Modeling Under-Five Mortality with Summary Birth History Data

Katie Wilson

Department of Biostatistics
University of Washington

April 18, 2018

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

Woman	Child	DOB	DOD
1	1	1/10/1990	2/25/1993
1	2	4/19/1992	NA
2	1	11/1/1991	NA
…	…	…	…

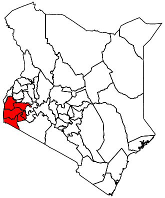
Full birth history (FBH)

Woman	No. Children	No. Deaths
1	2	1
2	3	0
3	1	1
…	…	…

Summary birth history (SBH)

Motivating Example: Under-Five Mortality in the Nyanza Province

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



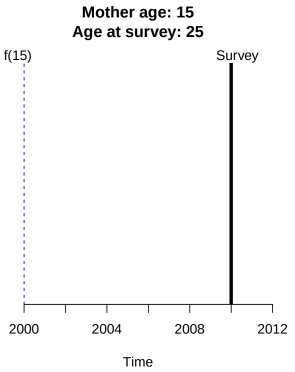
	# Women	# Births	# Deaths
Census 2009	128,791	382,826	52,530
DHS 2008–2009	1,318	3,870	648
MICS 2011	5,895	18,554	2,594
DHS 2014	1,165	3,639	447

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

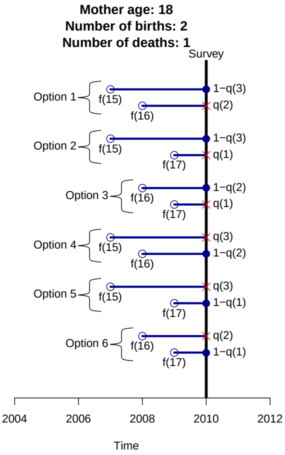


Our Method

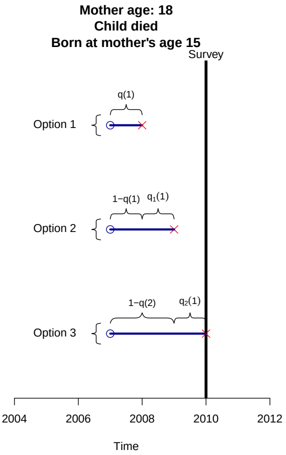
- General idea: reverse engineer the data generating process via data augmentation in a Bayesian framework
- In **step 1**, we define auxiliary variables for birth years and (if applicable) death years for the SBH data, thereby creating FBH from SBH
    - **Sub-step 1:** Enumerate all possible options 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 $\boldsymbol{q}$ and $\boldsymbol{f}$, where the likelihoods are

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

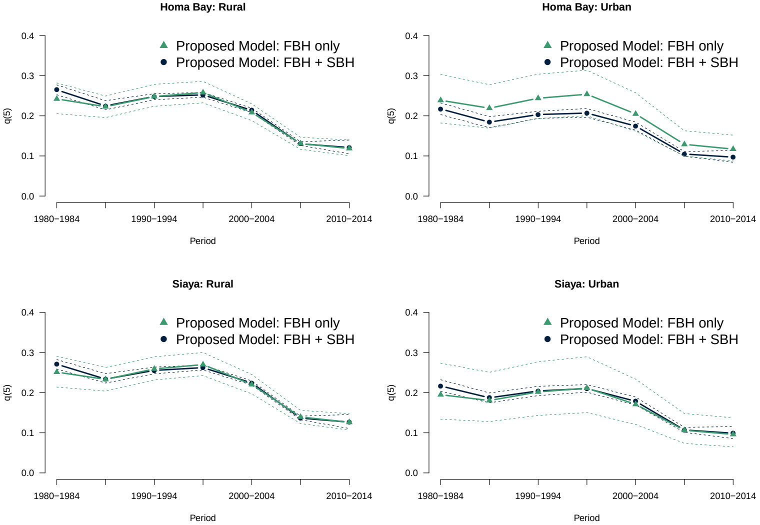
with

- Z_a: indicator for death between ages a and $a+1$
- $Y(m)$: indicator for birth at age m

