A Bayesian Model to Estimate Male and Female Fertility Patterns at a Subnational Level

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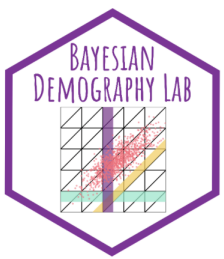
September 11, 2024



Importance of measuring male fertility

- Male fertility measurement is overlooked (Coleman 2000)
- Increasing involvement of men in fertility decisions (Lappegård et al. 2011)
- Trajectories in male fertility can differ systematically from those of women due to:
  - **different reproductive age spans** (Schoumaker 2019)
  - **unbalanced sex ratios** (Dudel & Klüsener 2016)
  - **distinct cultural norms** (Dudel & Klüsener 2021)

Objectives

- **Goal** $\rightarrow$ construction of a Bayesian model to estimate **male** and **female period TFR** at a **subnational** level
  - Essential component of population change
  - Shape local policies
- **Data example** $\rightarrow$ **US counties** during the **period 1982-2019**
  - High heterogeneity in fertility behaviors across time and space
  - High quality data registration systems

Challenges

- Data on births disaggregated by **paternal ages** are often unavailable
  - Countries with **inefficient data registration systems** or lacking **high quality surveys**
  - Small regions with **masked ages** at **childbearing** due to **privacy concerns**
- Even in developed countries, birth registration systems have started recording childbearing ages of men quite recently
- The share of births with missing paternal ages is much higher than for maternal ages (Dudel & Klüsener 2016)

Methodological Framework

Build on the **Bayesian model** by Schmertmann & Hauer (2019)

Idea $\rightarrow$ Estimation of period Total Fertility Rate (TFR) without knowledge of births by maternal ages

