A RAND NOTE

WHAT ACCOUNTS FOR THE DECLINE IN INFANT MORTALITY IN PENINSULAR MALAYSIA, 1946-1975?

Julie DaVanzo, Jean-Pierre Habicht

June 1984

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The World Bank
The Rockefeller Foundation
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PREFACE

The infant mortality rate in Peninsular Malaysia has declined dramatically since World War II. This Note investigates possible reasons, using household-level data that document both infant mortality and its correlates. Although the results are specific to Malaysia, they should shed light on the experience of other countries with similar changes over this period.

The Note, exploring reasons for the mortality decline in Malaysia and differences between mortality correlates in high- and low-mortality *eras*, complements the authors' analysis of differences between mortality correlates in high- and low-mortality *areas* of the country. The latter is reported in Khairuddin, Peterson, DaVanzo, and Habicht, "Why Are Infant and Child Mortality Rates in Peninsular Malaysia Higher in Kedah, Kelantan, Perlis, and Trengganu?" (forthcoming).

This research was supported by grants to The Rand Corporation from the World Bank and from the Ford and Rockefeller Foundations. The Note also serves as a background paper to the 1984 World Development Report of the World Bank and as a publication of the Cornell University Agricultural Experiment Station, Division of Nutritional Sciences.

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SUMMARY

The infant mortality rate has declined dramatically in Peninsular Malaysia since World War II. This study uses individual-level retrospective data on infant mortality and its correlates (from the Malaysian Family Life Survey) to examine possible reasons for this decline. One important factor has been the substantial increase in mothers' education. Improvements in water and sanitation also played a role; however, the reductions in breastfeeding that have taken place in Malaysia have kept the infant mortality rate from declining as rapidly as it would have otherwise. In this analysis, the detrimental effects of reduced breastfeeding have more than offset the beneficial effects of improvements in water and sanitation. The majority of the infant mortality decline, however, is not explained by changes in the variables considered here, but is due to factors not investigated here--most likely, increases in income and improvements in medical and health care.

ACKNOWLEDGMENTS

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I. INTRODUCTION

One of the more gratifying phenomena of the 20th century has been the decline of mortality rates in general and of infant mortality in particular. Nearly three-quarters of the total increase in longevity in recorded history has occurred since 1900 (Preston, 1976). Life expectancy at birth has doubled since the beginning of this century (Gwatkin, 1980). Mortality declines have been greatest in developing countries, such as Malaysia. Since World War II, many of these countries have recorded gains in life expectancy at least three times as large as those achieved in Western Europe at a comparable stage in its mortality transition (Gwatkin, 1980). As Gwatkin notes, "such rapid progress coming at such low initial levels of life expectancy was . . . quite without precedent in history" (p. 617). These mortality declines are the major reason for the rapid population growth in developing countries since World War II.

Declining infant mortality explains much of the general decline in mortality. In most populations, more people die during the first year of life than at any other single age. For example, 28 percent of all deaths in Peninsular Malaysia in 1957 occurred in the first year of life (Malaysia, Department of Statistics, 1976).[1] Furthermore, over the period of rapid mortality decline in developing countries, infant mortality rates have shown the largest absolute declines. In Malaysia, they have declined from about 100 infant deaths per 1000 live births in the 1940s to about 30 in the 1970s (Fig. 1).

The sheer value of life aside, reducing infant mortality has high priority for developing countries because children are a major resource for both poor families and the nation, and because decreases in infant mortality usually lead to reductions in fertility. Consequently, Third World governments would like to find means of reducing infant mortality even more. To do so, they need to know exactly what changes have

[1]By 1974 the figure had fallen to 17 percent--still very large in relation to the 1974 life expectancy at birth of 64 years for males and 69 years for females.

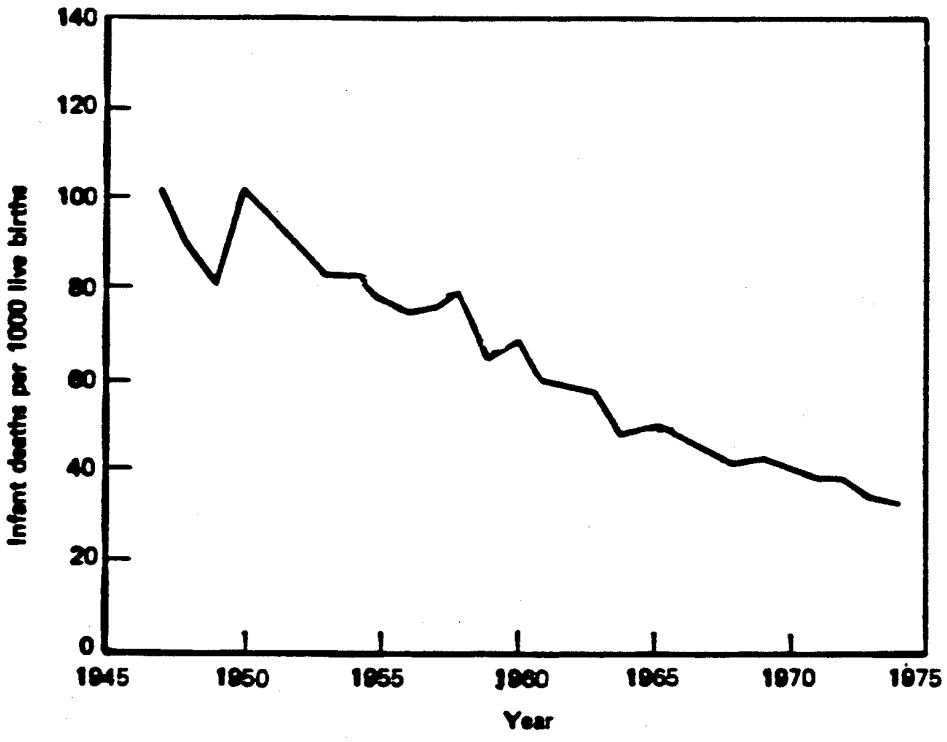

Fig. 1 -- Trend in the infant mortality rate in Peninsular Malaysia (from Malaysian Vital Statistics)

contributed to this decline and what factors, if any, have kept the decline from being greater.

Many hypotheses have been advanced to explain the dramatic declines in infant mortality. Like overall mortality, infant mortality is allegedly associated with socioeconomic development, programs to control communicable diseases, health education, and improvements in nutrition, sanitation, and medical and health care. However, some factors may have a particular effect on infant mortality. These include pre- and post-natal care, child health services, infant feeding, and family planning (which can promote proper spacing of children and reduce other high-risk births). Despite a pervasive sense that these factors do affect infant mortality, to our knowledge there has been no assessment of their relative roles in explaining declines.[2]

[2]Preston (1980) has provided such an assessment for overall mortality (life expectancy) in developing countries, using countries as

In this paper, we attempt to fill that gap in knowledge, using data on Malaysia from 1946 to 1975. During this period, Malaysia experienced rapid economic growth and profound social and demographic change, including the dramatic decline in infant mortality rates shown in Fig. 1. Our data, from the Malaysian Family Life Survey, are unique in that they (1) cover this period of dramatic change; (2) document not only infant mortality over this period, but also many of its key determinants,[3] and (3) document these variables at the micro level, enabling us to study the structure of mortality relationships based on variations among individuals (rather than among broader aggregates).

Our empirical work is guided by our prior use of these data to study biological and behavioral influences on infant mortality (Butz, DaVanzo, and Habicht, 1982; DaVanzo, Butz, and Habicht, 1983; Butz, Habicht, and DaVanzo, 1984). In the present study, we focus on variables that strongly influenced infant mortality in our previous study and changed considerably over the 1946-1975 period. These include:

- *Socioeconomic factors*
  - -- mother's education
- *Sanitation and nutrition variables*
  - -- household water and sanitation
  - -- type and duration of breastfeeding
- *Demographic variables*
  - -- mother's age at the child's birth
  - -- whether a short interval preceded the birth
  - -- ethnic composition of births

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his units of analysis. Also see Palloni (1981), Gwatkin (1980), McKeown and Record (1962), and references therein.

[3]This contrasts, for example, with the World Fertility Surveys, which also document trends in infant mortality over a similar period, but which lack corresponding historical information on most of its determinants.

We are unable to assess the role of other variables that may have contributed to the decline in infant mortality but are not documented retrospectively in our data--for example, increases in income and expansion of government health programs.

Most of the variables documented in our data have changed in such a way that they would contribute to a decline in infant mortality (for example, increases in mothers' education, improvements in household sanitation, and reductions in the proportion of short intervals between births). We assess the relative contributions of these changes. However, the change in one variable that we consider--breastfeeding--would have led to an *increase* in mortality had other changes not taken place. We assess the extent to which decreases in breastfeeding have slowed the decline in infant mortality. These empirical analyses are presented in Sec. III, following a description in Sec. II of our data, the variables we examine, and our analytic methods. The final section summarizes our findings and discusses their implications.

