5,378	14,415	1,830	2.680	.127

Source: Colombia Household and Individual Survey, 1976.

The proportion of children dead by age of mother, shown in Table 5.1, turns out to be approximately the same for both sets of data. The only instance where the two surveys differ is the age group 15 to 19, where the household survey gives a proportion of children dead of .087 whereas the individual survey gives a proportion of .105. This difference is not very significant, however, as the proportions are based on a small number of cases and are thus subject to large sampling error; the number of deaths in this group is 43 for the household survey and only 25 for the individual survey. For the other age groups the two surveys give very similar proportions of children dead, as it can be seen from Figure 5.1.

Figure 5.1 Proportion of Children Dead by Age of Mother in 1976. Household and Individual Surveys



As the two sets of data are very similar it was decided, for the sake of simplicity, to illustrate the application of the indirect estimation procedures only to the information collected in the individual survey.

5.2 THE METHODS

We shall present results obtained applying three different indirect estimation techniques. The methods themselves will not be described, as they are well known and have either been published or are about to be published. We have selected these methods because they are believed to be better and because they allow for possible changes in mortality over time, something the original indirect methods did not.

The methods applied are the following:

(a) A method proposed by William Brass which allows for a decline in mortality over time.

(b) A method devised by Griffith Feeney, which may also be applied in conditions of changing mortality.

(c) A method derived by James Trussell that provides estimates of mortality for selected ages as well as the number of years before the time of the survey to which the estimates apply. There are two variants of the Trussell method: one assumes constant fertility and the other allows for changes in fertility.

5.3 THE BRASS METHOD

We consider first a method proposed by Brass[1]. The data required by the method are the following:

(a) The mean number of children ever-born to women in the first two age groups (15-19 and 20-24) or in the second and third age groups (20-24 and 25-29). These values are denoted P_1 and P_2 or P_2 and P_3 respectively. The method may be applied to either set; for the sake of simplicity we will use only P_2 and P_3. It seems prudent not to use the data for the first age group, which is subject to large sampling errors due to a small number of cases: women age 15-19 have many fewer children than women in the next two age groups.

(b) The rate of decline of mortality over time, expressed in the logit scale. Given estimates of mortality at two points in time, t_1 and t_2, the value required is defined as follows

$$\frac{\text{logit}\, l^{t_1}(x) - \text{logit}\, l^{t_2}(x)}{t_1 - t_2}$$

In our case we know the evolution over time of mortality up to age 2. The value of the index defined above, however, varies considerably depending on the calendar period used. To simplify the application we have used a single value corresponding approximately to the average rate of decline between 1956-60 and 1971-75, which is two per cent per year (see Table 4.9).

(c) The proportion of children dead by age of mother, denoted D_i with $i = 1, 2, \ldots, 6$ corresponding to the age groups 15-19, 20-24, . . ., 40-44.

The results obtained by the Brass procedure are shown in Table 5.2 and consist of six ages x such that the probability $q(x)$ of dying between birth and age x corresponds to one of the observed values of D_i. For example, the proportion of children dead for the age group 30-34 is $D_4 = .101$; according to the method this value corresponds to $q(6.4)$, that is, the probability of dying between ages 0 and 6.4.

[1] Brass, William, *Methods for Estimating Fertility and Mortality from Limited and Defective Data,* University of North Carolina, Chapel Hill, 1975.

Table 5.2: Mortality Estimates Obtained by Applying Brass's Indirect Method (Assuming an Annual 2% Decrease in Mortality) to Information Collected in the Individual Survey; Compared with Estimated Obtained Directly from Selected Two-Year Cohorts

				Direct Calculation	
Subscript i	Age Groups of Women x,x+4	Proportion of Dead Children $D_i = q(x)$ (per 1000)	Age of Children x	Years of Birth of Cohort 1976.5-x	Probability of Dying Before Age x 1000 q(x)
1	15-19	105	.9	1975-1976	63
2	20-24	87	2.0	1974-1975	66
3	25-29	94	3.8	1972-1973	101
4	30-34	101	6.4	1970-1971	116
5	35-39	130	10.3	1966-1967	121
6	40-44	145	15.0	1961-1962	136

The indirect estimates may be compared with "observed" or direct estimates of mortality based on births occurring in a particular period. Continuing with the example in the previous paragraph, 6.4 years before the survey defines a period in early 1970. We take the cohorts of children born in 1970 and 1971 (using two years to obtain more data than would be available for a single year cohort) and calculate a life table for selected ages. From this life table we may obtain by interpolation a value comparable with Brass's estimate, that is, the probability of dying between ages 0 and 6.4 years. These calculations are given in Table 5.3, and the results are included in Table 5.2 to facilitate comparison with the indirect estimates.

Table 5.3: Direct Mortality Estimation at Selected Ages for 2-Year Cohorts of Births

Year of Birth $t,t+1$	Number of Births B	Number of Dead Below Age x_1 ${}_{x_1}D_0$	Ages x_0	Ages x_1	Surviving $l(x_0)$	Surviving $l(x_1)$	Selected Age x	Surviving $l(x)$
1975-1976	1,082	58	0.50	1	.9515	.9339	.9	.9374
1974-1975	1,391	80	1.00	2	.9472	.9342	2.0	.9342
1972-1973	1,380	138	2.00	5	.9072	.8929	3.8	.8986
1970-1971	1,448	164	5.00	10	.8843	.8825	6.4	.8838
1966-1967	1,317	154	5.00	10	.8900	.8973	10.3	.8787
1961-1962	1,118	147	5.00	10	.8800	.8711	15.0	.8644*

*Extrapolated assuming $l(15) = l(10) - .75\,(l(5) - l(10))$.

Comparison of the estimates of $q(x)$ obtained by Brass's method with the direct estimates provides an idea of the efficiency of the indirect procedure. For ages 15-19 and 20-24 all indirect procedures (including Brass) tend to over-estimate the probabilities of death due to the relatively high mortality of children of very young mothers. For the remaining ages the indirect estimates are quite similar to the direct ones, as can be seen from Figure 5.2. The method proposed by Brass has lead to satisfactory estimates. One shortcoming of the procedure is that it requires, as a basic input, the rate of mortality decline, which in practice is not known for most developing countries.