Data Requirements

- **Counts of children under 5**
- **Counts of women aged 15-49**

Prior requirement

- **Child mortality estimates**
- **Standard age-specific fertility schedules**

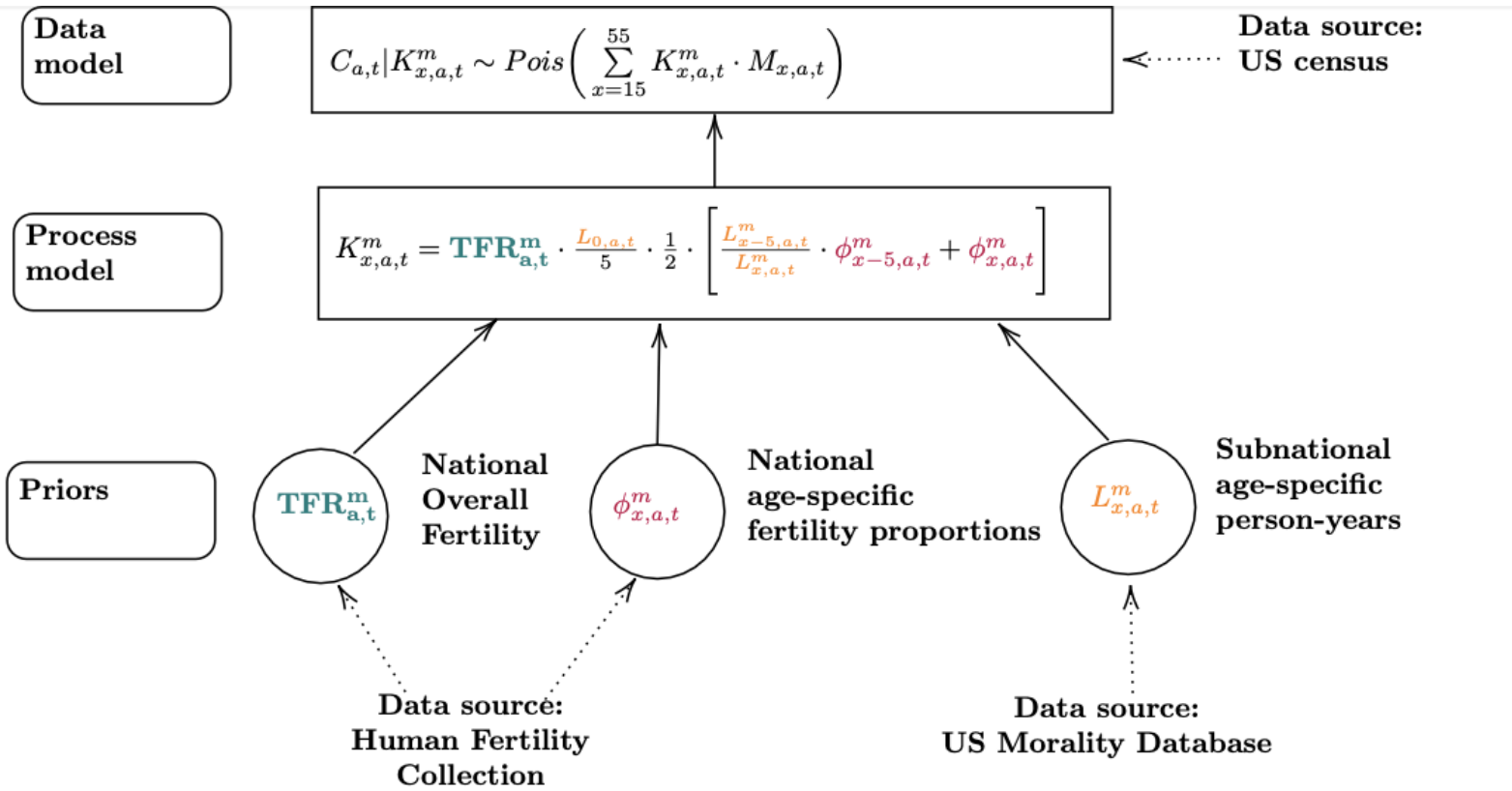
Proposed extension

Extend the previous **Bayesian model** to estimate **male** and female **fertility** at a **subnational level**

Extensions

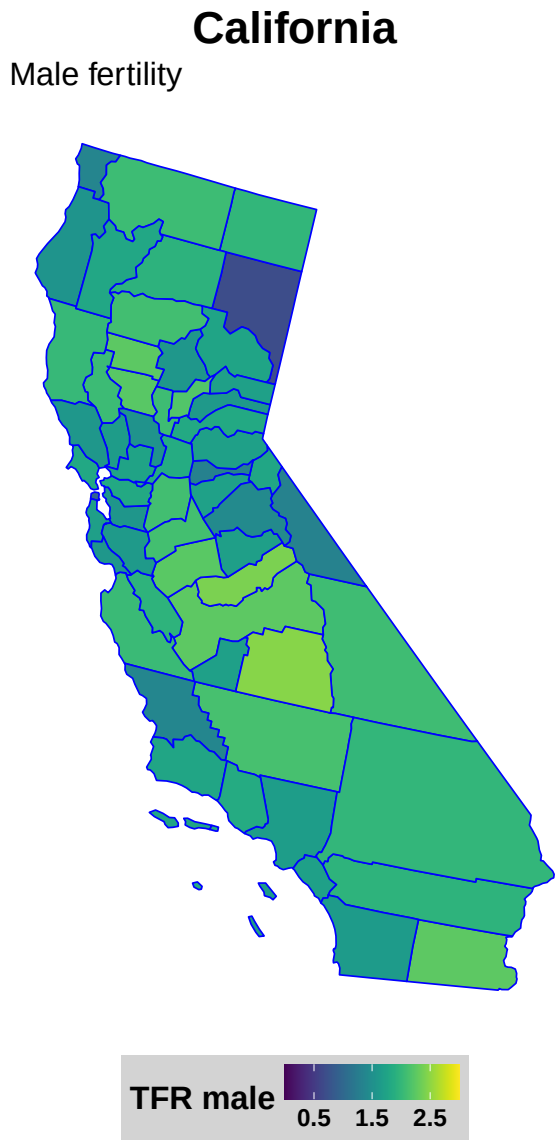
- Inclusion of **men aged 15-59**
- Incorporation of **subnational mortality estimates**
- Account for spatial dependencies $\rightarrow$ **information pooling**
- Account for temporal dependencies $\rightarrow$ **temporal smoothing**