II. DATA AND METHODS

DATA

We use data from the 1976-77 Malaysian Family Life Survey (MFLS) (Butz and DaVanzo, 1978). This population-based probability-sample survey comprised three rounds in the same panel of households, four months apart, beginning in August 1976. The sample consists of randomly selected private households that each contained at least one ever-married woman 50 years old or younger at the initial visit. A total of 1262 households (88 percent of the eligible probability sample) completed Round 1 of the survey. These households are contained in 52 primary sampling areas in Peninsular Malaysia, of which 49 were randomly selected; the other three were purposively selected to give additional representation to Indian households and households in fishing communities.

The key questionnaire for this analysis is the Round-1 Female Retrospective Life History questionnaire (MF2), which includes life events as early as the 1940s for some respondents. This questionnaire includes a complete life history of all of a woman's pregnancies and related events. For each pregnancy, the woman was asked the date and type of outcome. The sample for this analysis is the 5357 live births that occurred between 1941 and 1975 to women in the MFLS sample.[4]

For each of these live births, information was collected on the lengths of unsupplemented and supplemented breastfeeding and whether the child died and, if so, the date of death. The retrospective data also contain a residential history, including characteristics of houses where respondents have lived (such as type of water and toilet sanitation, with whom lived). Another questionnaire, the household roster, documents the mother's birth date, ethnicity, and education level.

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[4]The analysis excludes births that occurred less than a year before the date of interview.

Variables Considered in this Analysis

With this information we have computed the following variables for each live birth to women in our sample. For each, we describe how the variable is measured and why it should affect infant mortality.

- *Infant mortality*: whether the child died in its first year of life.
- *Mother's education:* years of schooling completed. Higher mother's education is a well-established correlate of lower infant mortality (see review in Cochrane et al., 1980). When its effect on infant mortality is independent of income, it probably reflects mother's knowledge of how to care for children and her awareness and use of appropriate health care services. Since income is not included in our analyses, our education variable will undoubtedly also reflect effects of income, which measures a household's ability to afford the inputs--a good diet, modern medical care--that contribute to good health.
- *Household water and sanitation*: whether the house where the family lived when the child was born had piped water or toilet sanitation. These presumably measure exposure to gastrointestinal disease through contaminated water and to other diseases through lack of personal hygiene.
- *Breastfeeding*: number of months of unsupplemented and supplemented breastfeeding in the first twelve months of life.[5] Duration of breastfeeding may measure nutritional intake and

[5] If a baby dies soon after birth or for reasons unrelated to feeding, breastfeeding will be short *because* the baby died or was ill-unto-death. Such a reverse-causation bias can result in serious overestimates of the apparent effect of breastfeeding in reducing infant mortality (Habicht, DaVanzo, and Butz, 1984). We have tried to correct for this potential bias here by imputing the length of breastfeeding to all infants whose mothers said that the reason they did not breastfeed or breastfed less than three months was because the baby died or was ill. We also impute breastfeeding durations to babies who stopped breastfeeding within the last 12.5 percent of their lifespan. Such cases were more frequent among children who died than would be expected, given the distribution of breastfeeding durations, and we infer that

protection against certain diseases through maternal antibodies. Extent of supplementation or substitution reflects the likelihood of ingestion of pathogens with breastmilk supplements or substitutes.

- *Interactions of breastfeeding durations and water and sanitation variables.* Breastfeeding, especially if unsupplemented, reduces exposure to contaminated water. Hence, the detrimental effects of inadequate water and sanitation should be less the longer breastfeeding lasts. Similarly, breastfeeding should have less of a beneficial effect on survival if hygienic water supplies are available. (See Butz, Habicht and DaVanzo, 1984; and Butz, DaVanzo, and Habicht, forthcoming.)
- *Mother's age at child's birth*: entered as a spline (piece-wise linear) to allow very young (age <18) mothers to exhibit different mortality risks from those of mothers in more prime childbearing years.[6] Young maternal age is a well-known correlate of higher infant mortality (United Nations, 1973; Nortman, 1974; Puffer and Serrano, 1975).
- *Length of preceding birth interval*: whether the interval preceding this child's birth was short (<15 mos.).[7] This variable is associated with infant mortality directly and also

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these infants who nursed until shortly before death are more likely both to have ceased nursing and to have died because of third causes (illness) than to have died because they ceased nursing.

For all these babies who stopped nursing because they died or were about to die, we imputed the durations of unsupplemented and supplemented breastfeeding they most likely would have received had they survived. We imputed these durations of breastfeeding conditional on the infant's age and type of breastfeeding at cessation of breastfeeding, based on the experiences of other babies who had the same type of breastfeeding at that age but whose breastfeeding was not curtailed by death or illness-unto-death. For infants who lived less than one week and did not initiate breastfeeding, we assign the unconditional means of unsupplemented and supplemented breastfeeding of all infants in the sample whose breastfeeding was not interrupted by death or illness-unto-death. For more detail on these procedures, see Habicht, DaVanzo, and Butz (1984).

[6]We do not allow for an effect of older maternal age because, as described below, our analyses exclude observations on births to older women.

[7]This variable is defined only for birth orders of two or higher.

indirectly through its effect on birthweight (DaVanzo, Butz, and Habicht, 1983; DaVanzo, Habicht, and Butz, 1984).

- *Mother's ethnicity*: Chinese, Indian, or Malay (the omitted group). Infant mortality rates in Malaysia show consistent ethnic variation (Malaysian Department of Statistics, various years), even when other mortality determinants that are correlated with ethnicity are controlled (DaVanzo, Butz, and Habicht, 1983).[8]

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[8] Although all the variables in this list have been shown to have statistically significant relationships with variations in infant mortality, they do not directly measure actual causes of death and are usually only imperfect measures of their proximate determinants. For example, our sanitation variable indicates whether the household had any type of toilet at the time of the child's birth but not the specific type of toilet. Such "errors in variables" will lead to underestimates of the importance of any factor that is measured with error.

Initially, all of the variables included in our earlier analysis (DaVanzo, Butz, and Habicht, 1983) were considered for this analysis. Some of these variables are not included here because they did not relate significantly to variations in infant mortality in the samples used here, did not exhibit consistent variation over time, or were judged to mainly mediate the effects of variables that are considered here. These excluded variables include household income, the infant's birth order (with first birth order and high birth order treated separately); the presence of grandparents, other relatives, and other young children in the household; whether the baby was born in a hospital; degree of rurality of the area where the parents lived when the baby was born; household crowding; and the baby's sex and birthweight. In a related study (Khairuddin et al., forthcoming) we show that region of the country is not a significant correlate of infant mortality when the variables considered here are controlled.

The income variable used in our previous study was constructed from retrospective reports of hours worked and wages of the mother and her husband and of his other income. It is adjusted by complex imputation procedures, which were based on the more detailed data on families' income and wealth at the time of the study and on retrospective information on income correlates (e.g., occupation, employment status, type of area of residence). The resulting income variable was probably liable to greater error than any other variable in that study and it was never significantly related to infant mortality there. For the present study we further adjusted that variable so it would reflect the real economic growth that took place in Malaysia over the period considered here. (These procedures are described in notes available from the authors, on request.) The coefficients of this adjusted variable, however, were often positive and were significant for the 1961-75 period. It is undoubtedly true that infant mortality differentials by income in Malaysia have narrowed over time, especially given the Malaysian government's efforts to equalize the distribution of health services across the country by extending services into poorer, rural

Quality of the MFLS Data on Infant Mortality

We have investigated the quality of the MFLS retrospectively reported data on infant mortality and associated life events (Haaga, 1983) and find that the secular trend in infant mortality in the MFLS data and the mortality differences between Malays and Chinese are generally similar to those indicated by Malaysian vital statistics.[9] Figure 2, for example, compares trends in infant mortality rates calculated from the MFLS and Malaysian Vital Statistics. These comparisons show no evidence for decreased reporting of mortality events in the distant past.[10] The good quality of these retrospective mortality data probably stems, in part, from their having been collected as part of an entire life history of salient events in which respondents and interviewers used the occurrence of one type of event to prompt memory of the occurrences of others. Furthermore, the dates of probably the most salient of those events--birth dates of children--were verified with documents (birth certificates and identity cards) in most cases.

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areas. However, we find it hard to believe that, other things the same, a baby born into a well-to-do family is significantly more likely to die than one born into a very poor family. Furthermore, the estimate of a positive income effect gave us some very peculiar results when we attempted to account for reasons for mortality decline and to use the coefficients for one period to predict the infant mortality rate in the other period. Given the well-known problems in constructing an appropriate measure of income even when good information is available on its components (e.g., see Kusnic and DaVanzo, 1980), we decided that we could not measure income retrospectively with sufficient reliability to include it in the analysis. Since education is highly correlated with income, especially in explaining income growth in Malaysia (Smith, 1983), our education variable should reflect income changes to some extent. The water and sanitation variables also are positively correlated with income and should reflect its influence.

[9]The MFLS infant mortality rate for Indians is higher than that indicated by vital statistics for the entire population of Malaysian Indians. The MFLS Indian sample is relatively small.

