

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

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Research Talk (virtual), Yale-NUS College

Dec 14<sup>th</sup>, 2020

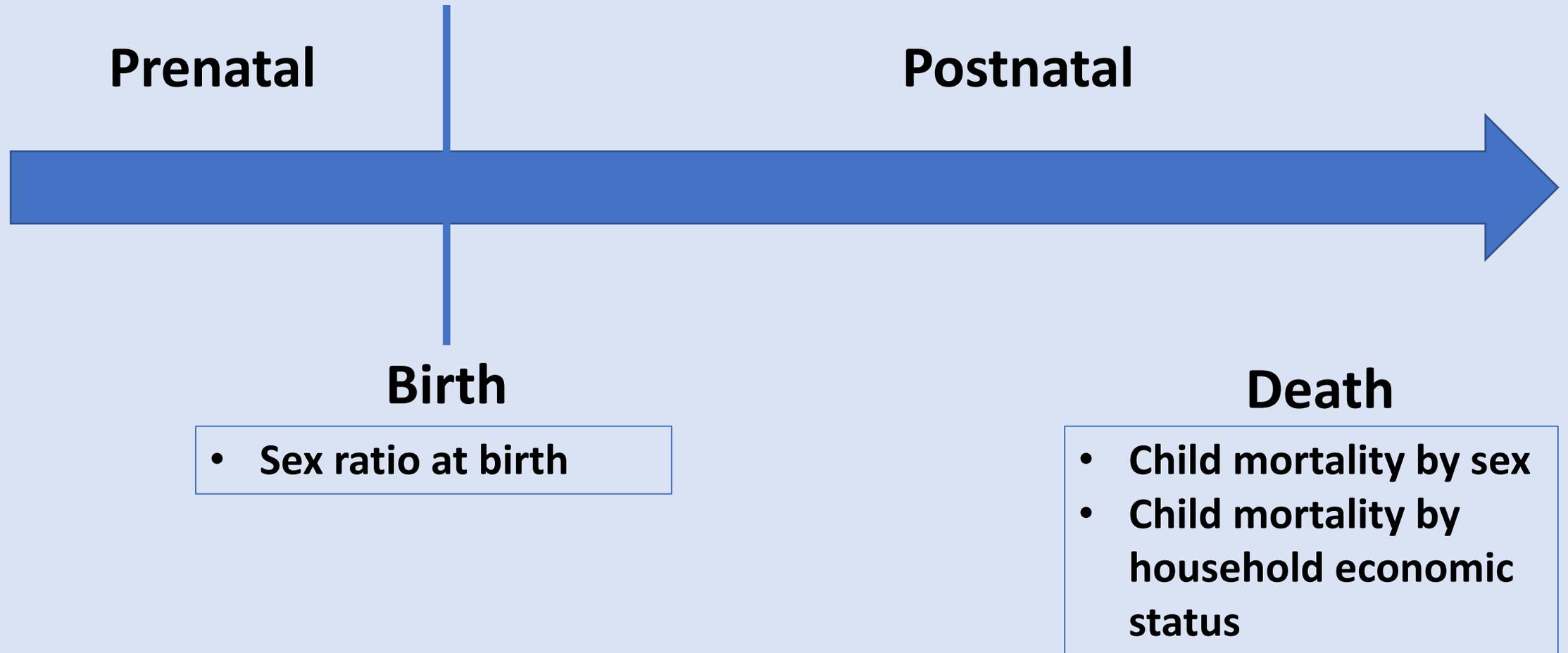
جامعة الملك عبد الله  
للعلوم والتقنية  
King Abdullah University of  
Science and Technology



# Research Areas

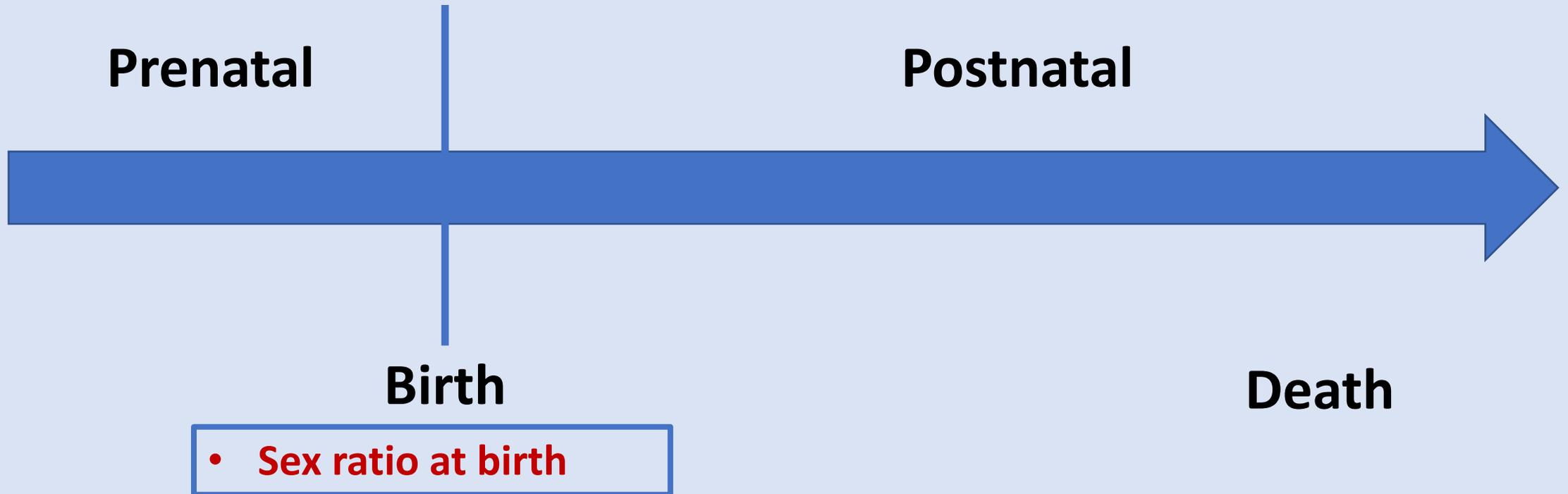
- **Statistical approaches: Bayesian methods, regression, time series**
- **Demography**
- **Global health**

# Current Research: Disparity in Prenatal and Postnatal Survival



# A Boy or a Girl?

## Sex Ratio at Birth and Prenatal Sex Discrimination



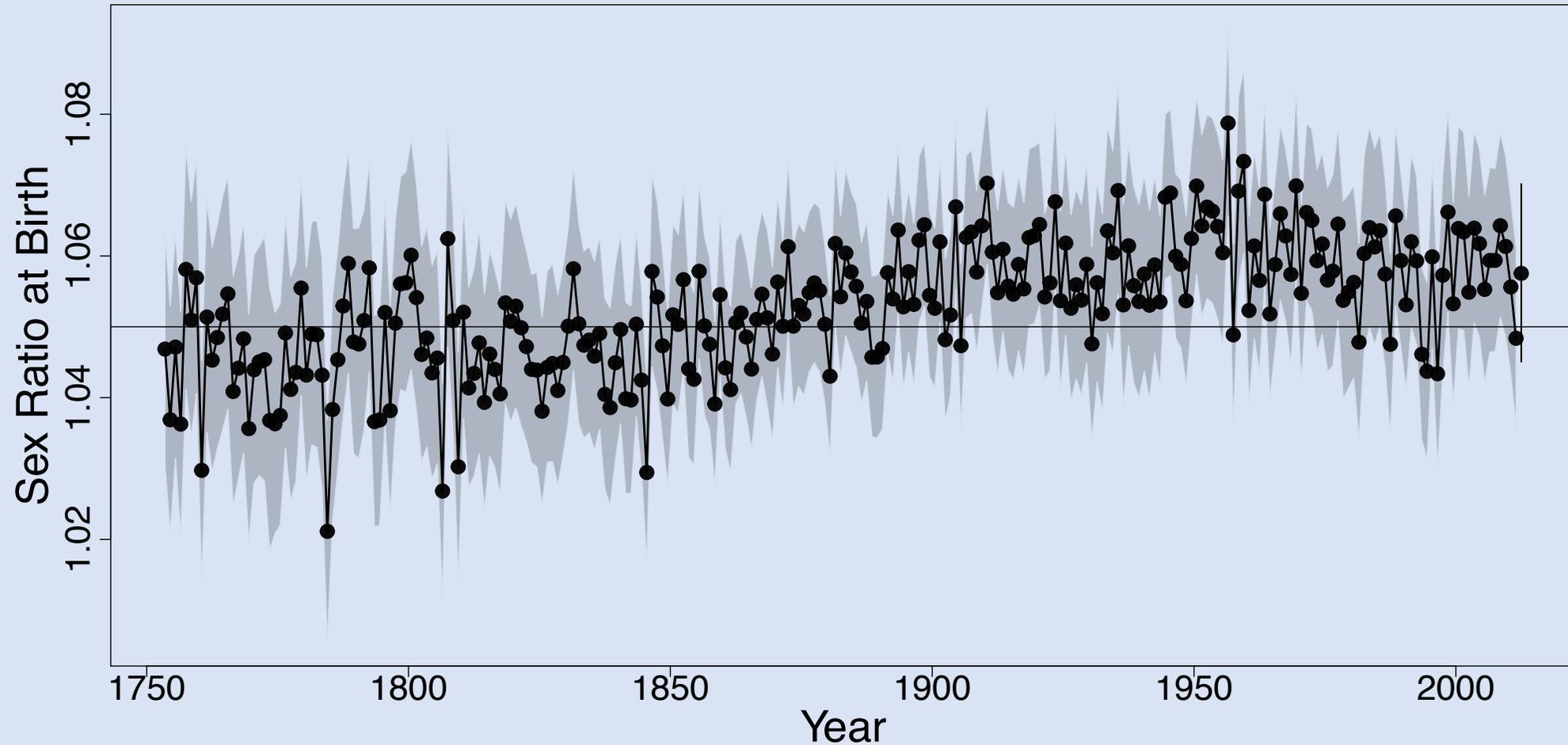
# Sex Ratio at Birth (SRB) - It is Not 50/50

