A RAND NOTE

INFANT MORTALITY DECLINE IN MALAYSIA, 1946-1975: THE ROLES OF CHANGES IN VARIABLES AND CHANGES IN THE STRUCTURE OF RELATIONSHIPS

Julie DaVanzo, Jean-Pierre Habicht

May 1986

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ABSTRACT

Individual-level retrospective data from the Malaysian Family Life Survey are used to examine why the infant mortality rate (IMR) has declined rapidly in Malaysia since World War II. Substantial increases in mothers' education and improvements in water and sanitation have contributed. However, breastfeeding reductions have kept the IMR from declining as rapidly as it would have otherwise. The detrimental effects of reduced breastfeeding more than offset the beneficial effects of water and sanitation improvements. The majority of the IMR decline, however, is not explained by changes in the variables considered here, or in their relationships with infant mortality.

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INFANT MORTALITY DECLINE IN MALAYSIA, 1946–1975: THE ROLES OF CHANGES IN VARIABLES AND CHANGES IN THE STRUCTURE OF RELATIONSHIPS

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INTRODUCTION

One of the more gratifying phenomena of the twentieth 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, and infant mortality rates have shown the largest absolute declines. In Malaysia, for example, the infant mortality rate declined from about 100 infant deaths per thousand live births in the 1940s to about 30 in the 1970s (fig. 1).

Many hypotheses have been advanced to explain these 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. Some factors, however, may have affected infant mortality particularly, including pre- and post-natal care, child health services, infant feeding, and family planning (which can promote spacing of children and reduce high-risk births). Despite the widespread assumption that these factors do affect infant mortality, few studies have systematically assessed their relative roles in reducing it.[1]

This paper attempts to do so, 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 but also many of its key determinants over this period;[2] 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 mother's education, household water and sanitation, type and duration of breastfeeding, whether a short interval preceded the birth, and on the ethnic composition of births. These are variables that strongly influenced infant mortality in our previous study and that changed considerably over the 1946–1975 period. Of course, other variables, not well measured or available in our data, may have contributed to the decline in infant mortality—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 as to promote that decline (for example, increases in mothers' education, improvements

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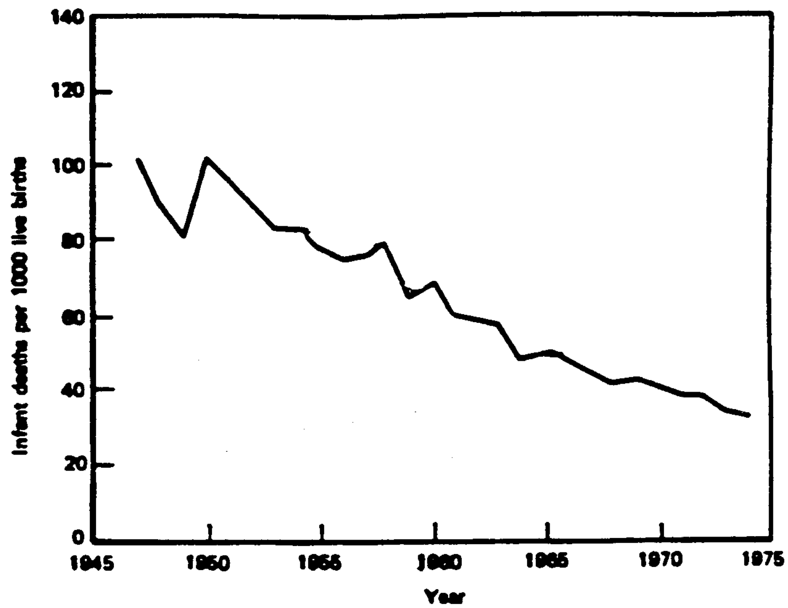

Figure 1.—Trend in the infant mortality rate in Peninsular Malaysia (from Malaysian Vital Statistics)

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. We also consider whether the relationships of these variables with infant mortality have changed over time and whether such changes have contributed to the decline in infant mortality.

DATA AND METHODS

Data

The Malaysian Family Life Survey (MFLS) was conducted in 1976–1977 (Butz and DaVanzo 1978) and is a population-based probability sample consisting of randomly selected private households, each containing 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 purposely selected to give additional representation to Indian households and households in fishing communities.

The key questionnaire used here is the Round-1 Female Retrospective Life History questionnaire (MF2), which examines life events as early as the 1940s for some respondents. It includes a complete life history 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. To avoid the need for more complex survival analysis techniques, births that occurred less than a year before the date of interview (less than 4 percent of all reported births) are excluded.

For each live birth, we have information on the lengths of unsupplemented and supplemented breastfeeding, on 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.