[10]See ahead for the probable reason why the MFLS infant mortality rates are higher than the vital statistics rates before 1955.

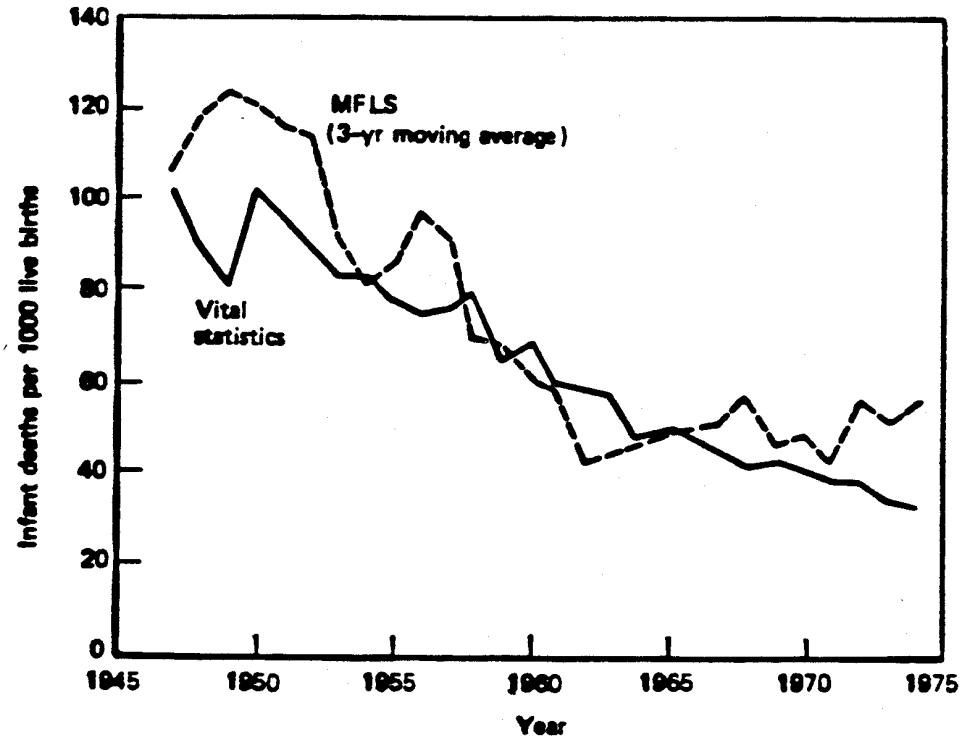

Fig. 2 -- Comparison of Infant Mortality Rate Trends in the MFLS and Malaysian Vital Statistics (from Haaga, 1983)

Mothers' Ages and Children's Years of Birth Represented in the MFLS Sample

The MFLS is essentially a random sample of women in their childbearing years at the time of the survey in 1976, and hence should provide a random sample of births around that time. It will not, however, provide a random sample of births in earlier years. Because there was upper age limit (age 50 in 1976) in selecting women for the MFLS sample, the retrospective survey will not document the experiences of older women in earlier years. This is illustrated in Appendix Table A.1, which shows the mothers' ages that are covered in each calendar year covered by the data. For example, in 1960 the oldest women in the sample were age 34 and in 1950 they were age 24.[11]

[11]The MFLS survey design could lead to two other possible biases:

Trends in Age-Specific Infant Mortality Rates in the MFLS Data

Table 1 shows infant mortality rates by mother's age and child's year of birth for each age/year cell covered by the MFLS.[12] The columns of the table show the relationship between mother's age and the child's probability of dying in the first year of life, holding constant the year of birth. Infants born to very young and very old mothers face a higher risk of infant mortality, as is widely recognized in the literature (e.g., United Nations, 1973; Nortman, 1974; Puffer and Serrano, 1975). For years before 1966, the MFLS does not contain any women who were in the high-risk ages of 40 or older. This may be why the MFLS mortality rates shown in Fig. 2 for the early 1960s were below those from the Vital Statistics. However, the MFLS sample of births in earlier years, say, before 1955, is disproportionately composed of women in the young high-risk ages (≤19). This may explain why Fig. 2 shows MFLS infant mortality rates for those years that exceed those reported in the Vital Statistics.

Within age groups, the infant mortality rates in Table 1 have generally decreased over time, with the most rapid decline generally occurring between the 1956-60 and 1961-65 periods. Since 1960 the declines have been more modest and are erratic for women under age 25 and over age 34. This may reflect a changing selectivity of the kinds of women who give birth at these higher-risk ages, since fertility rates have decreased the most at the extreme ages of childbearing (Hirschman and Fernandez, 1980, Table 4).

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(1) The MFLS sample will not be a random sample of all women in the birth cohorts that are represented because some women in these cohorts will have died or emigrated before the date of the survey and their fertility and infant mortality experiences will not be recorded. In Peninsular Malaysia, however, mortality rates during childbearing years have been low enough for the cohorts studied here (Khairuddin, 1974) that this bias should not significantly affect the results reported here. (2) Since the MFLS sample is restricted to ever-married women, the experiences of those who have never been married will not be represented. This should result in negligible bias since out-of-wedlock childbearing is very rare in Malaysia.

[12]These rates are truly age-specific rates. For example, the rate for 1961-65 for women aged 20-24 refers to those aged 20-24 in each of these years. It does *not* refer to the cohort of women aged 20-24 at the beginning or end of that time period. See Appendix Table A.2.

Table 1

INFANT MORTALITY RATES BY MOTHER'S AGE AND CHILD'S YEAR OF BIRTH

Mother's Age at Child's Birth	Year of Child's Birth							
	1941-45	1946-50	1951-55	1956-60	1961-65	1966-70	1971-75	Average
< 19	147	104	119	106	49	60	87	93
20-24	---	73	62	62	32	46	32	47
25-29	---	---	57	38	37	23	13	28
30-34	---	---	---	48	52	50	35	46
35-39	---	---	---	---	24	52	19	34
40+	---	---	---	---	---	48	65	61
Average	147	91	79	64	40	41	31	48

Note: See App. Table A.2 for age/year coverage in each cell and for cell sizes.

METHODS

Overview

The goal in this paper is to see how well we can explain the infant mortality decline that has occurred in Malaysia since World War II. To do this we use retrospective information on a number of socioeconomic, demographic, sanitation, and nutritional variables that are related to variations in mortality and are alleged to be factors contributing to improvements in child survival. We estimate the relationship between

infant mortality and those explanatory variables available in the Malaysian Family Life Survey (MFLS) that both (1) affect infant mortality and (2) have shown sufficient variation over time that they could affect the mortality trend. For example, we do not include the infant's sex in our analysis because this well-known correlate of mortality differentials exhibits very little systematic variation over time. We also do not consider some proximate determinants, such as birthweight, that affect infant survival, since they largely mediate the effects of other variables such as short birthspacing that are included in the analysis. Another variable we exclude is the calendar year of the child's birth. This variable is highly correlated with variables that have varied systematically over time and might have robbed them of some of their explanatory power had we included it.[13] We have already discussed above the variables we consider, their definitions, and the reasons for their inclusion.

After estimating the relationship of these variables to infant mortality, we see how well the change in these variables can explain the mortality decline that actually occurred. We assess the relative role of changes in each explanatory variable. We also assess whether the structure of the relationship between infant mortality and its determinants has changed over time and assess the importance of these structural changes in explaining the mortality decline.

Fixed Structure

We first assess the contributions of changes in explanatory variables assuming a *fixed* structure of coefficients. For this analysis, reported in Table 2 ahead, we restrict our sample to births in the years 1956-75 to women under age 30. We restrict the sample in this way in order to hold constant the age range of the sample in each year (see Appendix Table A.3).[14] This age range will represent the majority of births in any year, given the age pattern of childbearing in Malaysia (see sample sizes in Appendix Table A.2).

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[13] Of course, calendar year may be proxying real changes that have occurred, for example, public health improvements. To assess its residual role, we regress residuals (actual less predicted infant mortality) from our infant mortality regression against calendar year. We have also run the infant mortality regressions including calendar year and discuss, but do not present, those results.

[14] Had we included years before 1956, our sample for those years

Table 2 presents two sets of regressions for this sample. The first is estimated by ordinary least squares (OLS). This linear probability model permits a simple decomposition of the change in the infant mortality rate and describes attributable risks, the absolute increment in mortality due to the change in a particular factor. The second set is estimated by logit, which is the appropriate technique if variables affect the relative odds of dying rather than the absolute mortality differential. For the logit model, we assess the roles of changes in explanatory variables in explaining the changes in the probability of infant mortality that are implied by the logit coefficients evaluated at the sample mean probability.[15] The implications of the OLS and logit analyses are very similar in their statistical significance[16] and the relative importance of particular variables.[17]

The OLS coefficients, β_i, each show the change in the probability of infant mortality due to a one-unit change in a particular variable, X_i. We have multiplied each coefficient by the actual change in that variable that occurred between two points in time, i.e., $\beta_i \Delta X_i$, to show the amount of mortality change due to the *actual* change in that variable. The sum of all of these, $\Sigma \beta_i \Delta X_i$, is the overall change in infant mortality explained by the regression.

