

Measuring and understanding inequalities in parental loss

New statistical methods and estimates

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Introduction

- Demographer, with a background in statistics
- Interested in demographic questions in contexts where populations/outcomes are hard to measure
- A large part of my work centres on developing Bayesian methods for demographic estimation



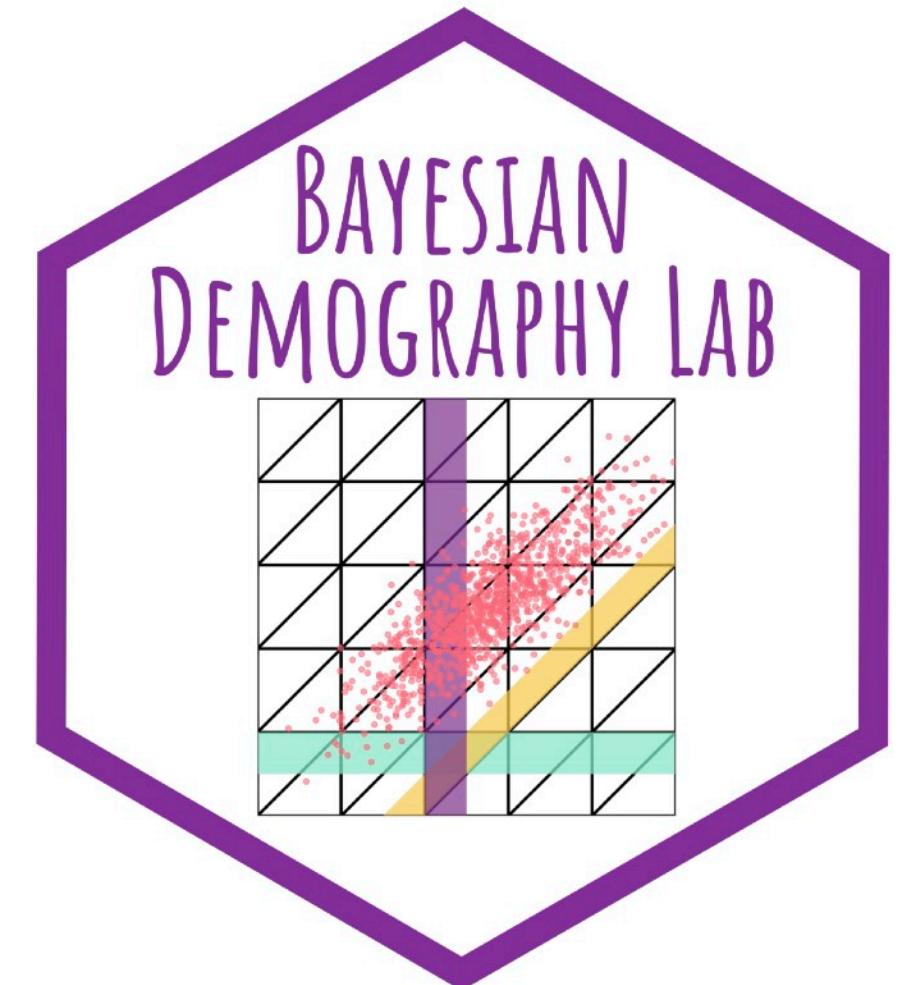
Grew up in Hobart, Tasmania, Australia



Masters/PhD at UC Berkeley

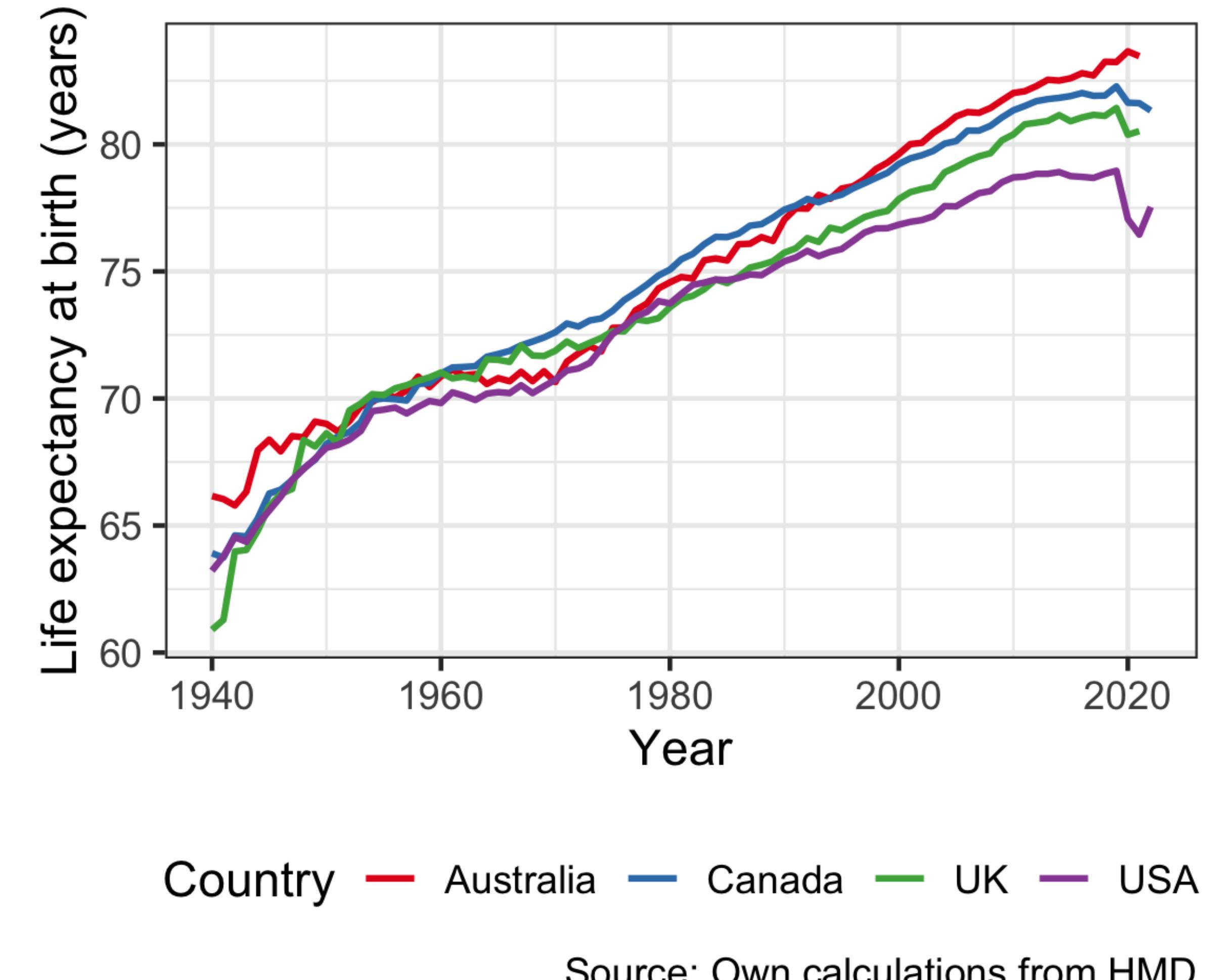


Associate Prof at University of Toronto



Motivation

- Life expectancy in the United States has been stagnating (Abrams et al, 2023)
- The rise of young- and middle-age adult mortality is a well-documented contributor (Polizzi and Dowd, 2024)
- Disparities in mortality by race/ethnicity persist (Dwyer-Lindgren et al, 2022, Hendi 2024)