Haaga (1986) has investigated the quality of the MFLS retrospectively-reported data on infant mortality and associated life events and finds that the secular trend in infant mortality and the mortality differences between Malays and Chinese are generally similar to those indicated by Malaysian vital statistics. These comparisons show no evidence for decreased reporting of mortality events in the distant past.

The MFLS is essentially a random sample of women in their childbearing years at the time of the survey; hence it should provide a random sample of births around that time. It will not, however, provide a random sample of births in earlier years. Because of the upper age limit (age 50 in 1976), the retrospective survey will not document the experiences of older women in earlier years. For example, in 1960 the oldest women in the sample were age 34, and in 1950 they were age 24.[3]

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.[4] The columns 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 mortality, as is widely recognized in the literature (e.g., United Nations 1973; Nortman 1974; Puffer and Serrano 1975). These differentials imply that it is important to adjust for maternal age composition in comparing infant mortality rates in different periods of time.

Within age groups, the infant mortality rates in table 1 have generally decreased over time, with the most rapid declines generally occurring between the 1956–1960 and 1961–1965 periods.[5] In this paper we explore the reasons for the decline between the 1946–1960 and 1961–1975 periods.

Methods

Samples for Analysis. Our analysis considers two time periods: 1946–1960 and 1961–1975, which make up a time span that saw a large decrease in infant mortality. To define our samples comparably for the two periods, we restrict them for both periods to women who were age 20 or less in the initial year of the period (in 1946 the oldest women in the MFLS sample was 20). We then follow these two cohorts—those age 20 or less in 1946 and those 20 or less in 1961—over the next 15 years of their lives. Appendix table A.1 shows the ranges of mothers' ages represented in these two samples.[6]

Explanatory Variables Considered. To trace the infant mortality decline we use retrospective information on several socioeconomic, demographic, sanitation, and nutritional variables that are related to variations in mortality and are alleged to promote child survival. We estimate the relationship between infant mortality and those explanatory variables available in the MFLS that (1) affect infant mortality and (2) have varied enough over time to have affected the mortality trend. Initially, all of the variables included in our earlier work (DaVanzo, Butz, and Habicht 1983) were considered for this analysis. We have excluded some of them because they did not relate significantly to variations in infant mortality in the samples used here, did not

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							
	1941–1945	1946–1950	1951–1955	1956–1960	1961–1965	1966–1970	1971–1975	Average
≤19	147[a]	104[c]	119[c]	106[c]	49[c]	60[b]	87[b]	93
20-24	--	73[b]	62	62	32	46	32	47
25-29	--	--	57[b]	38	37	23	13	28
30-34	--	--	--	48[b]	52	50	35	46
35-39	--	--	--	--	24[a]	52[c]	19[c]	34
40+	--	--	--	--	--	48[a]	65[b]	61
Average	147[a]	91[c]	79	64	40	41	31	48

Note: Total number of births is 5357; unless otherwise noted each cell includes over 250 births.

[a] Based on less than 50 births

[b] Based on 50 to 99 births

[c] Based on 100 to 199 births

exhibit consistent variation over time (e.g., infants' sex), or were judged mainly to mediate the effects of variables considered in this study (e.g., birthweight). These excluded variables are: household income; the infant's birth order (with first birth order and high birth order treated separately); the mother's age at the time of the child's birth (treated as nonlinear); 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. We also exclude the calendar year of the child's birth. This variable is highly correlated with variables that have varied systematically over time, and it might have robbed them of some of their explanatory power had we included it. We consider the following variables:[7]

1. *Infant mortality:* whether the child died in its first year.
2. *Mother's education:* years of schooling completed.
3. *Household water and sanitation:* whether the house where the family lived when the child was born had piped water or toilet sanitation.
4. *Breastfeeding:* number of months of unsupplemented and supplemented breastfeeding in the first 12 months of life.[8]
5. *Interactions of breastfeeding durations and water and sanitation variables:* Breastfeeding, especially if unsupplemented, reduces exposure to contaminated water. Therefore, 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 (Butz, Habicht, and DaVanzo 1984; and Habicht, DaVanzo, and Butz, forthcoming).

6. *Length of preceding birth interval:* whether the interval preceding this child's birth was short (< 15 mos.).[9]
7. *Mother's ethnicity:* Chinese, Indian, or Malay (the omitted group).[10]

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

Fixed Structure Analysis. We first assess the contributions of differences in explanatory variables between the two time periods, assuming the same structure of relationships in the two periods, and estimate a logit regression for this pooled sample. We then 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 ($\bar{P}$): $\partial P/\partial X_i = \beta_i\bar{P}[1 - \bar{P}]$. Each $\partial P/\partial X_i$ shows the change in the probability of infant mortality due to a one-unit change in a particular variable, X_i. Each of these is multiplied by the actual average change in that variable occurring between the two periods—i.e., $(\partial P/\partial X_i)\ \Delta X_i$—to show the amount of mortality change due to the *actual* average change in that variable. The sum, $\Sigma(\partial P/\partial X_i)\Delta X_i$, approximates the overall change in infant mortality explained by the regression. This analysis is reported in table 2 below.

