“New multivariate methodology for assessing the effect of child mortality on the total fertility rate and its components”

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Introduction

- New multivariate methodology to assess the effect of child mortality on fertility
- Discrete-time survival models of parity progression
- Progression probabilities are used to generate multi-dimensional life tables
- Each multi-dimensional life table follows women one year at a time by age, parity, duration in parity, and child mortality state between ages 10 and 50
Significance of Study

- Development of multi-dimensional life tables that include child mortality
- The applicability of the methodology to the period data
- Simple results out of complicated models
- Handling the reverse causation
What is period data?

Source: Retherford et al. 2009
What is cohort data?

Source: Retherford et al. 2009
Child Mortality-Fertility relationship (Mechanisms)

- Child mortality has two different effects on fertility:
  - Replacement effect
  - Insurance effect

- **Replacement effect**: Parent’s trial to replace a dead child in order to have specific surviving number of children:
  - Biological (in traditional societies)
  - Volitional (in modern societies)

- Replacement is not always complete:
  - Needs conscious family decisions
  - Fecundity impairment
  - Sex preference
Insurance effect: Parent’s adjustment of fertility in anticipation of possible future child death to insure the survival of minimum number of children

Hard to measure and estimate the effect
Methodological issues:

- Heterogeneity: a third factor (e.g. rising income) causing an irrelevant (spurious) relation b/w mortality and fertility by affecting both

- Endogeneity/Exogeneity

- Autocorrelation
Review of Literature
(Existing methods)

- Methods Based on Parity Progression Ratios and Birth Intervals
  - Calculate parity progression ratios or the interval between one birth and the next by categories of child mortality experience
    - Gives direct estimates of the effect of child mortality on fertility
    - Controls for reverse causation by calculating the effect of child mortality on fertility by birth order
    - Includes birth orders of different cohorts in the same analysis (disadvantage)
  - Use the stopping probability - i.e., the probability that a given birth is a last birth - as the dependent variable of a logistic regression model.
    - Controls for different cohorts.
    - Not applicable for period data
    - Unable to estimate the effect of child mortality on TFR.
**Review of Literature (Existing methods)**

- **Methods That Use Children Ever Born as a Dependant Variable in Regression Models**
  - Regress children ever born on a variety of socioeconomic predictors, including child mortality
    - *Replacement effect* is examined by comparing the fertility behavior of those who have and those who have not a child loss experience
    - *Insurance effect* is studied through fertility differentials of those who perceived a declining level of child mortality in the community and those who think otherwise
    - Usually unable to control for reverse causation
    - Children ever born has a positive correlation with number of child deaths
    - Includes birth orders of different cohorts in the same analysis
  - Olsen technique: requires corrections after running a regression of the number of births on the number of deaths, to estimate the extent of child replacement
    - Reverse causality is the main problem
Based on discrete-time survival models multivariate multi-dimensional life tables of parity progression are constructed.

The basic dimensions of these life tables are age, parity, duration in parity, and child mortality (number of child deaths).

By multivariate is meant that a life table can be constructed by values or categories of one socioeconomic predictor while holding the other socioeconomic variables constant.
The multi-dimensional life tables yield various measures of the quantum and tempo of fertility and child mortality:

- PPRs, ASFRs, TFR, mean and median ages at childbearing (both all births and by birth order), mean and median closed birth intervals, mean number of child deaths per women, child mortality rates by age of woman (not age of child, who can be of any age at death), and mean and median age of woman at child death

Because the life tables are multivariate, all measures derived from them are also multivariate
Methodological Background

- Life tables
  - Griffith Feeney’s method

- The $P_{it}$ method
  - Constructs multivariate life tables of parity progression
  - The dimensions are parity and duration in parity
  - The fertility measures estimated: PPR, TFR, and mean and median age at first birth/closed birth intervals