Figure 5.2 Mortality Estimates — Brass's Indirect Method (2 Percent Annual Decrease) and Direct Calculations for Two-Year Cohorts

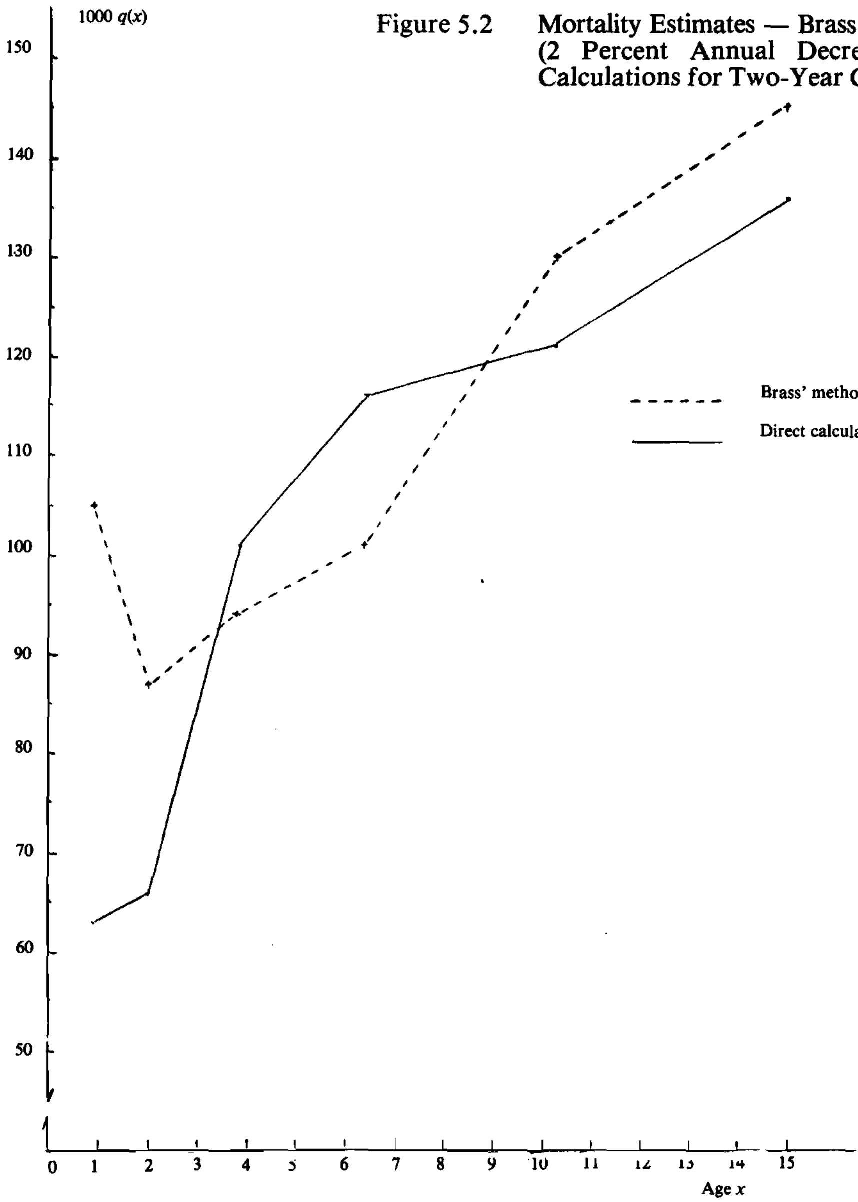


Table 5.4. Estimate of Infant Mortality Through the Years, Obtained by Applying Feeney's Method to Information Collected in the Individual Survey.

Sub-script	Mothers' Age Groups	Individual Survey Starting at Age 15.9 Proportion of Dead Children	Infant Mortality	Time
i	$x, x+4$	D_i	$1000\,q(1)$	t
1	15-19	.105	112.4	1975.5
2	20-24	.087	69.6	1974.0
3	25-29	.094	64.6	1972.4
4	30-34	.101	63.2	1970.2
5	35-39	.130	76.0	1967.6
6	40-44	.145	77.7	1964.7
7	45-49	.172	84.4	1961.4

5.4 THE FEENEY METHOD

We now consider a method proposed by Feeney[1]. The data required are:

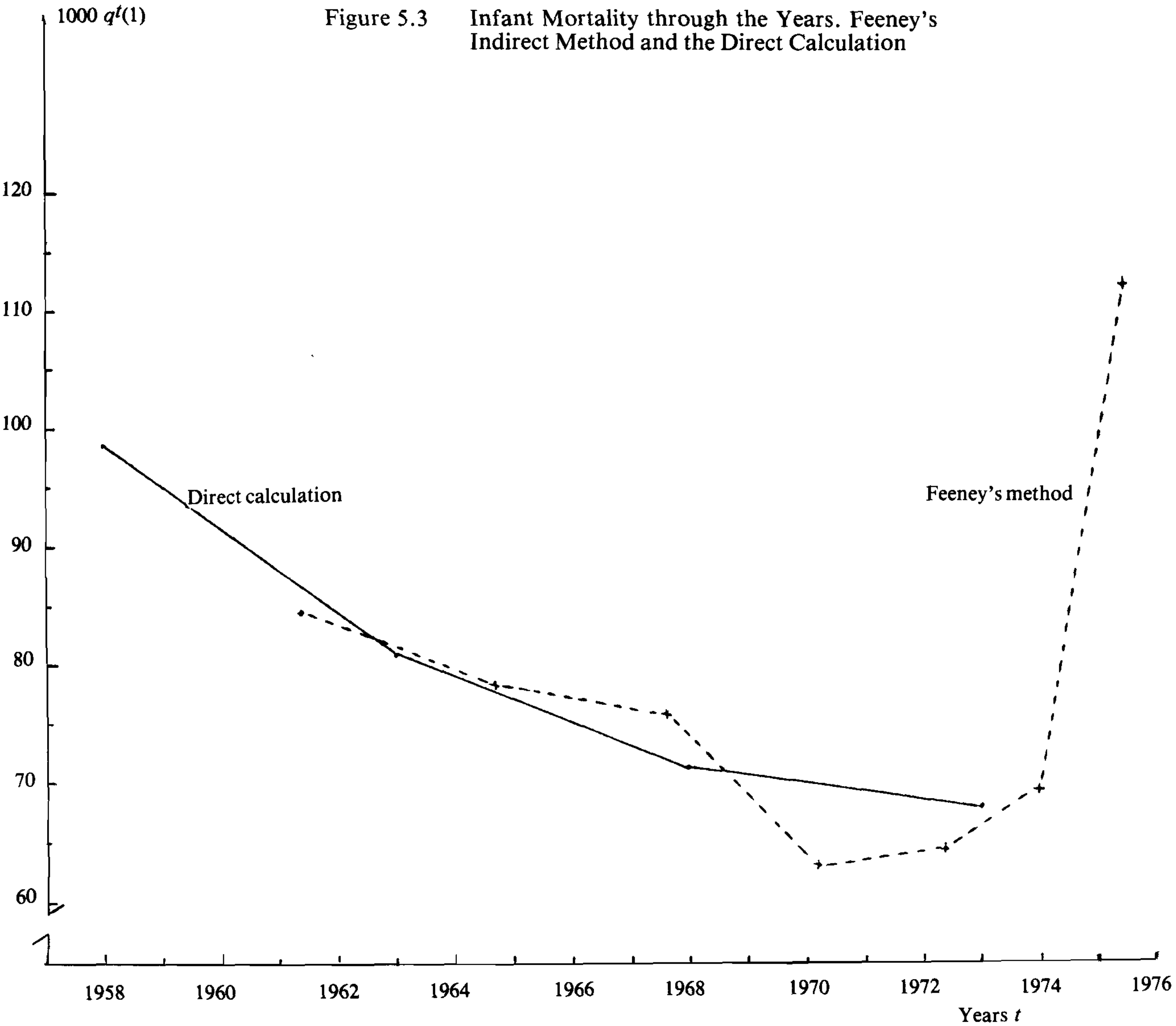
(a) The mean number of children born to women in the first four age groups, denoted P_1, P_2, P_3, P_4. These means are used to estimate the initial age of the reproductive period.