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would have systematically excluded the older members of this age group. (See Table A.3.)

[15] $\partial P / \partial X_i = \beta_i P(1-P)$.

[16] As expected from Haggstrom (1983).

[17] Neither analysis allows for intrahousehold correlation of errors. Since the observations are live births, there is frequently more than one observation per mother. This creates the possibility that influences on different infants born to the same mother may be correlated. We partially control for this by including variables specific to the infant and variables specific to the mother or household. However, unmeasured mother-specific influences may remain. The resulting coefficient estimates reported below are unbiased on this account, but the reported standard errors may be smaller than is actually the case. Hence, the true precision of estimates may be less than is reported here. This is probably more true for family variables (for example, stable maternal characteristics like schooling level) than for child characteristics, since the former are likely to be more highly correlated across infants in the same family.

For our two time points we use the five-year periods at the beginning and end of our 1956-1975 period, i.e., 1956-60 and 1971-75. We have computed the means of all variables for the subsamples of births that occurred in each of these subperiods.

We repeat this same exercise for the logit estimates, after converting the logit coefficients to probability units.[18] We also present predicted average probabilities for subperiods from the logit estimates. These are the average of predicted probabilities for each individual, calculated as $P_i = 1/(1 + e^{-logit_i})$.

Changing Structure

The analysis described in the previous subsection assumes that the structure of relationships explaining mortality variations has not changed over time--that changes over time in the explanatory variables are the only reasons for mortality decline. However, over a period of dramatic socioeconomic, demographic, and public health change, it is possible that the structure of the relationships has also changed. Preston (1980) contends that about half of the increase in life expectancy in developing countries between 1940 and 1970 was due to structural change.

To assess the role of structural change, we allow for different regression coefficients for two time periods--1946-60 and 1961-75. By extending our time span back to 1946, we cover a longer period than in the fixed structure analysis--a period over which there was a larger decrease in infant mortality. However, in 1946 the oldest woman in the MFLS sample was 20. To define our samples comparably for the 1961-75 period, we restrict our sample in this later period to women who were age 20 or less in 1961. We then follow these two cohorts of women--those aged 20 or less in 1946 and those 20 or less in 1961--over the next 15 years of their lives. Appendix Table A.4 shows the ranges of mothers' ages represented in these two samples.

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[18] The sum $\Sigma\beta_i\Delta X_i$ for the logit estimates shows the change in the average logit, but is not directly transformable into probability units because of the nonlinearity of the logit transformation.

We have pooled these two samples and have estimated both OLS and logit regressions that allow for different coefficients for the two periods. (We do this by interacting each variable with a 1961-75 dummy.) We test whether the 1946-60 and 1961-75 coefficients differ for each variable and find that the OLS and logit estimates often yield different conclusions about whether the effect of a particular variable differs significantly between the 1946-60 and 1961-75 periods.[19]

We then use the earlier-period structure and the later-period variable values to see how well the earlier structure would predict the mortality decline that actually occurred. We also repeat this exercise "backwards," multiplying the later-period coefficients by the earlier-period variable values to see if the more recent structure can explain mortality in the past. The difference between the actual infant mortality rate in a subperiod and that predicted by that period's values of variables and the other period's structure is the portion attributable to structural change.[20]

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[19]An alternative approach would have been to interact all explanatory variables with a linear variable measuring child's year of birth, using a sample like that used in the fixed-structure analysis. The approach we use has the advantage of enabling us to extend the years covered by the analysis back to 1946.

[20]For example, in a linear model estimated for two subperiods, j and k, $\widehat{\overline{IMR}}_t = \overline{IMR}_t = \Sigma\beta_{it}\bar{X}_{it}$, t = j or k, where i indexes variables.

Hence $\overline{IMR}_j - (\widehat{\overline{IMR}}_k \mid \beta_k, \bar{X}_j) = \Sigma\beta_{ij}\bar{X}_{ij} - \Sigma\beta_{ik}\bar{X}_{ij} = \Sigma(\beta_{ij} - \beta_{ik})\bar{X}_{ij}$.

III. EMPIRICAL ANALYSIS

FIXED STRUCTURE

Table 2 presents the results of our analysis that estimates the roles of various variables in explaining infant mortality decline over the 1956-75 period assuming a fixed structure of coefficients.

The first two columns show the actual changes in variables that took place between the beginning (1956-60) and end (1971-75) of this period. Between these two subperiods the infant mortality rate of babies born to women less than age 30 decreased by over half--from 60.6 to 29.9. Over this same period mothers' education increased; piped water and toilet sanitation became more prevalent; fewer births followed a short interval or were to very young women; and relatively more births occurred to Chinese women. Each of these changes could potentially contribute to a decline in infant mortality, since these differentials were associated with lower infant mortality in our previous study (DaVanzo, Butz, and Habicht, 1983). However, over this same period, durations of breastfeeding became shorter. This could contribute to an increase in infant mortality.

In col. (3) we present OLS regression coefficients showing the relationships between infant mortality and these explanatory variables for the sample of births to women less than age thirty over this 1956-75 period. All coefficients have the expected signs and nearly all are statistically significant. The logit estimates in col. (5) give practically identical qualitative results. As in our previous studies (Butz, Habicht, and DaVanzo, 1984; Butz, DaVanzo, and Habicht, forthcoming), we find that the beneficial effect of breastfeeding is reduced when modern water and sanitation are present and vice versa.

Columns (4) and (6) put these coefficients and explanatory variable changes together to show the amount of infant mortality decline due to the change in each explanatory variable. The results are summarized in Table 3. All in all, the OLS regression in col. (4) explains 9.2 deaths per thousand of the 30.6 per thousand decline in the infant mortality rate that actually occurred between 1956-60 and 1971-75--less than a

Table 2

OLS AND LOGIT REGRESSIONS EXPLAINING INFANT MORTALITY AND DECOMPOSITION OF THE DECREASE IN THE INFANT MORTALITY RATE (IMR) BETWEEN 1956-60 AND 1971-75 ASSUMING A FIXED STRUCTURE OF COEFFICIENTS

(Sample=Births between 1956 and 1975 to women less than age 30; n=3289)

	Variable Means		OLS Regression		Logit Regression	
	(1)	(2)	(3)	(4)	(5)	(6)
Explanatory Variable	$\bar{X}_{1956-60}$	$\bar{X}_{1971-75}$	Coefficient (t-statistic)	Change in IMR due to change in variable $[\beta^*(\bar{X}_{1971-75} - \bar{X}_{1956-60})*1000]$	Coefficient (t-statistic)	Change in IMR due to change in variable*
Socioeconomic Factors						
Mother's Education (Yrs.)	1.66	4.34	-0.00259 (-2.22)	-6.9	-0.0900 (-2.48)	-9.2
Sanitation and Nutrition Variables						
Piped Water (D)	0.356	0.542	-0.0370 (-3.03)	-6.9	-0.999 (-3.01)	-7.1
Toilet Sanitation (D)	0.797	0.818	-0.0778 (-4.05)	-1.6	-0.699 (-2.04)	-0.6
Mos. Unsupplemented Breastfeeding (Full BF)	1.41	0.58	-0.0133 (-3.19)	+10.9	-0.254 (-1.65)	+8.0
Mos. Supplemented Breastfeeding (Part BF)	5.96	4.49	-0.0108 (-6.06)	+15.9	-0.154 (-4.57)	+8.7
Full BF X Water	0.410	0.266	0.00632 (2.07)	-0.9	0.226 (1.95)	-1.2
Full BF X Toilet	1.23	0.492	0.00749 (1.67)	-5.5	0.0492 (0.30)	-1.4
Part BF X Water	1.69	1.39	0.00386 (2.51)	-1.2	0.103 (2.46)	-1.2
Part BF X Toilet	4.25	3.11	0.00692 (3.47)	-7.9	0.0617 (1.46)	-2.7

Table 2--Continued

Demographic Variables						
Preceding Interval <15 Mos. (D)	0.160	0.137	0.0303 (3.16)	-0.7	0.682 (3.10)	-0.6
Mother's Age (Spline) <18 Yrs.	17.85	17.97	-0.00299 (-0.32)	-0.4	0.0104 (0.05)	+0.0
>18 Yrs	4.96	6.31	-0.00262 (-2.50)	-3.5	-0.0758 (-2.68)	-4.0
Ethnicity						
Chinese (D)	0.357	0.385	-0.0438 (-5.04)	-1.2	-1.39 (-4.99)	-1.4
Indian (D)	0.170	0.124	-0.0154 (-1.37)	+0.7	-0.287 (-1.05)	+0.5
Intercept	1.00	1.00	0.240 (1.43)	---	0.996 (-0.29)	---
R^2	---	---	0.0339	---	---	---
χ^2	---	---	---	---	102.	---
Infant Mortality Rate	60.6	29.9	---	---	---	---
Sum of entries above:	---	---	---	-9.2	---	-12.3

D = Dummy variable

*$\partial P/\partial X \cdot (\bar{X}_{1971-75} - \bar{X}_{1956-60}) \cdot 1000$.