Changing Structure Analysis. The analysis just described assumes that the structure of relationships explaining mortality variations did not change over time—that changes over time in the explanatory variables are the only reasons for mortality decline. Over a period of dramatic socioeconomic, demographic, and public health change, however, it is possible that the structure of the relationships 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 the two time periods, 1946–1960 and 1961–1975. We pool the samples for the two time periods and estimate a logit regression that interacts each variable with a 1961–1975 dummy. We test whether the 1946–1960 and 1961–1975 coefficients differ for each variable, enabling ourselves to identify the variables whose influence has changed significantly between the two time periods. We can also see whether the intercept term, the influence of factors not considered in the analysis, changed over time. This analysis is reported in table 4.

The earlier-period structure and the later-period variable values permit us to see how well the earlier structure would have predicted the mortality decline that actually occurred. This exercise is repeated "backward," multiplying the later-period coefficients by the earlier-period variable values to see if the more recent structure can explain mortality in the past.[11] The difference between the actual infant mortality rate in a period and that predicted by that period's values of variables and the other period's structure is what Preston has termed the portion attributable to overall structural change. These predictions are reported in table 5.

Table 2.—Logit regression explaining infant mortality, and decomposition of the decrease in the infant mortality rate between 1946–1960 and 1961–1975, assuming the same structure of relationships in both periods

Explanatory variable	Variable means (1) 1946-1960 mean ($\bar{X}$)	(2) 1961-1975 mean ($\bar{X}$)	(3) t-statistic for difference between $\bar{X}_{46-60}$ and $\bar{X}_{61-75}$	Logit regression (4) Coefficient (t-statistic)	(5) Change in IMR due to change in variable[a]
Socioeconomic factors					
Mother's education (in years)	1.45	3.91	2.57**	-0.141*** (-4.09)	-17.1
Sanitation and nutrition variables[b]					
Piped water[c]	0.324	0.516	11.8***	-1.06*** (-3.54)	-10.1
Toilet sanitation[c]	0.775	0.822	3.43***	-0.984*** (-3.32)	-2.3
Months unsupplemented breastfeeding (full breastfeeding)	1.62	0.78	-9.30***	-0.309** (-2.47)	+12.8
Months supplemented breastfeeding (part breastfeeding)	6.17	5.10	-6.44***	-0.171*** (-6.16)	+9.1
Full breastfeeding x water	--	--	--	0.214** (2.14)	-1.5
Full breastfeeding x toilet	--	--	--	0.0886 (0.63)	-3.3
Part breastfeeding x water	--	--	--	0.0886** (2.31)	+0.6
Part breastfeeding x toilet	--	--	--	0.0713** (1.99)	-2.0
Demographic variables					
Preceding interval <15 months[c]	0.155	0.141	-1.14	0.692*** (3.70)	-0.5
Ethnicity					
Chinese[c]	0.355	0.389	2.08**	-1.44*** (-5.95)	-2.4
Indian[c]	0.146	0.136	-0.86	-0.209 (0.85)	+0.1
Intercept	1.00	1.00	--	-0.539** (-2.22)	—
χ^2	--	--	--	170	--
Infant mortality rate	72.3	33.3	5.20***	--	--
Sum of entries above	--	--	--	--	-16.5
n	1742	1804	--	3546	--

EMPIRICAL ANALYSIS

Fixed Structure

Table 2 presents estimates of the roles of various variables in explaining infant mortality decline over the 1946–1975 period, assuming the same structure of relationships in the 1946–1960 and 1961–1975 periods. As discussed above, the sample for each period consists of births to the cohort of women age 20 or less at the beginning of each period (i.e., age 34 or less at its end).

Table 2.—Continued

Explanatory variable	Variable means (1) 1946-1960 mean ($\bar{X}$)	(2) 1961-1975 mean ($\bar{X}$)	(3) t-statistic for difference between $\bar{X}_{46-60}$ and $\bar{X}_{61-75}$	Logit regression (4) Coefficient (t-statistic)	(5) Change in IMR due to change in variable[a]
Total effects of breastfeeding, water, and sanitation					
Full breastfeeding (evaluated at sample means for water and toilet)	--	--	--	-0.687*** (-2.86)	+6.2
Part breastfeeding (evaluated at sample means for water and toilet)	--	--	--	-0.616*** (-2.59)	+4.1
Piped water (evaluated at sample means for breastfeeding)	--	--	--	-0.848*** (-2.58)	-2.9
Toilet sanitation (evaluated at sample means for breastfeeding)	--	--	--	-1.02*** (-3.63)	-1.1

[a] $(\partial P/\partial X)(\bar{X}_{1961-1975} - \bar{X}_{1946-1960}) \cdot 1000$

[b] See lower panel for total effects.