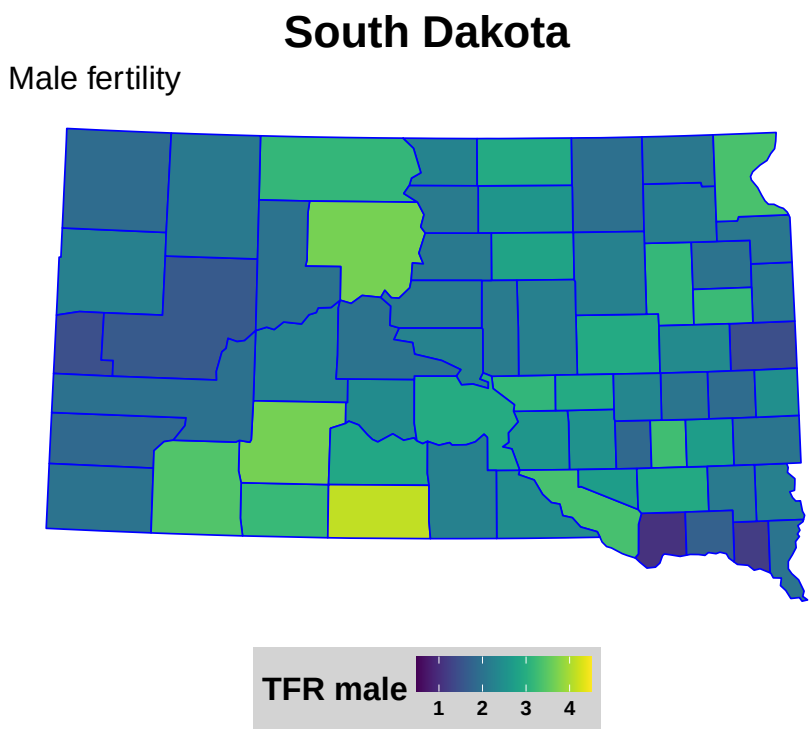
Bayesian model summary



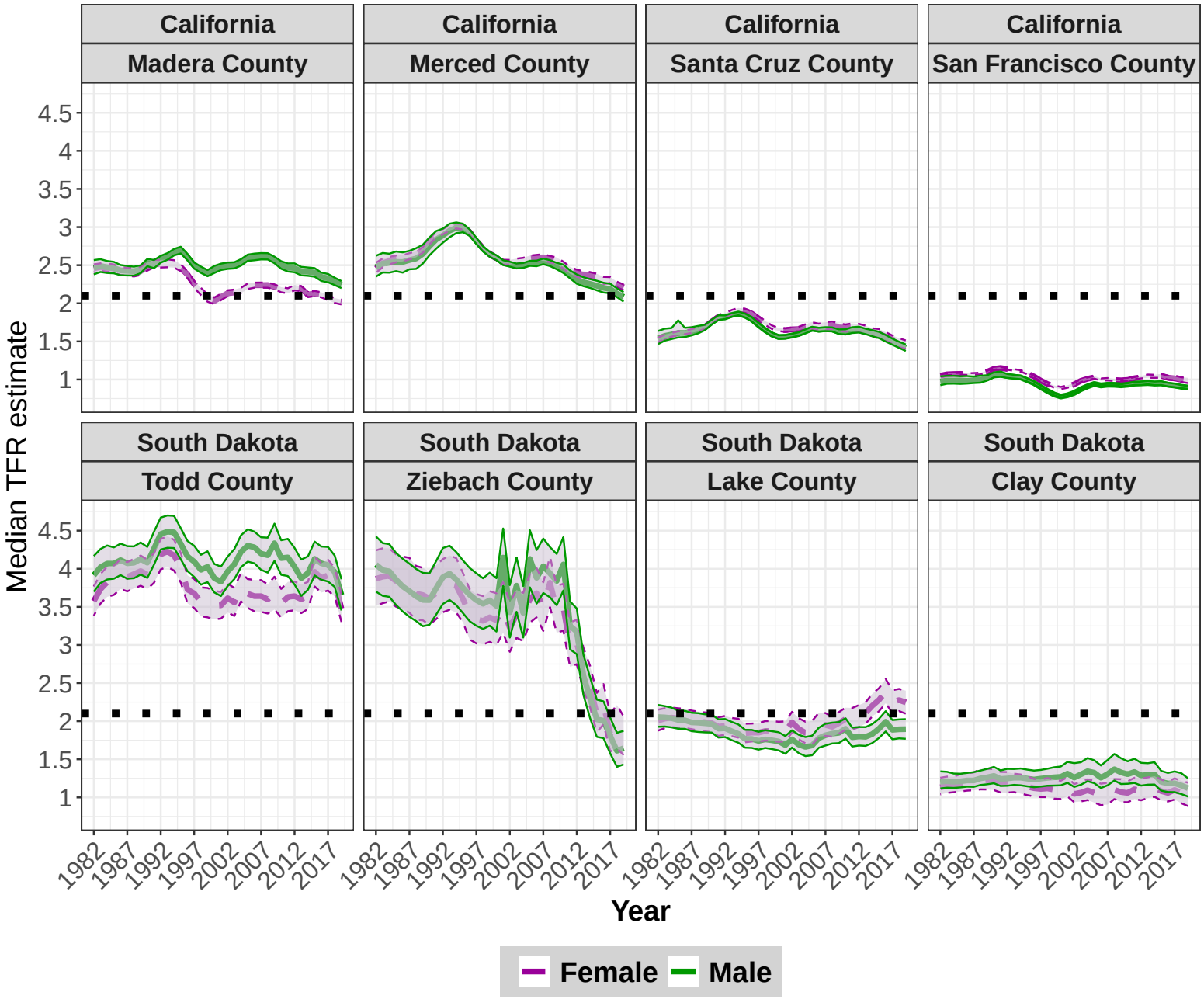
Final Goal→ Draw samples from the **marginal posterior distribution** $TFR^s_{a,t}|$data, other parameters