Beyond death counts: changing the viewpoint

- Focus on **parental loss**
- An increase in adult mortality implies an increase in children who have lost a parent at a young age
- Taking key demographic quantities and changing the viewpoint
- Analyzing demographic rates from a different perspective uncovers new information about social phenomena (e.g. Bumpass and Lu 2000; Alburez-Gutierrez 2022)

The importance of studying parental loss

- The premature death of a parent is negatively associated with a range of outcomes (educational, health, economic) (Niederkrotenthaler et al. 2012; Pham et al. 2018; Patterson et al. 2022)
- Differing levels of parental death in different societies has implications for evolution of family structure, support of extended kin (Umberson 1995; Daw et al. 2016; Jiang et al. 2023)
- Macro implications of support required from healthcare and foster care systems (Roehrkasse 2021)
- Substantial racial/ethnic disparities in mortality translate into vastly different exposures to parental death, contributing to cumulative disadvantage (Umberson 2017, Umberson et al. 2017)

How do we estimate parental loss?

- Quantifying the number of children who have lost a parent is not necessarily straightforward
- Not recorded on death certificates, linked data is restricted
- Parental loss captured in some surveys, but sample sizes are small, some groups are underrepresented, and cause of death is usually not known

How do we estimate parental loss?

- Estimation is possible using vital rates (births and deaths) and demographic projection models
- But these have strong assumptions, and do not allow for the combination of data sources, or uncertainty quantification
- (Bayesian) statistical methods provide a framework to extend classical demographic methods to overcome some limitations

This talk

- Two projects on parental loss in the United States context
 - Youth who have lost a parent due to drugs and firearms
 - Time lived without parents
 - Highlight differences by race/ethnicity
- Methodological contributions:
 - Extend existing demographic methods to estimate parental loss by cause
 - Develop a Bayesian statistical framework to combine multiple data sources on parental loss

Youth experiencing parental
deaths due to drug poisonings
and firearm violence

Motivation

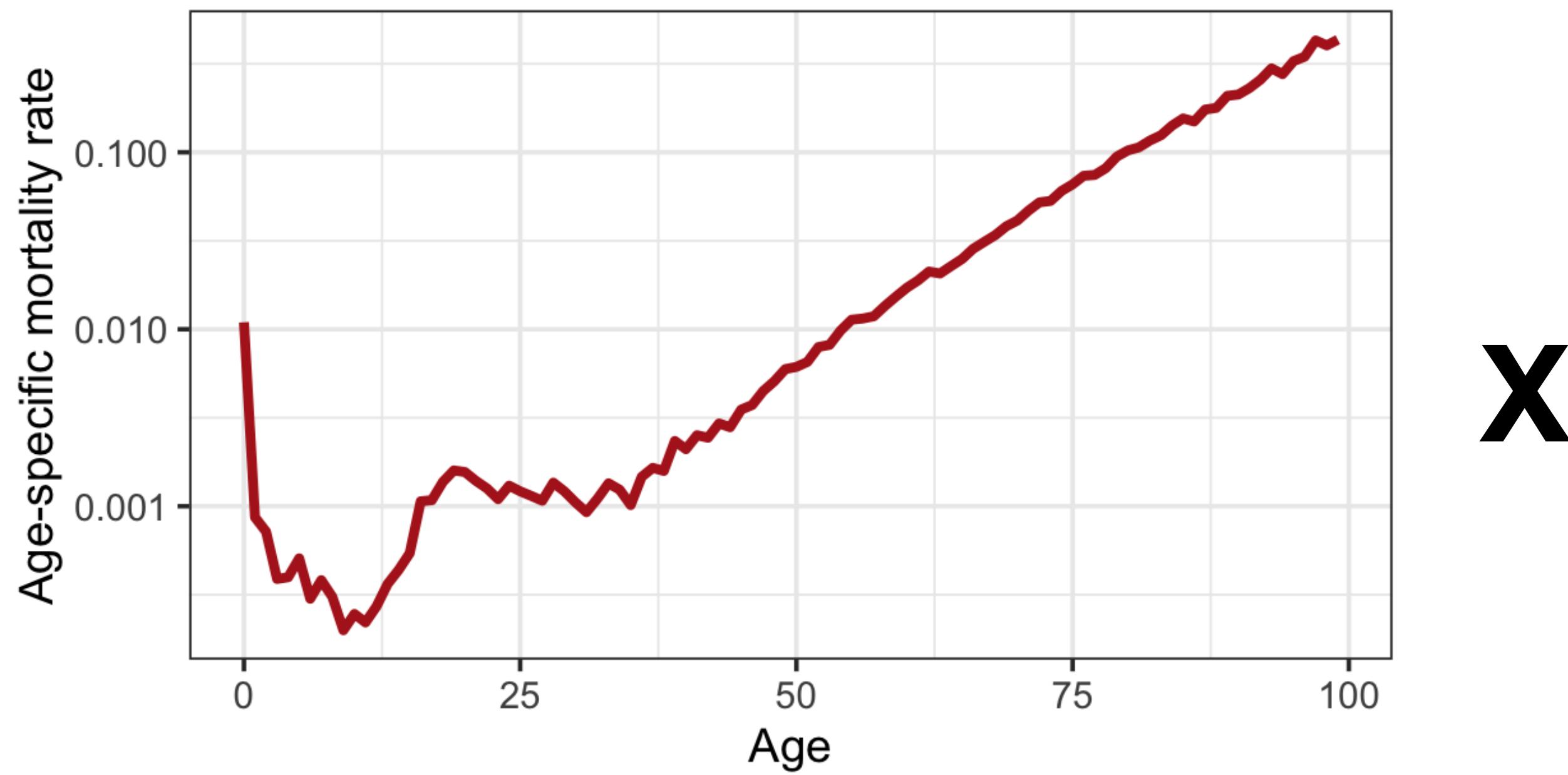
- The United States is experiencing dual and overlapping public health crises: drug poisonings and firearm deaths
- Since 1999, over 1 million people have died due to drug overdoses, and more than 750,000 by firearms (NCHS 2024)
- The majority of these deaths occur to those aged 15-54, a period when many have young children (NCHS 2024)
- Drug and firearms deaths have also increased for youths (<18 years); drug poisonings now the third leading cause of death (Goldstick et al 2022, Woolf et al 2023)
- Dual burden for youth: increased mortality, and losing a parent

There are no data available on parental loss by cause, so we obtain estimates using a demographic projection model