[c] Dummy variable

* Statistically significant at the 10 percent level (two-tail test, $|t| \geq 1.65$)
** Statistically significant at the 5 percent level (two tail test, $|t| \geq 1.96$)
*** Statistically significant at the 1 percent level (two-tail test, $|t| \geq 2.58$)

The first two columns show the actual changes in variables that took place between the two time periods. Column (3) presents *t*-statistics indicating whether the differences are significantly different from zero, and shows that all but two are significant.[12] Between these two periods, the infant mortality rate of babies born to women age 20 or less at the beginning of the period decreased by over half, from 72.3 to 33.3. Over this same time span mothers' education increased, piped water and toilet sanitation became more prevalent, and relatively more births in our sample 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). Over this same period, however, durations of breastfeeding became shorter, which could contribute to an increase in infant mortality.

In column (4) we present logit regression coefficients showing the relationships between infant mortality and these explanatory variables, assuming the same structure of relationships in both periods. All coefficients have the expected signs and nearly all are statistically significant. As in our previous studies (Butz, Habicht, and DaVanzo 1984; Habicht, DaVanzo, and Butz, forthcoming), we find that the beneficial effect of breastfeeding is reduced when modern water and sanitation are present, and vice versa.

Column (5) puts 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 by adding the column (5) entries in the top panel: the regression in column (4) and the differences in the mean values of the explanatory variables between the 1946–1960 and 1961–1975 periods explain 16.9 of the 39.0 deaths per thousand decline in the infant mortality rate for the cohorts considered here—43 percent of the actual decline.

Table 3.—Change between 1946–1960 and 1961–1975 in the infant mortality rate due to changes in breastfeeding, water, and sanitation

Change in variable (ΔX)	Change in infant mortality rate due to ΔX	
Decrease in unsupplemented breastfeeding, holding water and sanitation constant	+6.2	
Decrease in supplemented breastfeeding, holding water and sanitation constant	+4.1	
Decreases in breastfeeding		+10.3
Increase in piped water, holding breastfeeding constant	-2.9	
Increase in toilet sanitation, holding breastfeeding constant	-1.1	
Improvements in water and sanitation		-4.0
Interaction of decrease in breastfeeding and improvements in water and sanitation	-2.9	
Total		+3.4

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

Source: Derived from column (5) of Table 2.

The results in column (5) indicate that increases in mother's education and in piped water for women who do not breastfeed[13] have been the largest contributors to the part of the infant mortality decline between the two periods that we are able to explain. Improvements in toilet sanitation and increases in the proportion of births to Chinese women also make modest contributions to the decline. However, 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 make it difficult to use table 2 to assess the actual roles of changes in breastfeeding and water and sanitation. Nonetheless, by adding the second through ninth items in column (5) we can tell that the changes in breastfeeding, water, and sanitation together imply an *increase* of 3.4 deaths per thousand.

Table 3 separates the roles of the opposing breastfeeding and water and sanitation trends. Here we estimate (1) the mortality changes due to the breastfeeding decreases, holding constant the level of water and sanitation at their overall sample means;[14] (2) the mortality changes due to the water and sanitation improvements, holding breastfeeding constant; and (3) the mortality changes due to the interaction of these two changes.

The data in table 3 imply that, holding water and sanitation constant at their overall sample means, the breastfeeding declines between 1946–1960 and 1961–1975 contributed to a 10.3 per thousand *increase* in the infant mortality rate. In other words, had breastfeeding not declined (holding water and sanitation constant), the infant mortality rate would have declined another 10 deaths per thousand births. Over this period water and sanitation did improve, but when we hold the breastfeeding variables constant at their 1946–1975 mean values, these water and sanitation improvements contributed only 4.0 deaths per thousand to the mortality decline. (These effects are fairly small because water and sanitation improvements are not very important for infant survival when breastfeeding is prevalent and of long duration, as it was over much of the 1946–1975 period.) The interaction effect (which has been calculated residually in light of the total effect of all changes in breastfeeding, water, and sanitation indicated in column (5) of table 2) is 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 tables 2 and 3 indicate strongly that reductions in breastfeeding have prevented the infant mortality rate 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 and others are estimated to have prevented mortality from declining even further, we are not able to explain the majority of the actual decline with these variable changes. Below we investigate whether some of the relationships between infant mortality and its determinants have changed over time and whether these might help explain the mortality decline.