California and South Dakota in 2015





Male and female TFR in selected counties



Preliminary conclusions

- Using **county-level population counts** by age and sex allows to derive **subnational** period TFR estimates without the need of information on parental ages.
- No striking differences between **male** and **female fertility**
- Country-specific characteristics determine a high **spatial heterogeneity** and **distinct temporal trajectories**.

Future research

- Account for **internal migration**
- Test the model on other countries
- Better examine the relationship between sex-specific **TFR** and **unbalanced sex ratios**.

Any Questions??

Looking forward to your feedback!

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Acknowledgements: ERC Grant GENPOP n. 865356

Essential Bibliography

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Bayesian model

Data model:

$$C_{a,t}|K^s_{x,a,t} \sim \text{Pois}\left(\sum_{x=15}^{\omega^s} K^s_{x,a,t} \cdot E^s_{x,a,t}\right)$$

$$K^s_{x,a,t} = TFR^s_{a,t} \cdot \frac{\tilde{L}_{0,a,t}}{5} \cdot \frac{1}{2} \cdot \left[\frac{\tilde{L}^s_{x-5,a,t}}{\tilde{L}^s_{x,a,t}} \cdot \phi^s_{x-5,a,t} + \phi^s_{x,a,t}\right]$$

with $w^F = 45$ and $w^M = 55$

- **Overall fertility** ($TFR^s_{a,t}$)
- **Age- and sex-specific fertility proportions** ($\phi^s_{x,a,t}$)
- **Age- and sex-specific person-years** ($L^s_{x,a,t}$)

Priors on fertility parameters

Prior on TFR

$$TFR^s_{a,t} \sim \mathcal{N}(TFR^{nat,s}_t, \sigma^2_{TFR^s_{a,t}})$$

Prior on age-specific fertility patterns

$$\gamma^s_{x,a,t} = m^s_x + y^s_{1,x}\beta^s_{1,a,t} + y^s_{2,x}\beta^s_{2,a,t}$$

$\gamma^s_{x,a,t} = \log\left(\frac{\phi^s_{x,a,t}}{\phi^s_{15,a,t}}\right)$

Pooling information over countries

$$\beta^s_{p,a,t} \sim \mathcal{N}(\mu_{\beta^s_{p,t}}, \sigma^2_{\beta^s_{p,a,t}})$$

Smoothing over time

$$\mu_{\beta^s_{p,t}} \sim \mathcal{N}(2\mu_{\beta^s_{p,t-1}} - \mu_{\beta^s_{p,t-2}}, \sigma^2_{\mu_{\beta^s_{p,t}}})$$

