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TIMING OF CHILD REPLACEMENT EFFECTS ON FERTILITY IN MALAYSIA*

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Abstract

This paper is concerned with marital fertility and focuses especially on the timing of responses triggered by experienced child mortality. The death of a child is immediately taken into account in the fertility decision process; it may have both instantaneous and lagged, semi-parametric effects on the hazard of a conception. We present a rigorous, new method to derive replacement rates from hazard model estimates. The analysis is applied to micro-data from Peninsular Malaysia over the period 1950-1988. We find replacement rates ranging from near-zero to 0.5, depending on the child's sex, parity, age at death and ethnicity. Even though infant and child mortality rates have dropped dramatically over the period of our sample, child replacement has been only a minor contributing factor to the fertility decline. Women in the Chinese subpopulation exhibit son preference in their fertility behavior, whereas Malay women do not exhibit preference for a particular gender composition of their offspring.

Keywords: fertility, child replacement, infant mortality, sex preference

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1 INTRODUCTION

Many studies have shown a high correlation between infant mortality and total fertility rates, both in their time trends and cross-sectionally. At a micro level, it has been found that the risk of a birth is significantly higher following the death of a child in the family (Ben-Porath 1976, Olsen 1983, Mauskopf and Wallace 1984). This paper focuses on these increased levels of fertility using micro-data from Peninsular Malaysia over the period 1950-1988. The data contain information on the timing of all conceptions and child mortality experiences of the respondents. They enable us to study the instantaneous and lagged impacts of a child’s death on the hazard of a conception. We present a rigorous, new method to derive replacement rates from hazard model estimates. These replacement rates provide insight in the contribution that declining infant and child mortality rates in Malaysia have had on the concurrent fertility reduction.

Malaysian Context

Malaysia, a developing country in South-East Asia, enjoyed a decline of its infant mortality rate (IMR) from about 100 per 1000 live births in the early 1950s to 14.3 in 1987 (Vital Statistics, Panis and Lillard 1993b). Over the same period, the total fertility rate (TFR) dropped from about 6.5 to 4.0 in the late 1970s, and stabilized at that level (Vital Statistics, Govindasamy and DaVanzo 1992). Figure 1 illustrates the trends in these demographic indices. The infant mortality and total fertility rates have received considerable attention in the literature and among government policy makers (Population Projections 1987). They are indicative of a country’s public health status, and have far-reaching impacts on population growth and economic development.

Peninsular Malaysia, which accounts of approximately 85% of the total population of the country, is comprised of three dominant ethnic groups: Malays (58%), Chinese (32%) and Indians (10%) (Vital Statistics 1988). While all groups have generally experienced the same demographic and economic developments, large ethnic differences persist. Chinese infant mortality rates have been consistently lower than those of Malays and Indians, mainly because of higher medical care utilization among Chinese women (Panis and Lillard 1993b). The stabilization of fertility rates since the late 1970s is largely due to a stagnation of the decline among the Malay subpopulation. By 1975, the Malay
total fertility rate had reached 4.6, and actually increased somewhat thereafter (Hirschman 1986, Govindasamy and DaVanzo 1992). Chinese fertility rates kept falling sharply, from 6.5 in 1958 via 3.6 in 1975 to 2.4 in 1986. The Indian fertility experiences are very similar to the Chinese.¹

There have been several sizable government programs to improve infant and maternal health, heavily subsidized by the Ministry of Health (Ilamid et al. 1988, Nithiyananthan 1991). In 1966, the National Family Planning Board was established which aimed at improvement of the health and welfare of the family through voluntary acceptance of family planning, and at a reduction of the population growth rate from 3% in 1966 to 2% by 1985. However, that fertility policy was revised in 1982, when the prime minister argued that Malaysia had sufficient land area and natural resources to support a population of 70 million, substantially more than the 13 million of 1982 (Hirschman 1986). This culminated in the formulation of the New Population Policy, which aimed at a reduction of the pace of fertility decline (Govindasamy 1991).

There also are large ethnic differences in incomes and economic roles. Malays dominate the agricultural sector, whereas Chinese and Indians tend to work in the modern economy of tin, rubber

and commerce. On average, the Chinese earn roughly 65% more than Malays (Anand 1983). The annual growth rate of per capita Gross National Product has been around 5% since the 1960s, only interrupted by a recession in the mid-1980s; by 1988, per capita GNP was approximately 5,065 Ringgit (US$ 1,940) (Ling 1988, Mazumdar 1989).

Following independence from Great Britain in 1957, the average educational attainment among Malays was lower than among other ethnic groups. Government policies aimed at closing this gap have been successful, as recent cohorts show approximately equal enrollment rates across ethnicities (Pong 1993, DeTray 1984, Lillard and Willis 1993).

In the following section we summarize prior studies into child replacement behavior. Section 3 develops the empirical model, highlighting its capability to capture differential behavior following the death of a child. Section 4 briefly describes the data and sample selection criteria. Section 5 presents parameter estimates. Child replacement behavior is discussed in section 6. Section 7 concludes and summarizes the main findings.

2 LITERATURE REVIEW

A joint decline of infant mortality and fertility rates as observed in Malaysia is typical for developing countries. The sources of this correlation may be categorized according to the direction of the effect. First, high fertility may cause high mortality: rapid successive conceptions may prevent full recovery of the mother’s body. This maternal depletion may have negative implications for the child’s health, both directly and through an increased likelihood of premature delivery (Miller et al. 1991). High parities are also often associated with excess mortality, but Hobcraft et al. (1985) find that much of the elevated risk is probably produced by close birth spacing. Second, high mortality may induce high fertility. The death of a nursling truncates breastfeeding, thereby shortening the postpartum infertile period and increasing the risk of a conception (Pebley and DaVanzo 1988). There may also be behavioral responses by parents who aim for a certain family size (Ben-Porath 1976, Anderson 1983). When a child dies, a couple may attempt to ‘replace’ the child, i.e., increase its exposure to the risk of conception in order to maintain the desired number of children. Also, in an environment with poor child survival rates, parents may ‘hoard’ children, i.e., attempt to conceive more children than actually desired in anticipation that some will die. Third, infant mortality and fertility may
be correlated because both investments in child health and demand for children are functions
of the same prevailing relative prices, income, preferences and environmental variables. There
may be competition for resources (time and money) among siblings, especially when they are of
approximately equal age (Olsen and Wolpin 1983). In a joint model of infant mortality and fertility,
Pitt and Rosenzweig (1989) find evidence of higher fertility among women who tend to underinvest
in the health of their children. Parents’ preferences concerning the gender composition of their
offspring may play a role both in the allocation of resources (Simmons et al. 1982, Sah 1991,
Johansson and Nygren 1991) and in the decision to have more children (Leung 1988, Ben-Porath
and Welch 1980).

Panis (1992) developed and estimated an empirical joint model of fertility and child mortality,
using random effects to account for time-invariant couple-specific unobserved characteristics and
allowing for correlation between unobservables in mortality and fertility. The essential features of
that model are replicated below. His data came from the second (1988) wave of the Malaysian
Family Life Survey (MFLS-2), which also underlies the present analysis. He did not find any
evidence of hoarding behavior. Further, after controlling for experienced child mortality, he found
no significant residual correlation between mortality and fertility.

On the basis of that work, we consider infant mortality as exogenously given in this paper, and
we ignore hoarding behavior. We focus on the possibility of increased exposure to fertility risk
following the death of a child. This risk may increase because of interrupted lactation and/or
through consciously sought replacement behavior. Since we do not explicit model breastfeeding
and contraceptive behavior, we are unable to empirically distinguish these two causal mechanisms.\footnote{In the interest of brevity, we group both causes of increased fertility behavior under the term ‘replacement behavior’.