**Naturally**



# Natural SRB 1.03~1.07

## Sweden



# Inflated SRB in Some Countries

In reality,  
in some countries

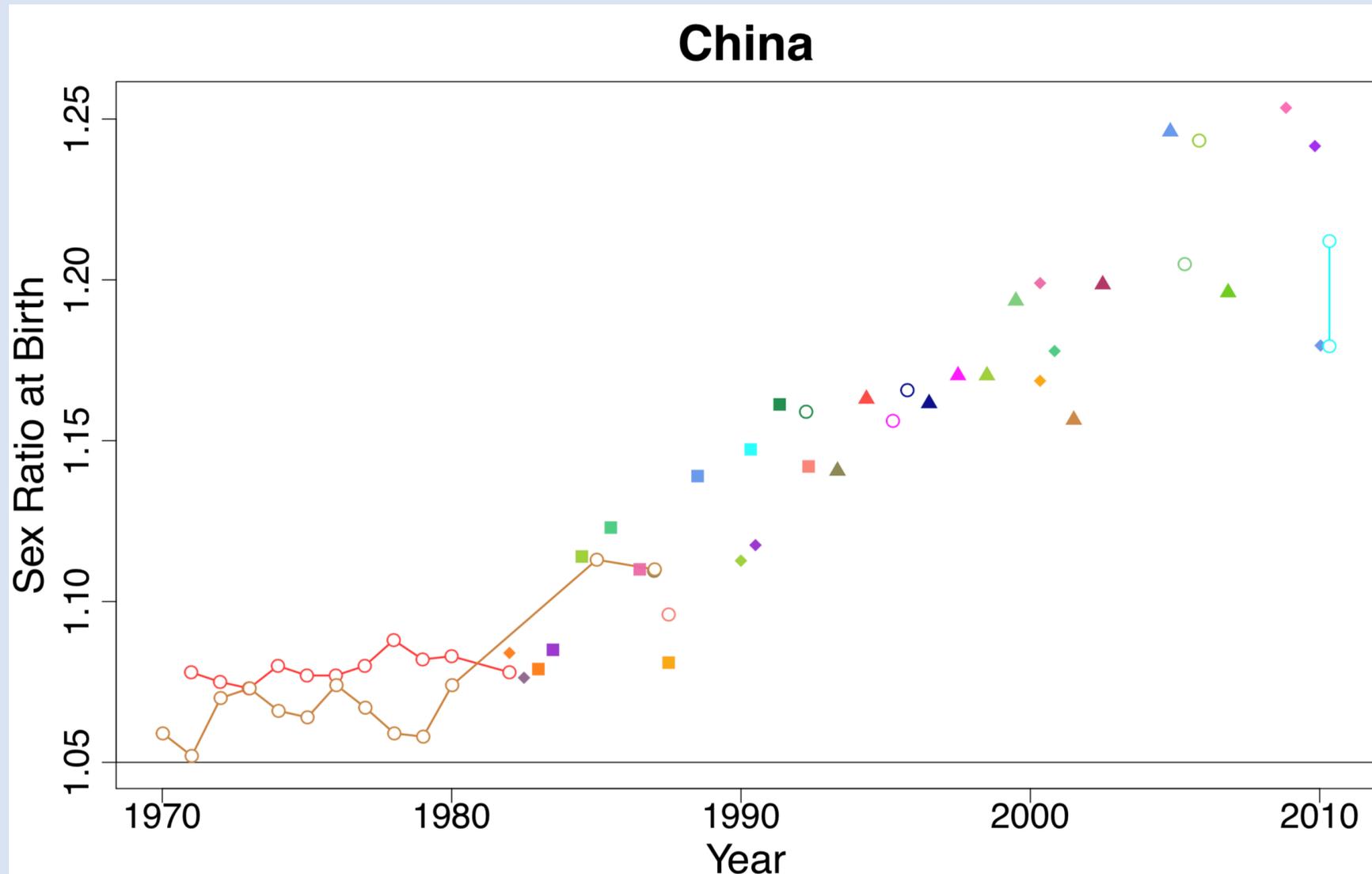
**100**  
**Female**  
**Births**

**> 110**  
**Male**  
**Births**

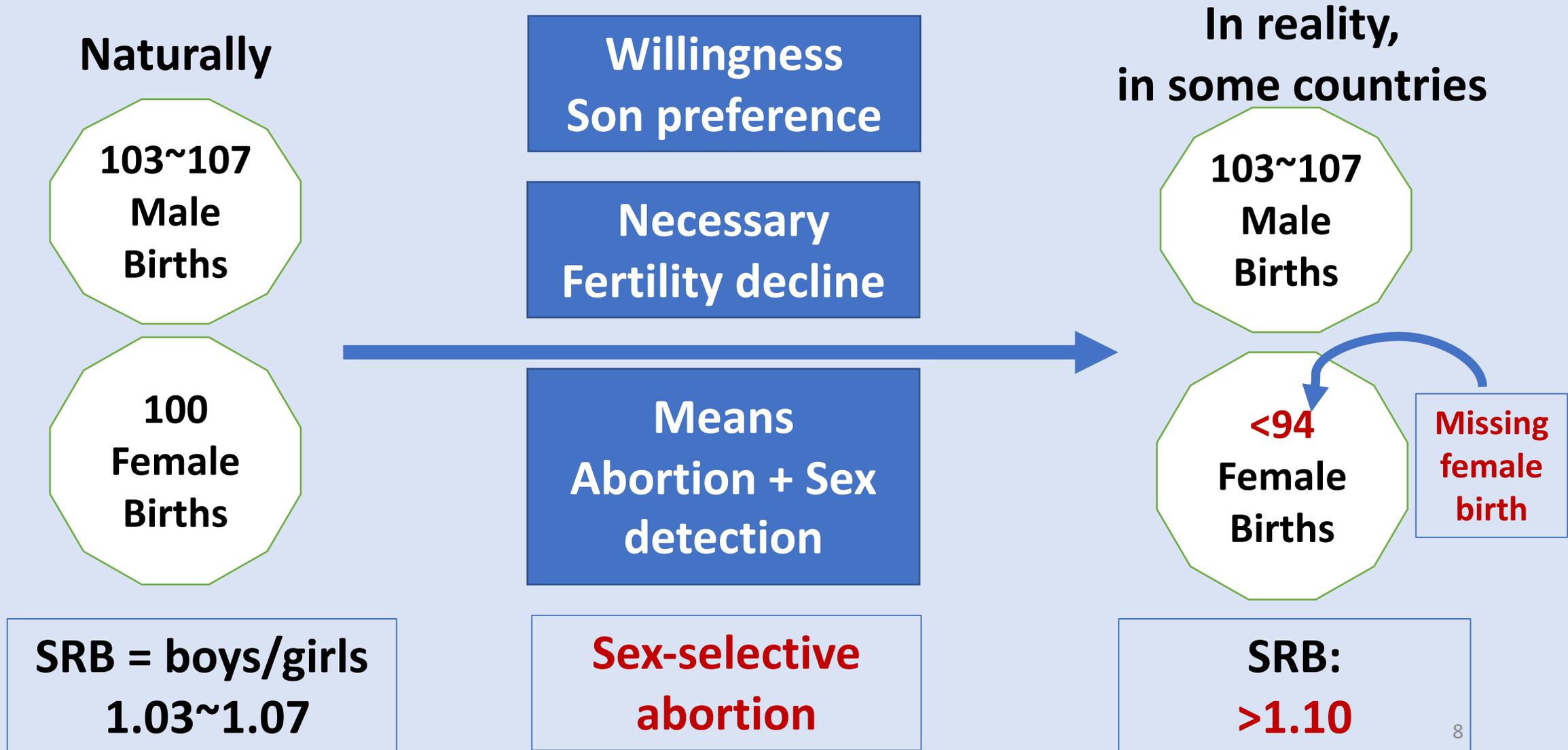


**SRB:**  
**>1.10**

# Inflated SRB in Some Countries



# Sex Ratio at Birth (SRB) – Why the Inflation?



# 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



## 40,800 female births doomed in Vietnam every year

By Minh Nga July 19, 2020 | 05:24 pm GMT+7



## Three women: stories of Indian trafficked brides

September 30, 2020 6.31pm AEST

## Why many Indian and Chinese men may need to delay marriage or remain bachelors

Radheshyam Jadhav | Pune | Updated on July 01, 2020 | Published on July 01, 2020

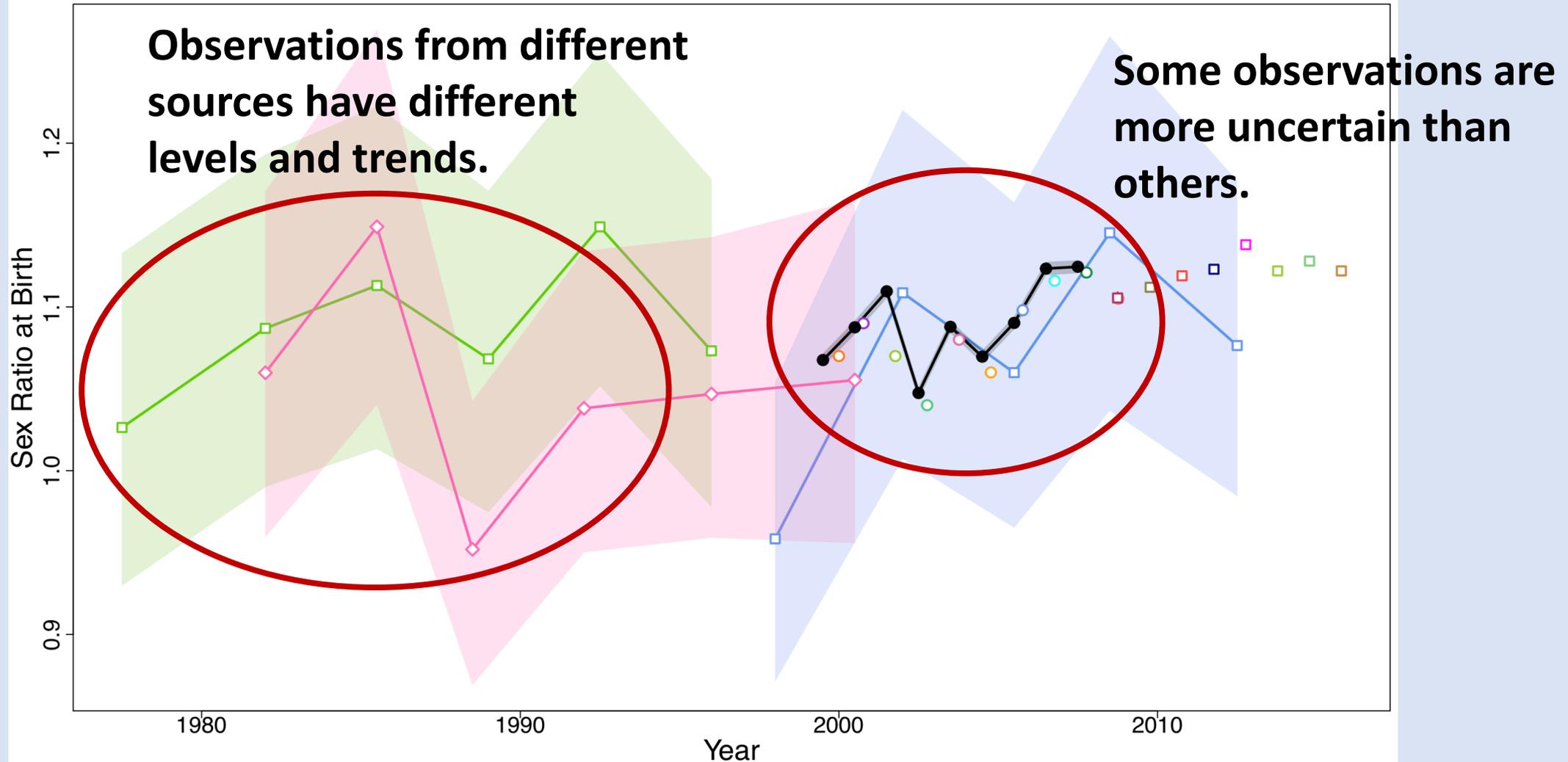
Sources: Three women (2020), from [The Conversation](#). 40,800 female births (2020), from [VNExpress](#).