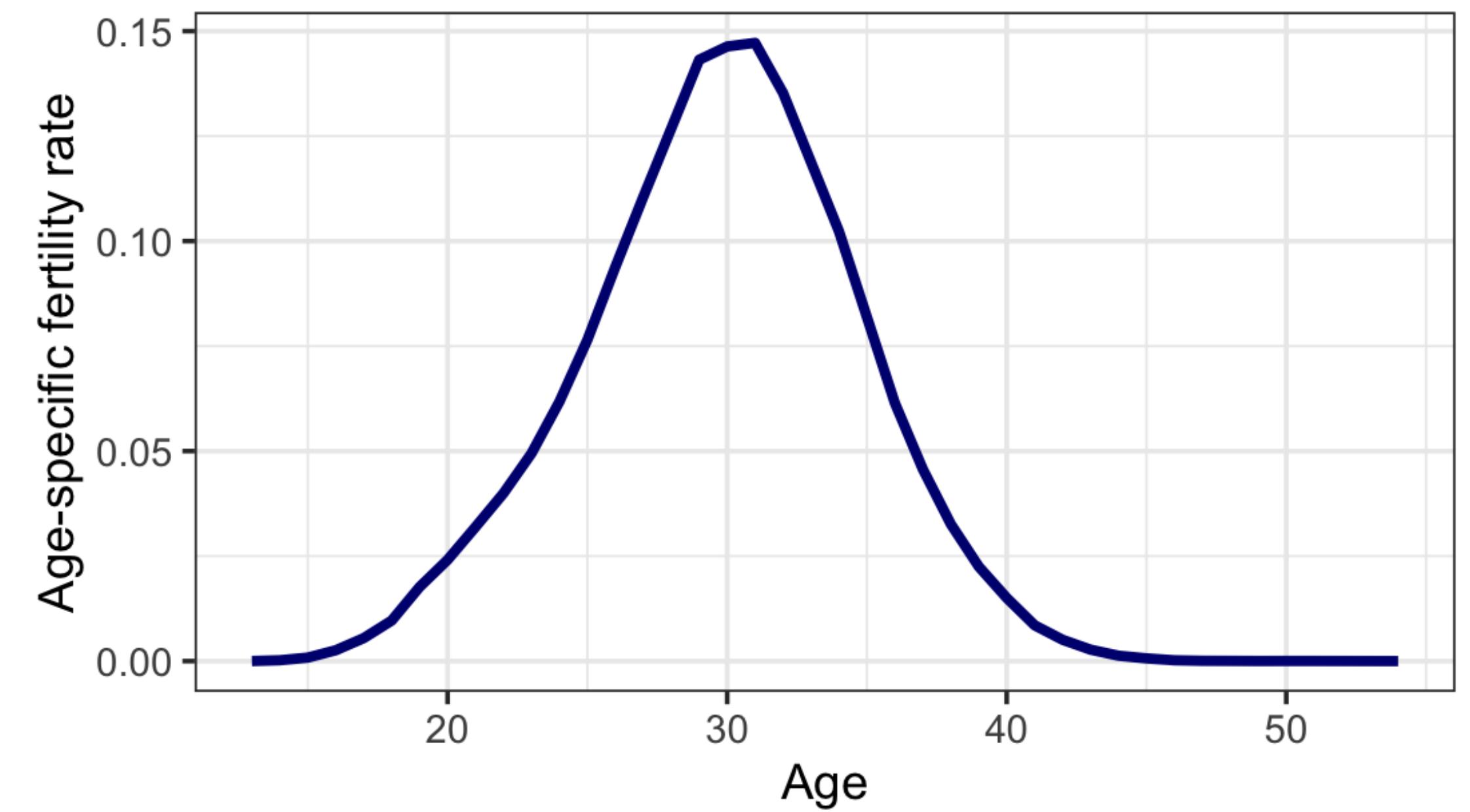
Estimating parental loss with demographic rates

Estimating parental loss with demographic rates

Intuition: If you know the mortality rates by age and the fertility rates by age in a population, then you can estimate expected number of mothers / fathers still alive



X



Estimating parental loss with demographic rates

Goodman, Keyfitz, and Pullum (1974) laid out the mathematical foundations for quantifying surviving kin using demographic rates. E.g.

$$M_1(a) = \int_{\alpha}^{\beta} \left(\frac{l_{a+x}}{l_x} \right) W(x \mid t - a) dx$$

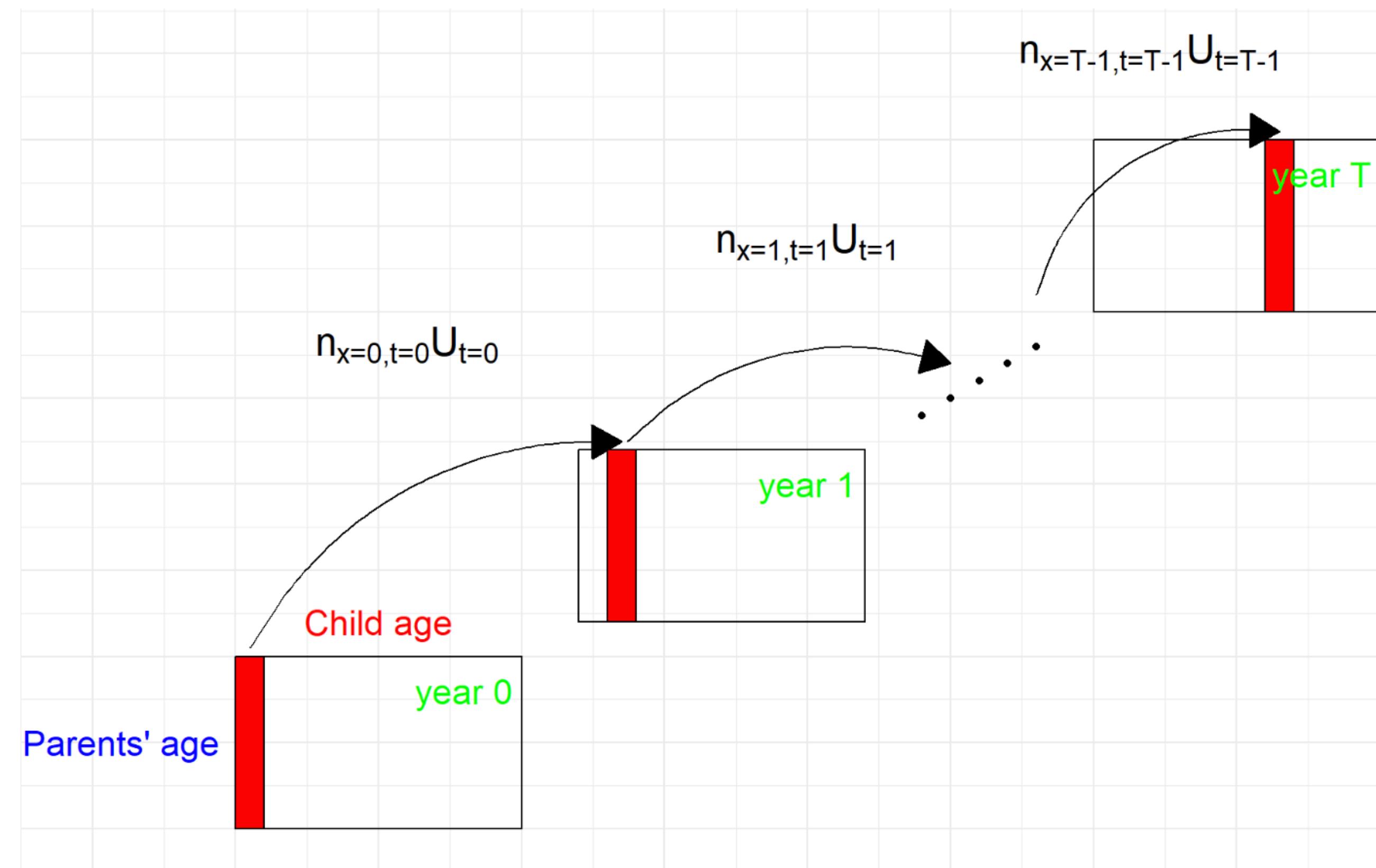
Probability that mother is still alive when daughter is age a