In an excellent treatment of behavioral links between child mortality and fertility, Ben-Porath
(1976) notes that couples may not have a constant desired family size. Over the course of the
family life cycle, couples learn about childbearing and child mortality. These experiences may
well lead them to adjust their desired number of children, and possibly diminish or increase their
propensity to replace deceased children. He also notes that hoarding and replacement behavior
are substitutes: if families have learned to expect high mortality and respond to it by hoarding,
fertility should not respond strongly to actual mortality. Further, under the assumption that child
expenditures and discomforts precede the benefits associated with raising children, child mortality translates into a reduction of net child benefits. A decline in the child mortality rate thus implies a lower expected cost of child services and a higher desired number of children. Depending on the elasticity of demand for child services, this may reduce the positive correlation between child mortality and fertility. Ben-Porath analyzes fertility responses to experienced child mortality using a retrospective survey of Jewish women in Israel that was fielded in 1971. He does not control for hoarding, but finds that the death of a child in the family leads to significantly lower probabilities of stopping at a given birth, particularly at low birth orders. He also finds that child deaths reduce the length of birth intervals. He concludes that replacement is a significant phenomenon, and that it occurs fairly quickly.

Wolpin (1984) develops and estimates a finite-horizon dynamic stochastic model in which couples decide on their fertility behavior at any point in time, taking explicit account of their current family size and uncertain future child mortality. He assumes that contraception is perfect and that couples are able to time conceptions without error; infant mortality is assumed to be stochastic. He applies his model to a small Malay subsample of the first (1976) wave of the Malaysian Family Life Survey (MFLS-1). Surprisingly, his model predicts inverse hoarding: an increase in child mortality probability reduces the number of children ever born in Malaysia. Wolpin finds a very small replacement rate: an infant death induces an increase in the number of children ever born by at most 0.015. As Wolpin concedes, his results may be driven by many important simplifying assumptions that were made in the interest of computational tractability.

Olsen (1983) quantifies child replacement rates, also using the MFLS-1. Applying a fixed effects model for the waiting time until the next conception, he finds a child replacement rate of about 32%. He attributes slightly less than half of this replacement rate to physiological factors, i.e., to early return of menses due to truncated breastfeeding. In addition, he estimates a hoarding rate of approximately 14%. In a joint paper with Wolpin (Olsen and Wolpin 1983), he found only small and insignificant hoarding effects in Malaysia.

Higher replacement rates were found in Brazil by Mauskopf and Wallace (1984). They estimated a model in which child mortality and replacement births were assumed to follow a bivariate binomial distribution. The average replacement rate was 0.60, with better educated women exhibiting higher replacement rates.
In a third paper employing the MFLS-1, Chang (1988) analyzes the timing of conceptions in Malaysia. Her results on child replacement behavior are mixed, depending on the choice of model and sample inclusion criteria. Controlling for the length of the preceding birth interval, and including incomplete fertility spells, she finds that the death of a child is associated with a higher hazard of conception. The paper attempts to reveal gender preferences, but the results are mixed. It should be noted that she did not interact gender preference variables with ethnicity.

Several other papers point at a mild preference for sons, particularly among the Chinese subpopulation in Malaysia. In an international comparison, Cleland et al. (1983) find that many developing countries exhibit a weaker or stronger degree of son preference; they classify Malaysia as having 'moderate' son preference.

Gender preference may express itself in various types of behavior. In an excellent article on gender preference in fertility behavior, Leung (1988) critically evaluates standard assessment methods. He favors the use of hazard models in which right-censored conception intervals and time-varying covariates can be handled. Our model follows that specification and also controls for unobserved heterogeneity, as Leung does. In the empirical application based on the 1976 wave of the Malaysian Family Life Survey, Leung finds son preference among Chinese and no preference among Malays in Malaysia.

This result is replicated by Pong (1992) using the 1988 wave of the Malaysian Family Life Survey. At higher birth orders, she finds both Chinese and Indians to have higher parity progression ratios, the fewer sons they have. The Malay majority population does not show this behavior. She points out that Chinese parents rely much more on sons' support for old age care than Malays.

In accordance with most economic literature on fertility, our conceptual framework builds on standard utility maximization theory to derive demand for child services. There is both a quality and a quantity component to child services (Becker and Lewis 1973); we only take the number of children into consideration. The choice variables in the production of children are marital status, contraception, breastfeeding (affecting the postpartum infertile period), induced abortions and coital frequency (Bongaarts 1978, Gertler and Molyneaux 1993). Given the differences in behavior that may be expected between married and unmarried women, we limit ourselves to marital fertility.³

³Very few fertility histories were dropped as a result of this restriction.
Contraceptive and breastfeeding behavior are not explicitly modeled; their determinants enter in reduced form. The demand for child services is conditional on the number and gender composition of the couple’s current children (Pollak 1969).

3 EMPIRICAL MODEL

Our empirical implementation models fertility as a sequential decision making process with a stochastic component. At each moment in time, the couple decides on behaviors that affect the risk of a conception, such as the use of contraception and coital frequency. The determinants of these proximate causes affect the hazard of a conception in reduced form. All information, including the loss of a child, is continuously updated and instantaneously taken into account, but we do not explicitly model dynamic optimizing behavior. Our unit of observation is a woman’s entire fertility history, with a hazard equation for each conception interval.

The duration until a next conception is assumed to follow a proportional hazard process (Cox 1972, Kalbfleisch and Prentice 1980) with multiple generalized Gompertz duration dependencies. The timing of a conception may depend on the duration since the last birth, the duration since the wedding date, maternal age, and in particular on the duration since a child died. The hazard of a conception thus depends on multiple ‘clocks’, and each duration dependence is specified to be piecewise log-linear (piecewise Gompertz). In other words, we make no restrictive parametric assumptions on the shapes of the duration effects.

We limit ourselves to marital fertility, i.e., the woman first becomes at risk of conceiving at the wedding date. Each subsequent conception interval starts at the date of termination of the previous pregnancy; this date typically is the birth date of the previous child, but may also be determined by a miscarriage, stillbirth or induced abortion.⁴ The log-hazard for conception \( j \) is given by: \(^5\)

\[
\ln h_j(t, \xi) = \gamma_1 \text{Dur}_j(t) + \gamma_2 \text{MomAge}(t) + \gamma_3 \text{MarDur}(t) + \gamma_4 \text{Time}(t) + \\
\gamma_5 \text{Mort}_j(t) + \beta_1 X_j(t) + \beta_2 Y_j(t) + \xi.
\]

⁴We do not account for a period of postpartum anovulation, the infertile period following a birth, because the duration of this period can be influenced by the mother through the duration and intensity of breastfeeding. As such, breastfeeding is a form of contraception and endogenous to the fertility process.

⁵For notational convenience, we suppress the observation (mother) subscript.
$Dur_j(t)$, $MomAge(t)$, $MarDur(t)$ and $Time(t)$ represent several duration dependencies, which are discussed below. $Mort_j(t)$ captures the effect of duration since the death of a child or a miscarriage, i.e., it captures replacement effects. $X_j(t)$ represents a number of explanatory variables in the analysis, including measures of income and prices; $Y_j(t)$ are measures of previous fertility outcomes of this mother, and $\xi$ represents unobserved characteristics of the mother (heterogeneity).

The data typically contain multiple conceptions per woman, which may be correlated. The dependence on endogenous, previous fertility outcomes (length of the preceding conception interval; parity) is represented by $Y_j(t)$; these prior outcomes are functions of the same unobserved maternal characteristics ($\xi$) as the index conception interval. The correlation between $Y_j(t)$ and $\xi$ requires that all conception intervals of a particular woman be estimated jointly, i.e., the unit of observation is an entire fertility history up until the survey date. Conditional on unobserved heterogeneity ($\xi$), all conception outcomes are independent — this feature is exploited in the estimation procedure (subsection 3.1). Each term of the fertility equation is now considered in detail, starting with our measures of experienced child deaths.