Why many Indian and Chinese men (2020), from [The Hindu Business Line](#).



# Data Model for SRB – Motivations

Vietnam



# Data Model for SRB

Accounts for uncertainty associated with observations

$$\log(y_i) \sim N(\log(\Theta_{c[i],t[i]}), \omega_{s[i]}^2 + v_i^2)$$

Index  $c[i], t[i]$ : country, year for the  $i$ -th observation

$y_i$ :  $i$ -th SRB observation

True SRB

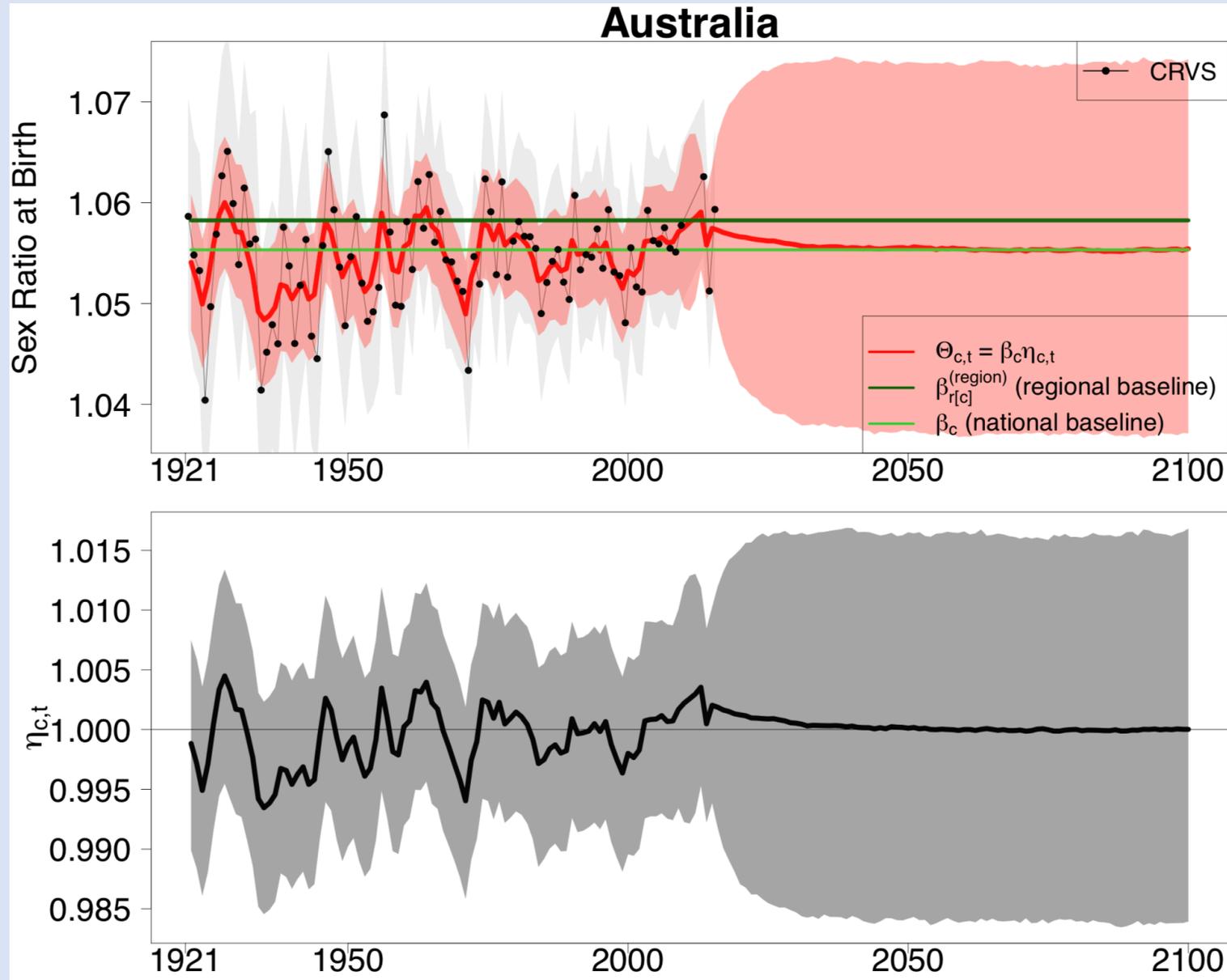
- $\omega_s^2$ : Non-sampling error variance, e.g. non-response, data input error
- Index  $s$ : data source types, e.g. administrative records, survey, census

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

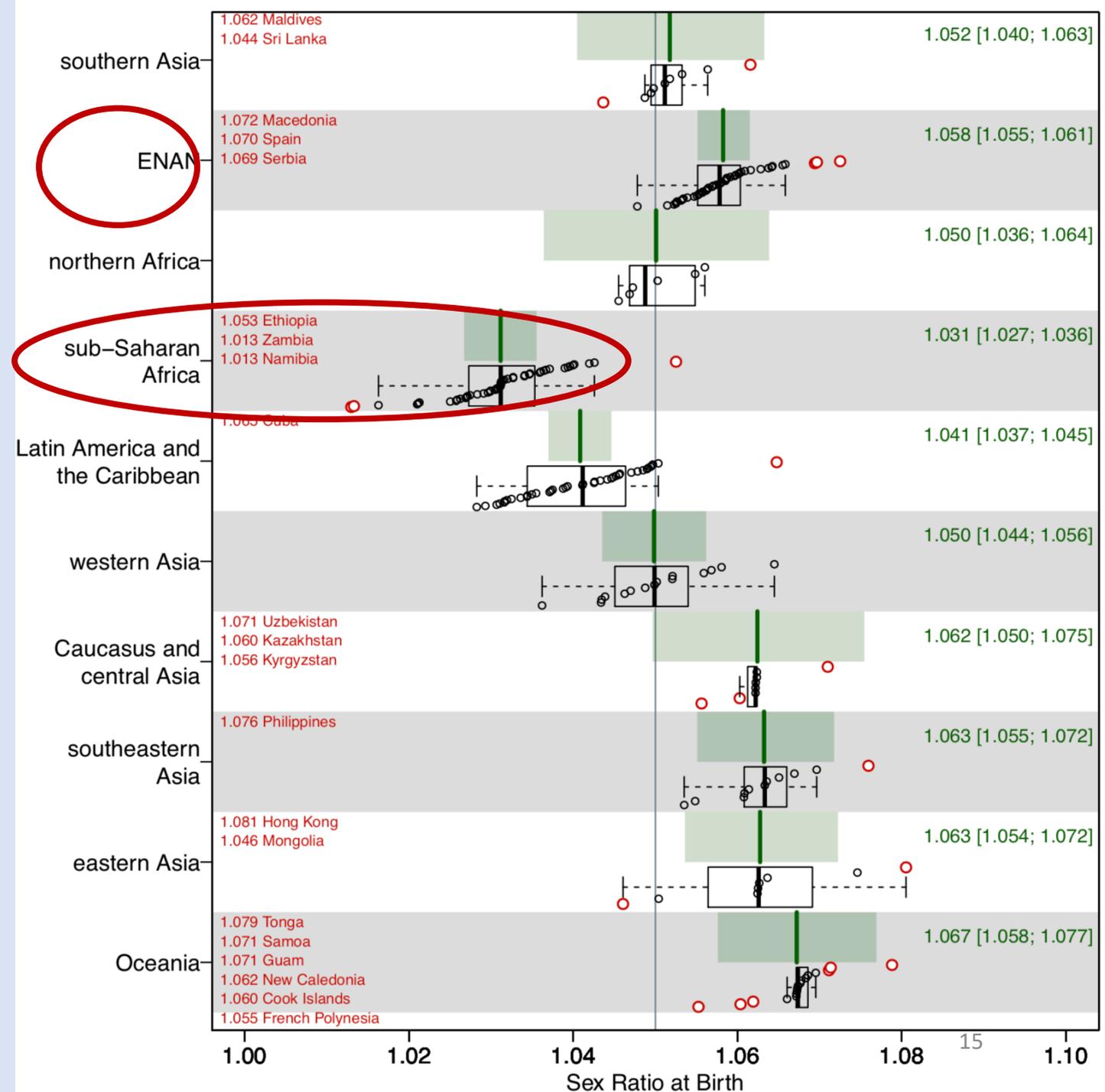
# Baseline Model

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

Country-specific SRB baseline:

$$\beta_c \sim N(\beta_{r[c]}^{(region)}, \sigma_\beta^2)$$

- Mean at  $\beta_{r[c]}^{(region)}$ , regional SRB baseline
  - Group countries into regions based on their majority ethnicity
  - To account for the heterogeneity in baseline SRB across ethnicity groups