Survival of mother

Age distribution of fertility

Enter the Matrix

- Caswell (2019+): takes the Goodman, Keyfitz, Pullum equations, and turns them into a matrix projection model
- Extends the idea of the cohort component projection model
- Treat the children and parents as two different, but connected, populations
- We extended to allow us to track deaths of parents by cause (drugs, firearms, all other causes)



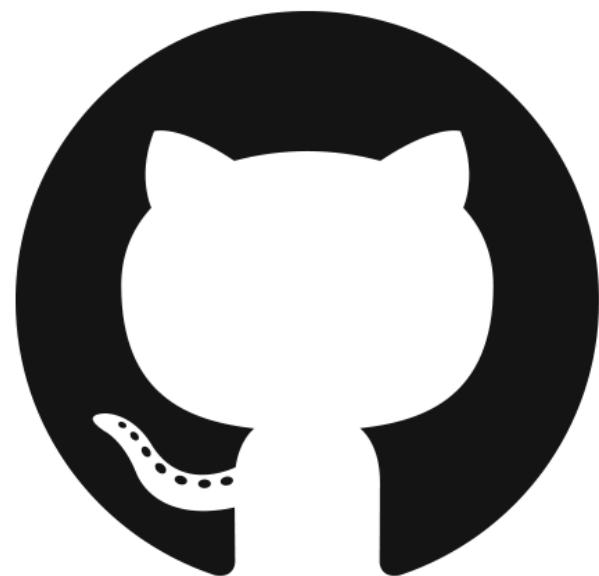
Data

Sources: National Center for Health Statistics (NCHS) and US Census Bureau

- Multiple causes of death (ICD10 codes) from 1999 (firearm-related, drug-related deaths, all other causes of death combined)
- Calculated cause-specific deaths for all NCHS/CDC bridged-race groups by one-year age, and sex
 - Non-Hispanic Black, non-Hispanic White, Hispanic, and Total
- Age- and race/ethnicity-specific female fertility rates
- Population counts by age, sex, and race/ethnicity

Reproducible materials

- Paper was published in *JAMA* earlier this year: doi:10.1001/jama.2024.8391
- All the data and code to produce the results, plots, and supplementary analyses is here: https://github.com/benjisamschlu/parental_deaths



Notes on Reproducibility

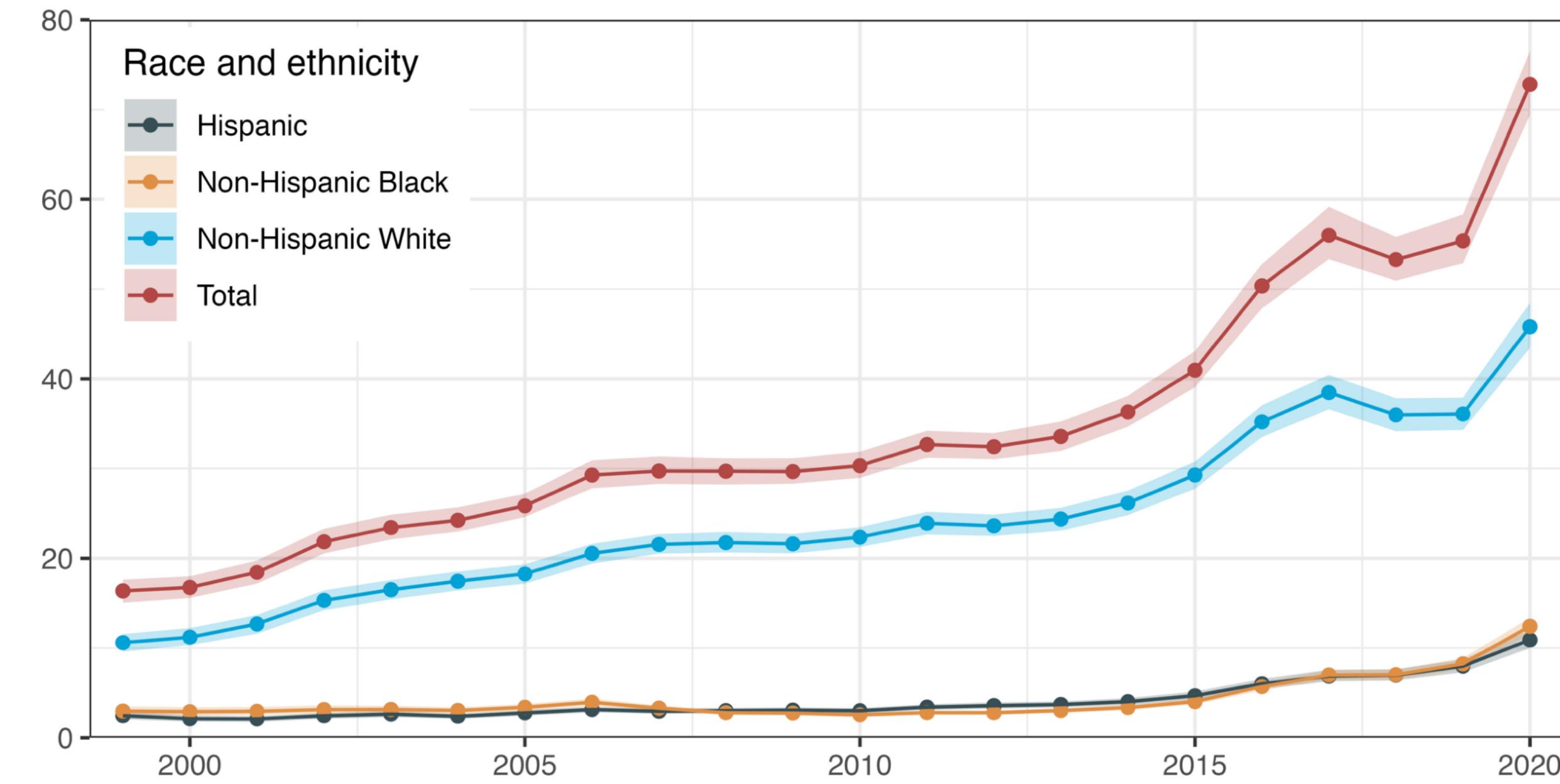
We use publicly available data and provide code that will download and/or munge these data as necessary. For full reproducibility, we also provide [all of our simulation files](#), which will allow for exact reproduction of our results. These files are stores on [the Harvard Dataverse](#); however, due to limitations on file size, we split each of the (>5GB) simulation files into 10 smaller chunks and provide code to recombine them (`./codes/00_combine_sim_files.R`). If you wish to fully reproduce our results, use the `00` code file to download the files noting that they take up approximately 55GB of space and require ~16GB of RAM (each file) to recombine.