(b) The proportion of children dead by age of mother, denoted D_i, with $i = 1, 2, \ldots, 7$ corresponding to the age groups 15-19, 20-24, . . ., 45-49.

The method yields seven estimates of $q(1)$ the probability of dying in the first year of life, one derived from each D_i, as well as estimates of the moment in time to which each estimate corresponds. The results obtained from applying the Feeney method are shown in Table 5.4 as well as Figure 5.3.

[1] Feeney, Griffith, Estimating Infant Mortality Trends from Child Survivorship, Data. *Population Studies.* 34: 109-128,1980.

Figure 5.3 Infant Mortality through the Years. Feeney's Indirect Method and the Direct Calculation



The estimates show a declining trend of mortality over time which is reversed at the end, that is, in the years closer to 1976. This irregularity is due to the fact that the estimates corresponding to the more recent periods are based on the experience of women aged 15-19 and 20-24, which are known to have infant mortality above the average. This type of result appears systematically in applications of Feeney's method.

In order to compare the indirect estimates with direct estimates we have calculated infant mortality rates for five-year birth cohorts. These data are plotted in Figure 5.3 using for each cohort the mid-point of the time lived along the first year of life; for example, for the cohort born in 1955-59 the mid-point of the first year of life is January 1, 1958. The results indicate that the level and trend of infant mortality between 1961 and 1973, approximately, are reasonably well estimated by the procedure proposed by Feeney.

5.5 THE TRUSSEL METHOD

We finally consider two methods proposed by James Trussell[1]. The first procedure assumes that fertility has been constant, whereas the second allows for a fertility decline over the past five years. The application of these two methods will be described in greater detail than the earlier procedures, and we shall include the regression equations used to derive the estimates, so that the reader will have all the elements required to apply the method.

Constant Fertility

Let us describe first the procedure which assumes constant fertility. The data required are:

(a) The average number of children ever born for the first three age groups, denoted P_1, P_2 and P_3.
(b) The proportion of children dead by age group of mother at the time of the survey, denoted D_i for $i=1$, 2, 3 and 4 corresponding to the age groups 15-19 to 30-34.

The Trussell method permits using data for women aged 35 and over to obtain estimates of child mortality after age 5. In this study we have restricted the application to ages under 35, as we are interested in comparing the results with direct estimates of mortality over time,

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[1] *Demographic Estimation: A Manual of Indirect Techniques.* Forthcoming manual prepared by the staff of the Committee on Population and Demography, National Research Council, National Academy of Sciences.

which can only be satisfactorily obtained for ages under five (and even these should be interpreted with caution). The results of applying the method are shown in the top panel of Table 5.5. Starting with the proportion of children dead D_i for each of the four age groups considered and the ratios P_1/P_2 and P_2/P_3, we apply the regression equations shown in Table 5.6, to obtain estimated probabilities of death between birth and selected ages (1, 2, 3 and 5 years). The same fertility information is used to apply a separate set of regression equations, also shown in Table 5.6, to obtain estimates of the number of years before the survey to which the estimates apply.

Table 5.5: Mortality Estimates Obtained by Direct Calculation and by Applying Trussell Methods to Information on Proportion of Children Dead (a) Assuming Constrant Fertility and (b) Assuming Changing Fertility in the Last Five Years

(a) Constant fertility

Age Group		Proportion of dead Children	Age of Children	Time Location (years before the Survey)	Probability of dying before x	
					Trussell's Estimate	Observed*
	i	$1000\, D_i$	*x*	*t(x)*	*1000 q(x)*	
15-19	1	105	1	1.0	113	66
20-24	2	87	2	2.3	92	84
25-29	3	94	3	4.1	95	90
30-34	4	101	5	6.3	102	104

P_1/P_2 = .152 P_2/P_3 = .452

(b) Changing fertility in the last five years

Women's Age Goups				Average No. of Children per Woman		$\frac{P^{71}_{i-1}}{P^{76}_{i}}$	Proportion of Children Dead	Age of Children	Time Location	Probability of Dying before x	
										Trussell's Estimate	Observed*
1971	*i-1*	*1976*	*i*	P^{71}_{i-1}	P^{76}_{i}		$1000\, D_i$	*x*	*t(x)*	*1000 q(x)*	
15-19	1	20-24	2	.207	1.101	.188	89	2	2.5	88	84
20-24	2	25-29	3	1.292	2.437	.530	94	3	4.6	92	91
25-29	3	30-34	4	3.023	4.045	.747	101	5	7.1	99	104

*The observed values are derived from information on mortality by five years periods (Table 4.9), using as a standard the cohort mortality experience 1968-1976 (Table 4.3) and adopting the logit life table system.