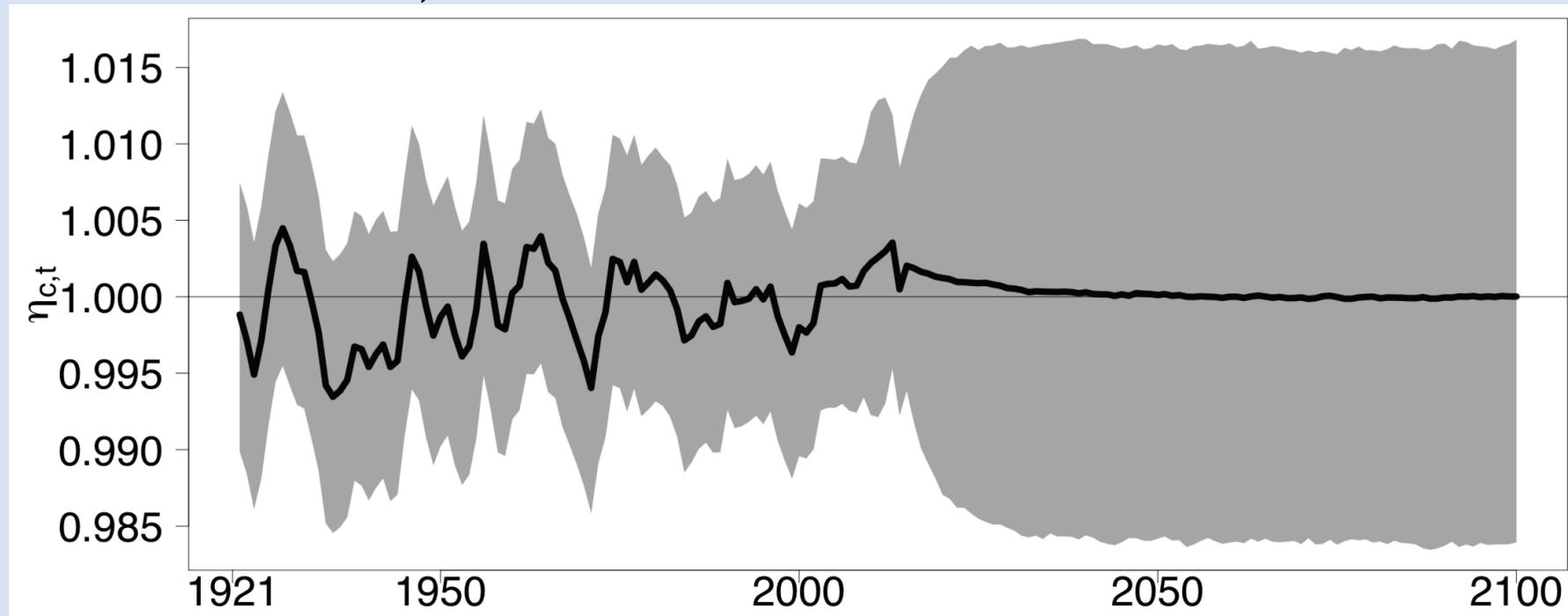
Baseline Model  $\Theta_{c,t} = \beta_c \eta_{c,t}$

Within country year-by-year natural fluctuation:

$$\log(\eta_{c,t}) \sim N\left(0, \frac{\sigma_\epsilon^2}{1 - \rho^2}\right), t = 1950$$

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

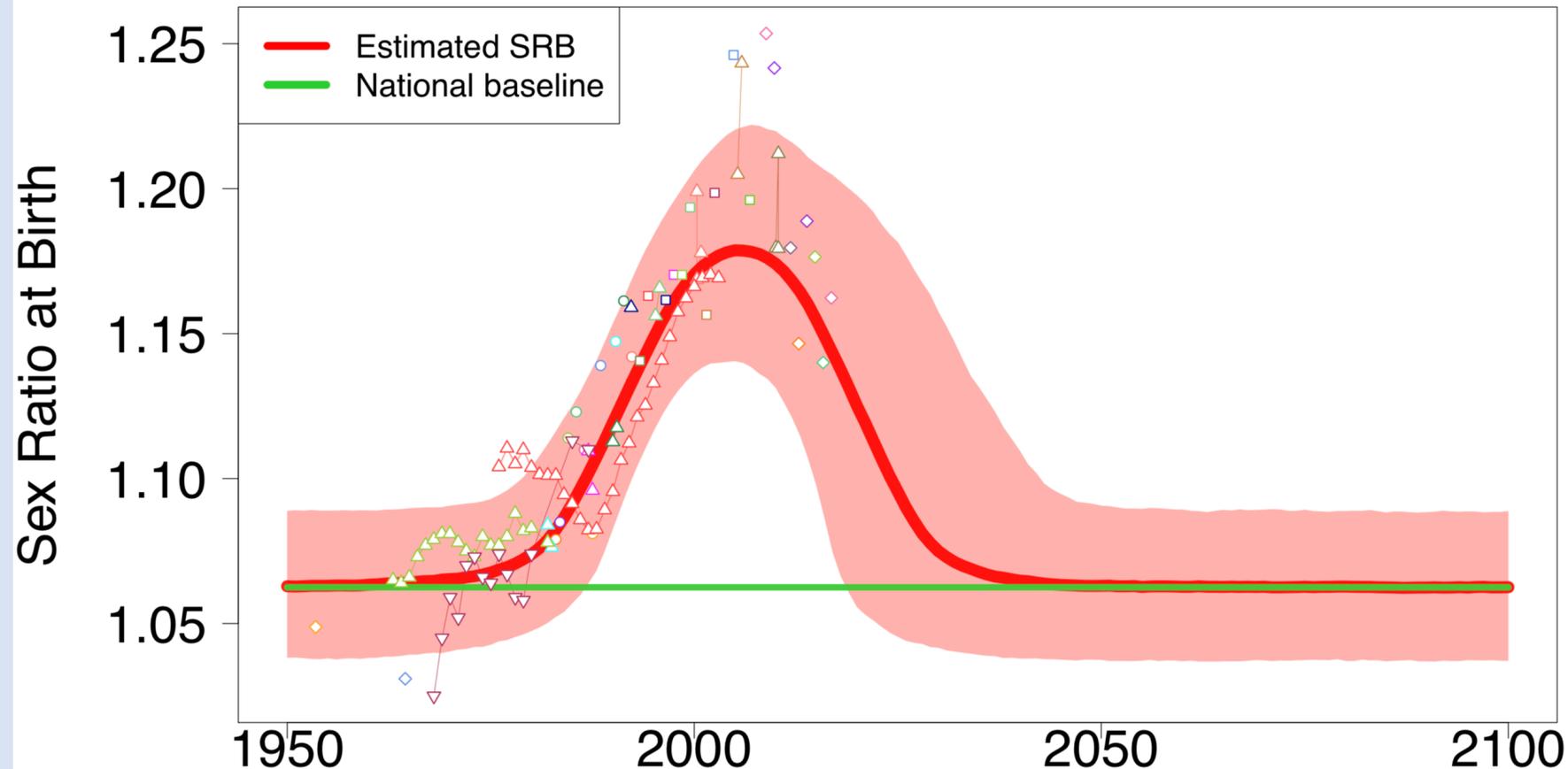
$$\epsilon_{c,t} \sim^{iid} N(0, \sigma_\epsilon^2)$$



# Inflation Model – Motivation

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

China



# 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

$$\delta_c \sim \text{Bernoulli}(\pi_c)$$

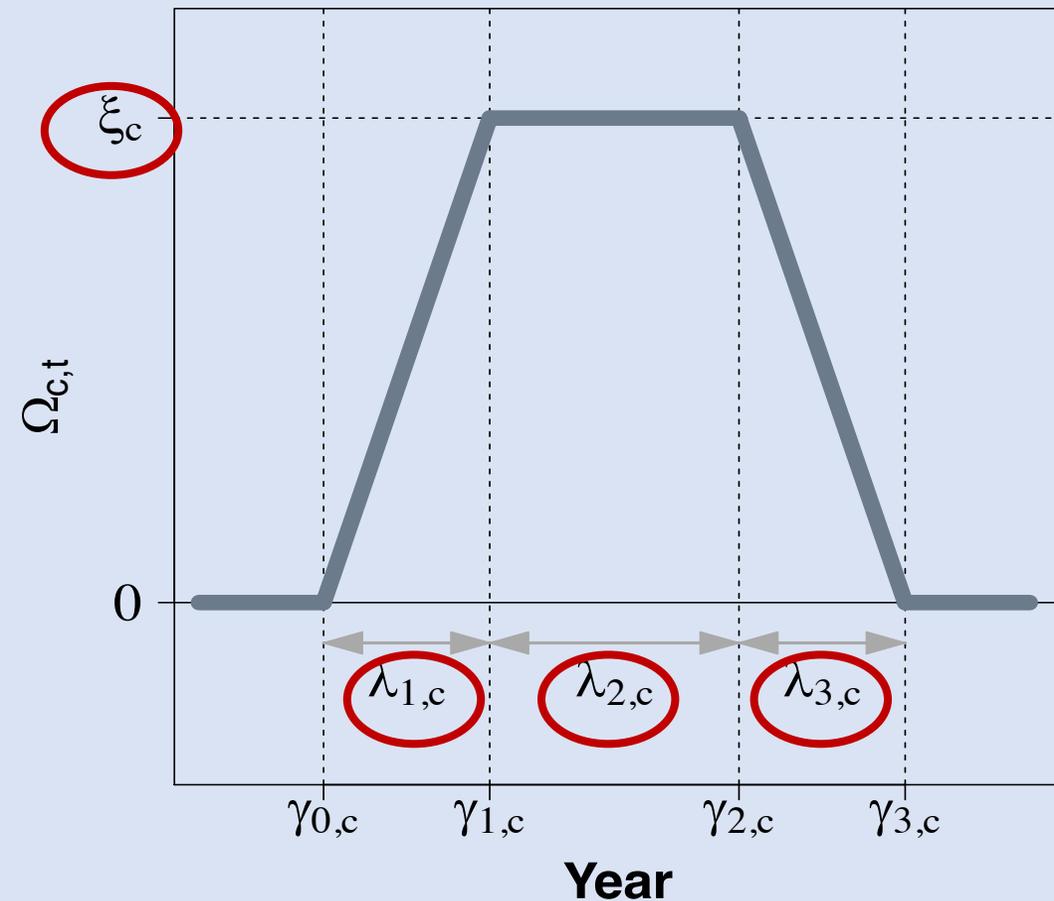
$$\text{logit}(\pi_c) \sim N(\mu_\pi, \sigma_\pi^2)$$

