Modeling Under-Five Mortality with Summary Birth History Data

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Motivation

- Reducing the number of deaths in children under five remains a key public health issue.
- One of the United Nations’ Sustainable Development Goals is to reduce child mortality to 25 deaths per 1,000 live births by 2030.
- Child mortality tends to be concentrated in developing regions where the information comes from surveys or census.
- Birth records tend to be of 2 forms: FBH and SBH.
- SBH data is easier and cheaper to collect, but does not directly provide temporal information on when births and deaths occurred.

<table>
<thead>
<tr>
<th>Woman</th>
<th>Child</th>
<th>DOB</th>
<th>DOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1/10/1990</td>
<td>2/25/1993</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>4/19/1992</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>11/1/1991</td>
<td>NA</td>
</tr>
</tbody>
</table>

Full birth history (FBH)

<table>
<thead>
<tr>
<th>Woman</th>
<th>No. Children</th>
<th>No. Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Summary birth history (SBH)
Motivating Example: Under-Five Mortality in the Nyanza Province

- Women ages 15–49
- FBH: DHS and MICS
  - ≈ 8,000 women
- SBH: Census
  - ≈ 129,000 women
- **Goal**: understand how under-five mortality varies in space and time

<table>
<thead>
<tr>
<th></th>
<th># Women</th>
<th># Births</th>
<th># Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Census 2009</td>
<td>128,791</td>
<td>382,826</td>
<td>52,530</td>
</tr>
<tr>
<td>DHS 2008–2009</td>
<td>1,318</td>
<td>3,870</td>
<td>648</td>
</tr>
<tr>
<td>MICS 2011</td>
<td>5,895</td>
<td>18,554</td>
<td>2,594</td>
</tr>
<tr>
<td>DHS 2014</td>
<td>1,165</td>
<td>3,639</td>
<td>447</td>
</tr>
</tbody>
</table>
Previous Approaches

- **Brass Method** (Brass, 1964; Coale and Trussell, 1977)
  - Requires for 5-year age groups of the mothers, the total number of women, number of children born, and number of children who died
  - Uses simulation results and model life tables to obtain estimates of under-five mortality back in time
  - Youngest women are being used to estimate current mortality rates

- **MAP** (Maternal Age Period-Derived; Rajaratnam et al., 2010): empirically estimate time distribution of births and deaths by mother’s age using FBH to obtain a yearly measure of the ratio of deaths to births

- **BHI** (Birth History Imputation; Hill et al., 2015; Brady and Hill, 2017): SBH women are randomly matched to FBH women

- None of these use a full probability model and some require pooling from other countries/surveys in order to achieve large enough samples
Ideal data generating mechanism

- $f(m)$: probability a woman gives birth at age $m$
- $q_a(1) = 1q_a$: probability a child dies between age $a$ and $a + 1$ given survival to age $a$
Our Method

- General idea: reverse engineer the data generating process via data augmentation in a Bayesian framework
- In step 1, we define auxiliary variables for birth years and (if applicable) death years for the SBH data, thereby creating FBH from SBH
  - Sub-step 1: Enumerate all possible options and select one
  - Sub-step 2: For the children that died, determine the age they died
- In step 2, we condition on these birth and death years and update the fertility and mortality parameters
**Our Method: Step 1**

**Sub-step 1:** For each woman, enumerate all possible birth years and death indicators and select one

**Sub-step 2:** For each death, enumerate all possible ages at death
Our Method: Step 2

Conditional on this new FBH, we update \( q \) and \( f \), where the likelihoods are

\[
Z_a \mid q_a(1) \sim \text{Bernoulli}(q_a(1)) \\
Y(m) \mid f(m) \sim \text{Bernoulli}(f(m))
\]

with

- \( Z_a \): indicator for death between ages \( a \) and \( a + 1 \)
- \( Y(m) \): indicator for birth at age \( m \)
Under-Five Mortality in the Nyanza Province: Model

