Estimating and Projecting Disparities in Pre- and Post-natal Survival using Bayesian Methods

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Research Areas

• Statistical approaches: Bayesian methods, regression, time series

• Demography

• Global health
Current Research: Disparity in Prenatal and Postnatal Survival

<table>
<thead>
<tr>
<th>Prenatal</th>
<th>Postnatal</th>
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<td>Birth</td>
<td>Death</td>
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<td>• Sex ratio at birth</td>
<td>• Child mortality by sex</td>
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<td>• Child mortality by household economic status</td>
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A Boy or a Girl?
Sex Ratio at Birth and Prenatal Sex Discrimination

- Prenatal
- Birth
  - Sex ratio at birth
- Postnatal
- Death
Sex Ratio at Birth (SRB) - It is Not 50/50

Naturally

- 100 Female Births
- 103~107 Male Births

SRB = Boys/Girls
1.03~1.07

Natural SRB 1.03\textasciitilde1.07

Sweden

Sex Ratio at Birth

Year
Inflated SRB in Some Countries

In reality, in some countries

100 Female Births

> 110 Male Births

SRB: >1.10
Inflated SRB in Some Countries
Sex Ratio at Birth (SRB) – Why the Inflation?

Naturally
- 103~107 Male Births
- 100 Female Births
- SRB = boys/girls 1.03~1.07

Willingness
- Son preference

Necessary
- Fertility decline

Means
- Abortion + Sex detection
- Sex-selective abortion

In reality, in some countries
- 103~107 Male Births
- <94 Female Births
- SRB: >1.10

Missing female birth
Sex Ratio at Birth (SRB) – A Distorted Reality

• Serious social consequences with prolonged distorted SRB:
  • Human trafficking
  • Marriage squeeze
  • Violation of human right

• Breaks population sex balance at the beginning of the life course:
  • Missing female births due to sex selection

Sources: Three women (2020), from The Conversation. 40,800 female births (2020), from VNExpress. Why many Indian and Chinese men may need to delay marriage or remain bachelors.
45 Million Missing Female Births during 1970-2017

Sex ratio at birth in 2017
- 1.10 and above
- 1.07 to 1.10
- 1.05 to 1.07
- 1.03 to 1.05
- Less than 1.03
- No data

Cumulative number of missing female births (in millions) 1970–2017

Some observations are more uncertain than others.

Observations from different sources have different levels and trends.
Data Model for SRB

Accounts for uncertainty associated with observations

\[ \log(y_i) \sim N(\log(\Theta_{c[i],t[i]}), \omega_s^2[i] + \nu_i^2) \]

- \( y_i \): i-th SRB observation
- True SRB
- \( \omega_s^2 \): Non-sampling error variance, e.g. non-response, data input error
- Index \( s \): data source types, e.g. administrative records, survey, census
- Index \( c[i], t[i] \): country, year for the i-th observation
- Sampling error variance due to sampling design, pre-computed
Bayesian Hierarchical Model for SRB

- Baseline model: for countries/areas without SRB inflation;

- Inflation model: for selected countries/areas with past/current/potential future SRB inflation.
Baseline Model Overview

\[ \Theta_{c,t} = \beta_c \eta_{c,t} \]

Index \( c \): country

Index \( t \): time, year

- \( \beta_c \) is country-specific baseline:
  - Constant within country
  - Differ across countries within a region
- \( \eta_{c,t} \) is year-by-year natural fluctuation:
  - An autoregressive AR(1) time series process
Baseline Model

$$\Theta_{c,t} = \beta_c \eta_{c,t}$$

Country-specific SRB baseline:

$$\beta_c \sim N(\beta^{(\text{region})}_r, \sigma^2_\beta)$$

• Mean at $$\beta^{(\text{region})}_r$$, regional SRB baseline
  • Group countries into regions based on their majority ethnicity
  • To account for the heterogeneity in baseline SRB across ethnicity groups
Baseline Model \( \omega_{c,t} = \beta_c \eta_{c,t} \)

Within country year-by-year natural fluctuation:

\[
\log(\eta_{c,t}) \sim N \left(0, \frac{\sigma^2}{1 - \rho^2} \right), t = 1950
\]

\[
\log(\eta_{c,t}) = \rho \log(\eta_{c,t-1}) + \epsilon_{c,t}, t > 1950
\]

\[
\epsilon_{c,t} \sim iid N(0, \sigma^2_{\epsilon})
\]
Inflation Model – Motivation

\[ \Theta_{c,t} = \beta_c \eta_{c,t} + \delta_c \Omega_{c,t} \]
Inflation Model

$$\Theta_{c,t} = \beta_c \eta_{c,t} + \delta_c \Omega_{c,t}$$

For countries at risk of SRB inflation: strong son preference.