# 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

$$\lambda_{1,c} \sim N(\mu_{\lambda_1}, \sigma_{\lambda_1}^2) T(0,)$$

$$\lambda_{2,c} \sim N(\mu_{\lambda_2}, \sigma_{\lambda_2}^2) T(0,)$$

$$\lambda_{3,c} \sim N(\mu_{\lambda_3}, \sigma_{\lambda_3}^2) T(0,)$$

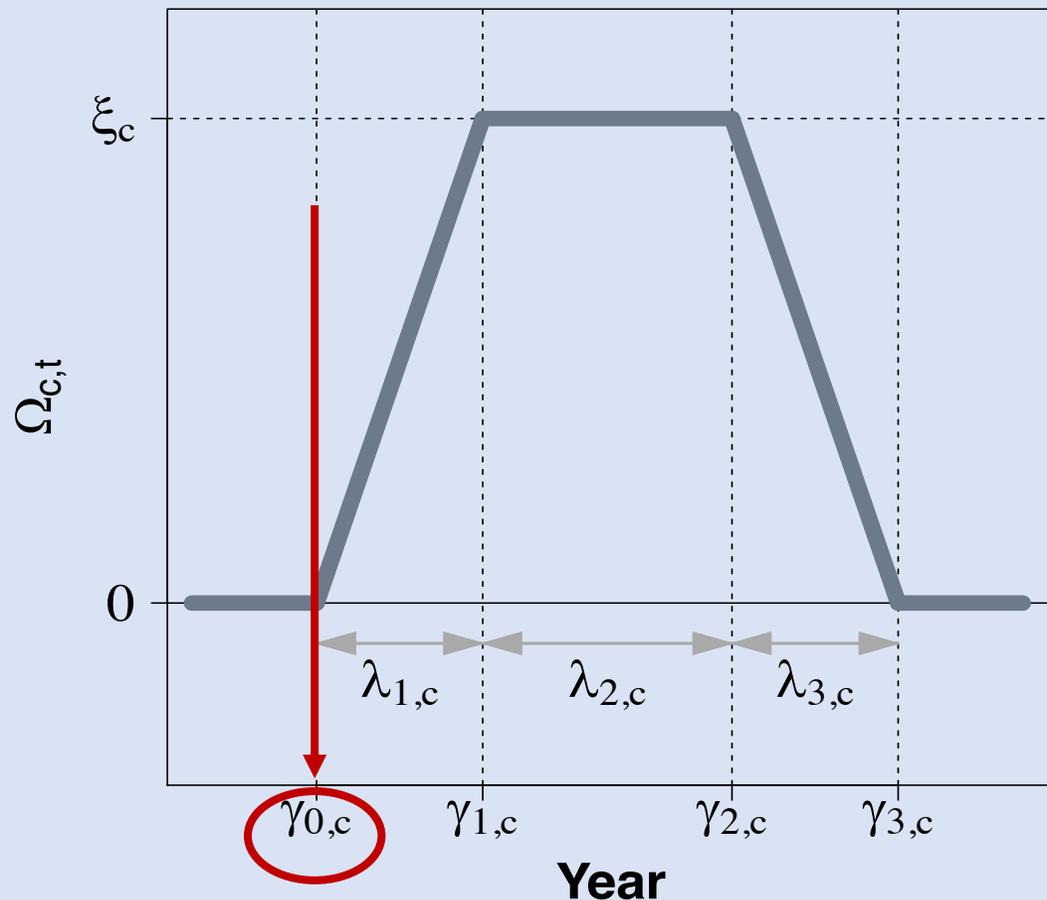
$$\xi_c \sim N(\mu_{\xi}, \sigma_{\xi}^2) T(0,)$$

# 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:

$$\gamma_{0,c} \sim t_3(f_{c,2.9}, \sigma_\gamma^2) T(f_{c,6},)$$

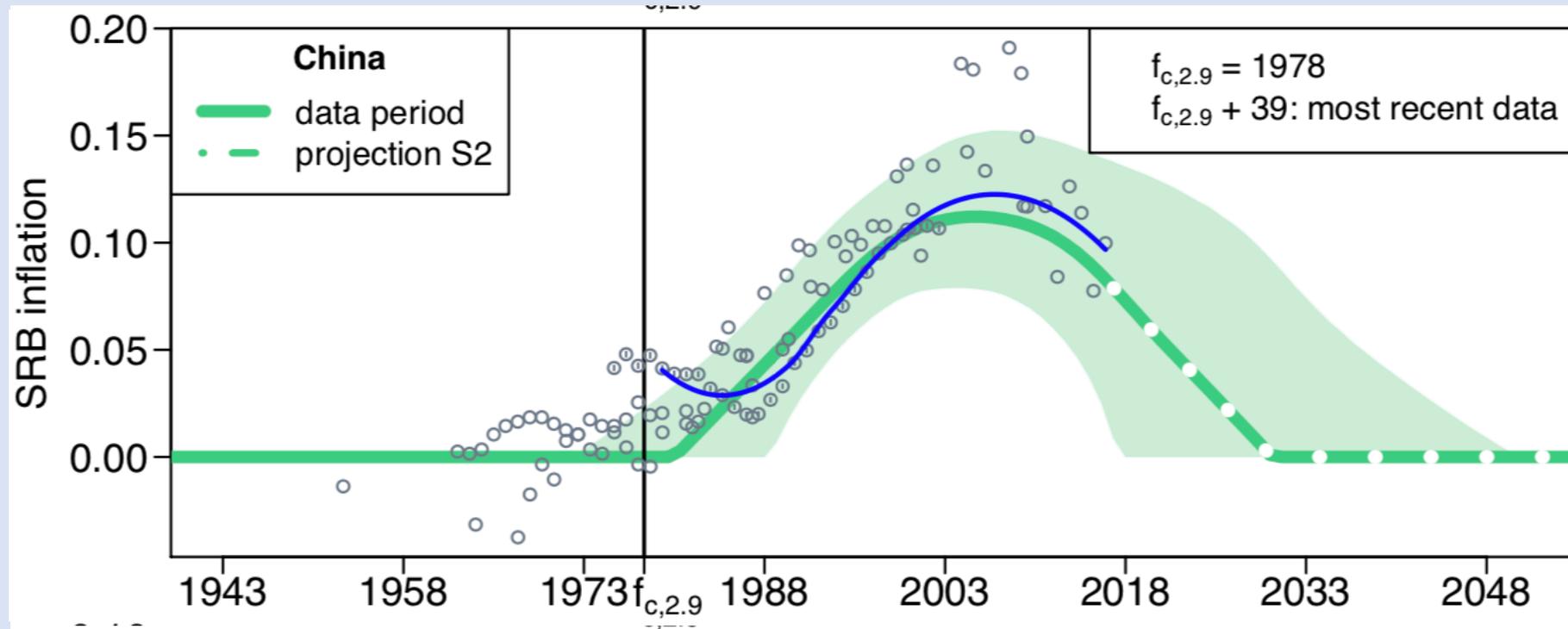
$f_{c,2.9}$ : year in which TFR declines to 2.9