Priors on mortality and standard deviation parameters

Prior on Person-years

$$\tilde{L}_{0,a,t} \sim \mathcal{N}(\hat{L}_{0,a,t}, \hat{\sigma}^2_{\hat{L}_{0,a,t}})$$

$$\tilde{L}^s_{x,a,t} \sim \mathcal{N}(\hat{L}^s_{x,a,t}, \hat{\sigma}^2_{\hat{L}_{0,a,t}})$$

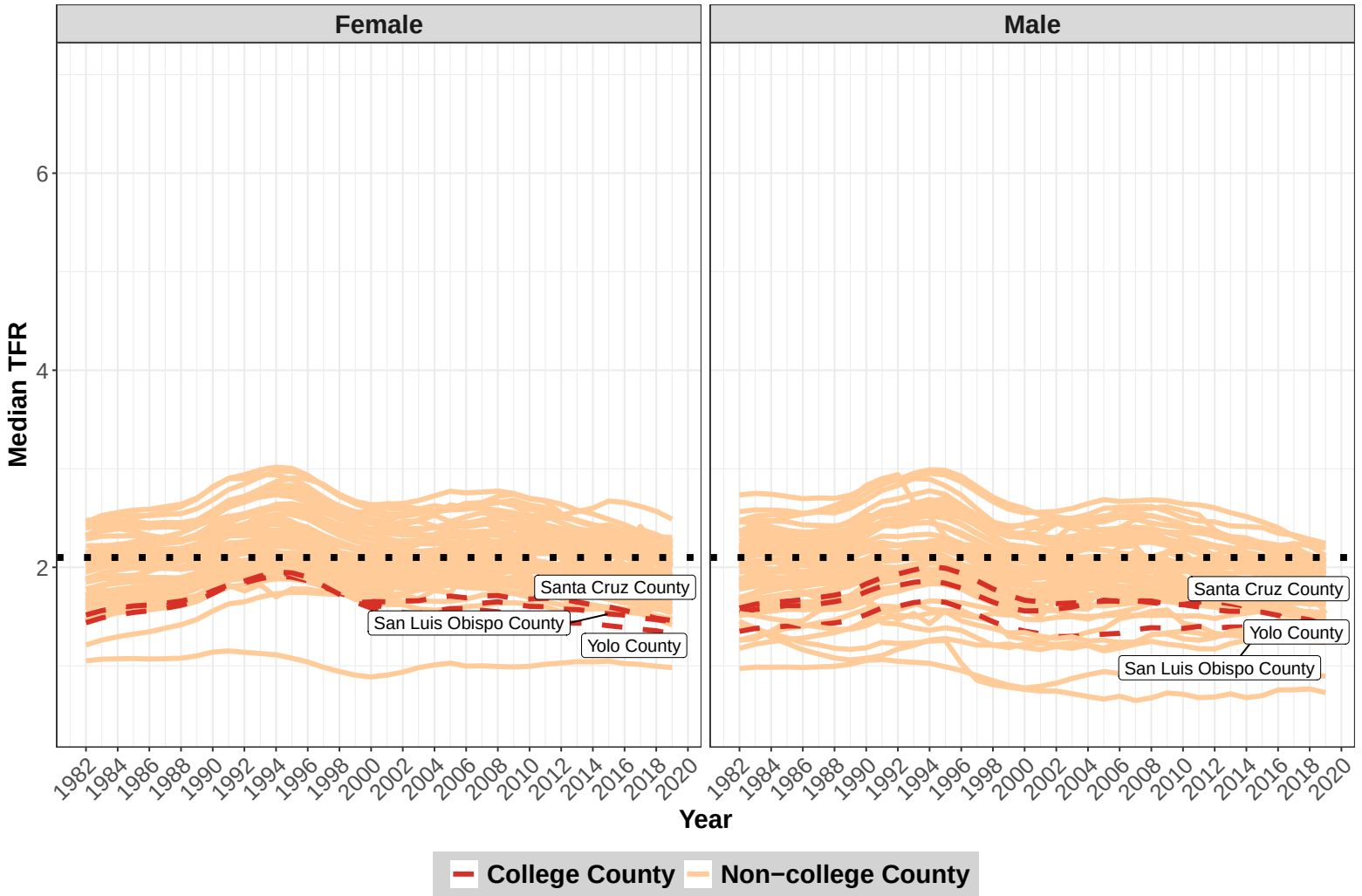
- $\tilde{L}^s_{x,a,t}$ from age-, period- and sex-specific subnational life tables
- Variances calculated from the standard errors available from the subnational life tables