**Child Mortality Measures $Mort_j(t)$ and Replacement Effects**

Replacement effects are detected by the inclusion of measures of experienced child mortality. We explicitly account for the possibility that the effect of a child death may gradually diminish over time. The replacement effect is specified as a duration dependence: the effect of the death of a child is a continuous function of time since the child died. If no child dies, $\gamma'_5Mort_j(t)$ does not enter the hazard specification; if two or more children die, it enters multiple times, cumulatively, and each effect is felt after the corresponding child dies.\(^6\) In the MFLS-2 data there are up to six child deaths within one family.

The death of a child is assumed to have both an instantaneous and a lagged effect. It causes a shift in the level of the conception hazard and an effect dependent on the time since the child died ($Mort_j(t)$). Suppose a child dies at time $t^d$; for $t < t^d$, $Mort_j(t)$ is a vector of zeroes. For $t > t^d$,

\(^6\)We assume that the effect continues to be present in conception intervals subsequent to the one during which the child died.
it consists of an intercept and a linear spline transformation of time since the child's death, \( t^d \):

\[
Mort_j(t) = \left( \begin{array}{c} 1 \\ \min[\tau, \nu_1] \\ \max[0, \min[\tau - \nu_1, \nu_2 - \nu_1]] \\ \vdots \\ \max[0, \min[\tau - \nu_{n-1}, \nu_n - \nu_{n-1}]] \\ \max[0, \tau - \nu_n] \end{array} \right),
\]

where \( \tau = t - t^d \) is the duration since the child died, and \( \nu_1 \) through \( \nu_n \) are nodes between which the replacement effect is linear in time. The first element of \( \gamma_5 \) is the initial shift, and the subsequent \( n + 1 \) elements are slope parameters of the duration pattern.

The replacement parameters (\( \gamma_5 \)) may differ by ethnicity and gender of the deceased child, which provides one test for gender preference. We also include a 'replacement' effect following a miscarriage or stillbirth. In the subsequent conception interval, the woman is subject to a hazard of conception as if the aborted pregnancy never took place, plus a differential effect to capture 'replacement' of the fetus that died.

**Duration Dependencies** \( Dur_j(t) \), \( MomAge(t) \), \( MarDur(t) \) and \( Time(t) \)

The baseline hazard duration dependence, in the absence of child mortality, consists of four additive components. \( Dur_j(t) \) reflects the duration since the woman became at risk of conceiving child \( j \), i.e., this clock starts ticking at the wedding date for first conceptions, and at the birth date of the previous child for subsequent conception intervals.\(^7\) Duration effect \( AgeMom(t) \) captures dependence on maternal age. It is modeled as a duration dependence, rather than as age at the beginning of the conception interval, to allow its effect to continuously change over the duration of the conception interval as the mother ages. The clock for mother's age starts ticking at some arbitrary point before the woman became at risk, in our application at her ninth birthday. \( MarDur(t) \) is duration since the wedding date, affecting all conception intervals the same. \( Time(t) \) reflects dependence on calendar time, which captures a residual time trend not accounted by trends in other variables. It starts ticking at a date before any woman in our application became at risk (January 1, 1930).

\(^7\)To be precise, it is the time since the last live birth or, if no child was born alive yet, since the wedding date. As mentioned above, if the previous pregnancy did not result in a live birth, an additional 'replacement' clock starts ticking at the miscarriage date.
The model does not a priori assume a specific functional form (e.g., Weibull, Gompertz, double exponential) for any of the duration dependencies. In other words, it is semiparametric in the sense of Sueyoshi (1992): nonparametric in the baseline hazard, but structured by the assumption of proportional effects from covariates and by a prespecified functional form of the heterogeneity component. We attain this nonparametric feature by specifying each duration dependence as an arbitrary linear spline transformation of time. This transformation is analogous to the duration pattern following a child’s death as described above, but without the intercept term. The sum of four linear spline transformations is again piecewise linear in the log-hazard.

The effects of $\text{MomAge}(t)$, $\text{MarDur}(t)$ and $\text{Time}(t)$ are two-fold. First, there is a cumulative effect as a result of the time that elapsed from the start of the source-specific clock to the beginning of the conception interval. Second, there is a duration effect over the course of the conception interval. For example, suppose a woman starts one conception interval at age 20 ($t_{20}$) and another conception interval at age 35 ($t_{35}$). Even if the effect of maternal age were linear throughout the woman’s reproductive life, it would affect the two conception hazards differently, because the cumulative effect of $\text{MomAge}(t)$ is different. At age 20, the maternal age clock contributes $\gamma_2 \text{MomAge}(t_{20})$ to the intercept, whereas $\gamma_2 \text{MomAge}(t_{35})$ has accumulated to age 35. The existence of maternal age nodes beyond age 20 also causes the duration pattern to differ across the two conception intervals.

**Exogenous Covariates $X(t)$**

$X(t)$ represents exogenous, possibly time-varying covariates. These include income, prices, education of the mother and ethnicity. Household income is measured by occupational earnings of the father, a measure of lifetime income. Its theoretical effect on fertility levels is ambiguous due to a potentially high elasticity of child quality with respect to income (Becker and Lewis 1973). For price of raising children we use the local cost of housing, included separately for urban and rural areas. We use indicator variables for agricultural profession of the father and for urban residence as measures of rates of returns in early stages of children’s lives. A child on a farm can help out with chores and light forms of labor, so the flow of services that they generate at young ages is larger in an agricultural environment than in the city. Education of the mother is also included in $X(t)$. Its effect may operate through a variety of mechanisms. It may proxy for the shadow price of her time, i.e., the price of bearing children. It may also reflect access to information, such as informa-
tion regarding reliable forms of contraception. It may capture socioeconomic status and possibly be connected to future education of the child and the resulting flow of child services. Finally, we include ethnicity in the specification of the log-hazard of conceptions. Ethnicity is interacted with several elements in the model. It captures behavioral differences across population groups that are not attributable to other observables.  

Measures of Previous Fertility Outcomes $Y_j(t)$ and Heterogeneity $\xi$

As mentioned above, correlation between previous fertility outcomes and mother- or couple-specific heterogeneity requires that all conception intervals of a particular woman be grouped into one observation. $Y_j(t)$ includes the length of the preceding conception interval, birth order and gender composition variables of prior children. The latter, interacted with ethnicity, allow us to test for gender preference.

We assume that all residual correlation across conception intervals operates through a random effect term, $\xi$, which is specific to the couple and common across conception intervals. The (unobserved) value of this heterogeneity term may reflect the degree of fecundity of the wife, her contraceptive behavior and the frequency with which the couple has intercourse (independent of age and marital duration). We assume that $\xi$ is distributed $N(0, \sigma^2_\xi)$, and that it is orthogonal to the vector of exogenous covariates, $X_j(t)$. It may, however, be correlated with measures of previous fertility outcomes, $Y_j(t)$.

Hoarding Behavior and Potential Endogeneity of Child Mortality

Our model assumes that experienced child mortality is exogenous to fertility behavior, and that there is no other source of correlation between mortality and fertility. This assumption excludes the possibility of hoarding behavior and ignores any other trade-off. The simplification is justified

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8 We do not control for the mother’s wages, since labor force participation and wages may be endogenous. The fertility specification is thus a reduced form.

9 Given that a certain fraction of couples cannot conceive any children because of reproductive deficiencies, the normality assumption may not be realistic. Han and Hausman (1990) found that parameter estimates in proportional hazard models are quite sensitive to misspecification of the baseline hazard, but relatively insensitive to misspecification of the distribution of the heterogeneity term.
by the results of Panis (1992). He accounted for hoarding and potential endogeneity of mortality in Malaysia by jointly estimating a model of fertility timing and child mortality. The fertility equation incorporated a measure of the expected child mortality that a particular couple faces in order to capture hoarding behavior. The log-hazard of a conception was given by:

$$\ln h_j(t, \xi) = \gamma' T_j(t) + \beta'_1 X_j(t) + \beta'_2 Y_j(t) + \lambda \ln h_j^m(t) + \xi,$$

(2)

where $T_j(t)$ is a stacked vector of several duration dependencies, as outlined above; $X_j(t)$ and $Y_j(t)$ are vectors of exogenous and potentially endogenous variables; $\ln h_j^m(t)$ represents a measure of expected mortality of the yet-to-be-conceived child; and $\xi$ is unobserved heterogeneity, allowed to be correlated with the heterogeneity components of child mortality. The expected mortality measure $\ln h_j^m(t)$ is estimated jointly by a mortality hazard equation. It includes all couple- and environment-specific determinants of child mortality that are known before the child is conceived.