Table 5.6: Trussell Regression Equations for Child Mortality Estimates (Family West, Coale-Demeny Life Tables-Fertility Constant)

(a) Basic Estimating Equation $\frac{q(x)}{D(i)} = a(i) + b(i)\frac{P_1}{P_2} + c(i)\frac{P_2}{P_3}$

Age	*i*	*x*	*a(i)*	*b(i)*	*c(i)*
15-19	1	1	1.1415	-2.7070	0.7663
20-24	2	2	1.2563	-0.5381	-0.2637
25-29	3	3	1.1851	0.0633	0.4177
30-34	4	5	1.1720	0.2341	-0.4272

(b) Basic Estimating Equation $t(x) = a(i) + b(i)\frac{P_1}{P_2} + c(i)\frac{P_2}{P_3}$

Age	*i*	*x*	*a(i)*	*b(i)*	*c(i)*
15-19	1	1	1.0970	5.5628	-1.9956
20-24	2	2	1.3062	5.5677	0.2962
25-29	3	3	1.5305	2.5528	4.8962
30-34	4	5	1.9991	-2.4261	10.4282

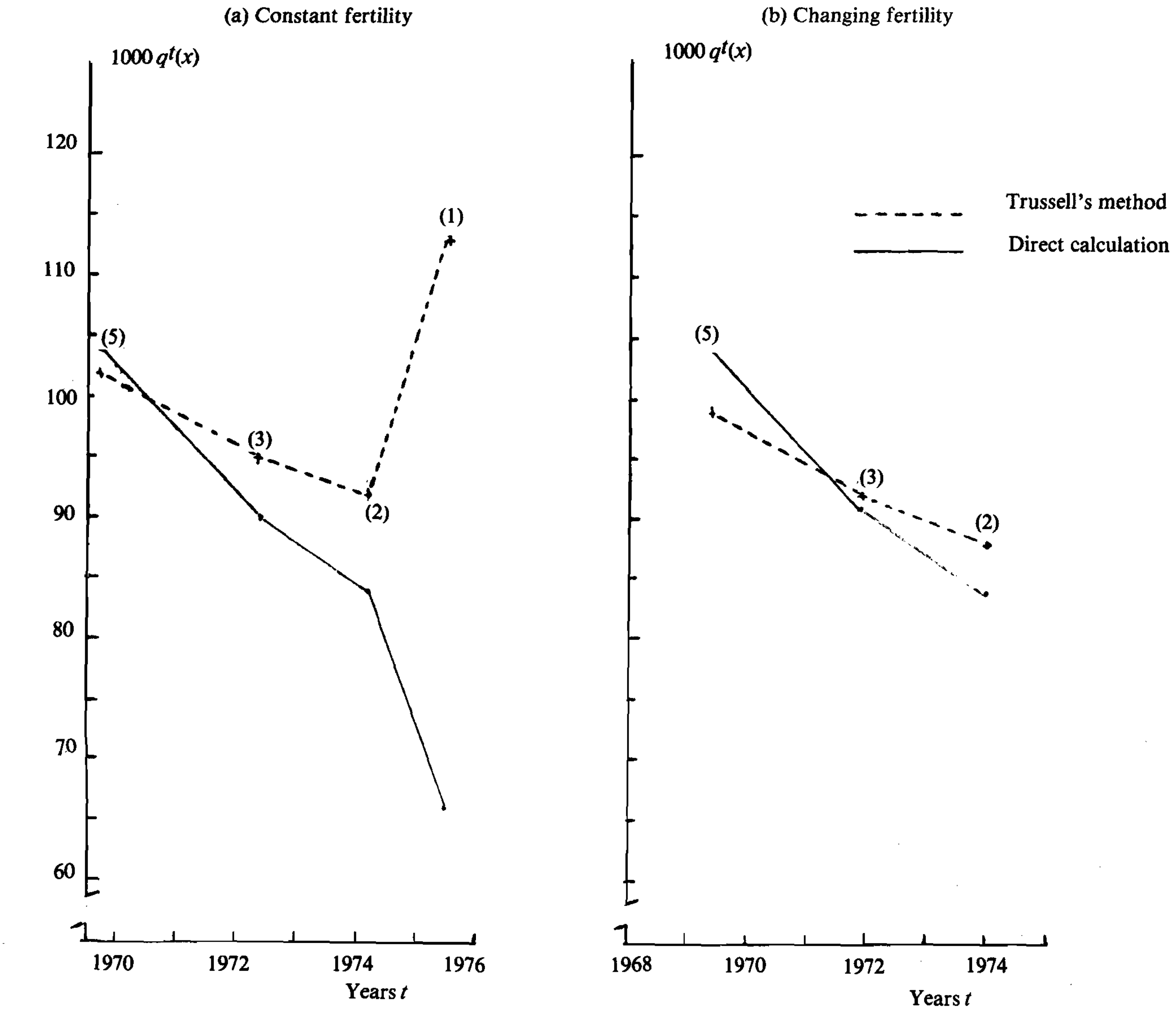
Formulae are extended up to age group 45-49. In this study only those given above are utilized.

In Table 5.5 we also show direct estimates of mortality, based on the life tables for five year periods given in Table 4.9, which are directly comparable with the indirect estimates obtained by the Trussell method. We shall not provide details of the procedure followed to derive these direct estimates except to note that we have adopted as a standard the life table for the cohort of children born between 1968 and 1976 (Table 4.3) and have estimated mortality levels for the periods required using the logit system of life tables[1].

A comparison of the direct and indirect estimates (see Figure 5.4) shows again that indirect procedures based on the first two age groups over-estimate mortality. The other two indirect estimates, however, are quite close to the observed levels (95 vs. 90 per thousand, and 102 vs. 104 per thousand). In addition to obtaining a reasonably good estimate of mortality rates, the procedure provides information about the time period when these rates were in effect.

[1] Brass, William. "On the scale of mortality" pp. 69-110. In *Biological Aspects of Demography*, edited by W. Brass. London: Taylor and Francis Ltd., 1971.

Figure 5.4 Mortality Estimates by Direct Calculations and Trussell's Method Assuming (a) Constant Fertility and (b) Changing Fertility in the Last Five Years



Changing Fertility

Let us now consider the second procedure proposed by Trussell, which allows for changes in fertility. The information required is:

(a) The mean number of children ever-born at two time points for the same five year cohort of women, in our case P_1, P_2 and P_3 for 1971 and P_2, P_3 and P_4 for 1976.

(b) The proportion of children dead by age group of mother, in our case D_2, D_3 and D_4 for 1976.

The data collected in the Colombian survey permit calculation of the mean number of children ever-born not only at the time of the survey in 1976, but also at any previous time. In our case we have calculated averages as of five years before the survey, that is in 1971. The values of P_i for 1971 and 1976 are shown in the lower panel of Table 5.5. It may be noted that these values vary over time, reflecting a decline in fertility. The mean number of children ever born to women aged 20 to 24, for example, was 1.29 in 1971 and 1.10 in 1976.

The set of regression equations which may be used to derive estimates of mortality for ages 2, 3 and 5 from the information on fertility and proportion of children dead are shown at Table 5.7. We also present the regression equations used to derive the number of years before the survey to which the estimates apply. The results of applying the method are shown in the lower panel of Table 5.5.