- Covariates:
  - Woman’s age band (10–14, 15–19, ..., 45–49) → fertility
  - Child’s age → mortality
  - County → fertility and mortality
  - Strata (urban or rural) → fertility and mortality
    - Smooth over time

- Other considerations:
  - Clusters (enumeration areas) for DHS and MICS
  - HIV bias
Under-Five Mortality in the Nyanza Province: Results

Homa Bay: Rural
- Period
- q(5)
- Proposed Model: FBH only
- Proposed Model: FBH + SBH

Homa Bay: Urban
- Period
- q(5)
- Proposed Model: FBH only
- Proposed Model: FBH + SBH

Siaya: Rural
- Period
- q(5)
- Proposed Model: FBH only
- Proposed Model: FBH + SBH

Siaya: Urban
- Period
- q(5)
- Proposed Model: FBH only
- Proposed Model: FBH + SBH
Under-Five Mortality in the Nyanza Province: Results

1980–1984

SBH + FBH: Posterior Median

SBH + FBH: 2.5th Percentile

SBH + FBH: 97.5th Percentile

FBH: Poterio Median

FBH: 2.5th Percentile

FBH: 97.5th Percentile
We propose a method for incorporating summary birth history data into analyses of under-five mortality trends

Use a data augmentation approach to “create” full birth history data from summary birth history data

Extensions to continuous time

Spatial smoothing

Thank you!


Our Method: Step 1

For notational simplicity, consider fertility $f(\cdot)$ and mortality $q(\cdot)$ constant over time.

**Sub-step 1:**

$$P\left(\text{children born at (mother's) ages } \{m_{b_1}, \ldots, m_{b_B}\}, \text{ children death indicators are } \{d_1, \ldots, d_B\} \mid f, q, B \text{ births, } \sum_{i=1}^{B} d_i = D \text{ deaths, mother survey age } m_s\right)$$

$$\propto \left\{ \prod_{i=1}^{B} f(m_{b_i}) \right\} \left[ q(m_s - m_{b_i}) \right]^{d_i} \left[ 1 - q(m_s - m_{b_i}) \right]^{1-d_i} \prod_{m \notin \{m_{b_1}, \ldots, m_{b_B}\}, m < m_s} (1 - f(m))$$

**Sub-step 2:**

$$P(\text{child } i \text{ dies at age } a \mid f, q, m_{b_i}, d_i, m_s) \propto q_{a-1}(1) \left\{ \frac{1 - q(a - 1)}{1} \right\}$$

Dies at age $a$ given survival to age $a - 1$
Under-Five Mortality in the Nyanza Province: Model

**Fertility:**

\[ Y(m) \mid f(m, \mathbf{x}) \sim \text{Bernoulli}(f(m, \mathbf{x})) \]
\[ \text{logit}(f(m, \mathbf{x})) = \phi_m(p) + \beta_m + \beta_r + \beta_s + \beta_{m,s} + \beta_{r,s} \]

- \( \phi_m(p) \) is a woman’s age group specific random walk of order 2

**Mortality:**

\[ Z_a \mid q_a(\mathbf{x}) \sim \text{Bernoulli}(q_a(\mathbf{x})) \]
\[ \text{logit}(q_a(\mathbf{x})) = \log \text{BIAS}_{\text{surv}}(p) + \beta(\mathbf{x}) + \nu_c \]
\[ \beta(\mathbf{x}) = \phi_a(p) + \beta_a + \beta_r + \beta_s + \beta_{a,r} + \beta_{r,s} \]

- \( \text{BIAS}_{\text{surv}}(p) \) an offset term to adjust for bias from HIV epidemics
- \( \nu_c \sim \text{iid } N(0, \sigma^2) \)
- \( \phi_a(p) \) is a child’s age group specific random walk of order 2
Under-five Mortality in the Nyanza Province of Kenya

Other slides