Allowing For Structural Change

Which coefficients have changed over time? Columns (1) and (2) of table 4 present a logit regression that allows coefficients to differ between the 1946–1960 and 1961–1975 periods. Column (3) presents t-statistics indicating whether the coefficient of each variable differs significantly between the two periods. At the bottom of the table we present similar information for the total effects of breastfeeding, water, and sanitation.

Only two coefficients—those of toilet sanitation (for babies who did not breastfeed) and the intercept—differ significantly at the 10 percent level between the two periods in table 4 (two-tailed test—$|t| > 1.64$).[15] For those who did not breastfeed, toilet sanitation is much more strongly associated with lower infant mortality before 1960 than afterward. In fact, the logit estimate is not significant for births after 1960; this is true also for the total effect of toilet sanitation shown at the end of table 4. A poor sanitation system apparently carries less risk when overall public health conditions improve (as they did in Malaysia between the two periods considered here). The large intercept difference between the two periods indicates 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. This difference is even more important ($t = -3.01$) when all other explanatory variables are set equal to their overall sample mean values.[16]

Mothers' education is the only variable (other than the full breastfeeding × water interaction) whose influence is substantially stronger after 1960 than before, and the difference between the periods is just short of significance in table 4. Indeed, the estimates in table 4 indicate a significant negative effect of education in the later

Table 4.—Logit regression explaining infant mortality for the 1946–1960 and 1961–1975 periods, allowing the structure of relationships to differ between the periods

Explanatory variables	Logit regression: 1946–1960 coefficients (t-statistic)	Logit regression: 1961–1975 coefficients (t-statistic)	t-statistic for difference between β_{46-60} and β_{61-75}
Socioeconomic factors			
Mother's education	-0.0365 (-0.71)	-0.159*** (-2.89)	-1.63
Sanitation and nutrition variables[a]			
Piped water[b]	-1.17** (-2.56)	-0.938** (-2.09)	0.37
Toilet sanitation[b]	-1.51*** (-2.84)	-0.417 (-0.86)	1.75*
Months full breastfeeding	-0.354** (-2.33)	-0.554 (-1.59)	-0.52
Months part breastfeeding	-0.187*** (-5.26)	-0.185*** (-3.42)	0.03
Full breastfeeding x water	0.104 (0.74)	0.602* (1.80)	1.37
Full breastfeeding x toilet	0.153 (0.90)	0.0293 (0.14)	-0.45
Part breastfeeding x water	0.0901* (1.69)	0.111* (1.75)	0.25
Part breastfeeding x toilet	0.119*** (2.62)	0.0297 (0.44)	-1.10
Demographic variables			
Preceding interval <15 months[b]	0.802*** (3.52)	0.394 (1.16)	-1.00
Ethnicity			
Chinese[b]	-1.25*** (-4.30)	-1.70*** (-3.91)	-0.85
Indian[b]	-0.516 (-1.55)	0.674 (0.17)	1.13
Intercept	-0.143 (-0.44)	-1.065*** (-2.67)	-1.80*
χ^2	202		
Total effects of breastfeeding, water, and sanitation			
Full breastfeeding (evaluated at period means for water and toilet)	-0.202*** (-3.22)	-0.219 (-1.35)	-0.10
Part breastfeeding (evaluated at period means for water and toilet)	-0.0657*** (-2.79)	-0.103*** (-3.11)	-0.94
Piped water (evaluated at period means for breastfeeding)	-0.446 (-1.51)	0.101 (0.27)	1.14
Toilet sanitation (evaluated at period means for breastfeeding)	-0.526* (-1.82)	-0.242 (-0.71)	0.63

[a] See lower panel for total effects.

[b] Dummy variable

* Statistically significant at the 10 percent level (two-tail test, $|t| \geq 1.65$)

** Statistically significant at the 5 percent level (two tail test, $|t| \geq 1.96$)

*** Statistically significant at the 1 percent level (two-tail test, $|t| \geq 2.58$)

period but no significant effect in the earlier period.[17] A similar pattern arises in comparing child mortality determinants in more and less developed regions of Malaysia: mother's education has a stronger effect in the more developed areas (Peterson et al. 1985). These results together suggest that mother's education may have been complementary with economic development in reducing infant mortality in Malaysia since World War II.[18] Certain minimal levels of the means to reduce mortality (e.g., scientific information about health care and diet, availability of health care) may be necessary for mother's education to have a beneficial effect. It is also possible that more education helps mothers make more appropriate weaning decisions and thus becomes a more important influence on infant mortality when breastfeeding becomes less prevalent and of shorter duration.[19]

Another noteworthy coefficient change, albeit not statistically significant, occurs for a short preceding birth interval. A short interval has a much larger detrimental effect before 1960, when its influence is statistically significant, than afterward, when its influence is no longer significant. This pattern is consistent with our finding elsewhere that improved nutrition (as proxied by increased income) mitigates the detrimental effect of a preceding short birth interval on birthweight, an important correlate of infant mortality (DaVanzo, Habicht, and Butz 1984). That is, short birthspacing is most detrimental when the mother is malnourished (which is likelier in the poorer, early period) and therefore more likely to be nutritionally depleted by a recent previous pregnancy.