We use [renv](#) for package management but below we also post the relevant session information to ensure full reproducibility.

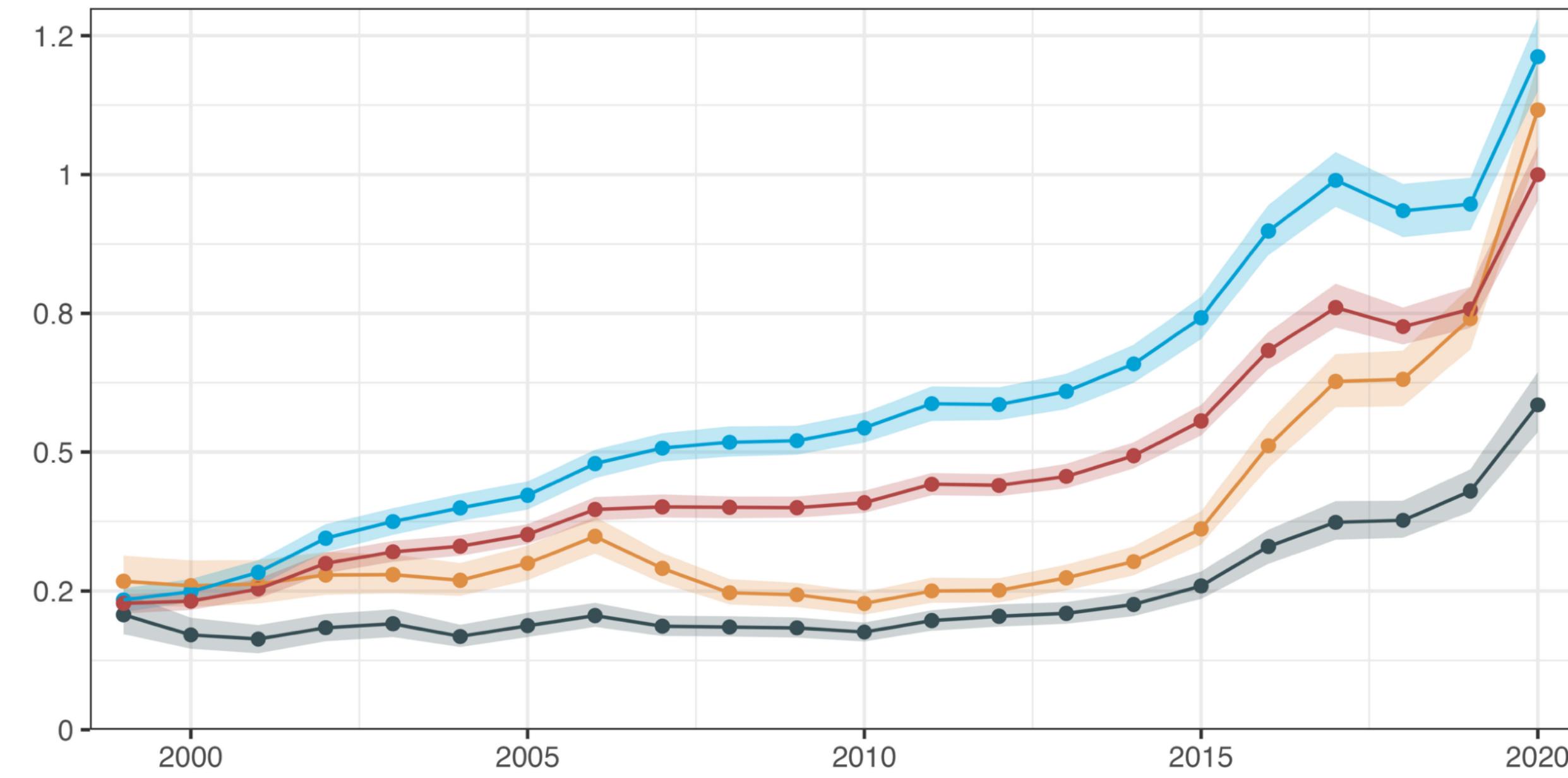
Results

Parental loss due to drugs

Number of youth <18 years impacted (95% CI), thousands

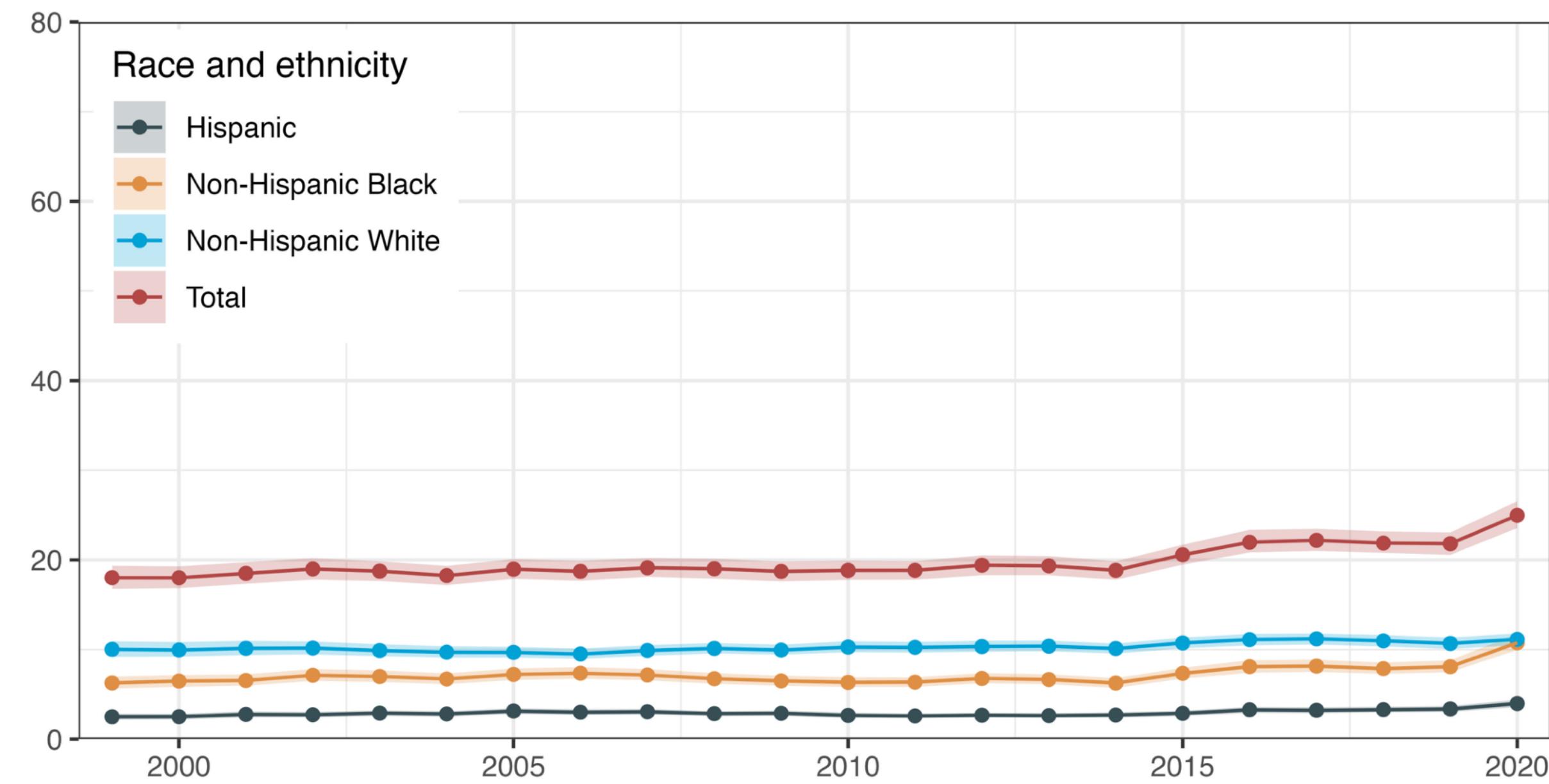


Youth impacted per 1,000 population (95% CI)