The coefficient on expected mortality, $\lambda$, was estimated at a low 0.0282 with a standard deviation of 0.0673. The correlation coefficient between heterogeneity components in the fertility ($\xi$) and child mortality equation was also small and insignificant: 0.0351 with a standard deviation of 0.1977. The restriction that both parameters are zero was easily accepted, even at a significance level of 25%. In other words, there was neither evidence of hoarding behavior nor of selectivity of child mortality in the fertility process. We therefore exclude the measure of expected mortality from our fertility analysis, and treat experienced child mortality as exogenous.

3.1 The Likelihood Function and Estimation Procedure

The model is estimated using full information maximum likelihood. There is a hazard equation for the timing of each conception; since there are are up to 16 conceptions of any one woman in the data, there are up to 17 fertility timing equations. Each of these equations forms a module of the likelihood function. We assume that residual correlations between all equations operate exclusively through the woman-specific component, $\xi$. This implies that, conditional on heterogeneity, all modules of the likelihood are independent, and may be multiplied to arrive at the joint conditional likelihood. The final step is to integrate over the heterogeneity distribution to obtain the marginal likelihood.
In simplified notation, the log-hazard of conception \( j \) is given by

\[
\ln h_j(t, \xi) = \gamma T_j(t) + \beta_1^1 X_j(t) + \beta_2^2 Y_j(t) + \xi,
\]

where \( T_j(t) \) represents a stacked vector of all piecewise linear duration effects. We first derive the baseline survivor function and then account for proportional shifts due to (potentially time-varying) covariates. Note that conditional on heterogeneity, \( \xi \) can be treated as a covariate that is constant for the duration of the episode. Denote the baseline survivor function for conception interval \( j \) by

\[
S_j^0(t) = \exp \left\{- \int_{t_j}^t e^{\gamma T_j(\tau)} d\tau \right\}.
\]

The ‘conditional’ (on heterogeneity) survivor function follows from the baseline survivor function by accounting for proportional shifts due to covariates and heterogeneity component \( \xi \). These covariates may be time-varying, but it is assumed that the conception interval can be broken into finite subintervals over which all covariates are constant. Proportional shifts are applied to the baseline survivor function within each subinterval, and the conditional survivor function results from rejoining the subintervals. Denote the covariate history by \( \chi(t) \). The conditional survivor function for conception episode \( j \) is given by

\[
S_j(t, \chi(t), \xi) = \prod_{i=1}^I \left[ \frac{S_j^0(t^{i+1})}{S_j^0(t^i)} \right] \exp\{\beta_1^1 X_j(t^i) + \beta_2^2 Y_j(t^i) + \xi\}
\]

where \( I \) is the number of subintervals over which covariates \( X(t) \) and \( Y(t) \) are constant, \( X(t^i) \) and \( Y(t) \) are vectors of covariate values between time \( t^i \) and \( t^{i+1} \), \( t^1 = t_j \) and \( t^{I+1} = t \).\(^{10}\) This expression alsoformulates the conditional (on \( \xi \)) likelihood of a censored spell, i.e., a conception interval that had not resulted in a conception at the time of the survey, \( t^* \). The conditional likelihood that the event occurred at time \( t^c \) (date of conception) is given by

\[
f_j(t^c, \chi(t^c), \xi) = S_j(t^c, \chi(t^c), \xi) h_j(t^c, \xi),
\]

which is also the conditional density function for the duration until conception \( j \) takes place.\(^{11}\)

These functions may be combined into the ‘conditional’ (on heterogeneity) likelihood for each

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\(^{10}\)Strictly speaking, \( t^i \) should carry additional subscript \( j \), since it refers to a particular point in time where the covariates of conception interval \( j \) change values.

\(^{11}\)The exact timing of the conception is unknown. We backdated the birth date event by nine months and created a window within which the conception occurred. The width of this window is by default taken to be one month, but may be wider in cases where the exact birthdate was not known. The conditional likelihood that a conception occurs in this window is the difference in survivor function values at the beginning and end of the window.
conception interval \( j \) covering both spells that resulted in a pregnancy (‘uncensored’) and that were still in progress at the time of the survey (‘censored’):

\[
L_j(\xi) = \begin{cases} 
S_j(t^*, \chi(t^*), \xi) & \text{if censored at the survey date } t^*; \\
 f_j(t^c, \chi(t^c), \xi) & \text{if the conception occurred at } t^c.
\end{cases}
\]

Denote the number of conception intervals by \( N \). The conditional likelihood of this fertility history is found by multiplying over \( L_j(\xi) \), since the only stochastic connection across conception episodes is (by assumption) through heterogeneity components. The conception modules are thus independent, and computation of the marginal likelihood is given by:

\[
L = \int_{-\infty}^{\infty} \frac{1}{\sigma \xi} \phi \left( \frac{\xi}{\sigma \xi} \right) \prod_{j=1}^{N} L_j(\xi) d\xi.
\]

The integral is computed numerically using Gauss-Hermite Quadrature (Davis and Rabinovitz 1967, Panis and Lillard 1993a). All first derivatives are computed analytically. The iterative search for the maximum value of the log-likelihood is done by the scoring method, where the information matrix is approximated by the sum of outerproducts of first derivatives (Berndt, Hall, Hall and Hausman 1974). Standard errors of the parameter estimates follow from the inverse of this approximation of the information matrix.

4 THE DATA

Our analysis is based on data from the Panel and Child subsamples of the Second Malaysian Family Life Survey (MFLS-2), fielded in 1988. It covers detailed retrospective information on fertility histories and other demographic issues (Haaga et al. 1992). Over 99% of the conceptions takes place between 1950 and 1988. The three main ethnicities in Peninsular Malaysia are Malays (58%), Chinese (32%) and Indians (10%) (Vital Statistics 1988); we exclude the latter group due to their small sample size.

The two main features of fertility trends in Peninsular Malaysia are a substantial overall decline of the Total Fertility Rate (TFR) and the divergence of Malay and Chinese rates (Figure 1). Rates computed from the MFLS-2 data set roughly correspond to these official patterns.

Infant mortality rates have declined steadily in Malaysia. The number of infant deaths per 1000 live
births among Chinese has been consistently lower than among Malays: the Malay IMR dropped from 48 in 1968 to 16.0 in 1987, while the Chinese rate went from 30 to 9.2 per 1000 live births (Vital Statistics, selected years). Consistent with Sine and Peterson (1992), we conclude that the MFLS-2 data track the trends and the ethnic discrepancy reasonably well.

<table>
<thead>
<tr>
<th>Variable description</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aggregate</td>
</tr>
<tr>
<td>maternal age at conception$^{12}$</td>
<td>26.7369</td>
</tr>
<tr>
<td>Chinese (omitted is Malay)</td>
<td>0.2909</td>
</tr>
<tr>
<td>Malay: father’s occupational (log) earnings$^{13}$</td>
<td>4.8244</td>
</tr>
<tr>
<td>Chinese: father’s occupational (log) earnings$^{13}$</td>
<td>5.3172</td>
</tr>
<tr>
<td>occupational earnings missing$^{14}$</td>
<td>0.1807</td>
</tr>
<tr>
<td>median (log) price of kampung house$^{15}$</td>
<td>10.5273</td>
</tr>
<tr>
<td>median (log) price of urban house$^{16}$</td>
<td>11.0582</td>
</tr>
<tr>
<td>urban area</td>
<td>0.2419</td>
</tr>
<tr>
<td>Malay: father has agricultural occupation$^{17}$</td>
<td>0.4058</td>
</tr>
<tr>
<td>Chinese: father has agricultural occupation$^{17}$</td>
<td>0.2243</td>
</tr>
<tr>
<td>education 1–6 years (omitted is no education)</td>
<td>0.4238</td>
</tr>
<tr>
<td>education 7–15 years</td>
<td>0.1858</td>
</tr>
<tr>
<td>previous pregnancy interval (years)$^{18}$</td>
<td>1.6806</td>
</tr>
<tr>
<td>Malay: number of surviving sons</td>
<td>2.4200</td>
</tr>
<tr>
<td>Chinese: number of surviving sons</td>
<td>2.2910</td>
</tr>
<tr>
<td>previous pregnancy intentionally aborted</td>
<td>0.0089</td>
</tr>
</tbody>
</table>

---

$^{12}$ The reported age structure over time does not reflect actual mean maternal ages at conception in Malaysia due to sample eligibility criteria.