Table 3

ACTUAL AND PREDICTED INFANT MORTALITY RATES (IMR) FOR 1956-60 AND 1971-75

Item	IMR, 1956-60	IMR, 1971-75	Decrease Between 1956-60 and 1971-75
Actual IMR in sample	60.6	29.9	-30.6
Predicted IMR based on OLS coefficients (standard error)	45.7 (±3.8)	36.5 (±3.9)	-9.2
Predicted IMR based on logit coefficients[a] (standard error)	47.7 (±1.8)	35.4 (±1.4)	-12.3

SOURCE: Based on OLS and logit coefficients in Table 2.

[a]Average of probabilities calculated from predicted logits for each observation that occurred in the subperiod.

third of the actual decline. (For 1956-60, the OLS regression predicts an infant mortality rate of 45.7 on the basis of the 1956-60 means of explanatory variables, compared with the actual rate of 60.6. For 1971-75, the predicted rate is 36.5, compared with the actual rate of 29.9.) The logit regression does a little better, predicting 12.3 deaths per thousand of the decline.

The results in both columns (4) and (6) indicate that increases in mother's education and in piped water for women who do not breastfeed[21] have been the largest contributors to the part of the infant mortality decline between 1956 and 1975 that we are able to explain. Improvements

[21]The coefficient of Piped Water alone shows its effect when both breastfeeding variables equal zero. For positive values of breastfeeding, the Water x Breastfeeding interactions must also be considered. This is considered in more detail in Table 4.

in toilet sanitation, increases in mother's age at childbearing, and increases in the proportion of births to Chinese women also make modest contributions to the decline. On the other hand, decreases in the durations of both unsupplemented and supplemented breastfeeding among women who do not have piped water or toilet sanitation contributed to *increases* in mortality over this period. The conditional nature of these estimates, and the fact that the interactions of the breastfeeding and water and sanitation variables must also be considered, makes it difficult to use Table 2 to assess the actual roles of changes in breastfeeding and water and sanitation. However, we can tell by adding all relevant terms in col. (4) or col. (6) together (i.e., adding the second through ninth items in col. (4) or (6)) that the changes in breastfeeding, water, and sanitation together implied an *increase* of 2.8 deaths per thousand in the infant mortality rate based on the OLS estimates and an increase of 2.5 deaths per thousand based on the logit estimates.

We try to separate the roles of the opposing breastfeeding and water sanitation trends in Table 4. In this table we estimate (1) the mortality changes due to the breastfeeding decreases, holding constant the level of water and sanitation at their overall sample means;[22] (2) the mortality changes due to the water and sanitation improvements, holding constant breastfeeding; and (3) the mortality changes due to the interaction of these two changes.

The data in Table 4 imply that, holding water and sanitation constant at their overall sample means, the breastfeeding declines that occurred between 1956-60 and 1971-75 contributed to a 8.6 per thousand *increase* in the infant mortality rate when the OLS estimates are used and a 6.7 per thousand increase based on the logit estimates. In other words, had breastfeeding not declined (holding water and sanitation constant), the infant mortality rate would have declined another 7 or 8 deaths per thousand births. Over this period water and sanitation did improve, but, when we hold the breastfeeding variables constant at their 1956-75 mean values, these water and sanitation improvements only

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[22] E.g., for the OLS estimates, the effect on the infant mortality rate of the decrease in full breastfeeding (FBF) is
$\Delta FBF\ (\beta_{FBF} + \beta_{FBFxW} \times W + \beta_{FBFxT} \times T)$,
where W indicates the average value of piped water and T the average value of toilet sanitation.

Table 4

Change between 1956-60 and 1971-75 in the Infant Mortality Rate due to Changes in Breastfeeding, Water, and Sanitation

ΔX	Change in IMR due to ΔX	
	OLS	Logit
Decrease in unsupplemented breastfeeding, holding water and sanitation constant	+3.6	+3.5
Decrease in supplemented breastfeeding, holding water and sanitation constant	+5.0	+3.2
Decreases in breastfeeding	+8.6	+6.7
Increase in piped water, holding breastfeeding constant	-1.8	-1.5
Increase in toilet sanitation, holding breastfeeding constant	-0.7	-0.2
Improvements in water and sanitation	-2.5	-1.7
Interaction of decrease in breastfeeding and improvements in water and sanitation	-3.3	-2.5
Total	+2.8	+2.5

SOURCE: Derived from OLS and Logit estimates in Table 2.

NOTE: All variables that are held constant are set at their overall sample mean values.

contributed 2.5 deaths per thousand to the mortality decline based on the OLS estimates and even less, 1.7 per thousand, based on the logit estimates. These effects are relatively small because water and sanitation improvements are not very important when breastfeeding is prevalent and of long duration, as it was over much of this period. The interaction effects (which have been calculated residually in light of

the total effect of all changes in breastfeeding, water, and sanitation indicated in cols. (4) and (6) of Table 2) are negative. This implies that the *increases* in the importance of water and sanitation improvements that occurred because of reduced breastfeeding outweighed the *decreases* in the importance of breastfeeding declines that occurred because of water and sanitation improvements.

The results in both Tables 2 and 4 indicate strongly that reductions in breastfeeding have put considerable upward pressure on the infant mortality rate and have prevented it from falling as rapidly as it would have otherwise. *The declines in breastfeeding have more than offset the beneficial influences of improvements in water and sanitation.*

Though some of the factors considered in Table 2 appear to have accounted for some of the mortality decline that occurred, and others are estimated to have prevented mortality from declining even further, we are not able to explain the majority of the actual decline.[23] This is shown both in Table 3, which compares the predicted infant mortality rates for the 1956-60 and 1971-75 periods with the actual rates, and in a regression of the OLS residuals (actual less predicted mortality rates) against year of child's birth:

$$\text{Residual} = .0859 - .00131 \ \text{Year}.$$
$$(2.19) \quad (-2.20)$$

That is, the unexplained variation in infant mortality rates is systematically related to the year of the child's birth.[24] These results

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[23] This contrasts markedly with the findings of our investigation of the reasons for the higher infant mortality rates in the four poorest states of Peninsular Malaysia (Khairuddin et al., forthcoming). In that analysis, differences in the mean levels of explanatory variables between these four states and the other seven states of Peninsular Malaysia account for the entire difference in their average infant mortality rates.

[24] The coefficient of year in this regression on residuals implies that the unexplained time trend between the 1956-60 and 1971-75 periods amounts to 19.7 deaths per thousand (.00131 x 15 years), much larger than the decline of 9.2 deaths per thousand explained by the OLS regression.

The addition of the explanatory variables does not greatly diminish the explanatory power of the child's year of birth: The coefficient of

imply that some factors unaccounted for in this analysis, that have varied systematically over time but are not highly correlated with the variables considered here, appear to be the primary reasons for the infant mortality declines that have occurred in Malaysia. In the next subsection we assess the role of changes over time in the structure of the relationships between infant mortality and its determinants in explaining the mortality decline. The final section speculates about what some of the important unmeasured factors might be.

ALLOWING FOR STRUCTURAL CHANGE

Which Coefficients Have Changed Over Time?

Columns (1), (2), (4), and (5) of Table 5 present OLS and logit regressions that allow coefficients to differ between the 1946-60 and 1961-75 periods. Columns (3) and (6) present t-statistics indicating whether the coefficient of each variable differs significantly between the two periods. At the end of the table we present similar information for the total effects of breastfeeding, water, and sanitation. As discussed in Sec. II, the sample for each period consists of births to the cohort of women age 20 or less at the beginning of the period (i.e., age 34 or less at its end).[25]

The equation specification for Table 5 is the same as in Table 2 except that we have excluded the mothers' age variables. We do this for several reasons: (1) Because the samples here are cohorts of women, age is systematically related to calendar year within each of the samples and could absorb effects of "time"; (2) there are too few women who gave birth before age 18 in the sample of births after 1960 to fit this part of the age spline reliably;[26] and (3) age effects are not large in Table 2.

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year in the regression on residuals (-.00131) is over 2/3 the size of the coefficient of year when it is the only variable regressed against infant mortality (-.00192). The coefficient of year in an OLS regression on infant mortality decreases only modestly (to -.00156 (t = -2.39)) when all the variables included in Table 2 are controlled. The coefficients of most explanatory variables change very little in magnitude or significance when child's year of birth is also controlled. The one exception is mother's education, whose coefficient decreases in absolute value, from -.00259 (t=-2.22) to -.00177 (t=-1.46).

[25] Means of the explanatory variables for the two samples, and t-tests indicating whether they differ significantly, are presented in Appendix Table A.5.

[26] In fact, preliminary estimates indicated a *positive* (though insignificant) slope of the Age <18 spline for births after 1960.