Prior on standard deviation parameters

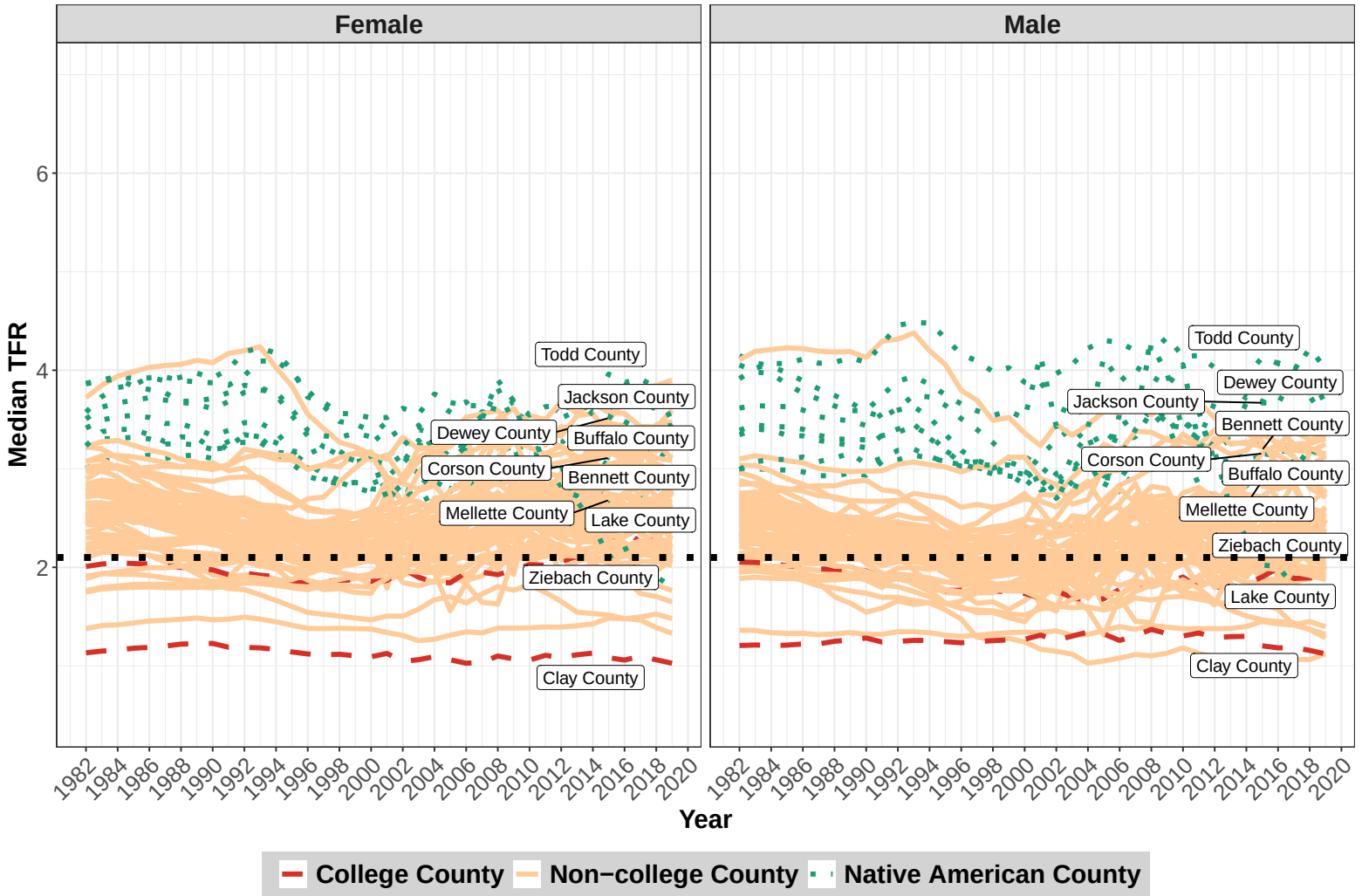
$$\sigma_{\beta^s_{p,a,t}}, \sigma_{TFR^s_{a,t}}, \sigma_{\mu_{\beta^s_{p,t}}} \sim \mathcal{N}^+(0, 1)$$