$^{13}$ Logarithm of the occupational earnings of the father, in 1970 Malaysian Ringgit. These are not his actual earnings, but an average for his occupation and his ethnicity, based on the post-enumeration survey of the 1970 Malaysian Census; see Anand (1983, table 6-11, pp. 230-236). The MFLS-2 and Anand distinguish (almost) the same 83 occupation categories. There is no variation over time in this measure, i.e., income growth is not captured.

$^{14}$ Missing because the father could not be identified in the data, or because he never worked; if earnings are missing, they are set equal to their ethnicity-specific mean over nonmissing observations.

$^{15}$ Median (log) price of a 10 year old kampung house in 1988 in the district in which the respondent lives. This measure is used in periods during which the respondent lived in a rural area. There are 78 districts in the data; in the rare cases where a respondent reported that she was living outside these districts while she was at risk of conceiving, we set the median log-price of a house equal to its mean over the 78 districts. There is no intertemporal variation in this variable, just cross-sectional.

$^{16}$ Median (log) price of a 10 year old, 2-story link house in 1988 in the district in which the respondent lives. This measure is used in periods during which the respondent lived in an urban area. Also see previous footnote.

$^{17}$ I.e., 40.58% of the Malays has an agricultural profession. Agricultural professions are farm managers and supervisors; farmers; agricultural and animal husbandry workers; forestry workers; fishermen, hunters, and related workers.

$^{18}$ Number of years between the moment that the woman became at risk and the moment that she became pregnant, in the previous conception interval.
We restrict the analysis to marital fertility, because the behavioral context for women who have given birth out of wedlock is too different from those in a marital relationship. Our sample contains 1,223 women: 559 Malays and 364 Chinese. Of these women, 43 had never been pregnant; the others accounted for 6,067 marital conceptions. There were up to 16 pregnancies per woman; more than half of the women had five pregnancies or more, and more than 10% had ten pregnancies or more. Note that many women in the sample have not completed their fertility histories yet. A total of 63 per 1000 ended in a miscarriage or stillbirth. The overall infant mortality rate is 49 per 1000 in our sample, and another 23 per 1000 children died between their first and tenth birthdays.

Table 1 reports means of the covariates in our model. These means are computed over birth intervals; for time-varying covariates, the value at the beginning of the conception interval is taken.

5 PARAMETER ESTIMATES

Table A.1 in the Appendix contains parameter estimates of the hazard model of fertility timing. The shift and subsequent duration pattern following the death of a child or a failed pregnancy are shown in Panel A. Panel B displays the effects of covariates and heterogeneity; Panel C presents estimates of the effects for time since the beginning of the conception interval. Panel D, finally, shows the dependencies on maternal age, marriage duration and calendar time. All parameters are jointly estimated. This section interprets the parameters and shows some illustrative simulations of the baseline hazard function. Child replacement responses are discussed more extensively in the next section, so we start with Panel B.

Socioeconomic Covariates and Unobserved Heterogeneity

If children are a normal good, as is generally accepted, demand for child services should be increasing with income. We find no significant income elasticity of child quantity. This may be a consequence of the imperfection of our measure of income, which is based on (ethnicity-specific) average earnings for the father's occupation in 1970 (Anand 1983). An advantage of this measure is that it is not

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19 We excluded the entire fertility histories of 19 women who had given birth out of wedlock.
sensitive to the current position on the earnings profile, but rather a measure of lifetime income. However, Malaysia has enjoyed an annual per capita income growth rate of roughly 5% since the 1960s (Ling 1988, Mazumdar 1989), and this substantial growth is not captured by our income measure. Our finding of a near-zero income elasticity is not inconsistent with the literature, though. Anderson (1983) and Chang (1988) find negative or insignificant relationships between income and fertility, while Wolpin (1984) finds very small positive effects. A possible explanation relies on the quality and quantity components of children. The income elasticity for child quality may be high; an increase in child quality raises the shadow price of child quantity (and vice versa), which may lead to an insignificant or negative observed relationship between income and child quantity (Becker and Lewis 1973).

Part of the cost of raising a child is the price of housing. This appears to affect fertility behavior in urban areas more than in rural areas. The house price elasticity of the fertility hazard in urban areas is slightly above 0.2, i.e., a 10% increase in housing costs decreases the hazard fertility by about 2%. There are probably economies of scale in raising children, especially in housing, but we did not exploit these in our specification.  

Women with primary education appear to have fewer conceptions than women without any education and, surprisingly, also fewer than women with secondary or tertiary schooling. The effects of education may operate through many vehicles, making its interpretation tentative. Education may be related to access to information, for example, to reliability rates of contraceptive methods, or to government policies. It may also enhance the ability to process that information. DaVanzo and Starbird (1991) found that education is negatively related to the probability of breastfeeding in Malaysia, and positively to the probability of contracepting; they found a near-zero net effect. Educated people may consider it a matter of course to also provide schooling to their children, i.e., it reveals a preference for high quality children. Finally, educated women tend to marry later (Brien and Lillard 1993), so they may compress their conception intervals in order to attain a desired family size.

The length of the preceding conception interval is included in piecewise linear form, only affecting second and higher birth orders. Consistent with most results in the literature (Rodriguez et al. 1983, Trussell et al. 1985) we find that a long preceding conception interval is associated with a relatively

---

21 In the absence of housing prices, the coefficient on urban area is not significant (not shown).
long period to the next conception, and that moderately short preceding intervals are associated with short waiting times. This result holds even with a control for heterogeneity, which is shown to be very significant. However, we also find that extremely short preceding pregnancy intervals tend to lengthen the next waiting time: if the woman became pregnant within six months after the previous birth, she will 'take a break' and wait longer before conceiving the next child.

The coefficients on number of surviving boys in the family reveal gender preferences. Malay fertility rates are virtually unaffected by the number of sons, whereas Chinese women clearly exhibit son-preference. These conclusions confirm the results of Leung (1988) and Pong (1992) in their analyses of the 1976 and 1988 waves of the Malaysian Family Life Survey. It should be noted that the simple measures of gender preference are the result of extensive experimentation with other forms. In particular, we did not find any evidence of a preference among Malays for a balanced family, i.e., a family with a roughly equal numbers of sons and daughters. Also, there was no evidence for the hypothesis that either ethnicity wants at least one child of both sexes. In other words, Malays do not exhibit a preference for any particular gender composition, whereas Chinese are perfectly happy with a family consisting of sons only.

**Duration and Parity Effects**

Consider the conception risk dependence on the period that the woman has been at risk (Panel C). We assume that all duration dependencies are piecewise linear (piecewise Gompertz) in the log-hazard, and the nodes can be inferred from Table A.1. Time is measured in years, so the slope parameters (×100) roughly represent annual percentage changes of the hazard.