- The $P_{ait}$ method
  - Constructs multi-dimensional life tables
  - The dimensions are age, parity, and duration in parity
  - The fertility measures estimated: all of the above and ASFRs, TFR, ASFR, mean and median age at birth
Griffith Feeney’s method

\[ p_B \]  PPR for transition from a woman’s own birth to her first marriage (B–M)

\[ p_M \]  PPR for transition from first marriage to first birth (M–1)

\[ p_1 \]  PPR for transition from first to second birth (1–2)

\[ p_2 \]  PPR for transition from second to third birth (2–3)

\[ p_8 \]  PPR for transition from eighth to ninth birth (8–9)

\[ p_{9+} \]  PPR for transition from ninth or higher-order birth to next higher-order birth (9+ to 10+)

\[
TFR = p_B p_M + p_B p_M p_1 + p_B p_M p_1 p_2 + p_B p_M p_1 p_2 p_3 + p_B p_M p_1 p_2 p_3 p_4 + p_B p_M p_1 p_2 p_3 p_4 p_5 + p_B p_M p_1 p_2 p_3 p_4 p_5 p_6 + p_B p_M p_1 p_2 p_3 p_4 p_5 p_6 p_7 + p_B p_M p_1 p_2 p_3 p_4 p_5 p_6 p_7 p_8 + p_B p_M p_1 p_2 p_3 p_4 p_5 p_6 p_7 p_8 p_9+/(1 - p_{9+})
\]
Griffith Feeney’s method

<table>
<thead>
<tr>
<th>$t$</th>
<th>$P_t$</th>
<th>$S_t = S_{t-1} \times (1 - P_t)$</th>
<th>$F_t = 1 - S_t$</th>
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<tr>
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<td>1</td>
<td>0</td>
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<tr>
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<td>0.980391</td>
<td>0.019609</td>
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<td>5</td>
<td>0.124219</td>
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</tr>
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</tr>
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<td>7</td>
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<tr>
<td>9</td>
<td>0.06053</td>
<td>0.285814</td>
<td>0.714186</td>
</tr>
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0.268513 0.731487
The $P_{it}$ method

- **Discrete-time survival models**
  - Either discrete-time logit or complementary log-log
  - They give close to identical results
  - We use the complementary log-log model

- **Separate model for each parity transition**
  - B-M (birth to first marriage)
  - M-1 (first marriage to first birth)
  - 1-2 (first birth to second birth)
  - And so on (with an open parity interval at the end)
  - B-M and M-1 can be collapsed into 0-1 if needed
General features of the model for a particular parity transition

- **Response variable:**
  - $P$ (probability of either a first marriage or a next birth in a one-year interval)

- **Predictor variables:**
  - $t$ (duration in parity)
  - Socioeconomic predictor variables of interest (e.g., education and urban/rural residence)

\[
\log[-\log(1-P)] = a_0 + c_1 T_1 + c_2 T_2 + \ldots + c_{29} T_{29} + bx
\]
The $P_{ait}$ method

Possible transitions within parity transition 1-2 and higher

<table>
<thead>
<tr>
<th>$t$</th>
<th>$\alpha$</th>
<th>$\alpha+1$</th>
<th>$\alpha+2$</th>
<th>...</th>
<th>$\alpha+9$</th>
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<td>$S_{\alpha+2,i,0}$</td>
<td>...</td>
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<tr>
<td>1</td>
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<td>$S_{\alpha+1,i,1}$</td>
<td>$S_{\alpha+2,i,1}$</td>
<td>...</td>
<td>$S_{\alpha+2,i,1}$</td>
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<td>2</td>
<td></td>
<td></td>
<td>$S_{\alpha+2,i,2}$</td>
<td>...</td>
<td>$S_{\alpha+2,i,2}$</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$S_{\alpha+2,i,9}$</td>
</tr>
</tbody>
</table>
The \( P_{ait} \) method

- **Response variable:**
  - \( P \) (probability of either a first marriage or a next birth in a one-year interval)

- **Predictor variables:**
  - \( a \) (woman’s age) and \( t \) (duration in parity)
  - socioeconomic predictor variables of interest (e.g., education and urban/rural residence)

\[
P = 1 - \exp\{-\exp\left[b_0 + b_1T_1 + b_2T_2 + \ldots + b_9T_9 + A(c_0 + c_1t + c_2t^2) + A^2(d_0 + d_1t + d_2t^2)
+ U(e_0 + e_1t + e_2t^2) + E_M(f_0 + f_1t + f_2t^2) + E_H(g_0 + g_1t + g_2t^2) + U(h_1A + h_2A^2)
+ E_M(j_1A + j_2A^2) + E_H(k_1A + k_2A^2) + mUE_M + nUE_H]\}\] (3)
The $P_{aitmn}$ method