Table 5.7: Trussell Regression Equations for Child Mortality Estimates (Family West, Coale-Demeny Life Tables-Changing Fertility) Intersurvey Interval: 5 Years

(a) Basic Estimating Equation $\frac{q(x)}{D(i)} = a(i) + b(i)\frac{P(i-1,1)}{P(i,2)}$

Age	i	x	P(i-1,1)/P(i,2)	a(i)	b(i)
20-24	2	2	P(1,1)/P(2,2)	1.1838	-0.8901
25-29	3	3	P(2,1)/P(3,2)	1.1776	-0.3828
30-34	4	5	P(3,1)/P(4,2)	1.2757	-0.3939

(b) Basic Estimating Equation $t(x) = a(i) + b(i)\frac{P(i-1,1)}{P(i,2)}$

Age	i	x	P(i-1,1)/P(i,2)	a(i)	b(i)
20-24	2	2	P(1,1)/P(2,2)	1.3999	5.9156
25-29	3	3	P(2,1)/P(3,2)	1.1637	6.4668
30-34	4	5	P(3,1)/P(4,2)	-0.4262	10.1371

Formulae are extended up to age group 35-39. In this study only those given above are utilized.

We may now compare the indirect estimates of the probabilities of death derived by the Trussell procedure with the "observed" or direct estimates. Note that the allowance for declining fertility leads to a much better indirect estimate from the proportion of children dead to women aged 20-24. The decline in fertility explains part of the large differences noted in applying the first Trussell method as well as the Brass and Feeney procedures, which assume constant fertility. The remaining difference (88 vs. 84 per thousand) may still be due to the higher mortality of children of young women.

The indirect estimates based on the age group 25-29 are very close to the direct estimates (92 vs. 91 per thousand), whereas the difference between indirect estimates based on the group 30-34 and the direct estimates (99 vs. 104 per thousand) is larger than obtained under the constant fertility assumption. These comparisons are shown at Figure 5.4.

It may be concluded that the methods proposed by Trussell lead to reasonable estimates of infant and child mortality. In populations where fertility is declining allowance should be made for this fact. The results for the last age group — where the indirect procedures lead to estimates of 102 and 99 per thousand according as to whether fertility is assumed constant or declining, as compared with an observed value of 104 — should be interpreted cautiously. It should be recalled that the "observed" mortality up to age five in 1969 is based on assuming a model of mortality and should therefore be taken with reservation.

6 Conclusions

The main conclusions of the present study may be summarised as follows:

In Chapter 3 we presented evidence that the mortality data collected in the survey are of good quality. We noted that the age pattern of mortality is plausible, mortality increases with age of mother at the time of the survey, mortality is higher when the mother has a lower educational level, mortality varies as expected with age of mother at the time of birth of the child, mortality declines over time, male infant mortality is higher than female, the sex ratios at birth are reasonable, and the age distribution of the female population is acceptable.

In Chapter 4 we presented results obtained by applying direct estimation procedures. Of particular interest are the results concerning trends in infant mortality and mortality in the first two years of life by 5-year calendar periods between 1956-60 and 1971-75. Estimates of trends over time are not available for Colombia. Perhaps the best available estimate of mortality at a given point in time is based on data on children ever born and children surviving collected in the 1973 census, and leads to a rate of mortality between ages 0 and 2 of 88 per thousand for 1968-69[1]. This estimate is confirmed in this study, as we obtain a rate of 85 per thousand for the 5 year period 1966-70. On the other hand, the previously available estimate of infant mortality, 74 per thousand for 1968-69, is much higher than the estimate obtained in the present study, which is 68 per thousand for 1966-70. We place more confidence in the results obtained in the survey than in the previous estimates, which are based on data of lower quality. There are interesting differences in infant and child mortality between subgroups of the population, including differentials by sex, type of place of residence, educational level of the mother and region of residence.

In Chapter 5 we have examined three indirect procedures which lead to estimates of mortality based on data on the proportion of children dead by current age of the woman and provide indications of mortality trends over time. One of these methods, due to Trussell, has been described in more detail than the others, including the regression equations which permit obtaining the estimates. We have presented two variants of the method, one which assumes constant fertility and one which allows for changes in fertility over time. Having applied all these methods to the Colombian survey we conclude that indirect methods lead to valid estimates. This is an important result because in developing countries infant and child mortality are frequently estimated using indirect techniques.

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[1] Behm, Hugo and Rueda, J.O., *La mortalidad en los primeros años de vida en países de la América Latina, Colombia 1968-69,* CELADE, Serie A, 1032, San José, 1977.

Appendix I Calculation of life tables from data on children classified by age at the time of the survey or age at death

This appendix describes the procedure used in the construction of life tables for birth cohorts.
Each child is observed from birth. For each child we know whether he/she is alive or dead at the time of the survey (mid 1976), as well as his/her age at the time of the survey or at death. In both cases age is grouped in the following categories, indexed by the subscript i

Subscript	Age Groups
1	under 1 month
2	between 1 and less than 3 months
3	between 3 and less than 6 months
4	between 6 months and less than 1 year
5	between 1 and less than 2 years
6	between 2 and less than 5 years
7	between 5 and less than 10 years
8	10 years or more

The first step is to calculate the time lived by each child within each of the above age groups except the last. The concept of time lived is best explained by reference to an example. Consider a child age 1 in completed years, that is, a child who has reached the first birthday but not the second. For the purposes of the example it is immaterial whether the child is alive or dead at the time of the survey. The time lived by that child includes all age groups preceeding the first year, that is, he has lived one twelfth of a year between ages 0 and 1 month, two twelfths of a year between ages 1 and 3 months, three twelfths of a year between ages 3 and 6 months and six twelfths of a year between ages 6 months and 1 year. The total time lived during these ages is 1 year. This calculation may be done accurately, because the child lived through the entire length of all intervals considered. We cannot, however, calculate precisely the time lived between the ages 1 and 2 years, as all we know is that the child passed age 1 but has not reached age 2. In these cases we will assume that the child lived half of the interval considered, whether he was still alive, or dead, in that interval. The total time lived in our example is thus 1.5 years. If we consider a child age between 2 and 5 exact years at the time of the survey or at death, the total time lived is precisely 2 years between ages 0 and 2 and an estimated 1.5 years between ages 2 and 5, or a total of 3.5 years.
This procedure leads to an estimate of the total time lived in each age interval by the sample of children. This estimate is expressed in years and denoted $_nE_x$ where x indicates the lower bound and n denotes the width of the interval or age group considered.
The ratio between the number of deaths reported between exact ages x and $x+n$, denoted $_nD_x$, and the total time lived in that interval, $_nE_x$, defines the "annual mortality rate" for that age interval, denoted $_nm_x$:

$$_nm_x = {_nD_x}/{_nE_x}$$

From the annual mortality rate for ages x to $x+n$ we can estimate the probability of surviving from age x to age $x+n$, denoted $_np_x$ in life table notation, as follows:

$$_np_x = 1\text{-}2n\,{_nm_x}/(2+n\,{_nm_x}).$$

This relationship represents an approximation, as it is based on the assumption that the life table survivorship function $l(x)$ is linear between ages x and $x+n$, an assumption which is not entirely correct. The approximation, however, is satisfactory in all cases considered in this study, because the range from 0 to 1 years — where the assumption of linearity would be grossly incorrect — has been subdivided into four age groups within each of which the assumption of linearity is admissible.
Table I.1 illustrates the calculation of the quantities defined above, namely the time lived, the annual mortality rate and the probability of surviving each age interval. The illustration uses the data for the whole sample, consisting of 14,415 children for whom we know the survivorship status at the time of the survey.

Table I.1: Colombia. Mortality Experience of the Total Sample. Illustration of the calculation of time lived, mortality rates, and survival probabilities, by age.

Subscript of Interval	Exact Age at start of Interval	Length of Interval	Deaths in Interval i	Living in 1976 at Age i	Number of People Who Started Interval i Alive	Time Lived	Annual Mortality Rates $(x, x+n)$	Probability of Survival from x to $x+n$
i	x	n	D_i	S_i	$\sum_{j=i}^{8} (D_j+S_j)$	$_nE_x$	$_nm_x$	$_np_x$
1	0	1/12	560	25	14 415	1176.9	.4758	.9611
2	1/12	2/12	151	131	13 830	2281.5	.0662	.9890
3	3/12	3/12	183	185	13 548	3341.0	.0548	.9864
4	6/12	6/12	255	305	13 180	6450.0	.0395	.9084
5	1	1	286	704	12 620	12125.0	.0236	.9767
6	2	3	254	1 833	11 630	31759.5	.0080	.9763
7	5	5	89	3 158	9 543	39597.5	.0022	.9888
8	10		52	6 244	6 296	x	x	x
Total			1 830	12 585				
Total births			14 415					

The first two columns establish a correspondence between the subscript i, used to simplify the presentation, and the symbols x and n which denote respectively the lower bound and the width of 3 months or three twelfths of a year.

The next two columns show the distribution of the 14,415 children observed by survivorship status and age at the interview or at death. The symbol D_i denotes the number of children dying at age i and S_i the number of surviving children age i at the time of the survey. Thus there are $D_4 = 255$ deaths to children aged between 6 months and less than 1 year, and $S_4 = 305$ children of those ages surviving at the time of the survey.

The next column contains an auxiliary quantity which simplifies calculation of the time lived in each age. Time lived $_nE_x$ is calculated as follows:

$$_nE_x = E_i = n \sum_{j=i}^{8} (D_j + S_j) - \tfrac{1}{2} n\, (D_i + S_i)$$

For example, the time lived between ages 0 and 1 months is $E_1 = 1176.9$ years. To obtain this result we first multiply the width of the interval (one twelfth) by the total number of births in the sample (14,415), obtaining 1201.3. Next we calculate the time *not* lived in the interval by the children who died in the interval (560) and those who had not completed the interval (25), which is ½.1/12 (560 + 25) = 24.4. Subtracting the latter quantity from the former gives

$$_{1/12}E_0 = 1201.3 - 24.4 = 1176.9.$$

The annual rate of mortality for the interval from 0 to 1/12 years is given by the ratio $_{1/12}D_0 / _{1/12}E_0$, and turns out to be $_{1/12}m_0 = .4758$.

The probability that a live birth will survive the first month may then be estimated as

$$_{1/12}P_0 = 1 - 2(1/12)_{1/12}m_0 / (2 + (1/12)_{1/12}m_0) = .9611$$

Having calculated the function $_nP_x$ we may calculate any other life table function, in particular the probability l_x of surviving to exact age x, which is defined as

$$l_{x+n} = l_x \, _np_x,$$

with an initial value $l_0 = 1$. Thus the probability of surviving to age 1 month is $l_{1/12} = l_0 \, _{1/12}P_0 = .9611$, and to age 3 months is $l_{3/12} = l_{1/12} \, _{2/12}P_{1/12} = .9505$.

One may also calculate the cumulative probability $q(x)$ of dying before exact age x, defined as

$$q(x) = 1 - l_x;$$

for example the probability of dying in the first 3 months after birth is $1 - .9505 = .0495$.

It is also possible to calculate the probability $_np_x$ of surviving from ages x to $x+n$ for any value of n. It is of interest, for example, to calculate the probability of surviving from birth to age 1; to obtain this we must multiply the survivorship probabilities corresponding to the four age intervals into which we have divided the first year of life:

$$ {}_{1}p_{0} = {}_{1/12}p_{0}\ {}_{2/12}p_{1/12}\ {}_{3/12}p_{3/12}\ {}_{6/12}p_{6/12} $$

$$ = (.9611)\,(.9890)\,(.9864)\,(.9804) = 0.9192 $$

Table I.2 shows the life table derived from Table I.1, including the life table functions l_x and $q(x)$ for ages $x=0, 1/12, 3/12, ½, 1, 2, 5$ and 10.

Table I.2. Life Table.

Age x	Surviving to Age x l_x	Probability of Dying Between 0 and x $q(x)$
0	1	0
1/12	0.9611	0.0389
3/12	0.9505	0.0495
6/12	0.9376	0.0624
1	0.9192	0.0808
2	0.8978	0.1022
5	0.8765	0.1235
10	0.8667	0.1333

The probability of dying between ages 0 and 1, known as the infant mortality rate, is .0808 or 80.8 per thousand, as seen from Table I.2.

A more detailed and complete discussion of these ideas may be found in the text by Pressat.[1]

[1] Roland Pressat. *L'Analyse Démographique.* Presses Universitaires de France, Pans, 1961.

Appendix II Direct Estimation of Mortality by 5-year Calendar Periods

In order to estimate period mortality by direct calculation of the life table function ${}_t d_x$, we need to know the number of deaths at exact ages x to $x + t$ in the periods considered, as well as the corresponding number of births.

One difficulty we must face is that it is not possible to determine exactly in what period a death has occurred. For example if a child was born in 1960 (the month of birth is known) and died between the ages of 2 and 5 exact years, the death must have occured somewhere between 1962 and 1965; our uncertainty spans 4 years.