For the first conception, the woman became at risk at the wedding date. Two nodes, at six and twenty-four months, appear to be sufficient to capture the pattern. The hazard of a conception is very high immediately after the wedding and drops off steeply in the first six months. It is then approximately constant for the next eighteen months, and tapers off after two years. For subsequent conceptions, the hazard increases strongly in the first twelve months after the previous live birth, followed by eighteen months of moderate increases. The highest conception hazard is

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22 These measures are only included in the regressions for birth orders four and higher. Since almost all women will have at least three conceptions, the effects of gender preference are probably best distilled from higher birth orders.
reached two-and-a-half years after the last delivery, then declines at a diminishing pace.

We tested whether the dependence on duration since the last live birth was different for higher-order parities. The restriction that all patterns (not the intercepts) are equal for second and higher birth orders was not rejected. The intercept for the second conception interval is different from third and subsequent intervals. Beyond the third conception, however, there is no more significant effect of parity per se. This finding is consistent with most fertility analyses which control for maternal age (Trussell et al. 1985, Chang 1988).

Panel D shows the effects of maternal age, marriage duration and calendar time. We find that the contribution of maternal age goes up until age 15, is practically flat between age 15 and 30, and then drops off. The negative slope on the segment beyond age 30 is consistent with the literature (e.g., Trussell et al. 1985, Chang 1988, Pong 1992), but to our knowledge, the upward trend until age 15 has not been found before in marital fertility. Most women marry after age 15, but in our data set there are many women who married earlier. These young brides are overwhelmingly Malay; over 15% of Malay women married at age 9-14, and another 9% at age 15. The cell sizes are high enough to yield a significant estimate of the increasing fertility hazard before age 15.

Both the Malay and Chinese total fertility rate has dropped substantially since the 1950s. To the extent that the fertility decline is not explained by intertemporal variation of the model covariates, it is captured in the residual time trends. We find a Malay residual time trend that is actually increasing somewhat before 1960, and almost flat thereafter. The Malay fertility decline between 1960 and 1975, as observed in the raw data, is thus fully explained by our model specification. There is some evidence that the key to the pre-1975 decline lies in increasing age at marriage (Hirschman 1986, Lillard and Brien 1993). Chinese rates have dropped precipitously throughout the sample period, and the estimated residual time trend shows that more than 4% annually remains to be explained. The average age at marriage has consistently been higher for Chinese than for Malays, and has showed little variation over time.

The divergence of fertility rates may be the result of the New Economic Policy of 1971 and the New Population Policy of 1982 (Govindasamy 1991, Govindasamy and DaVanzo 1992). The New Economic Policy (NEP) implemented a number of policies to stimulate education and economic development among the Malay population. It led to a reduction of the cost of raising children for
Malay families, subsidized by the Chinese and Indians through a (relative) transfer of wealth and income. The New Population Policy (NPP) encouraged families of all ethnicities to relax the pace of fertility reduction. However, despite official government denials, many Malaysians have been led to believe that the New Population Policy is primarily directed at an increase in the Malay population (Hirschman 1986). The advantages of the incentives offered by the NPP are enjoyed to a much lesser extent by Chinese families, who find themselves faced with an increase in the relative price of children.

Figures 2 and 3 provide an illustration of the combined duration dependencies. They are generated through simulations based on the model estimates. The dependence on the duration of the conception interval is easily recognized in the hazard pictures, as it dominates the other effects. The asymptotes in figure 3 correspond to (one minus) progression ratios. They fall with parity, and are higher for the Chinese than for the Malay simulation.

6 CHILD REPLACEMENT BEHAVIOR

Returning to panel A of Appendix Table A.1, we find that the hazard of a conception jumps up at the death of a child, then drops off gradually over the next twelve months, and subsequently declines slowly. After the first twelve months, very little is left of the impact of the death. The pattern is very similar for the death of a son and a daughter.

Figure 4 illustrates the shift pattern following the death of a girl at the age of six months and at the age of four years. This simulation is for a third conception; the bottom hazard curve shows the duration pattern since the last live birth if both previous children survive. Note that the death of a child strongly increases the hazard of a conception, but that this increased level tapers off and almost disappears after approximately one year. If replacement takes place, it thus takes place

\footnote{For several hundred points in time we compute the baseline survivor function, account for proportional shifts due to covariates, and integrate out the heterogeneity component to obtain the simulated survivor function. The hazard figures are numerically computed relative declines of the survivor function; the accuracy of the numerical derivatives is guaranteed by taking very small intervals between simulation points. The default characteristics are a woman that was born in 1955 and married in 1975 with six years of education and otherwise average characteristics. The first child was born two years after the wedding; all subsequent children are born two years apart.}

\footnote{The simulation depicts a Malay woman, born in 1955, married in 1975 at age 20; this third conception interval starts four years after the wedding; primary education only; lives in an urban area; husband is not in an agricultural occupation; previous pregnancy interval was 15 months; husband occupational earnings and the price of a house are equal to their mean values.}
Figure 2 Simulated Hazard Functions of Conception (by ethnicity)

Figure 3 Simulated Survivor Functions of Conception (by ethnicity)

Figure 4 Replacement Effects Following the Death of a Girl 6 and 48 Months into the Conception Interval
within approximately one year after the death. Ben-Porath (1976) also noted that replacement is a fairly quick phenomenon. The increased hazard may be caused partly by an early return of menses as a result of interrupted breastfeeding, and partly by consciously sought replacement behavior, i.e., contraceptive behavior and increased coital frequency. Without explicit model equations for breastfeeding and contraceptive behavior, we are unable to decompose these effects.

Gender preference among Chinese women is also felt in replacement rates. We do not find different estimates of the replacement effects per se for Chinese and Malays. However, the proportionality of effects, combined with the general son preferences among Chinese discussed above, results in a difference between Malays and Chinese. Recall that Chinese women are less likely to conceive the more surviving sons they have (Panel B). The death of a son thus increases the Chinese log-hazard by $1.1952+0.1229$, and the Malay log-hazard by only $1.1952-0.0226$.

Mauskopf and Wallace (1984) found higher replacement rates among better educated women. We do not find such difference. Similarly, we find no evidence of an interaction of replacement effects with birth order. However, replacement rates will generally be lower for higher-order parities, because hazard rates taper off at higher ages of the mother.

**Expected Number of Conceptions and Replacement Rates**

The model enables us to compute a probability distribution of the number of conceptions during a particular woman’s reproductive life, and provides an estimate of replacement rates under a variety of circumstances. The procedure is as follows. First we compute the probability distribution for number of conceptions for a ‘typical’ woman, assuming that she never experiences a miscarriage or child death. In our application, we take a woman that marries at age 20, and reaches menopause at age 50,\(^{25}\) i.e., her reproductive life spans 360 months. The number of ways in which she may time $N$ conceptions over this reproductive life is equal to the number of combinations of $N$ draws out of 360 months (minus the number of infertile months due to pregnancy). Each combination carries a certain probability, and the probability that she conceives $N$ children is the sum of all these

---

\(^{25}\)She was born in 1945; has primary education; lives in an urban area; housing prices in her district are average; her husband is not in an agricultural profession and his earnings are average; all conceptions result in a live birth and none of her children dies; her first child is a boy, all subsequent children alternate in gender and she has no twins. She may conceive children until age 50, i.e., until 1995; we assume that the estimated time trend between 1975 and 1988 continue through 1995.
Table 2 Probability Distribution of Number of Conceptions