- Constructs multi-dimensional life tables that include child mortality
- The dimensions are age, parity, duration in parity, and child mortality
- The fertility measures estimated: all of the previous measures
- Plus child mortality and child replacement rates

Child mortality state is defined as the number of child deaths (regardless of child’s age at death) as of one year ago
Core Methodology

Panel 1: Possible child mortality transitions within parity transition 1-2:

\[ t \quad a \quad a+1 \quad a+2 \quad \ldots \quad a+9 \]

0 \[ M_0 \]

1 \[ M_0 \]

2 \[ M_0, M_1 \]

\[ \vdots \]

9 \[ M_0, M_1 \]

---

Panel 2: Possible child mortality transitions within parity transition 2-3:

\[ a \quad a+1 \quad a+2 \quad \ldots \quad a+9 \]

0 \[ M_0, M_1 \]

1 \[ M_0, M_1 \]

2 \[ M_0, M_1, M_2 \]

\[ \vdots \]

9 \[ M_0, M_1, M_2 \]
Core Methodology

- The new CLL model for transitions higher than 0-1:

\[ P = 1 - \exp\{-\exp[a + b_1 T_1 + b_2 T_2 + ... + b_9 T_9 + \]
\[ A(c_1 + c_2 t + c_3 t^2) + A^2(d_1 + d_2 t + d_3 t^2) + \]
\[ D_1(e_1 + e_2 t + e_3 t^2) + D_2(f_1 + f_2 t + f_3 t^2) + \]
\[ U(g_1 + g_2 t + g_3 t^2) + L(j_1 + j_2 t + j_3 t^2) + \]
\[ H(k_1 + k_2 t + k_3 t^2) + mU D_1 + nL D_1 + oH D_1]\} \]
Core Methodology (Partitioning Factor)

- The partitioning factor is defined as the proportion of women at age $a$, parity $i$, duration $t$, and child mortality $M_m$ who change their child mortality state to $M_{m+1}$ by age $a+1$

- **The “overall probability” approach**: uses the overall probability of failure (i.e., next birth) at age $a$, parity $i$, duration $t$, and child mortality state $m$, to estimate the partitioning factor

- **The “logit model” approach**: applies logit regression models to estimate the probabilities of change in child mortality state by age, parity, duration in parity, and child mortality state.
The child replacement rate (A Key Measure)

- Construct a multi-dimensional life table using the $P_{aitmn}$ approach by setting $m$ and $n$ equal to zero; $P_{ait00}$; after fitting the CLL model

- This multi-dimensional life table is referred to as the child-mortality-effect-free multi-dimensional life table, denoted as $\text{MDLT}_{\text{NCM}}$

- The multi-dimensional life table that incorporates child mortality is referred to as the child-mortality-effect-present multi-dimensional life table, denoted as $\text{MDLT}_{\text{WCM}}$
The child replacement rate (A Key Measure)

- The replacement rate is defined as the difference between the child-mortality-effect-present TFR and the child-mortality-effect-free TFR, divided by the overall mean number of child death per woman, $D$-bar

- Replacement Rate = $\frac{(TFR_{WCM} - TFR_{NCM})}{(D\text{-}bar)}$

- The replacement rate indicates the extent to which women replace dead children with additional births
Validity of the $P_{aitmn}$ Method

- The new methodology is validated using India’s first National Family Health Survey, conducted in 1992/93 (NFHS-1).

- The validity of the method is tested by applying it to both cohort and period data.

<table>
<thead>
<tr>
<th></th>
<th>CEB</th>
<th>TFR</th>
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<tbody>
<tr>
<td>Birth History</td>
<td></td>
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</tr>
<tr>
<td>$P_{it}$ Method</td>
<td>5.03</td>
<td>5.03</td>
</tr>
<tr>
<td>$P_{ait}$ Method</td>
<td>4.93</td>
<td>4.97</td>
</tr>
<tr>
<td>$P_{aimn}$ Method</td>
<td>4.89</td>
<td></td>
</tr>
<tr>
<td>Cohort</td>
<td>5.03</td>
<td>3.51</td>
</tr>
<tr>
<td>Period</td>
<td>3.20</td>
<td>3.13</td>
</tr>
</tbody>
</table>
Application of the $P_{aitmn}$ method