In view of this difficulty our study of mortality by calendar periods will be subject to two limitations: (a) we will only study mortality up to exact age 2 years, and (b) we will analyse 5-year calendar periods.

The first limitation reduces the uncertainty about the time of death by restricting the analysis to the younger ages where more detailed categories are used. At the two extremes of the range 0-2 years we note that the uncertainity spans only two months for deaths in the first month after birth, and at most 2 years for deaths of children age 1 completed year.

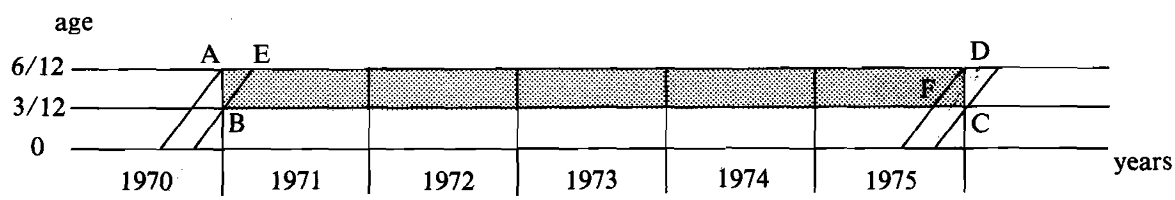
The second limitation reduces the relative importance of "estimated" as opposed to "registered" deaths in a given period. Consider again the two extremes of the range 0 to 2 years. For deaths to children under 1 month old, the number that must be estimated represents deaths in only 1 of the 60 months considered. At the other extreme, among deaths to children age one completed year, the number estimated represents deaths in 1 out of 5 years considered.

The procedure used to calculate ${}_t d_x$ for a given 5-year calendar period will be illustrated with an example. Consider the period 1971 to 1975 and ages 3 to 6 months. The rate in question is

$${}_t d_x = {}_{3/12}d_{3/12} = \frac{\textit{Deaths in the period 1971-75 to children aged 3/12 to 6/12 years}}{\textit{corresponding births}}$$

The Lexis diagram below may help explain this example

LEXIS DIAGRAM
Deaths between 3 and 6 months in 1971-75



Deaths between the ages 3/12 and 6/12 registered in 1971-75 fall in the rectangle ABCD, corresponding to life lines that start between July 1970 and September 1975 and end in that rectangle.

The number of deaths required is *not* known, but may be estimated by dividing the rectangle in three parts:

— the triangle ABE, corresponding to the first trimester of 1971, and representing deaths of children born between July and September, 1970.

— the parallelogram EBFD, covering the period 1971-75 and representing deaths of children born between October 1970 and June 1975.

— the triangle FCD, corresponding to the last trimester of 1975 and representing deaths of children born between July and September, 1975.

The number of deaths in the rectangle ABCD is then estimated as the sum of

— half the deaths between ages 3/12 and 6/12 of children born between July and September 1970, since those children live part of the age interval in 1970 and part in 1971.

— all the deaths between ages 3/12 and 6/12 of children born betwen October 1970 and June 1975, since those children live the whole of the age interval 3 to 6 months in the period 1971-75,

— half the deaths between ages 3/12 and 6/12 of children born between July and September 1975, since those children live part of those ages in 1975 and part in 1976.

the "corresponding" number of births is in turn estimated as the sum of three components:
— half the births between July and September 1970,
— all births between October 1970 and June 1975, and,
— half the births between July and September 1975.

A similar reasoning leads to estimates of deaths and corresponding births for other ages. The following table specifies the information used to estimate each component for the period 1971-75.

Components of the Numbers of Deaths and Births Used
in the Calculation of $_t d_x$ for Ages 0 to 2
in the Period 1971-75

Age Interval	Deaths and Corresponding Births Considered in Total	Number of Months	Deaths and Corresponding Births Considered in Part	Number of Months
0-1/12	January 71 — November 75	59	December 70 and 75	1
1/12-3/12	December 70 — September 75	58	October — November 70 and 75	2
3/12-6/12	October 70 — June 75	57	July — September 70 and 75	3
6/12-1	July 70 — December 74	54	January — June 70 and 75	6
1-2	January 70 — December 73	48	January — December 69 and 74	12

The calculation for other 5-year calendar periods is done following the same principle.

See Greville, I.N.E., Methodology of the National and State Life Tables for the United States; 1969-71. Vol. 1, number 3, National Center for Health Statistics, Rockville, Maryland, 1975.

Appendix III Life Table, by Age of Mother

Table III.1 Life Table (direct calculations)

	Age of Mother in 1976						
	15-19	20-24	25-29	30-34	35-39	40-44	45-49
Age (x) . . .	Probability of dying between 0 and x, 1000 q(x)						
1/2	841	531	442	477	703	707	743
1	1,212	664	618	669	804	882	1,021
2		858	814	840	1,012	1,017	1,291
5		1,075	1,001	1,000	1,257	1,314	1,531
10		1,251	1,091	1,083	1,329	1,443	1,627
Births	237	1,157	2,052	2,423	2,911	2,889	2,746
Deaths (under age 10)	25	101	191	242	370	406	443

Appendix IV Data used for Direct Estimation

In this appendix we present a series of tables containing the basic information used in the construction of the life tables given in Chapter 4. There is a total of 9 tables, giving the number of surviving children by age at the time of the survey and the number of dead children by age at death, classified by the following variables:

1 birth cohort
2 age of mother at the time of the survey
3 age of mother at the time of the birth of the child
4 birth order
5 birth order and age of mother at the time of birth of the child
6 sex and birth cohort
7 type of place of residence
8 educational level of the mother
9 region of residence

Table IV.1 Data Used in the Calculations of Life Tables: Live Births and Child Deaths, by Various Characteristics

(1) By period of birth (cohorts)

Age Groups	Born 1941-1959		Born 1960-1967		Born 1968-1976	
	Dead	Alive	Dead	Alive	Dead	Alive
0-1/12	168	—	197	—	195	25
1/12-3/12	48	—	48	—	55	131
3/12-6/12	63	—	62	—	58	185
1/2-1	89	—	81	—	85	305
1-2	102	—	97	—	87	704
2-5	81	—	103	—	70	1,833
5-10	40	—	39	849	10	2,309
10 or more	40	2,794	11	3,450	1*	—
Total	631	2,794	638	4,299	561	5,492
Number born	3,425		4,937		6,053	

*The time lived by this obviously inconsistent case has been included in all calulations