$f_{c,6}$ : year in which TFR declines to 6

\*TFR: total fertility rate

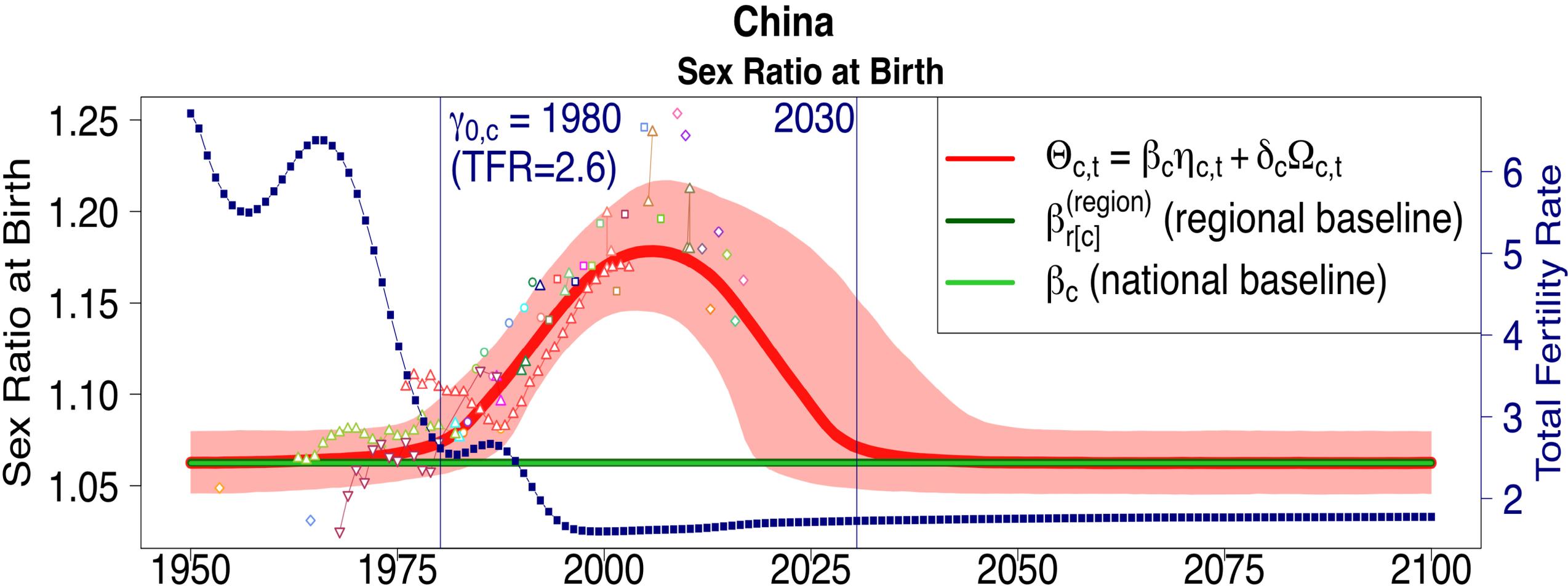
# Inflation Model and Data

Parametric form of  $\Omega_{c,t}$  captures the observed shape of inflated SRB



Data:  $y_i - \hat{\beta}_c$

# SRB Estimation and Projection Results for China



# Scenario-Based SRB Projection till 2100

Some at-risk countries have normal SRB



Willingness  
Son preference

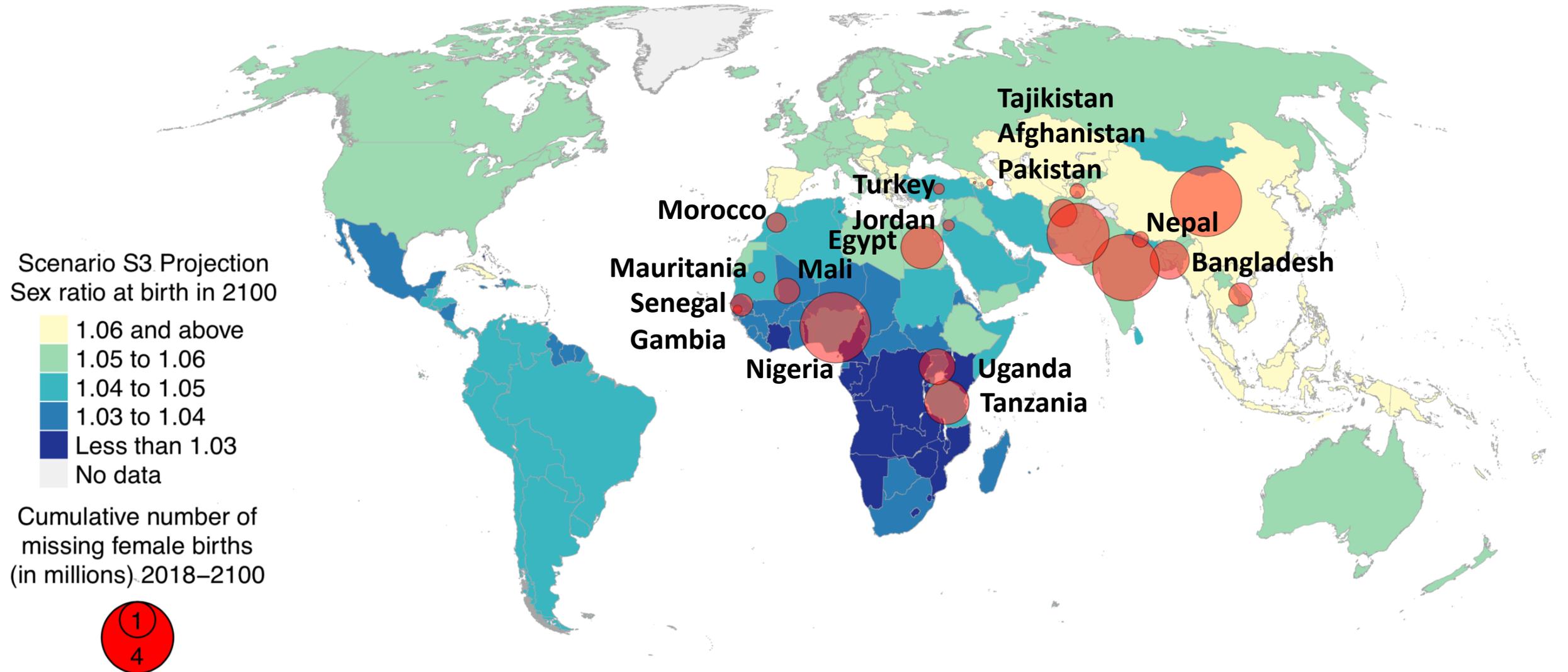
Necessary  
Fertility decline

Means  
Abortion + Sex  
detection

Sex-selective  
abortion

- 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  $\delta_c = 1$ 
$$\Theta_{c,t} = \beta_c \eta_{c,t} + \Omega_{c,t}$$

# SRB & Missing Female Births Projection till 2100

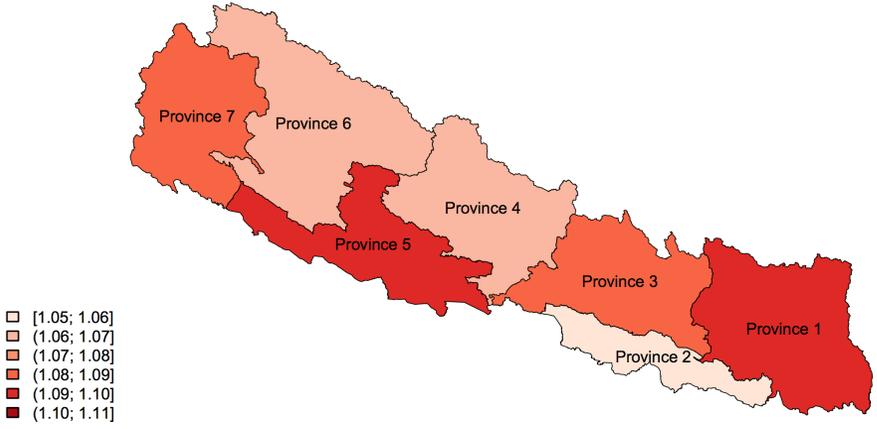


# SRB inflation within a country

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

## Nepal

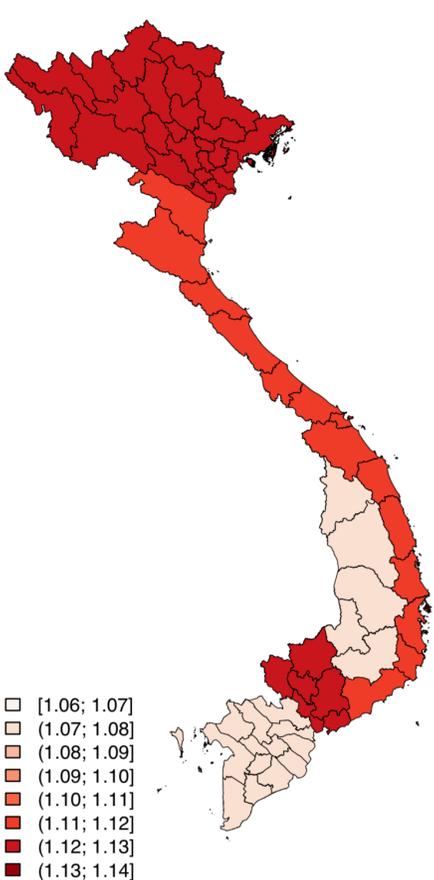
Sex Ratio at Birth Projection (2020)



Chao, F., KC, S., & Ombao, H. (2020). *arXiv preprint arXiv:2007.00437*.

## Vietnam

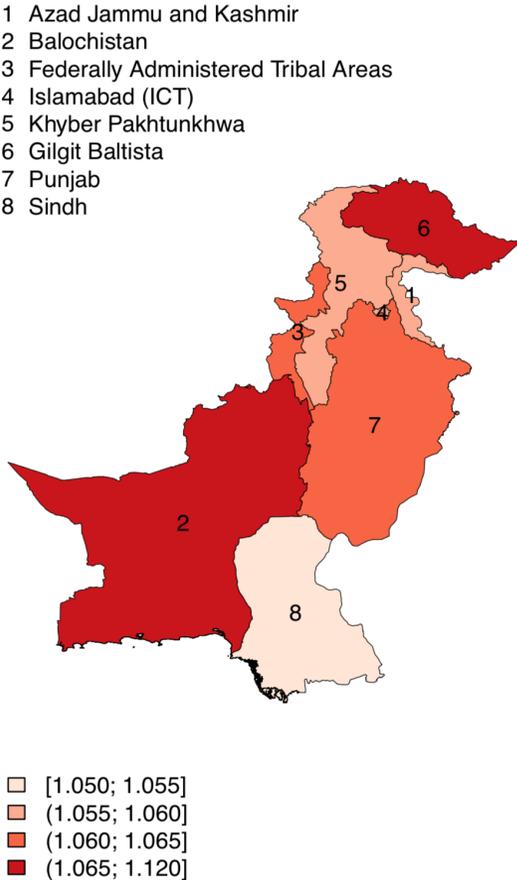
Sex Ratio at Birth Projection (2020)



Chao, F., Guilmoto, C. Z., & Ombao, H. Manuscript in preparation.