- The new methodology is applied to India’s three National Family Health Surveys (NFHS-1, NFHS-2, and NFHS-3)

- The application is to both cohort and period data

- The methodology is applied separately for each survey to assess the child mortality-fertility relationship and the role of socioeconomic predictors
Cohort Analysis

Table 6.2: Unadjusted and adjusted total fertility rate (both $TFR_{WCM}$ and $TFR_{NCM}$), mean number of child deaths per woman, child replacement rate, and mean age of women at child death: Women age 45-49, Cohort analysis, India's NFHS surveys

<table>
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<tbody>
<tr>
<td></td>
<td>Unadjusted</td>
<td>Adjusted</td>
<td>Unadjusted</td>
<td>Adjusted</td>
<td>Unadjusted</td>
<td>Adjusted</td>
</tr>
<tr>
<td>$TFR_{WCM}$</td>
<td>4.89</td>
<td>4.74</td>
<td>4.46</td>
<td>4.27</td>
<td>4.00</td>
<td>3.77</td>
</tr>
<tr>
<td>$TFR_{NCM}$</td>
<td>4.58</td>
<td>4.48</td>
<td>4.16</td>
<td>4.00</td>
<td>3.69</td>
<td>3.53</td>
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<tr>
<td>Difference</td>
<td>0.31</td>
<td>0.26</td>
<td>0.31</td>
<td>0.27</td>
<td>0.31</td>
<td>0.24</td>
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<tr>
<td>CM</td>
<td>0.94</td>
<td>0.91</td>
<td>0.75</td>
<td>0.70</td>
<td>0.58</td>
<td>0.54</td>
</tr>
<tr>
<td>RR</td>
<td><strong>0.33</strong></td>
<td><strong>0.29</strong></td>
<td><strong>0.41</strong></td>
<td><strong>0.39</strong></td>
<td><strong>0.53</strong></td>
<td><strong>0.45</strong></td>
</tr>
<tr>
<td>MAWCD</td>
<td>29.5</td>
<td>29.4</td>
<td>29.0</td>
<td>28.7</td>
<td>28.9</td>
<td>28.5</td>
</tr>
</tbody>
</table>
Period Analysis

Table 7.2: Unadjusted and adjusted total fertility rate (both TFR_{WCM} and TFR_{NCM}), mean number of child deaths per woman, child replacement rate, and mean age of women at child death: Women age 10-49, 5-year period analysis, India's NFHS surveys.

<table>
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<tbody>
<tr>
<td></td>
<td>Unadjusted</td>
<td>Adjusted</td>
<td>Unadjusted</td>
<td>Adjusted</td>
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<td>Adjusted</td>
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<tr>
<td>TFR_{WCM}</td>
<td>3.13</td>
<td>2.92</td>
<td>2.77</td>
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<td>TFR_{NCM}</td>
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<td>2.66</td>
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<td>2.57</td>
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<td>Difference</td>
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<tr>
<td>CM</td>
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<td>0.52</td>
<td>0.52</td>
<td>0.58</td>
</tr>
<tr>
<td>MAWCD</td>
<td>28.4</td>
<td>28.4</td>
<td>28.0</td>
<td>27.9</td>
<td>28.1</td>
<td>28.1</td>
</tr>
</tbody>
</table>
Conclusion
(Contribution)

- By introducing a new comprehensive methodology this research overcomes the shortcomings of the existing literature on studying the effect of child mortality on fertility.

- The contribution of this research is methodological.
Conclusion (Limitations)

- The biggest limitation of this research is the calculation of standard errors of estimates
  - The jackknife method is usually used
  - Requires months of super fast computer time

- Availability of data on contraception and breastfeeding

- This research does not use an age cut-off for child mortality. But:
  - Majority of child deaths occur at the very early stages of a child’s life
Conclusion (New Avenues)

- Disaggregate the multi-dimensional life tables in order to construct completed birth histories for the initial population of the life table
  - This allows one to estimate new measures of replacement effect such as replacement rate for women with one, two, or more child deaths.

- Limit the child deaths to specific child age such as under 1 year of age, or under 5 years of age and etc
  - This allows studying the effect of infant mortality or 0-4 age child mortality on fertility