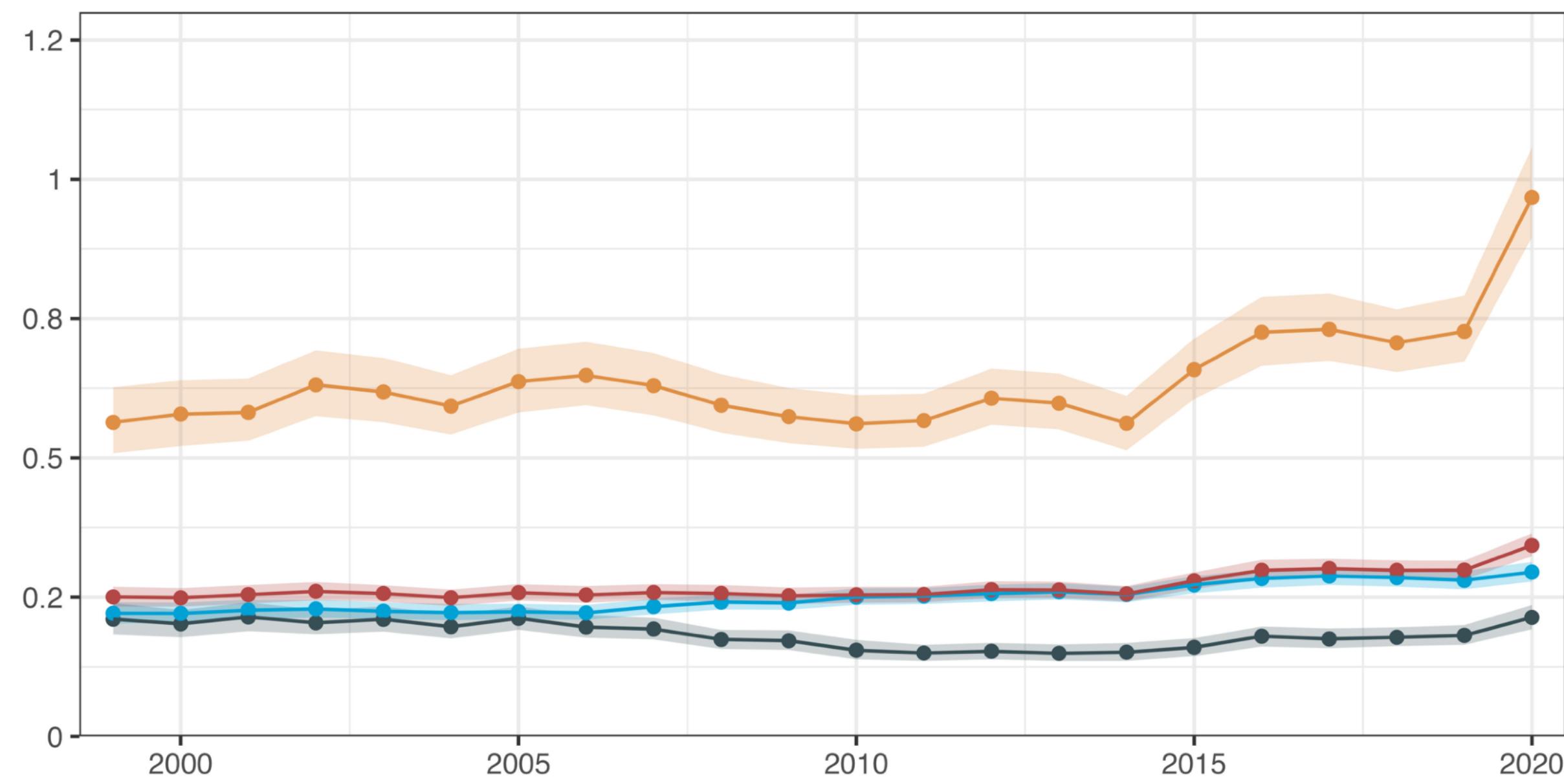


Due to firearms

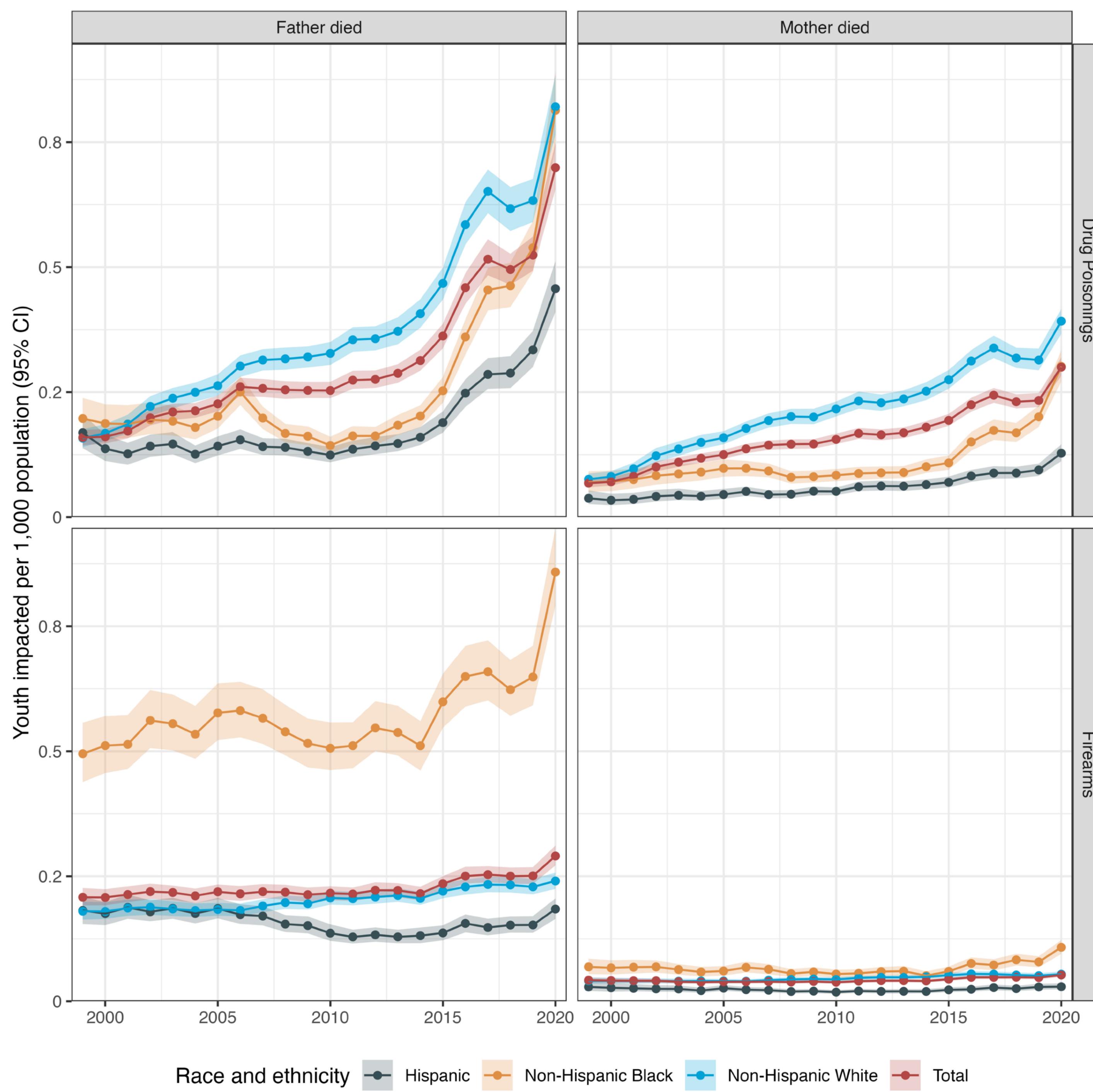
Number of youth <18 years impacted (95% CI), thousands