About half the coefficients differ significantly at the 10-percent level between the two periods in either the OLS regression or in both the OLS and logit regressions (two-tailed test, i.e., $|t| > 1.64$). Where differences arise, it is usually the case that effects are stronger before 1960 than afterwards. For toilet sanitation (for those who do not breastfeed), this is true in both the OLS and logit estimates, indicating a fall not only in the attributable risk (additional deaths) but in the relative risk as well.[27] This variable is much more strongly associated with lower infant mortality before 1960 than afterwards. In fact, the logit estimate is not significant for births after 1960. This is true also for the total effects of toilet sanitation shown at the end of Table 5. An inappropriate sanitation system appears to carry less risk when overall public health conditions improve (as they did in Malaysia between the two periods considered here).

The intercept also differs significantly between the two periods in both the OLS and logit analysis, indicating that when all explanatory variables are set to zero (which is a possible value for all variables considered here), the mortality risk is significantly lower in the later period.[28]

Mothers' education is the only variable (other than the Full Breastfeeding x Water interaction) whose influence is substantially stronger after 1960 than before, and the difference between the periods is nearly significant in the logit estimates. The number of lives saved due to an additional year of education does not differ significantly between the 1946-60 and 1961-75 periods in the OLS estimates. Since a year of education is associated with as many lives saved when the mean infant mortality rate exceeded 70 (before 1960) as when it was less than half that value (after 1960), the reduction in relative risk due to an

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[27]The average infant mortality rate declined by more than half between the two periods for the samples considered here (from 72.3 in 1946-60 to 33.3 in 1961-75). Hence a decrease in attributable risk would not necessarily also cause a decrease in relative risk.

[28]Because all explanatory variables are interacted with the 1961-75 dummy, we cannot necessarily extend this conclusion to other values of the explanatory variables.

Table 5

OLS and Logit Regressions Explaining Infant Mortality for the 1946-60 and 1961-75 periods.

(Samples for each period are births over the period to the cohort of women aged 34 or younger at the end of the period)

	OLS Regression			Logit Regression		
	(1)	(2)	(3)	(4)	(5)	(6)
Explanatory Variables	1946-60 coefficients [n=1742 (t)]	1961-75 coefficients [n=1804 (t)]	t-statistic indicating whether β 46-60 and β 61-75 differ significantly	1946-60 Coefficients (t)	1961-75 Coefficients (t)	t-statistic indicating whether β 46-60 and β 61-75 differ significantly
Socioeconomic Factors						
Mother's education	-0.00185 (-0.76)	-0.00389 (-2.30)	-0.69	-0.0365 (-0.71)	-0.159 (-2.89)	-1.63
Sanitation and Nutrition Variables (See bottom of table for total effects.)						
Piped water (D)	-0.0689 (-3.24)	-0.0293 (-1.61)	1.42	-1.17 (-2.56)	-0.938 (-2.09)	0.37
Toilet sanitation (D)	-0.239 (-7.42)	-0.0830 (-2.89)	3.61	-1.51 (-3.84)	-0.417 (-0.86)	1.75
Mos. full breastfeeding	-0.0310 (-5.76)	-0.0160 (-2.24)	1.69	-0.354 (-2.33)	-0.554 (-1.59)	-0.52
Mos. part breastfeeding	-0.0246 (-8.56)	-0.0120 (-4.44)	3.20	-0.187 (-5.26)	-0.185 (-3.42)	0.03
Full BF × Water	0.00694 (1.78)	0.00946 (1.82)	0.39	0.104 (0.74)	0.602 (1.80)	1.37
Full BF × Toilet	0.0226 (3.88)	0.00905 (1.19)	-1.42	0.153 (0.90)	0.0293 (0.14)	-0.45
Part BF × Water	0.00530 (2.06)	0.00314 (1.36)	-0.63	0.0901 (1.69)	0.111 (1.75)	0.25
Part BF × Toilet	0.0191 (6.11)	0.00714 (2.36)	-2.87	0.119 (2.62)	0.0297 (0.44)	-1.10

Table 5--Continued

Demographic Variables						
Preceding Interval < 15 mos (D)	0.0618 (4.27)	0.0165 (1.11)	-2.18	0.802 (3.52)	0.394 (1.16)	-1.00
Ethnicity						
Chinese (D)	-0.0664 (-5.08)	-0.0414 (-3.07)	1.33	-1.25 (-4.30)	-1.70 (-3.91)	-0.85
Indian (D)	-0.0382 (-2.19)	0.0126 (0.70)	2.21	-0.516 (-1.55)	0.674 (0.17)	1.13
Intercept	0.375 (12.8)	0.176 (6.51)	-5.00	-0.143 (-0.44)	-1.065 (-2.67)	-1.80
R^2	0.071		---	---	---	
χ^2	---	---	---	202.		
Total Effects of Breastfeeding, Water, and Sanitation						
Full breastfeeding (evaluated at period means for water and sanitation)	-0.0112 (-5.82)	-0.00368 (-1.38)	2.32	-0.202 (-3.22)	-0.219 (-1.35)	-0.10
Partial breastfeeding (evaluated at period means for water and sanitation)	-0.00742 (-5.76)	-0.00449 (-3.58)	1.63	-0.0657 (-2.79)	-0.103 (-3.11)	-0.94
Piped water (evaluated at period means for breastfeeding)	-0.0250 (-1.96)	-0.00579 (-0.47)	1.08	-0.446 (-1.51)	0.101 (0.27)	1.14
Toilet sanitation (evaluated at period means for breastfeeding)	-0.0795 (-5.25)	-0.0395 (-2.42)	1.80	-0.526 (-1.82)	-0.242 (-0.71)	0.63

NOTE: D = dummy variable.

additional year of education is much greater in the later period. Indeed, the logit estimates in Table 5 indicate a significant negative effect of education in the later period, but no significant effect in the earlier period. A similar pattern arises in comparing infant and child mortality determinants in high- and low-mortality regions of Malaysia: Mother's education is somewhat more important in explaining mortality differentials in the low-mortality areas (Khairuddin et al., forthcoming). These results together suggest that mother's education has been complementary with economic development in reducing infant mortality in Malaysia since World War II.[29] It may be that certain minimal levels of the means to reduce mortality (scientific information about health care and diet, availability of health care) may be necessary for mother's education to have a significant beneficial effect. It is also possible that more education helps mothers make more appropriate weaning decisions, and hence becomes a more important influence on infant mortality when breastfeeding becomes less prevalent and of shorter duration.[30]

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[29]We had originally expected the opposite: that mother's education would be more important in the earlier period and in low-income/high-mortality areas, for in those environments there should be fewer ways to substitute for the advantages that mother's education conveys. Rosenzweig and Schultz (1982) found this substitution hypothesis to hold in urban areas of Colombia, using actual data on local health programs. Mott (1982), using data from the Kenyan World Fertility Survey, found that primary and secondary school attendance had progressively less influence in explaining infant mortality over time in Kenya.

Another reason for expecting a stronger effect of education when infant mortality is high is that education has a stronger effect on post-neonatal mortality than on neonatal mortality (e.g., DaVanzo, Butz and Habicht, 1983) and the former constitutes a larger portion of infant deaths when infant mortality rates are high.

Preston (1980) by contrast, like us, finds education to be relatively more important in more recent years. He considers the influence of literacy on life expectancy in developing countries in 1940 and 1970, using country aggregates as his units of analysis.

[30]This possibility was suggested by Doug Ewbank in his insightful discussion of this paper at the 1984 meeting of the Population Association of America. This led us to investigate this possibility directly by including an interaction of duration of unsupplemented breastfeeding and mother's education. (The relative advantage of full breastfeeding should be less for mothers who know how to provide appropriate supplementary or substitute feeding to their infants.) However, this interaction term was never statistically significant when added to regressions otherwise like those in Tables 2 and 5, though its coefficient was positive, as expected.

The remaining variables in the regression sometimes differ significantly between the two periods in their effect in terms of lives saved, i.e., in the OLS estimates.[31] However, none of these variables differ significantly between the 1946-60 and 1961-75 periods in their influence on the relative odds of mortality, i.e., in the logit estimates. By and large, the relationships of these variables with infant mortality are the same as we saw earlier in Table 2.

The logit model seems the more appropriate one here in light of the considerable decrease in the average infant mortality risk between the 1946-60 and 1961-75 periods. Indeed, the greater stability of the coefficients between the two time periods reinforces this belief. Many of the significant differences found between periods in the OLS estimates appear to be mainly due to the declining average risk. In the logit model the only significant structural differences between the 1946-60 and 1961-75 periods arise for the intercept and toilet sanitation (for babies who do not breastfeed).

How Well Does the 1946-60 Structure Predict the 1961-75 Infant Mortality Rate (and Vice Versa)?