Finally, the influence of Indian ethnicity changes between the two periods. In the 1946–1960 period, Indian babies had a lower infant mortality rate than Malays; in the 1961–1975 period that pattern reversed. Moreover, the Indian–Chinese mortality differential is significantly greater ($t = 1.70$) after 1960 than before. In the 1946–1960 period, other variables held constant, an Indian baby had a log odds ratio of dying 0.73 higher than a Chinese baby; by 1961–1975, this figure had risen to 2.37. These figures are consistent with other findings from these data indicating that the wellbeing of Indians in Malaysia has deteriorated relative to that of the other two ethnic groups (DaVanzo, Habicht, and Butz 1984).

Significant explanatory power is gained by allowing all coefficients to differ between the two periods (χ^2 [13] = 32.3, $p < .01$). Closer examination reveals, however, that this is almost entirely due to the difference in the intercept term. Once the intercept term is allowed to differ between the two periods, significant explanatory power is not gained by allowing the coefficients of the explanatory variables to differ (χ^2 [12] = 17.6, $p > .10$).[20]

How well does the 1946–1960 structure predict the 1961–1975 infant mortality rate (and vice versa)? We have just seen that several coefficients differ in their effect on infant mortality between the 1946–1960 and 1961–1975 periods. In table 5 we assess the relative importance of these structural changes versus changes in variables in explaining the mortality decline between these two periods by seeing how well the 1946–1960 coefficients and the 1961–1975 values of explanatory variables predict the 1961–1975 infant mortality rate.[21] The difference between this predicted 1961–1975 mortality rate and the actual 1946–1960 rate is the portion of mortality decline attributable to changes in variables. The difference between this predicted 1961–1975 mortality rate and the actual 1961–1975 rate is the portion of mortality decline due to structural change (i.e., coefficients). This exercise enables us to see how well we would have predicted the infant mortality rate if we had known only the early period coefficients and had correctly forecast the changes that were going to occur in the explanatory variables. We repeat this exercise "backward," seeing how well the later-period coefficients would have predicted the mortality rate in the earlier period, given the values of the explanatory variables then.

Table 5.—Infant mortality rates: Predictions based on parameters in table 4

Item	1946-1960	1961-1975	Change
A. Observed infant mortality rate	72.3	33.3	-39.0
	Predicted IMR 1946-1960	Predicted IMR 1961-1975	Change[a]
B. Predicted IMR using 1946-1960 coefficients	72.3(±1.8)	63.4(±1.7)	-8.9
C. Predicted IMR using 1961-1975 coefficients	40.4(±1.0)	33.3(±1.0)	-7.1
D. Change due to change in "structure"	-31.9	-30.1	

Note: Numbers in parentheses are standard errors.

[a] Due to change in explanatory variables

Rows B and C show that changes in the values of variables explain little of the mortality decline. The 1946–1960 coefficients, when applied to the 1961–1975 values of explanatory variables, imply that the infant mortality rate would decrease from 72.3 in 1946–1960 to 63.4 by 1961–1975. The actual 1961–1975 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.[22]

We conclude that the better part of the decline in the infant mortality rate between 1946–1960 and 1961–1975 is due not to changes in the levels of the variables we have considered here but to changes in the structure of mortality relationships, mainly the intercept. 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).

SUMMARY AND CONCLUSIONS

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

Our main findings are the following:

(1) On average, mothers' education more than doubled over the study period, contributing to the decline in their infants' mortality. In addition, the beneficial effect of mothers' education on infant survival appears to have become stronger over the study period. Hence, further advances in education should lead to further improvements in infants' survival prospects. Another analysis of these data (Peterson et al. 1985) found that education is somewhat more influential in affecting child mortality in low-mortality, high-income areas than in the opposite type of areas. Therefore, socioeconomic development may have complemented, instead of substituted for, the

the beneficial effect of mothers' education in promoting infant and child survival in Malaysia.