Youth impacted per 1,000 population (95% CI)



By parent



Takeaways

- An estimated more than 1 million youth lost a parent due to drugs or firearms over the period 1999-2020
- In 2020, drugs and firearms accounted for almost a quarter of all parental deaths (double the 1999 level)
- Black youth experienced a disproportionate burden of parental deaths, primarily due to firearm deaths among fathers
- A whole generation of youth who have lost a parent to traumatic causes
- Large racial differences of early parental loss, cumulative disadvantage and weathering over the life course
- Shifting policy to think about the indirect impact on families (US Surgeon General 2024)

Methodological assumptions and limitations

These are model-based estimates!

- Definition of a parent, assumption of two parents
- Homogeneity of fertility
- Race classification, no multi-racial groups
- Uncertainty is most likely underreported

We did validation and sensitivity tests, but potential for future methodological work

Estimating years of life lived without parents

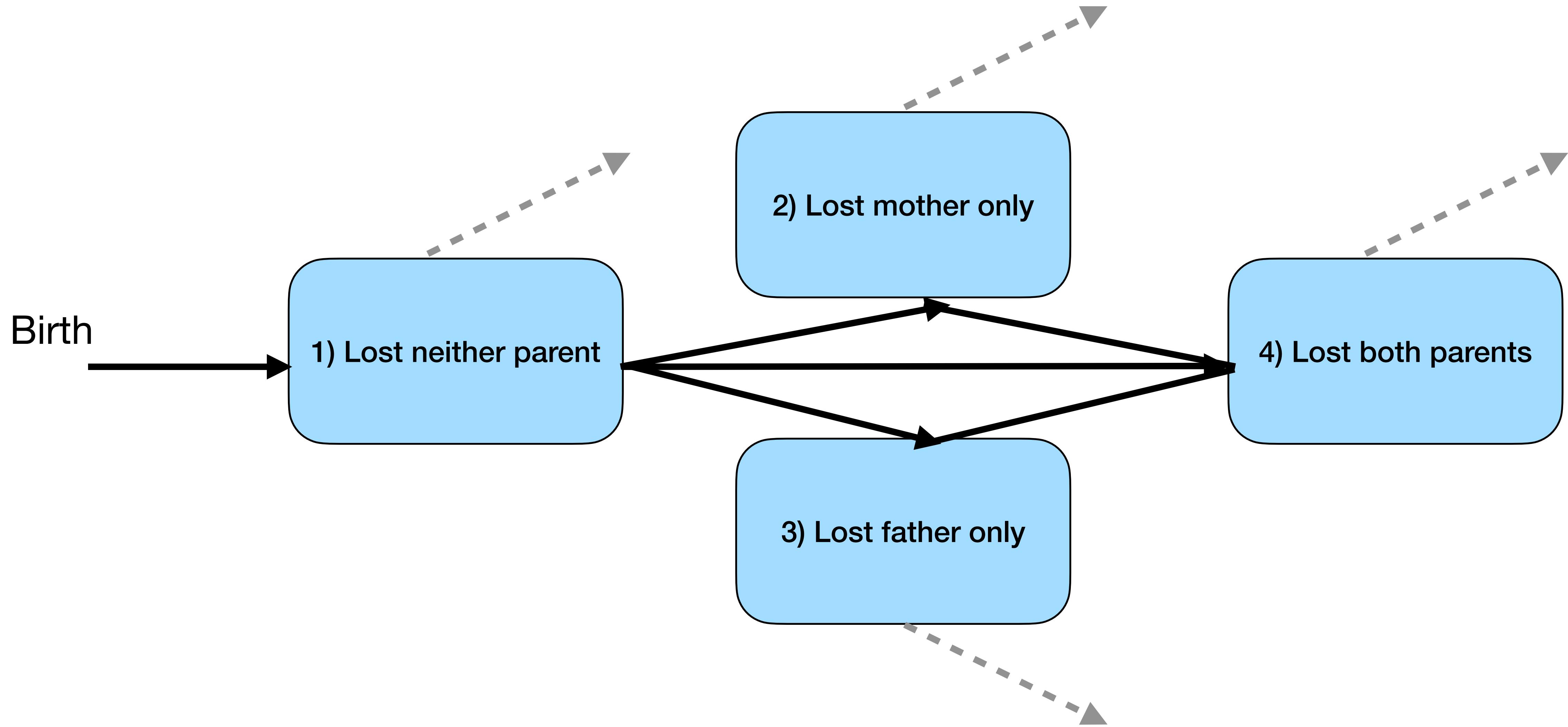
Motivation

- Shifting focus from magnitude to timing and **length of exposure to parental loss**
- How much time can we expect to have with our parents?
- A function of mortality/fertility of parents and also mortality of ego
- Presence of parents at key points in life course (Cox et al 2016, Liu et al 2022)
- Shared lifetimes, shared resources, multigenerational mobility and capital (Song and Mare 2019)
- Uncertainty about lifespan of family members affects planning (van Raalte 2011, Grote and Pfrombeck 2020)