## Pakistan

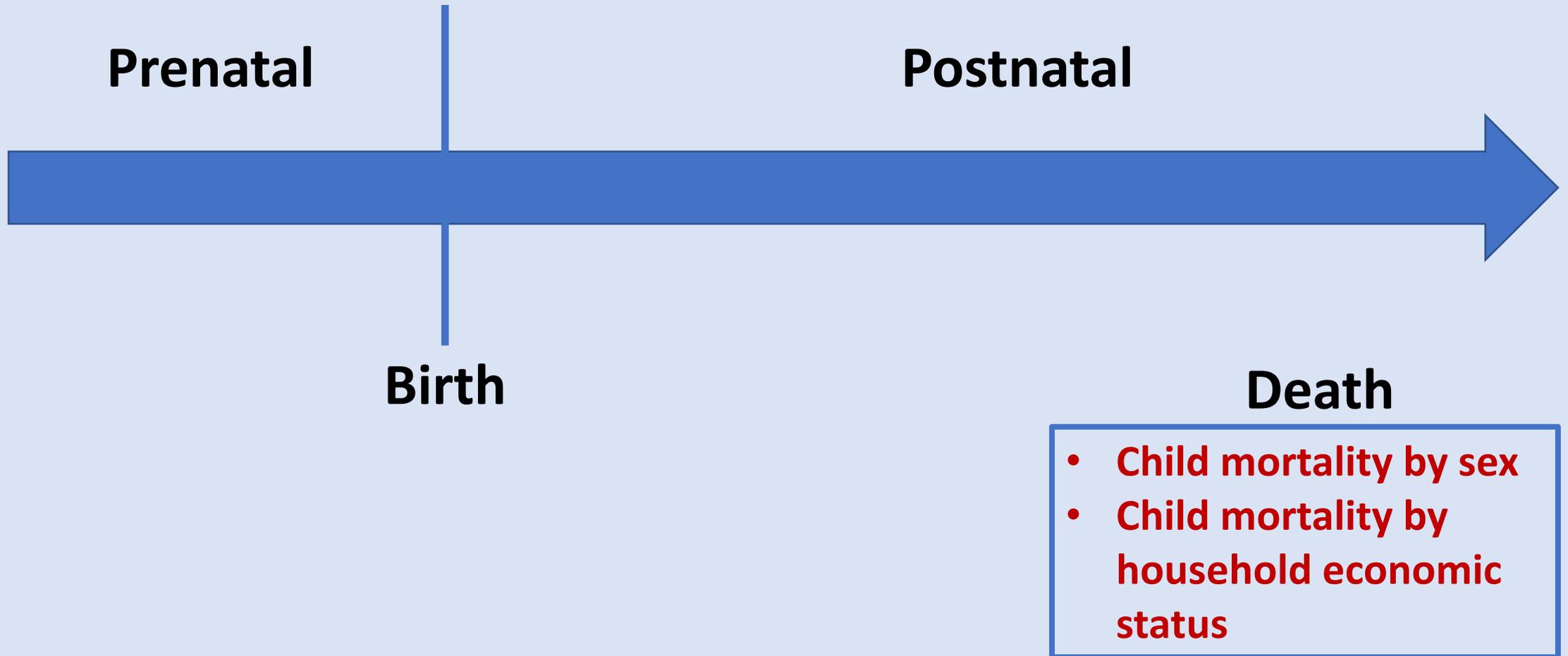
Sex Ratio at Birth, Pakistan (2000)



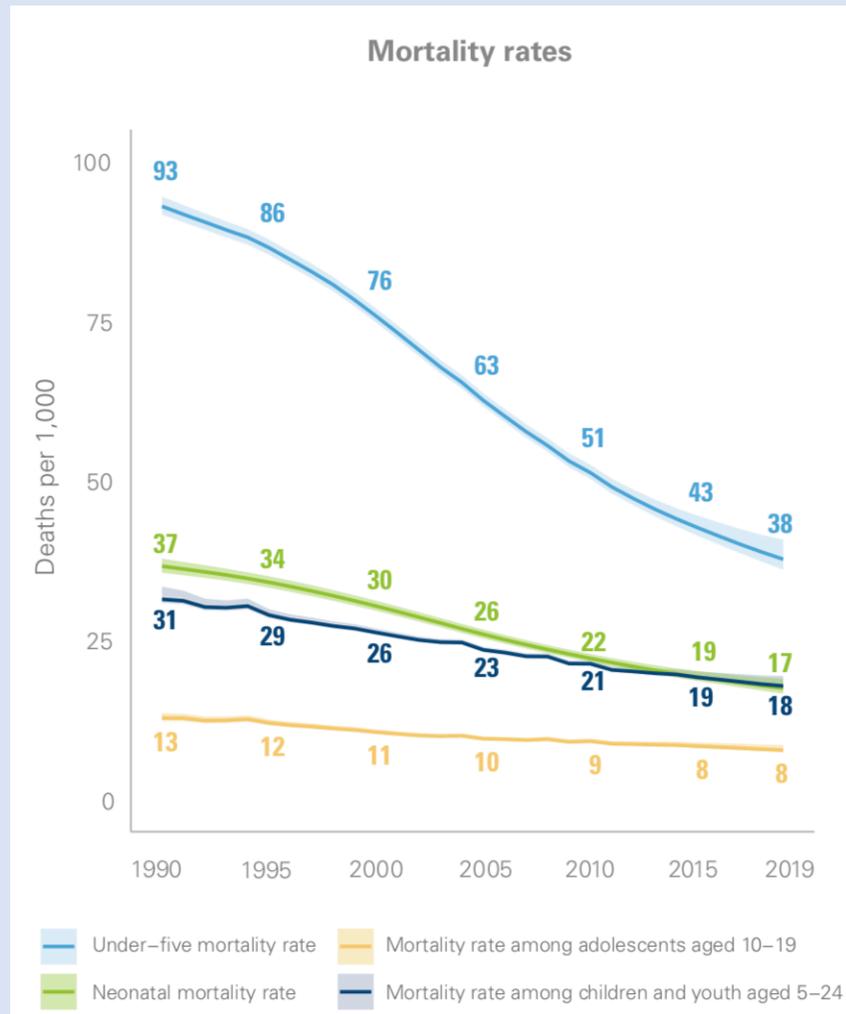
- 1 Azad Jammu and Kashmir
- 2 Balochistan
- 3 Federally Administered Tribal Areas
- 4 Islamabad (ICT)
- 5 Khyber Pakhtunkhwa
- 6 Gilgit Baltista
- 7 Punjab
- 8 Sindh

Chao, F., Wazir, M. A. & Ombao, H. Manuscript in preparation.

# Looking into Child Mortality Disparity



# 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

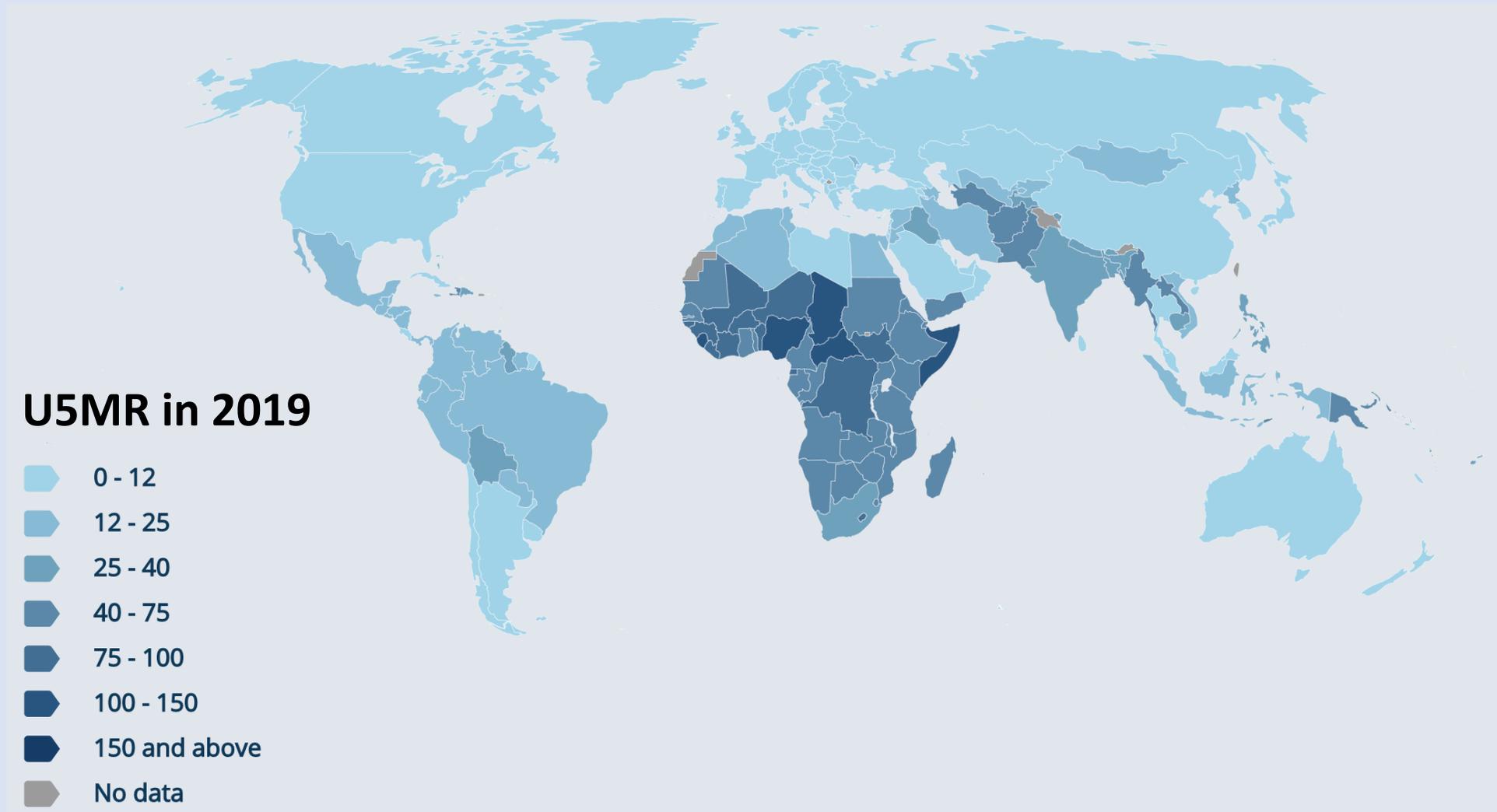
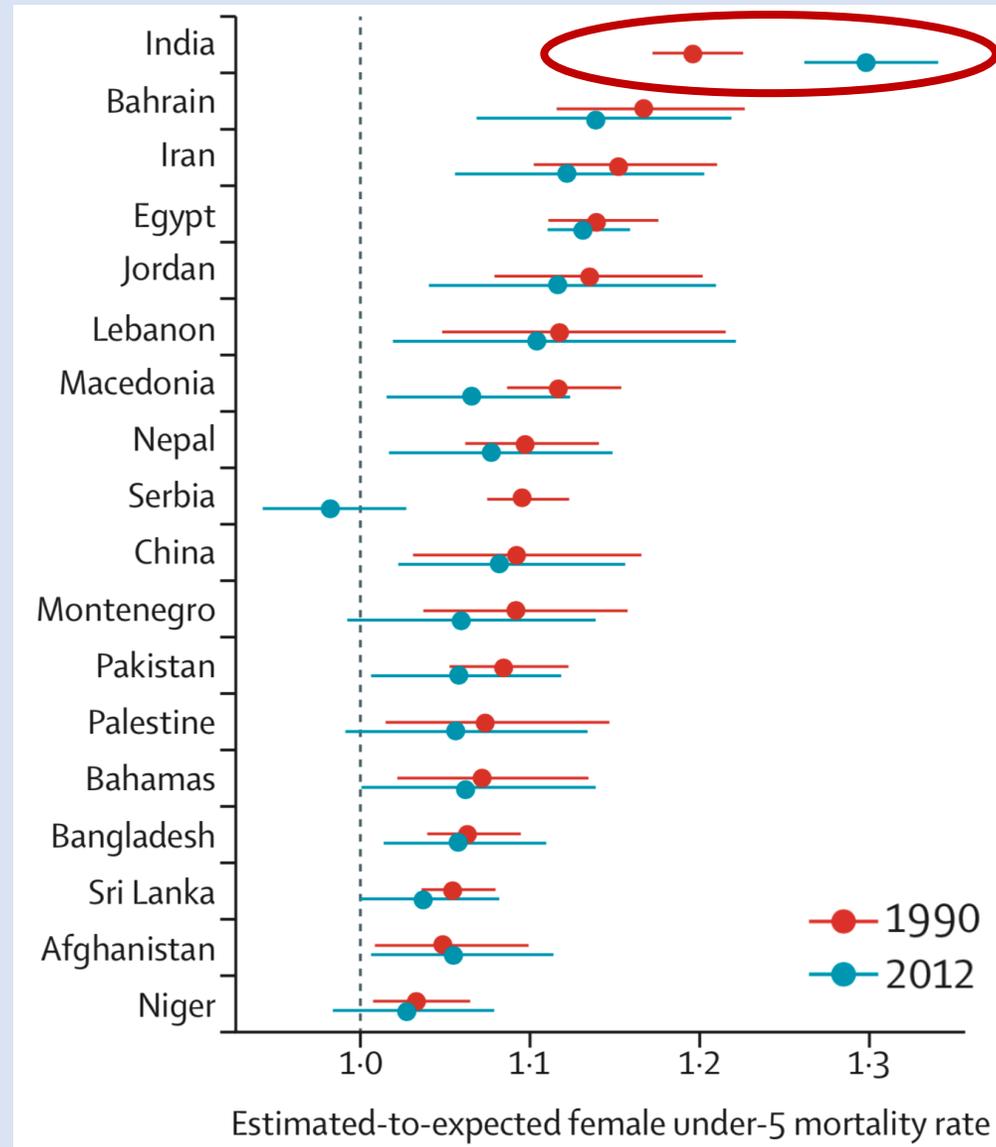