(2) Improvements in water and sanitation also contributed to the infant mortality decline, especially for babies who did not breastfeed.[23] 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, may have smaller relative effects on infant mortality than did previous improvements. Targeting 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. 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 other researchers (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; this exclusion 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 (Preston 1976, 1980) that structural change explains mortality decline as much as or more than do changes in a set of socioeconomic and other variables.[24]

Although we conclude that structural change explains the greater part of the infant mortality decline, 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 toilet sanitation (for babies who were not breastfed). Toilet sanitation has a considerably less beneficial influence on infant survival for babies born after 1960 than before. Therefore, 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.[25]

What might these other factors be? Although we hesitate to put a label on what we are unable to explain, there are several possibilities. 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).[26] Because an important share of income growth was due to increases in education (Smith 1983), however, our education variable has probably 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,[27] 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 1981:257). 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 1946–1960 and 1961–1975 periods.[28]

NOTES

[1] A recent study by Merrick (1985) has provided such an assessment for child mortality in urban areas of Brazil. His units of analysis are mothers. Preston (1980) has considered the influences of some of these factors for overall mortality (life expectancy) in developing countries, using countries as his units of analysis. In his recent "revisit" he also considers the infant mortality rate (Preston 1984). Also see Palloni (1981), Gwatkin (1980), Gray (1974), McKeown and Record (1962), and references therein.

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

[3] The MFLS survey design could lead to two other possible biases: (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 greatly affect our results; (2) Because the MFLS sample is restricted to ever-married women, the experiences of those who have never married will not be represented. This should result in negligible bias as out-of-wedlock childbearing is very rare in Malaysia.

[4] These rates are truly age-specific. For example, the rate for 1961–1965 for women age 20–24 refers to those age 20–24 in each of these years. It does *not* refer to the cohort of women age 20–24 at the beginning or end of that time period.

[5] Since 1960 the declines have been more modest and are erratic for women under age 20 and over age 34. This may reflect a changing selectivity of the kinds of women who give birth at these higher-risk ages, because fertility rates have decreased the most at the extreme ages of childbearing (Hirschman and Fernandez 1980: table 4).

[6] We also performed the analysis restricting our sample to births in the years 1956–1975 to women under age 30, thus holding constant the age range of the sample in each year. The results of that analysis, reported in DaVanzo and Habicht (1984), are similar to those presented here.

[7] See DaVanzo, Butz, and Habicht (1983) and DaVanzo (1984) for discussions of the mechanisms through which these variables affect infant mortality.

[8] If a baby dies soon after birth or for reasons unrelated to feeding, breastfeeding will be short *because* the baby died or was deathly ill. Such a reverse-causation bias can result in serious overestimates of the apparent effect of breastfeeding in reducing infant mortality (Habicht, DaVanzo, and Butz 1986). 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. 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 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 detail on the procedures used to impute breastfeeding, see Habicht, DaVanzo, and Butz (1986). As we note there, we have found that it makes much more difference *whether* we impute breastfeeding values to cases subject to the reverse-causation bias than *how* we impute to them.

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

[10] 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 the proximate determinants for these causes. For example, our water variable indicates whether the household had piped water at the time of the child's birth but does not measure the quantity or quality of that water. Such "errors in variables" will lead to underestimates of the importance of any factor that is measured or reported with error.

[11] The predicted average mortality probability for each period is the average of predicted probabilities for each individual, each calculated as $\hat{P}_i = 1/(1 + e^{-\widehat{\text{logit}_i}})$. This enables us to "predict" a period's rate correctly, using its own coefficients and variable values; this is not possible by simply using variable means because of the nonlinearity of the logit transformation.

[12] As noted above, we have generally restricted the analyses to variables that changed significantly over

time. The two that did not change significantly (short birth interval and Indian ethnicity) are included in the analysis because their coefficients demonstrated noteworthy changes between the two time periods, as discussed below.

[13] 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 the bottom panel of table 2 and in table 3.

[14] For example, the effect on the infant mortality rate of the decrease in full breastfeeding (FBF) is $\Delta\text{FBF} \cdot (\delta_{\text{FBF}} + \delta_{\text{FBF}\times W} \cdot W + \delta_{\text{FBF}\times T} \cdot T)$, where δ_X indicates $\partial P/\partial X$ for variable X, W indicates the average value of piped water, and T the average value of toilet sanitation.

[15] By contrast, seven of the thirteen coefficients differed significantly when ordinary least squares (OLS) estimation was used (DaVanzo and Habicht 1984). Where differences arose, usually effects were stronger before 1960 than afterward. Many of the significant differences found between periods in the OLS estimates appear to be to be mainly due to the declining average risk. The average infant mortality rate declined by more than half between the two periods for the samples considered here (from 72.3 in 1946–1960 to 33.3 in 1961–1975). Hence a decrease in attributable (additive) risk would not necessarily also cause a decrease in relative risk. The logit model seems the more appropriate one here in light of the considerable decrease in the average infant mortality risk between the 1946–1960 and 1961–1975 periods. The greater stability of the coefficients between the two time periods reinforces this belief.