(2) By age of mother at time of survey

Age groups	15-19		20-24		25-29		30-34	
	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
0-1/12	14	6	34	9	63	7	68	2
1/12-3/12	3	25	11	34	12	35	18	20
3/12-6/12	2	25	13	71	15	36	29	23
1/2-1	6	28	15	89	34	81	45	51
1-2	—	71	16	227	35	182	39	106
2-5	—	54	10	431	26	540	32	364
5-10	—	3	2	191	6	775	11	851
10 or More	—	—	—	4	1	204	2	762
Total	25	212	101	1,056	192	1,860	244	2,179
Number born	237		1,157		2,052		2,423	

Age Groups	35-39		40-44		45-49	
	Dead	Alive	Dead	Alive	Dead	Alive
0-1/12	126	1	129	—	126	—
1/12-3/12	38	13	32	2	37	2
3/12-6/12	40	17	43	11	41	2
1/2-1	29	39	50	14	76	3
1-2	58	85	64	24	74	9
2-5	64	248	57	148	65	48
5-10	15	627	31	427	24	284
10 or more	7	1,504	14	1,843	28	1,927
Total	377	2,534	420	2,469	471	2,275
Number born	2,911		2,889		2,746	

(3) By age of mother at time of birth of the child

Age Groups	Less than 20		20-24		25-29		30 or more	
	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
0-1/12	140	6	163	9	119	7	138	3
1/12-3/12	40	26	40	33	31	36	40	36
3/12-6/12	40	28	63	70	44	35	36	52
1/2-1	70	42	81	81	53	92	51	90
1 or More	173	2,361	217	3,893	153	2,961	138	2,724
Total	463	2,463	564	4,068	400	3,131	403	2,905
Number born	2,926		4,650		3,531		3,308	

(4) By order of birth

Age Groups	Order 1		Order 2-3		Order 4 or more	
	Dead	Alive	Dead	Alive	Dead	Alive
0-1/12	118	7	189	10	253	8
1/12-3/12	23	35	63	40	65	56
3/12-6/12	38	42	64	70	81	73
1/2-1	47	63	89	101	119	141
1 or More	121	2,730	240	3,908	320	5,301
Total	347	2,877	645	4,129	838	5,579
Number born	3,224		4,774		6,417	

(5) By order of births and age of mother at time of birth of the child

Age Groups	Less than 20		20-24		25-29		30 or more	
	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
				Order 1				
0-1/12	71	4	27	3	13	—	7	—
1/12-3/12	15	15	7	12	1	5	—	3
3/12-6/12	20	12	13	25	4	2	1	3
1/2-1	31	25	10	24	4	12	2	2
1 or More	81	1,398	27	971	11	281	2	80
Total	281	1,454	84	1,035	33	300	12	88
Number born	1,672		1,119		333		100	
				Order 2-3				
0-1/12	62	1	72	4	36	4	19	1
1/12-3/12	22	10	24	14	12	12	5	4
3/12-6/12	20	16	30	38	10	10	4	6
1/2-1	33	16	48	47	8	27	—	11
1 or More	81	884	102	1,873	38	841	19	310
Total	218	927	276	1,976	104	894	47	332
Number born	1,145		2,252		998		379	
				Order 4 or more				
0-1/12	7	1	64	2	70	3	112	2
1/12-3/12	3	1	9	7	18	19	35	29
3/12-6/12	—	—	20	7	30	23	31	43
1/2-1	6	1	23	10	41	53	49	77
1 or More	11	79	88	1,049	104	1,839	117	2,334
Total	27	82	204	1,075	263	1,937	344	2,485
Number born	109		1,279		2,200		2,829	

(6) By sex and periods of birth (cohorts)

Age Groups	Born 1941-59		Born 1960-67		Born 1968-76		Total	
	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
Males								
0-1/12	99	—	107	—	112	17	318	17
1/12-3/12	35	—	23	—	33	77	91	77
3/12-6/12	34	—	36	—	32	89	102	89
1/2-1	44	—	37	—	48	163	129	163
1-2	43	—	42	—	40	376	125	376
2-5	49	—	46	—	35	926	130	926
5-10	22	—	23	441	5	1,182	50	1,623
10 or More	24	1,425	4	1,751	1*	—	29	3,176
Total	350	1,425	318	2,192	306	2,830	974	6,447
Number born	1,775		2,510		3,136		7,421	
Females								
0-1/12	69	—	90	—	83	8	242	8
1/12-3/12	13	—	25	—	22	54	60	54
3/12-6/12	29	—	26	—	26	96	81	96
1/2-1	45	—	44	—	37	142	126	142
1-2	59	—	55	—	47	328	161	328
2-5	32	—	57	—	35	907	124	907
5-10	18	—	16	408	5	1,127	39	1,535
10 or More	16	1,369	7	1,699	—	—	23	3,068
Total	281	1,369	320	2,107	255	2,662	856	6,138
Number born	1,650		2,427		2917		6,994	

*The time lived by this inconsistent case was included in all calculations.

(7) by type of place of residence — urban and rural.

Age Groups	Urban		Rural	
	Dead	Alive	Dead	Alive
0-1/12	298	13	260	12
1/12-3/12	72	69	79	62
3/12-6/12	97	105	84	80
1/2-1	129	168	126	137
1-2	153	379	133	325
2-5	118	971	134	860
5-10	44	1,853	43	1,302
10 or More	31	3,853	21	2,388
Total	942	7,411	880	5,166
Number born	8,353		6,046	

Note: There were 16 cases where type of place of residence was not stated.

(8) By mother's level of education

Age Groups	Years of Schooling			
	0-2		3 or More	
	Dead	Alive	Dead	Alive
0-1/12	305	10	255	15
1/12-3/12	94	61	56	68
3/12-6/12	117	75	66	110
1/2-1	154	139	100	166
1-2	177	302	108	400
2-5	171	861	83	971
5-10	49	1,460	40	1,696
10 or More	28	3,121	24	3,115
Total	1,095	6,029	732	6,541
Number born	7,124		7,273	

Note: There were 18 cases where the level of education was not stated.

(9) By regions

Age Groups	Pacific		Central		Atlantic		Oriental-Bogota	
	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
0-1/12	137	7	166	5	86	5	171	8
1/12-3/12	33	27	47	32	23	33	48	39
3/12-6/12	45	31	55	52	27	36	56	66
1/2-1	64	65	75	80	53	77	63	83
1-2	77	126	94	174	47	185	68	219
2-5	62	327	75	531	48	442	69	533
5-10	19	568	31	922	14	702	25	966
10 or More	9	1,112	12	1,901	15	1,215	16	2,016
Total	446	2,263	555	3,697	313	2,695	516	3,930
Number born	2,709		4,252		3,008		4,446	