- weakly informative priors

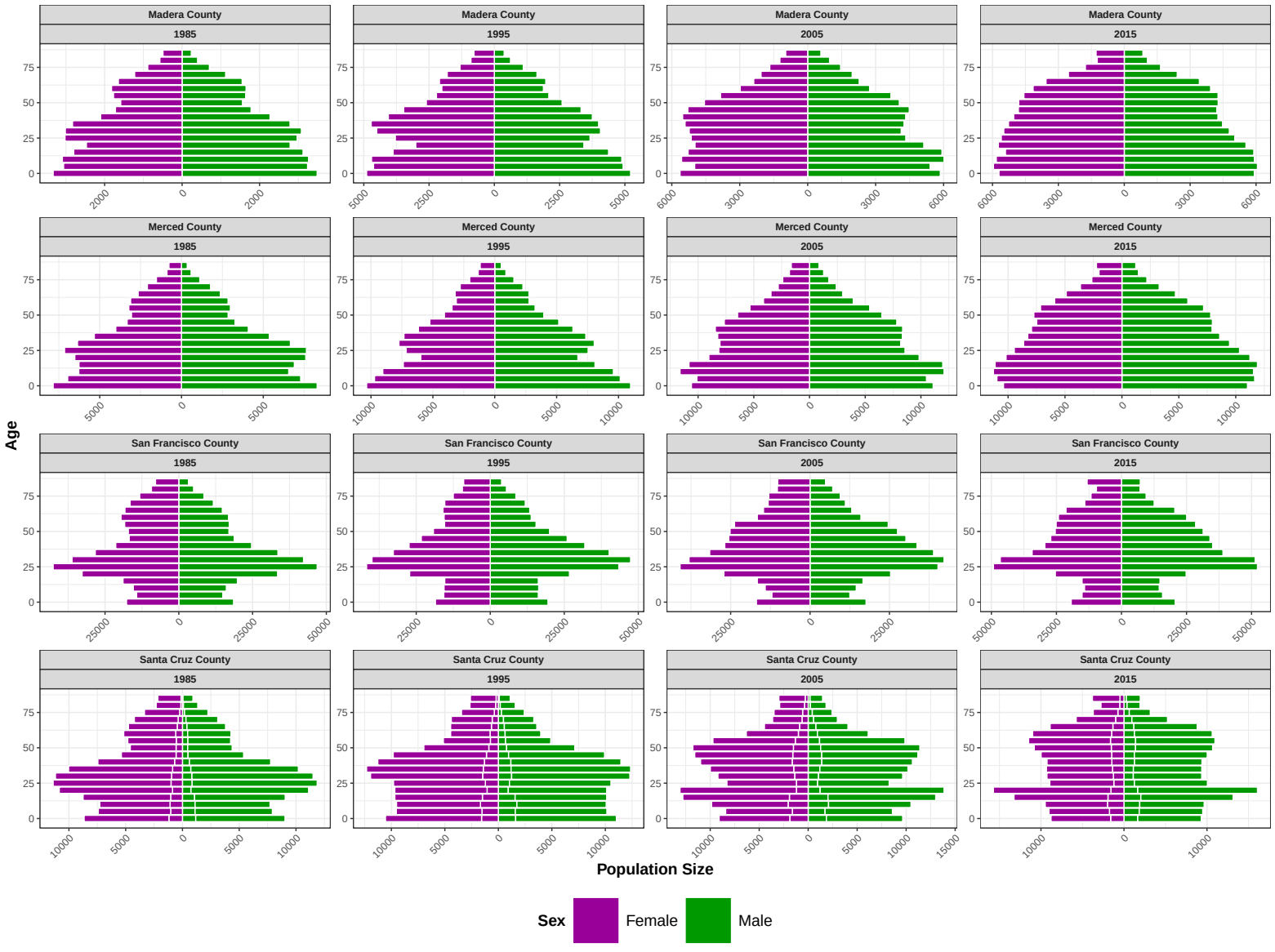
Appendix: California TFR trajectories



Appendix: South Dakota TFR trajectories



Appendix: population pyramids (1)



Appendix: population pyramids (2)