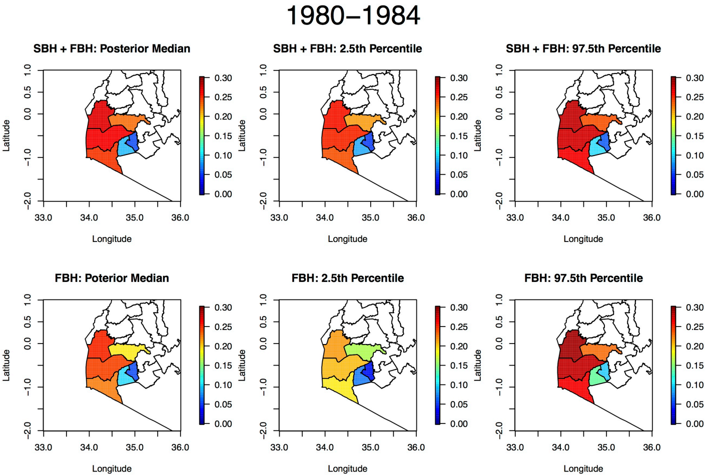
Under-Five Mortality in the Nyanza Province: Model

- Covariates:
  - Woman's age band (10–14, 15–19, ..., 45–49) $\to$ fertility
  - Child's age $\to$ mortality
  - County $\to$ fertility and mortality
  - Strata (urban or rural) $\to$ fertility and mortality
  - Time period (1970–1974, 1975–1979, ..., 2010-2014) $\to$ 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



Under-Five Mortality in the Nyanza Province: Results



Summary

- 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!

References I

Brady, E. and K. Hill (2017). Testing survey-based methods for rapid monitoring of child mortality, with implications for summary birth history data. *PloS one 12*(4), e0176366.

Brass, W. (1964). *Uses of census or survey data for the estimation of vital rates*. United Nations. Paper prepared for the African Seminar on Vital Statistics, Addis Ababa, 14–19 December, 1964.

Coale, A. J. and J. Trussell (1977). Annex i: estimating the time to which Brass estimates apply. *Population Bulletin of the United Nations* (10), 87–89.

Hill, K., E. Brady, L. Zimmerman, L. Montana, R. Silva, and A. Amouzou (2015). Monitoring change in child mortality through household surveys. *PloS one 10*(11), e0137713.

Rajaratnam, J. K., L. N. Tran, A. D. Lopez, and C. J. Murray (2010). Measuring under-five mortality: validation of new low-cost methods. *PLoS Medicine 7*(4), e1000253.

Our Method: Step 1

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

Sub-step 1:

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

$$\propto \left\{ \prod_{i=1}^{B} \underbrace{f(m_{b_i})}_{\text{prob of birth}} \left[\underbrace{q(m_s - m_{b_i})}_{\text{prob of death}}\right]^{d_i} \left[\underbrace{1 - q(m_s - m_{b_i})}_{\text{prob of survival}}\right]^{1-d_i} \right\}$$

$$\times \prod_{m \notin \{m_{b_1}, \ldots, m_{b_B}\}, m < m_s} \underbrace{(1 - f(m))}_{\text{prob of no birth}}$$

Sub-step 2:

$$P(\text{child } i \text{ dies at age } a \mid \boldsymbol{f}, \boldsymbol{q}, m_{b_i}, d_i, m_s) \propto \underbrace{q_{a-1}(1)}_{\substack{\text{dies at age } a \text{ given} \\ \text{survival to age } a - 1}} \left\{ \underbrace{1 - q(a-1)}_{\text{survives to age } a - 1} \right\}$$

Under-Five Mortality in the Nyanza Province: Model

Fertility:

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

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

Mortality:

$$Z_a \mid {}_1q_a(\boldsymbol{x}) \sim \text{Bernoulli}\left({}_1q_a(\boldsymbol{x})\right)$$
$$\text{logit}\left({}_1q_a(\boldsymbol{x})\right) = \log \text{BIAS}_{surv}(p) + \beta(\boldsymbol{x}) + \nu_c$$
$$\beta(\boldsymbol{x}) = \phi_a(p) + \beta_a + \beta_r + \beta_s + \beta_{a,r} + \beta_{r,s}$$

- $\text{BIAS}_{surv}(p)$ an offset term to adjust for bias from HIV epidemics
- $\nu_c \sim_{iid} N(0, \sigma^2)$
- $\phi_a(p)$ is a child's age group specific random walk of order 2

Under-five Mortality in the Nyanza Province of Kenya