We have just seen that several coefficients differ significantly in their effect on infant mortality between the 1946-60 and 1961-75 periods. In Table 6 we assess the relative importance of these structural changes vs. changes in variables in explaining the mortality decline that occurred between these two periods. We do this by seeing how well the 1946-60 structure and the 1961-75 values of explanatory variables predict the 1961-75 infant mortality rate. The difference between this predicted 1961-75 mortality rate and the actual 1946-60 rate is the portion of mortality decline attributable to changes in variables. The difference between this predicted 1961-75 mortality rate

[31] This is true for full and partial breastfeeding (each alone and the latter in interaction with toilet sanitation), a preceding short birth interval, and Indian ethnicity. It is also true for the total effects of full breastfeeding and of toilet sanitation, shown at the bottom of Table 5. Each of these effects is much stronger in the earlier period. In fact, Indian ethnicity and a short birth interval do not significantly influence infant mortality in the sample of births after 1960.

Table 6

INFANT MORTALITY RATES PREDICTIONS
BASED ON PARAMETERS IN TABLE 5

Item	Explanatory Variables for: (1) 1946-60	(2) 1961-75	Actual Change[a]
A. Actual IMR	72.3	33.3	-39.0
Estimates Based on OLS Coefficients in Table 5			
			Change Due to Change in Explanatory Variables[a]
B. Predicted IMR assuming 1946-60 structure	72.3 (±5.2)	64.5 (±8.2)	-7.8
C. Predicted IMR assuming 1961-75 structure	39.5 (±6.8)	33.3 (±5.1)	-6.2
D. IMR change due to change in structure[b]	-32.8	-31.2	
Estimates Based on Logit Coefficients in Table 5[c]			
			Change Due to Change in Explanatory Variables[a]
E. Predicted IMR assuming 1946-60 structure	72.3 (±1.8)	63.4 (±1.7)	-8.9
F. Predicted IMR assuming 1961-75 structure	40.4 (±1.0)	33.3 (±1.0)	-7.1
G. IMR change due to change in structure[d]	-31.9	-30.1	

Numbers in parentheses are standard errors.
[a]Column (2) - Column (1).
[b]Row C - Row B.
[c]We have converted the predicted logit to a probability for each observation and then have averaged over observations for that period.
[d]Row F - Row E.

and the actual 1961-75 rate is the portion due to structural change. We also repeat this exercise "backwards," seeing how well the later structure would have predicted the mortality rate in the earlier period, given the values of the explanatory variables then.

Changes in the values of variables explain relatively little of the mortality decline. The 1946-60 coefficients, when applied to the 1961-75 values of explanatory variables, imply that the infant mortality rate would decrease from 72.3 in 1946-60 to 64.5 by 1961-75 for the OLS coefficients and to 63.4 for the logit coefficients. The actual 1961-75 infant mortality rate was 33.3--more than 30 points lower than predicted. A similar conclusion is reached if we take the later period coefficients and use the earlier period values of variables. Here we would have predicted even less of the actual infant mortality change that occurred, because many of the coefficients fell between the 1946-60 and 1961-75 periods and hence the later regression is less sensitive to changes in variables. In both cases, the logit coefficients predict somewhat better than the OLS, a further indication that the logit model is the more appropriate of the two, though the OLS and logit predictions are remarkably similar. Nonetheless, the logit coefficients explain at most only 8.9 deaths per thousand of the actual 39 per thousand difference between the periods.

We conclude that the better part of the decline in the infant mortality rate that occurred between 1946-60 and 1961-75 is not due to changes in the levels of the variables we have considered here, but to changes in the structure of mortality relationships. Around 80 percent of the decline appears due to change in structure, a percentage very similar to that found by Preston in a similar exercise (Preston, 1976, Ch. 4).

IV. SUMMARY AND CONCLUSIONS

This analysis has identified several factors that have contributed to the dramatic decline in infant mortality that has occurred since World War II in Malaysia, as well as one factor that has prevented infant mortality rates from declining even more rapidly.

Our main findings are the following:

(1) On average, mothers' education more than doubled over the study period and contributed importantly to the decline in their infants' mortality. In addition, the beneficial effect of mothers' education appears to have become stronger over the study period. Hence, further advances in education should lead to further improvements in infants' survival prospects. In another analysis of these data (Khairuddin et al., forthcoming), we also found that education is somewhat more influential in that regard in low-mortality, high-income areas than in the opposite type of areas. It therefore appears that economic development may complement, instead of substitute for, the beneficial effect of mothers' education in promoting infant survival in Malaysia.

(2) Improvements in water and sanitation also contributed to the infant mortality decline, especially for babies who did not breastfeed. However, unlike education, these influences have become less important over time, especially for babies who are not breastfed. Hence further improvements in water and sanitation, a goal of Malaysia's Rural Environmental Sanitation Programme, can be expected to have smaller relative effects on infant mortality than did previous improvements. Targetting such improvements on areas where women breastfeed little or not at all, however, will increase their effectiveness in promoting infant survival.

(3) The substantial reductions in breastfeeding that have taken place since World War II have kept the infant mortality rate in Malaysia from declining as rapidly as it would have otherwise. In fact, we estimate that, in our sample, the detrimental effects on infant survival of the decline in breastfeeding have more than offset the beneficial effects of improvements in water and sanitation.

(4) Unlike some recent studies (e.g., Palloni, 1981), we find that changes in fertility levels and in the timing and spacing of births have had negligible effect in explaining the decline in infant mortality within the samples we have considered. We have excluded births to older women from our analysis, however, and this may have led to an understatement of the influence of changes in the age pattern of childbearing.

(5) Despite the contributions of the variables just discussed, we are unable to explain much of the actual decline in the infant mortality rate by changes in the variables considered here. Our finding, based on micro data on individual births, is similar to Preston's findings based on country aggregates (1976, 1980) that structural change explains as much or more of mortality decline as do changes in a set of socioeconomic and other variables.[32]

Although we conclude that structural change explains the greater part of the infant mortality decline that occurred, most influences on infant mortality have not changed significantly over time. When a relative risk (logit) model is used, the coefficients of only two variables differ significantly between the periods before and after 1960: the intercept and the coefficient of toilet sanitation (for babies who were not breastfed). Toilet sanitation had significantly less beneficial influence on infant survival for babies born after 1960 than before. Hence, this structural change has not contributed to the mortality decline. Instead, the explanation for the majority of the mortality decline lies in the influence of factors not considered in this analysis--i.e., in the intercept term. When all variables considered here are held constant, the risk of dying in infancy is much lower after 1960 than before.[33]

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[32]We reach this same conclusion from a variety of analytic approaches: predictions for particular time periods using the fixed-structure coefficients, regression of the fixed-structure residuals on time, seeing how much the time trend in infant mortality is reduced when other explanatory variables are added to the fixed-structure regression, and allowing for different structures in two periods and using one period's structure and the other's mean to predict infant mortality in the latter period.

[33]We have formally considered this only for the case where all explanatory variables are set to zero, but we are confident that the

What might these other factors be? Although we hesitate to put a label on what we are unable to explain, several possibilities seem likely. One is income growth. Higher incomes enable families to afford better medical care and better nutrition (which reduces the fatality rate from most diseases). Wage incomes (adjusted for cost of living) increased at an average annual rate of 2.4 percent per year in Malaysia over the period considered here (Smith, 1983). Since an important share of this income growth was due to increases in education (Smith, 1983), however, it is likely that our education variable has already absorbed some of this effect.

Improvements in medical and health care may also have contributed to the mortality decline. Since independence in 1957, the Malaysian government has spent increasing amounts of money on programs to combat the major endemic communicable diseases prevalent in the country,[34] to extend health services to the rural areas, and to provide preventive medical services. Maternal-child health care is one of the largest components of the rural health program. A recent report by the Malaysian government contends that "The rapid fall in child mortality was a direct consequence of these services provided by the Rural Health Programme" (Abu Bakar, 1981, p. 257). Many of these programs were begun after 1960 and may well have contributed to the large reduction in the infant mortality rate we find between the 1946-60 and 1961-75 periods.[35]

In conclusion, the greater part of the infant mortality decline in Malaysia is not explained by the factors considered in this analysis. Of the portion that is explained here, increases in mothers' education and improvements in water and sanitation appear to be the most important factors.

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same conclusion would arise for many other values of explanatory variables as well.

[34]There have been specific programs to control or eradicate tuberculosis, malaria, leprosy, yaws, filariasis, and dengue hemorrhaegic fever. In 1977, the government spent M$44.36 (around U.S. $20) per capita on health activities (WHO, 1980). The overall allocation to health increased seven-fold between 1956-60 and 1976-80 (derived from data presented in Abu Bakar, 1981, p. 260) and increased as a share of overall public expenditures.

[35]Without good retrospective data on households' economic well-being and the availability and scope of health services, we can of course only speculate about the importance of economic growth, expansion of health services, and other factors in explaining the infant mortality decline in Malaysia.