Image credit: UN IGME. Levels & Trends in Child Mortality: Report 2020.

# U5MR Disparity Between Girls and Boys

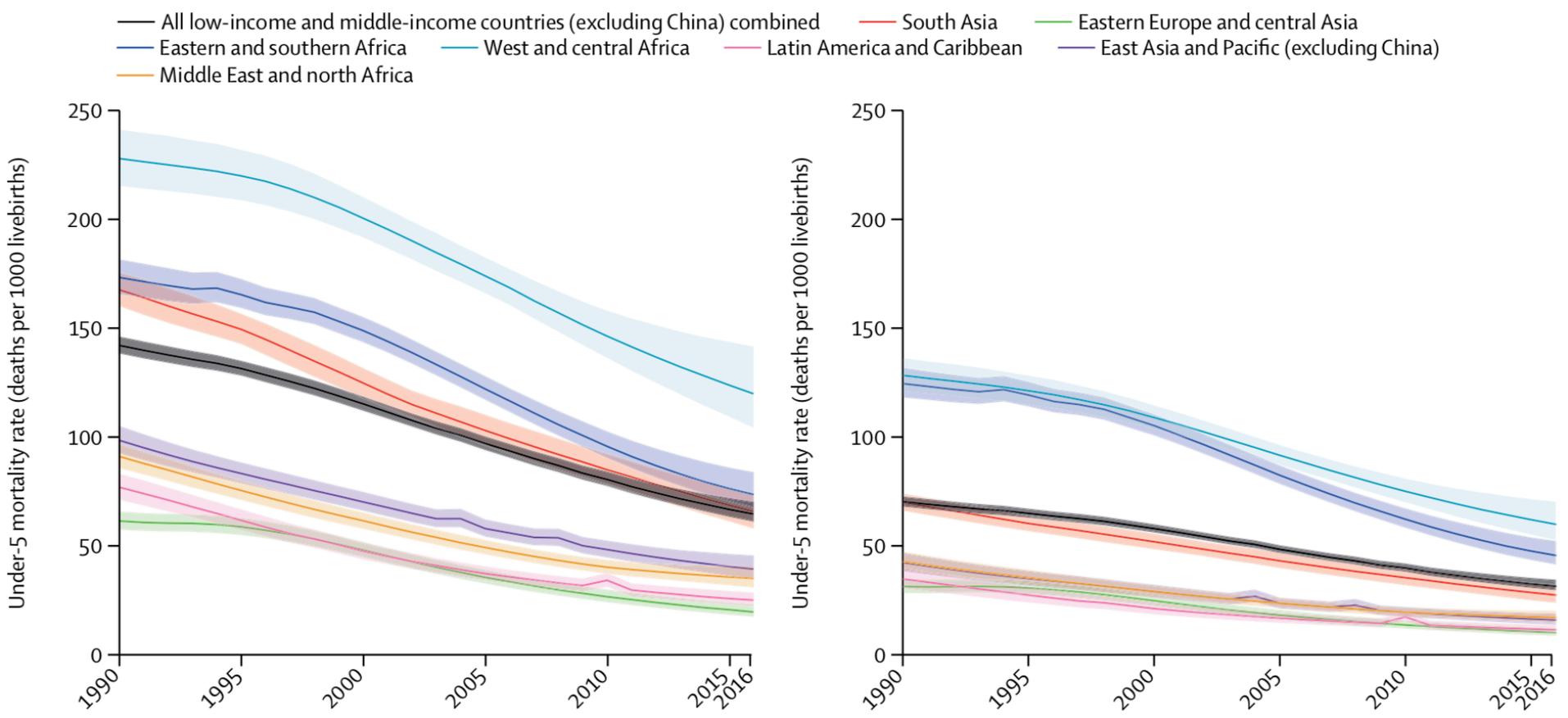
## Identify the Most Disadvantaged, Vulnerable Children

- 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.**

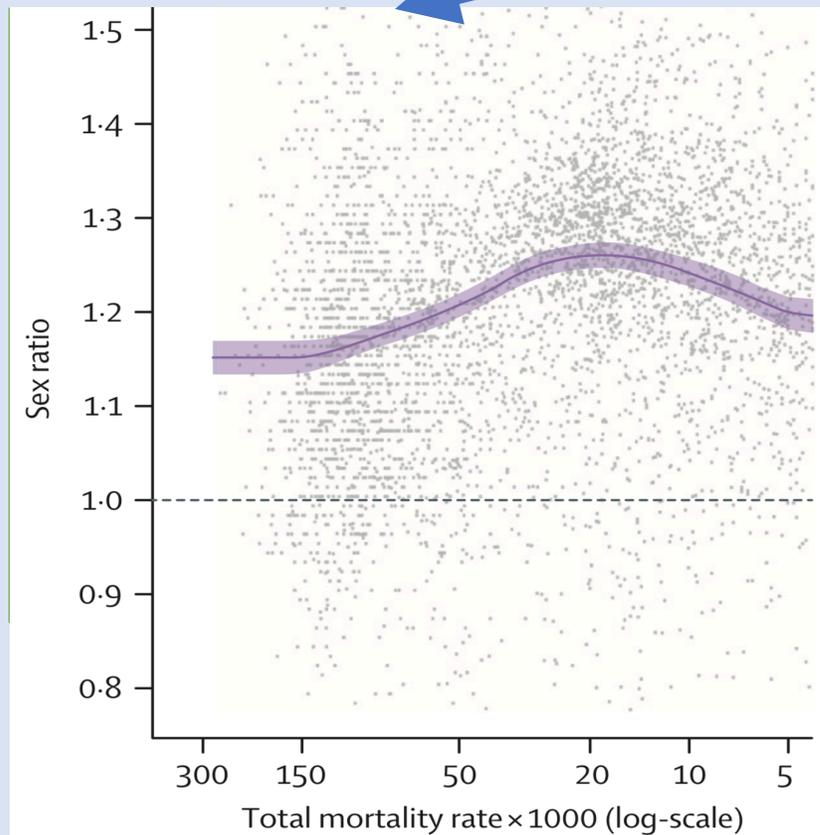


Chao, F., You, D., Pedersen, J., Hug, L., & Alkema, L. (2018). *Lancet GH*, 6(5), e535-e547.

# 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

$$\log(P_{c,t}) = \mu + \rho [\log(P_{c,t-1}) - \mu] + \epsilon_{c,t}$$

$$\epsilon_{c,t} \sim \text{iid } N(0, \sigma_{\epsilon}^2)$$

Image credit: Alkema, L., Chao, F., You, D., Pedersen, J., & Sawyer, C. C. (2014). *Lancet GH*, 2(9), e521-e530.

# Research to the Real World

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

Levels & Trends in **Child Mortality** | **Report 2020**  
Estimates developed by the UN Inter-agency Group for Child Mortality Estimation

Levels & Trends in **Child Mortality** | **Report 2019**  
Estimates developed by the UN Inter-agency Group for Child Mortality Estimation

Levels & Trends in **Child Mortality** | **Report 2018**  
Estimates developed by the UN Inter-agency Group for Child Mortality Estimation

Levels & Trends in **Child Mortality** | **Report 2017**  
Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation

Levels & Trends in **Child Mortality** | **Report 2015**  
Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation

Levels & Trends in **Child Mortality** | **Report 2014**  
Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation

UNICEF reports:  
[childmortality.org](http://childmortality.org)

\*Chao, F., You, D., Pedersen, J., Hug, L., & Alkema, L. (2018). *Lancet GH*, 6(5), e535-e547.

†Alkema, L., Chao, F., You, D., Pedersen, J., & Sawyer, C. C. (2014). *Lancet GH*, 2(9), e521-e530.

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- Alkema L, Chao F, You D, Pedersen J, Sawyer CC. National, regional, and global sex ratios of infant, child, and under-5 mortality and identification of countries with outlying ratios: a systematic assessment. *The Lancet Global Health*. 2014 Sep 1;2(9):e521-30.
- Chao F, You D, Pedersen J, Hug L, Alkema L. National and regional under-5 mortality rate by economic status for low-income and middle-income countries: a systematic assessment. *The Lancet Global Health*. 2018 May 1;6(5):e535-47.