[16] In this case, the intercept for 1946–1960 period is much larger in absolute magnitude ($-2.88[t = -19.81]$), but the *difference* in intercepts between the two time periods is nearly identical to that shown in table 4.

[17] The number of lives saved because of an additional year of education did not differ significantly between the 1946–1960 and 1961–1975 periods when the regression presented in columns (1) and (2) of table 4 was estimated by OLS. A year of education is associated with as many lives saved when the mean infant mortality rate was 72.3 (before 1960) as when it was less than half that value (33.3, after 1960), so the reduction in *relative* risk due to an additional year of education is much greater in the later period.

[18] 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. Similarly, Mott (1982), using data from the Kenyan World Fertility Survey, finds 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 than on neonatal mortality (e.g., DaVanzo, Butz and Habicht 1983). Post-neonatal deaths are a larger portion of all infant deaths when infant mortality rates are high.

Preston (1980), like us, found education to be relatively more important in 1970 than in 1940 in his analyses of the influence of literacy on life expectancy in developing countries.

[19] Douglas Ewbank suggested this possibility in his insightful discussion of this paper at the 1984 meeting of the Population Association of America, leading us to investigate the 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 like those in tables 2 and 4, although its coefficient was positive, as expected.

[20] When the intercept is the only coefficient that differs between the two periods, its value is -0.253 ($t = -1.00$) for 1946–1960 and -0.921 ($t = -3.46$) for 1961–1975. The difference between these two values is highly significant ($t = -3.75$).

[21] As noted above, we predicted a logit for each observation, converted it to a probability, and then averaged over observations for that period.

[22] In both cases, logit coefficients predict somewhat better than corresponding OLS coefficients (see DaVanzo and Habicht 1984: table 6), a further indication that the logit model is the more appropriate of the two, although the OLS and logit predictions are remarkably similar. Nonetheless, the logit coefficients explain at most only 8.9 of the actual 39 deaths per thousand difference between the periods.

[23] The relative roles of changes in mothers' education and water and sanitation in explaining the mortality decline in Malaysia are remarkably similar to those in a recent study of Brazil (Merrick 1985), which found the increase in maternal education to be the most important factor accounting for the decline in child mortality; increased access to piped water was also important, but less so than education.

[24] The similarity between our findings and Preston's is noteworthy because the analyses are based on two different types of data, subject to different biases. On the one hand, relationships estimated with country aggregate data may be biased because they are subject to the ecological fallacy. On the other

hand, our micro data are undoubtedly measured with more noise than Preston's aggregate data. These errors in variables could lead to underestimates of the regression coefficients (and, indeed, may be one reason why we cannot explain more of the mortality decline). However, this is not necessarily an intrinsic problem with our approach. In an analogous study of the reasons for the difference in infant mortality rates (IMR) between the poorest and richer states of Malaysia we found that differences in explanatory variables account for virtually all of the IMR difference (Peterson et al. 1985).

By contrast, Merrick (1985) explains around 80 percent of the decline in child mortality in Brazil with changes in the variables he considers. The difference between our results and Merrick's may be because he is (1) explaining mortality decline over a shorter, more recent period (1970–1976), (2) dealing with *child* mortality, and (3) not considering breastfeeding.

[25] Hence, much of what has been termed "structural change" is, at least in this analysis, largely the influence of factors not considered (or of measurement error in the explanatory variables, which would lead to underestimates of their effects).

[26] As noted above, we tried to include income in our analysis but found little effect with the retrospective measure available in our data, which may be subject to considerable measurement error.

[27] There have been specific programs to control or eradicate tuberculosis, malaria, leprosy, yaws, filariasis, and dengue hemorrhagic fever. Public development expenditure for health programs increased sevenfold between 1956–1960 and 1976–1980 (derived from data presented in Abu Bakar 1981:260) and increased as a share of overall public expenditures. In 1977, the government spent M$44.36 (around U.S. $20) per capita on health activities (WHO 1980). This is the level of per capita expenditure WHO has deemed necessary to achieve "health for all by the year 2000" (WHO 1984).

[28] Without good retrospective data on households' economic wellbeing 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.

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Table A.1.—Mothers' ages and children's years of birth represented in sample for tables 2–5

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	16	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
																															13	14	15	16	17	1959
																																13	14	15	16	1960
																																	13	14	15	1961
																																		13	14	1962

Mother's age at child's birth

RAND/N-2491-WB/RF/FF