<table>
<thead>
<tr>
<th>Number of conceptions</th>
<th>Malay</th>
<th>Chinese</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0091</td>
<td>0.0022</td>
</tr>
<tr>
<td>1</td>
<td>0.0201</td>
<td>0.0069</td>
</tr>
<tr>
<td>2</td>
<td>0.0559</td>
<td>0.0293</td>
</tr>
<tr>
<td>3</td>
<td>0.0781</td>
<td>0.0787</td>
</tr>
<tr>
<td>4</td>
<td>0.1272</td>
<td>0.2459</td>
</tr>
<tr>
<td>5</td>
<td>0.1395</td>
<td>0.2510</td>
</tr>
<tr>
<td>6</td>
<td>0.1503</td>
<td>0.2036</td>
</tr>
<tr>
<td>7</td>
<td>0.1332</td>
<td>0.1057</td>
</tr>
<tr>
<td>8</td>
<td>0.1072</td>
<td>0.0513</td>
</tr>
<tr>
<td>9</td>
<td>0.0761</td>
<td>0.0190</td>
</tr>
<tr>
<td>10</td>
<td>0.0506</td>
<td>0.0047</td>
</tr>
<tr>
<td>11</td>
<td>0.0294</td>
<td>0.0014</td>
</tr>
<tr>
<td>12</td>
<td>0.0151</td>
<td>0.0002</td>
</tr>
<tr>
<td>13</td>
<td>0.0057</td>
<td>0.0000</td>
</tr>
<tr>
<td>14</td>
<td>0.0018</td>
<td>0.0000</td>
</tr>
<tr>
<td>15</td>
<td>0.0005</td>
<td>0.0000</td>
</tr>
<tr>
<td>16</td>
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</tr>
<tr>
<td>17+</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

individual probabilities. Once the probability distribution has been found, the expected number of conceptions is easily computed. Then we change the scenario, and assume that, for example, the second child dies six months after birth. This affects the timing of third and subsequent conceptions, and changes the probability distribution of number of conceptions. The difference in expected numbers of conceptions yields the replacement rate. This simulation is repeated for a number of scenarios, whereby the ethnicity, gender, birth order and age-at-death of children is changed. Table 2 shows the probability distribution of the number of conceptions of this ‘typical’ woman. The expected number of conceptions for the Malay woman is 6.0695; for her Chinese counterpart it is 5.1490.26

Table 3 contains replacement rates under several scenarios. Malay women tend to have higher replacement rates, especially for girls. Not surprisingly, though, Chinese response rates to the death of a son are higher than Malay rates, at least at a low birth order. We find lower replacement

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26 Recall that one of the assumptions is that the first child is a boy. The expected number for a Malay woman is 6.0421 if the first is a girl; for a Chinese woman it is 5.2336. Subsequent children alternate in gender; which of the two bases is used in the computation of replacement rates depends on the birth order of the child that dies and its gender.
rates at higher parities, which is due to lower fertility levels at older ages.

These simulations were done for a woman who married in 1965 at age 20. Since the Malay residual time trend in the later part of our sample is almost flat, a Malay woman that is 20 years younger will have approximately the same number of children, and her replacement rates will thus be approximately equal, too. Chinese women that married in 1985 at age 20, however, are expected to have fewer conceptions, and their replacement rates will thus be lower as well. If the second child, a girl, dies at ages one months or four years, the expected number of conceptions increases by 0.1615 and 0.1536, respectively; if the second child were a boy, these rates would be 0.2686 and 0.2230. Few Chinese women that married in 1985 at age 20 are expected to have more than five conceptions, and indeed, replacement rates for higher-order parities are very low. If a sixth child were to die, its replacement rate would range from 0.0011 for a daughter that died at age four to 0.0052 for a son that died after one month.

<table>
<thead>
<tr>
<th>Table 3 Replacement Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Number of Conceptions</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>First child dies at age 1 month</td>
</tr>
<tr>
<td>First child dies at age 4 years</td>
</tr>
<tr>
<td>Second child dies at age 1 month</td>
</tr>
<tr>
<td>Second child dies at age 4 years</td>
</tr>
<tr>
<td>Sixth child dies at age 1 month</td>
</tr>
<tr>
<td>Sixth child dies at age 4 years</td>
</tr>
<tr>
<td>Tenth child dies at age 1 month</td>
</tr>
<tr>
<td>Tenth child dies at age 4 years</td>
</tr>
<tr>
<td>Second pregnancy fails after 3 months</td>
</tr>
<tr>
<td>Sixth pregnancy fails after 3 months</td>
</tr>
</tbody>
</table>

The last two rows in the table report ‘replacement rates’ of a miscarriage after 3 months gestation. If the previous pregnancy ended in a miscarriage or stillbirth, the log-hazard of a conception starts off significantly higher at 0.6195 above the level that would prevail if no intervening pregnancy had taken place. The differential effect slowly diminishes over the next two years, and more strongly thereafter. Even though the shift is not as large as shifts caused by the death of a son or daughter, its effect is felt over a longer period of time, and the resulting replacement rates are thus rather high. If the second pregnancy aborts spontaneously at one trimester gestation, the expected number of
conceptions increases by 0.4762 for Malays and 0.4906 for Chinese; corresponding 'replacement' rates for a failed sixth pregnancy are 0.1049 and 0.1415, respectively. Fanis and Lillard (1993a) and Sine and Peterson (1992) found indications of fetal mortality underreporting, which may imply that we underestimate actual miscarriage replacement rates. The bias on other aspects of our model is probably very small, though, because most underreports concern pregnancies that were terminated during the first trimester. These failures do not interrupt the fertility process so strongly as stillbirths would.

7 CONCLUSION

The focus of this paper is on increased levels of fertility following the death of a child. Not only does the death of a child trigger a higher risk of conception, there also appears to be a 'replacement' effect following a miscarriage or stillbirth. The replacement rates vary from near-zero to about 0.5, depending on ethnicity, birth order, age at death and gender of the child. Malay women respond slightly stronger to the death of a girl than of a boy; Chinese replacement rates of deceased sons are substantially higher than of daughters. Responses to the death of a first or second born are stronger than those following the death of a higher birth order child — this is due to reduced fertility of a woman at higher ages, and a shorter period until menopause, i.e., a shorter period to replace the child. Replacement effects confound the behavioral response and a biomedical effect in which the death of a nursing infant truncates breastfeeding, shortens the period of postpartum amenorrhea and thus increases the risk of a conception. Our analysis does not distinguish these two mechanisms.

Chinese women exhibit a preference for sons: the higher the number of surviving sons, the lower the probability of conceiving another child. Chinese son preference also expresses itself through higher Chinese replacement rates for sons than for daughters. Malay women do not show a preference for a particular gender composition of their offspring; we find no evidence of preference for a family with approximately equal numbers of sons and daughters, or for at least one son and one daughter.

The most striking feature of fertility trends in Malaysia is the nationwide decline between the late-1950s and the mid-1970s, and the divergence of Malay and Chinese trends afterwards. While Malay fertility rates remained stable, the Chinese continued to experience a rapid decline of fertility,
almost to the level corresponding to zero population growth. Mean age at marriage among Malay women in the MFLS-2 increased from 15.8 among women born in the 1930s to 19.3 among those born between 1950 and 1957. Our simulations show that this increase translates into 1.0 fewer expected number of conceptions, i.e., increased age at marriage accounts for the largest part of the fertility decline. Infant and child mortality rates combined fell by approximately eight percentage points between the late 1950s and the mid 1970s; given an average replacement rate of, say, 20%, this corresponds to a TFR reduction of 1.6% of the number of conceptions that woman has, i.e., about 0.1 conceptions. Education of the mother is also of only marginal importance. Before 1960, the fraction of Malay women with primary education was 30.12%, and a mere 0.29% had secondary or tertiary education. In the period after 1975, these percentages had increased to 41.98% and 42.25%, respectively (MFLS-2). While these gains are impressive, their impact on fertility is small. Simulations show that this increase in educational attainment is responsible for only 0.14 fewer expected conceptions per woman.

The reduction in total fertility rate among Chinese women was substantial, from 6.5 in 1958 to 2.4 in 1986. Over this period, the mean age at marriage among Chinese was consistently higher than among Malays, and remained approximately constant. Similar to the Malay case, increased levels of education and lower infant and child mortality rates each account for a reduction of approximately 0.1 children per woman. This leaves the bulk of the reduction captured in the residual time trend, i.e., unexplained by observables in the model. The New Economic Policy of 1971 strongly favors Malays over Chinese in education and employment opportunities; the New Population Policy of 1982 encourages all Malaysian residents to proliferate, but may have been interpreted by the population as especially aimed at Malays. The divergence of Malay and Chinese rates after the mid-1970s may be explained by an increase in the cost of raising Chinese children relative to Malay children.
REFERENCES


DeTray, Dennis (1984): “Schooling in Malays: Historical Trends and Recent Enrollments”, The
RAND Corporation, N-2011-AID.