Country-specific SRB inflation binary detector:

• 0: no inflation
• 1: with inflation

$$\delta_c \sim Bernoulli(\pi_c)$$

$$\text{logit}(\pi_c) \sim N(\mu_\pi, \sigma_\pi^2)$$
Inflation Model

\[ \Theta_{c,t} = \beta_c \eta_{c,t} + \delta_c \Omega_{c,t} \]

Upward SRB inflation factor: trapezoid function

Sex ratio transition model

- Country-specific increase, stagnation, decrease, max inflation

\[ \lambda_{1,c} \sim N(\mu_{\lambda_1}, \sigma_{\lambda_1}^2)T(0,) \]
\[ \lambda_{2,c} \sim N(\mu_{\lambda_2}, \sigma_{\lambda_2}^2)T(0,) \]
\[ \lambda_{3,c} \sim N(\mu_{\lambda_3}, \sigma_{\lambda_3}^2)T(0,) \]
\[ \xi_c \sim N(\mu_{\xi}, \sigma_{\xi}^2)T(0,) \]
Inflation Model

\[ \Theta_{c,t} = \beta_c \eta_{c,t} + \delta_c \Omega_{c,t} \]

Upward SRB inflation factor: trapezoid function

Sex ratio transition model

- Country-specific start year includes fertility decline effect:

\[ \gamma_{0,c} \sim t_3 (f_{c,2.9}, \sigma^2_\gamma) T(f_{c,6},) \]

- \( f_{c,2.9} \): year in which TFR declines to 2.9
- \( f_{c,6} \): year in which TFR declines to 6

*TFR: total fertility rate
Inflation Model and Data

Parametric form of $\Omega_{c,t}$ captures the observed shape of inflated SRB Data: $y_i - \widehat{\beta}_c$
SRB Estimation and Projection Results for China

\[ \gamma_{0,c} = 1980 \quad \text{(TFR=2.6)} \]

\[ \Theta_{c,t} = \beta_c \eta_{c,t} + \delta_c \Omega_{c,t} \]

\[ \beta^{(\text{region})}_{t[c]} \quad \text{(regional baseline)} \]

\[ \beta_c \quad \text{(national baseline)} \]

Scenario-Based SRB Projection till 2100

- At-risk countries may have inflated SRB in the future
- Mostly African countries
- Scenario-based SRB projections:
  - No inflation $\delta_c = 0$
    \[ \Theta_{c,t} = \beta_c \eta_{c,t} \]
  - With inflation $\delta_c = 1$
    \[ \Theta_{c,t} = \beta_c \eta_{c,t} + \Omega_{c,t} \]

Some at-risk countries have normal SRB

Willingness Son preference

Necessary Fertility decline

Means Abortion + Sex detection

Sex-selective abortion

SRB & Missing Female Births Projection till 2100

SRB inflation within a country

Bayesian hierarchical models with modifications can be used for estimating SRB inflation on subnational level.

Nepal

Vietnam

Pakistan


Looking into Child Mortality Disparity

- Child mortality by sex
- Child mortality by household economic status
Under-5 Mortality Rate (U5MR)

- Most deaths before age of 5 are due to preventable or treatable causes
  - Infectious diseases: Pneumonia, diarrhoea and malaria
  - Basic lifesaving interventions: childbirth delivery care, postnatal care, vaccinations
- U5MR has dropped by almost 60% since 1990

Great Disparity in U5MR Remains Across Countries

U5MR in 2019

- 0 - 12
- 12 - 25
- 25 - 40
- 40 - 75
- 75 - 100
- 100 - 150
- 150 and above
- No data

U5MR Disparity Between Girls and Boys
Identify the Most Disadvantaged, Vulnerable Children

• Naturally, boys have higher mortality than girls before age of 5.

• Postnatal sex discrimination can change the pattern.

• In some countries, the risk of dying before age 5 for girls is higher than expected.

U5MR Disparity Between Household Economic Status
Identify the Most Disadvantaged, Vulnerable Children

Great disparity in U5MR between the poorest and the richest households.

U5MR Disparity Bayesian Model

True ratio of U5MR between 2 groups

\[ S_{c,t} = W_{c,t} P_{c,t} \]

Year-by-year deviation:
- Model on log-scale
- An autoregressive AR(1) time series process

\[ \log(P_{c,t}) = \mu + \rho [\log(P_{c,t-1}) - \mu] + \epsilon_{c,t} \]
\[ \epsilon_{c,t} \sim iid N(0, \sigma^2_{\epsilon}) \]

Research to the Real World

U5MR disparity studies*† have been used by the UNICEF to inform policy makers and resource allocation.

References


• Nga M. 40,800 female births doomed in Vietnam every year. VNExpress. 2020 Jun 19.

• Pune R.J. Why many Indian and Chinese men may need to delay marriage or remain bachelors. The Hindu Business Line. 2020 Jul 1.