Appendix
Table A.1

MOTHER'S AGES AT CHILD'S BIRTH ACCORDING TO CHILD'S YEAR OF BIRTH AND MOTHER'S YEAR OF BIRTH IN THE MFLS RETROSPECTIVE LIFE HISTORY

Year of Child's Birth

1941	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	Year of Mother's Birth
15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	1926
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	1927
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	1928
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	1929
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	1930
			13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	1931
				13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	1932
					13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	1933
						13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	1934
							13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	1935
								13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	1936
									13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	1937
										13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	1938
											13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	1939
												13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	1940
													13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	1941
														13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	1942
															13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	1943
																13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	1944
																	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1945
																		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1946
																			13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	1947
																				13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1948
																					13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	1949
																						13	14	15	16	17	18	19	20	21	22	23	24	25	26	1950
																							13	14	15	16	17	18	19	20	21	22	23	24	25	1951
																								13	14	15	16	17	18	19	20	21	22	23	24	1952
																									13	14	15	16	17	18	19	20	21	22	23	1953
																										13	14	15	16	17	18	19	20	21	22	1954
																											13	14	15	16	17	18	19	20	21	1955
																												13	14	15	16	17	18	19	20	1956
																													13	14	15	16	17	18	19	1957
																														13	14	15	16	17	18	1958

Mother's age at child's birth

Rows show the calendar years of experience covered for each birth cohort and their ages in each year. Columns show the ages covered in each calendar year.

The youngest women in the sample were born in 1958. The earliest birth to women in the sample was in 1941. The youngest maternal age at child's birth was 13.

Table A.2

SAMPLES FOR CELLS IN TABLE 1

(Numbers in Parentheses Indicate Number of Observations for Each Cell)

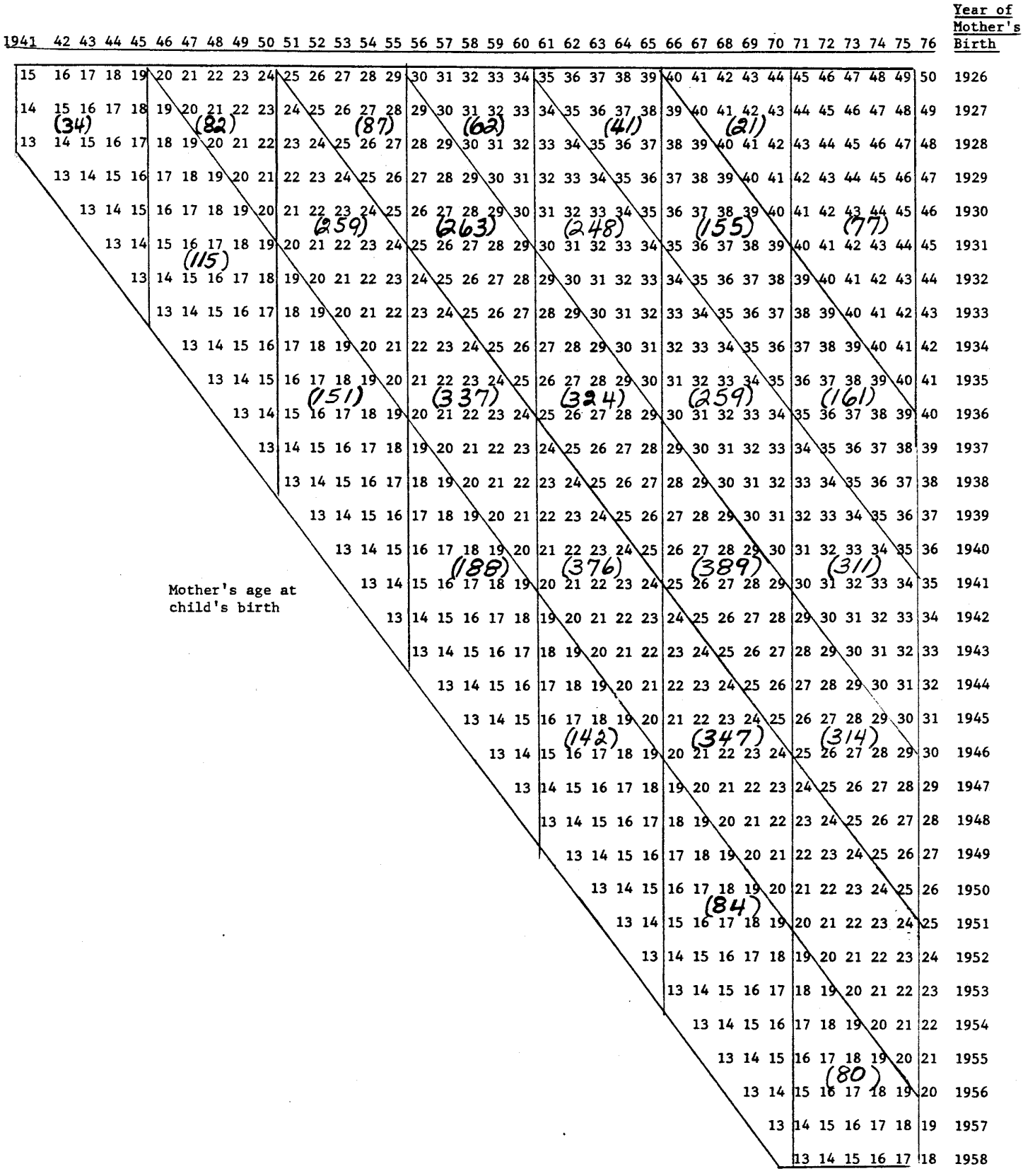

Table A.3

MOTHERS' AGES AND CHILDREN'S YEARS OF BIRTH
REPRESENTED IN SAMPLE FOR TABLE 2

Year of Child's Birth

1941	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	Year of Mother's Birth
15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	1926
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	1927
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	1928
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	1929
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	1930
			13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	1931
				13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	1932
					13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	1933
						13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	1934
							13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	1935
								13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	1936
									13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	1937
										13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	1938
											13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	1939
												13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	1940
													13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	1941
														13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	1942
															13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	1943
																13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	1944
																	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1945
																		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1946
																			13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	1947
																				13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1948
																					13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	1949
																						13	14	15	16	17	18	19	20	21	22	23	24	25	26	1950
																							13	14	15	16	17	18	19	20	21	22	23	24	25	1951
																								13	14	15	16	17	18	19	20	21	22	23	24	1952
																									13	14	15	16	17	18	19	20	21	22	23	1953
																										13	14	15	16	17	18	19	20	21	22	1954
																											13	14	15	16	17	18	19	20	21	1955
																												13	14	15	16	17	18	19	20	1956
																													13	14	15	16	17	18	19	1957
																														13	14	15	16	17	18	1958

Mother's age at child's birth

Table A.4

MOTHERS' AGES AND CHILDREN'S YEARS OF BIRTH
REPRESENTED IN SAMPLE FOR TABLE 5

Year of Child's Birth

1941	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	Year of Mother's Birth
15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	1926
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	1927
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	1928
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	1929
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	1930
			13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	1931
				13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	1932
					13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	1933
						13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	1934
							13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	1935
								13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	1936
									13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	1937
										13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	1938
											13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	1939
												13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	1940
													13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	1941
														13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	1942
															13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	1943
																13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	1944
																	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1945
																		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1946
																			13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	1947
																				13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1948
																					13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	1949
																						13	14	15	16	17	18	19	20	21	22	23	24	25	26	1950
																							13	14	15	16	17	18	19	20	21	22	23	24	25	1951
																								13	14	15	16	17	18	19	20	21	22	23	24	1952
																									13	14	15	16	17	18	19	20	21	22	23	1953
																										13	14	15	16	17	18	19	20	21	22	1954
																											13	14	15	16	17	18	19	20	21	1955
																												13	14	15	16	17	18	19	20	1956
																													13	14	15	16	17	18	19	1957
																														13	14	15	16	17	18	1958

Mother's age at child's birth

Table A.5

MEANS OF EXPLANATORY VARIABLES FOR 1946-60 AND 1961-75 AND TESTS OF WHETHER THEIR DIFFERENCES ARE SIGNIFICANT

Explanatory Variables (X)	(1) 1946-60 Mean of Variable (Std. Deviation)	(2) 1961-75 Mean of Variable (Std. Deviation)	(3) t-statistic Indicating Whether $\bar{X}_{46-60}$ and $\bar{X}_{61-75}$ Differ Significantly[α]
Socioeconomic Factors			
Mother's education	1.45 (2.27)	3.91 (3.32)	2.57
Sanitation and Nutrition Variables			
Piped water	0.324 (0.468)	0.516 (0.500)	11.8
Toilet sanitation	0.775 (0.417)	0.822 (0.383)	3.43
Mos. full breastfeeding	1.62 (3.18)	0.78 (2.02)	-9.30
Mos. part breastfeeding	6.17 (4.86)	5.10 (5.03)	-6.44
Demographic Variables			
Preceding Interval < 15 mos	0.155 (0.362)	0.141 (0.348)	-1.14
Ethnicity			
Chinese (D)	0.355 (0.479)	0.389 (0.488)	2.08
Indian (D)	0.146 (0.353)	0.136 (0.343)	-0.86

NOTES: Samples are the same as for Table 5. D = dummy variable.

[α]Allows for unequal variances.

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