APPENDIX: CONCEPTION HAZARD PARAMETER ESTIMATES

Table A.1: Panel A: Replacement Effects
(standard errors in parentheses; significance: * = 10%; ** = 5%; *** = 1%)

<table>
<thead>
<tr>
<th>Event Description</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift upon death of son</td>
<td>1.1952</td>
<td>(0.1579)</td>
</tr>
<tr>
<td>Slope since death of son, 0-12 months</td>
<td>-0.9750</td>
<td>(0.1764)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12+ months</td>
<td>-0.0210</td>
<td>(0.0057)</td>
</tr>
<tr>
<td>Shift upon death of daughter</td>
<td>1.1075</td>
<td>(0.1693)</td>
</tr>
<tr>
<td>Slope since death of daughter, 0-12 months</td>
<td>-0.9325</td>
<td>(0.1954)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12+ months</td>
<td>-0.0133</td>
<td>(0.0068)</td>
</tr>
<tr>
<td>Shift upon miscarriage</td>
<td>0.6195</td>
<td>(0.0921)</td>
</tr>
<tr>
<td>Slope since miscarriage, 0-24 months</td>
<td>-0.0722</td>
<td>(0.0947)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24+ months</td>
<td>-0.1329</td>
<td>(0.0643)</td>
</tr>
</tbody>
</table>

continued...
<table>
<thead>
<tr>
<th>Covariate</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>father's occupational (log) earnings</td>
<td>-0.0523</td>
<td>0.0435</td>
</tr>
<tr>
<td>occupational earnings missing</td>
<td>-0.1165 **</td>
<td>0.0473</td>
</tr>
<tr>
<td>median (log) price of kampung house</td>
<td>-0.0024</td>
<td>0.0161</td>
</tr>
<tr>
<td>median (log) price of urban house</td>
<td>-0.2269 ***</td>
<td>0.0823</td>
</tr>
<tr>
<td>urban area</td>
<td>2.4974 ***</td>
<td>0.9384</td>
</tr>
<tr>
<td>Malay: father has agricultural occupation</td>
<td>-0.1549 ***</td>
<td>0.0511</td>
</tr>
<tr>
<td>Chinese: father has agricultural occupation</td>
<td>0.0493</td>
<td>0.0715</td>
</tr>
<tr>
<td>education 1-6 years</td>
<td>-0.0892 **</td>
<td>0.0389</td>
</tr>
<tr>
<td>(omitted is no education)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>education 7-15 years</td>
<td>-0.0042</td>
<td>0.0634</td>
</tr>
<tr>
<td>previous conception interval (spline)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-6 months</td>
<td>0.2706 **</td>
<td>0.1372</td>
</tr>
<tr>
<td>6-18 months</td>
<td>-0.0504</td>
<td>0.0549</td>
</tr>
<tr>
<td>18+ months</td>
<td>-0.1005 ***</td>
<td>0.0172</td>
</tr>
<tr>
<td>previous pregnancy intentionally aborted</td>
<td>0.3349 **</td>
<td>0.1324</td>
</tr>
<tr>
<td>Malay: number of surviving sons</td>
<td>0.0225</td>
<td>0.0185</td>
</tr>
<tr>
<td>Chinese: number of surviving sons</td>
<td>-0.1229 ***</td>
<td>0.0217</td>
</tr>
<tr>
<td>standard deviation of heterogeneity component (σξ)</td>
<td>0.2925 ***</td>
<td>0.0345</td>
</tr>
</tbody>
</table>

continued...
Table A.1: Panel C: Parity and Duration of Conception Interval
(standard errors in parentheses; significance: * = 10%; ** = 5%; *** = 1%)

<table>
<thead>
<tr>
<th>Term</th>
<th>Coefficient</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>intercept parity 1</td>
<td>-3.7061***</td>
<td>(0.7360)</td>
</tr>
<tr>
<td>intercept parity 2 or higher</td>
<td>-5.9487***</td>
<td>(0.7388)</td>
</tr>
<tr>
<td>parity 3 or higher</td>
<td>-0.1941***</td>
<td>(0.0657)</td>
</tr>
<tr>
<td>parity 5 or higher</td>
<td>-0.0826</td>
<td>(0.0617)</td>
</tr>
<tr>
<td>parity 9 or higher</td>
<td>0.0050</td>
<td>(0.0785)</td>
</tr>
<tr>
<td>parity 13 or higher</td>
<td>-0.2515</td>
<td>(0.1854)</td>
</tr>
<tr>
<td>slope on duration since the wedding, 0-6 months</td>
<td>-1.8722***</td>
<td>(0.2077)</td>
</tr>
<tr>
<td>6-24 months</td>
<td>0.0109</td>
<td>(0.0885)</td>
</tr>
<tr>
<td>24+ months</td>
<td>-0.1852***</td>
<td>(0.0334)</td>
</tr>
<tr>
<td>slope on duration since last live birth, 0-12 months</td>
<td>1.2767***</td>
<td>(0.0646)</td>
</tr>
<tr>
<td>12-30 months</td>
<td>0.1858***</td>
<td>(0.0328)</td>
</tr>
<tr>
<td>30-60 months</td>
<td>-0.3000***</td>
<td>(0.0284)</td>
</tr>
<tr>
<td>60+ months</td>
<td>-0.1758***</td>
<td>(0.0216)</td>
</tr>
</tbody>
</table>

continued...

---

30 The 'intercept parity 1' applies to the first conception only; the 'intercept parity 2 or higher' applies to all subsequent conception intervals. The other parity indicator variables are marginal (cumulative). E.g., the intercept for the second conception interval is -5.9487; for the third and fourth intervals -5.9487-0.1941; for the fifth through eighth interval -5.9487-0.1941-0.0826; et cetera.
31 Applicable only to the first birth order.
32 Applicable only to second and higher birth orders.
Table A.1: Panel D: Maternal Age, Marital Duration and Calendar Time
(standard errors in parentheses; significance: * = 10%; ** = 5%; *** = 1%)

<table>
<thead>
<tr>
<th>Category</th>
<th>Coefficient</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope on maternal age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pre 15 years</td>
<td>0.6874***</td>
<td>0.1152</td>
</tr>
<tr>
<td>15-30 years</td>
<td>-0.0047</td>
<td>0.0064</td>
</tr>
<tr>
<td>30+ years</td>
<td>-0.1158***</td>
<td>0.0088</td>
</tr>
<tr>
<td>Slope on duration since the wedding (^{33})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-5 years</td>
<td>-0.1236***</td>
<td>0.0273</td>
</tr>
<tr>
<td>5+ years</td>
<td>0.0097</td>
<td>0.0087</td>
</tr>
<tr>
<td>Slope on calendar time, Malays,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pre 1960</td>
<td>0.0338***</td>
<td>0.0067</td>
</tr>
<tr>
<td>1960-75</td>
<td>-0.0044</td>
<td>0.0043</td>
</tr>
<tr>
<td>1975+</td>
<td>-0.0026</td>
<td>0.0052</td>
</tr>
<tr>
<td>Chinese</td>
<td>-0.4478</td>
<td>0.3080</td>
</tr>
<tr>
<td>Slope on calendar time, Chinese,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pre 1960</td>
<td>0.0723***</td>
<td>0.0094</td>
</tr>
<tr>
<td>1960-75</td>
<td>-0.0468***</td>
<td>0.0055</td>
</tr>
<tr>
<td>1975+</td>
<td>-0.0429***</td>
<td>0.0090</td>
</tr>
<tr>
<td>ln (L)</td>
<td>-25478.46</td>
<td></td>
</tr>
</tbody>
</table>

\(^{33}\) Applicable to all birth orders
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