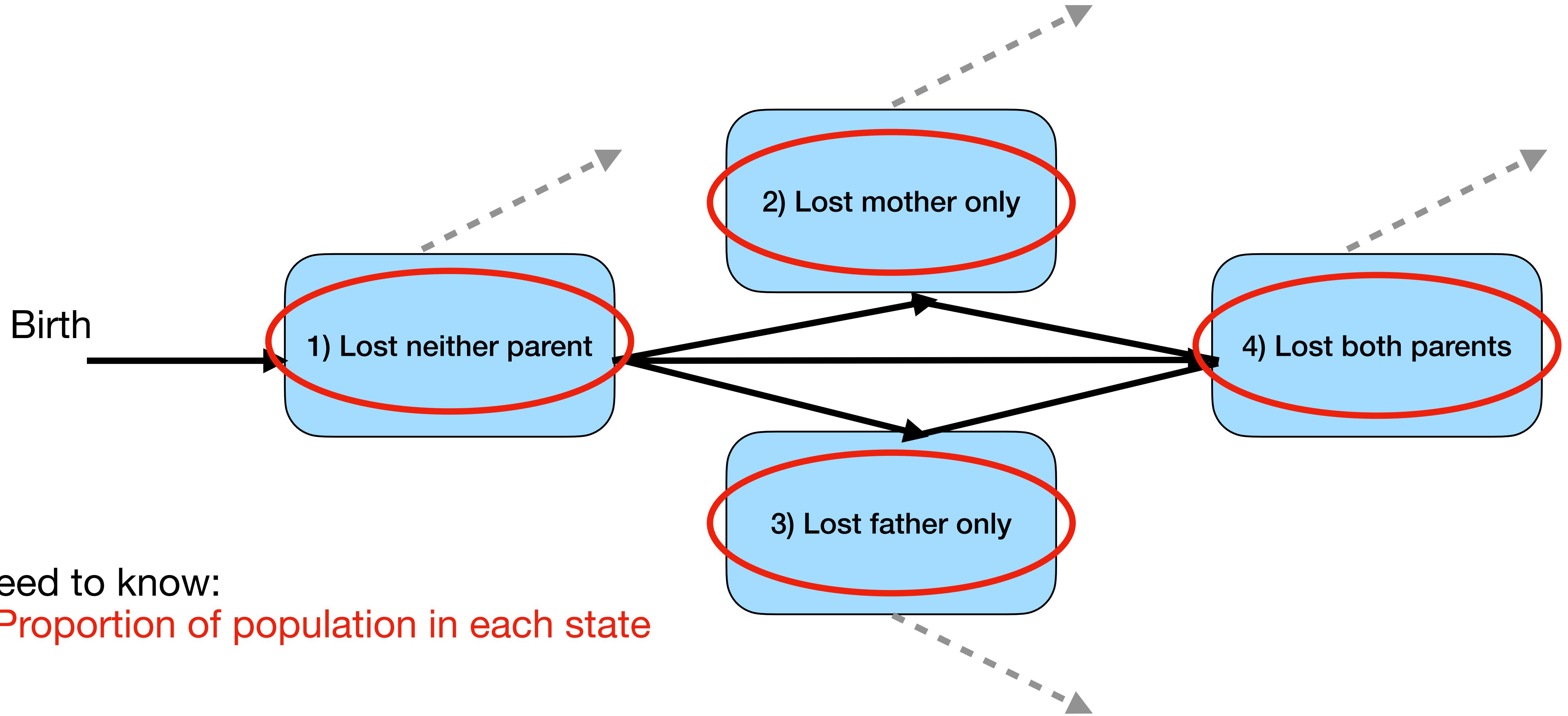
Estimating time lived without parents

- We use a multistate life table approach
- Multistate lifetables track the mortality experience for a cohort of people over age, partitioning them into different ‘states’
- Here, our states relate to parental loss: 1) lost neither, 2) lost mother only, 3) lost father only, 4), lost both
- Key quantity of interest: life expectancy above age x in each state j , $e_x(j)$
- For example: $e_0(1)$ is an estimate of the number of years a baby could expect to live with both of their parents alive

States of parental loss



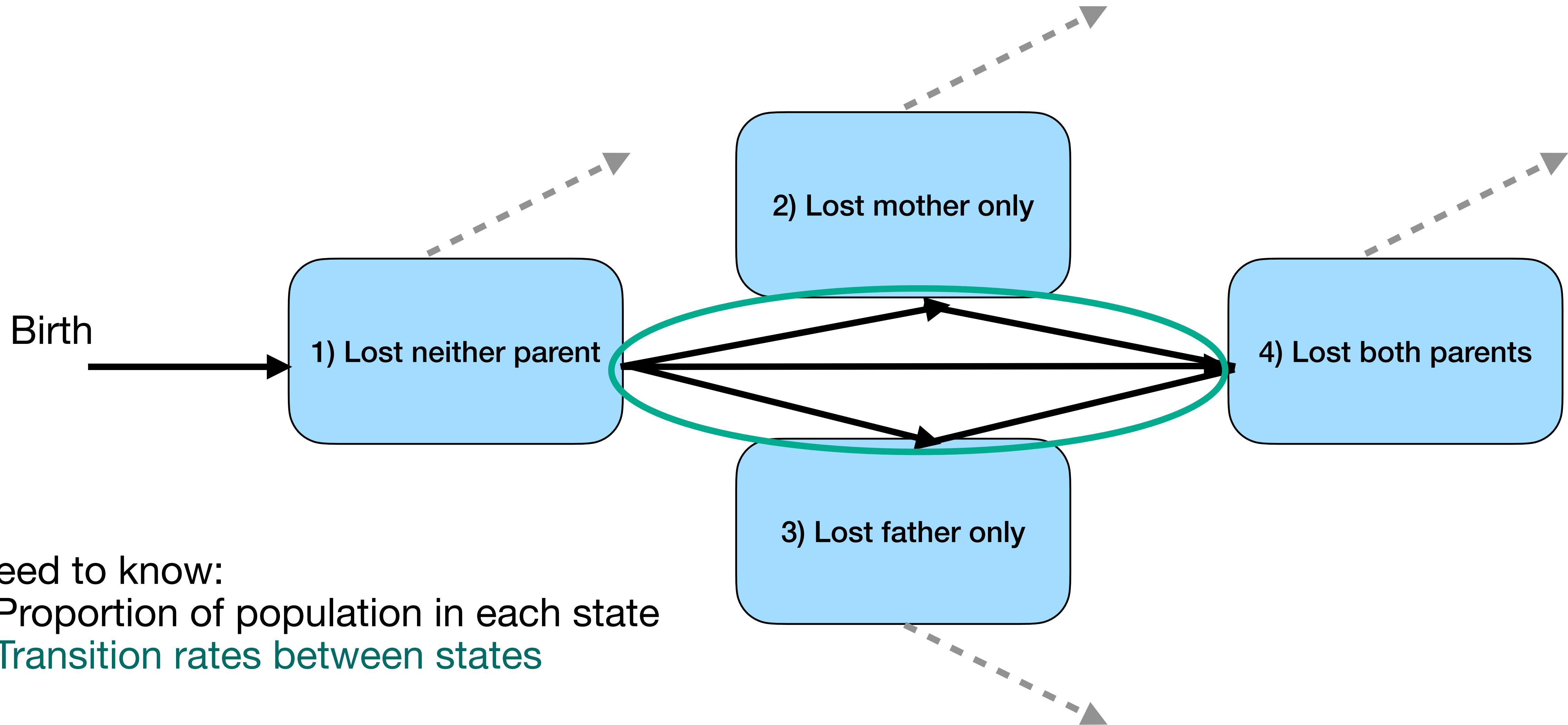
States of parental loss



Need to know:

- Proportion of population in each state

States of parental loss



Need to know:

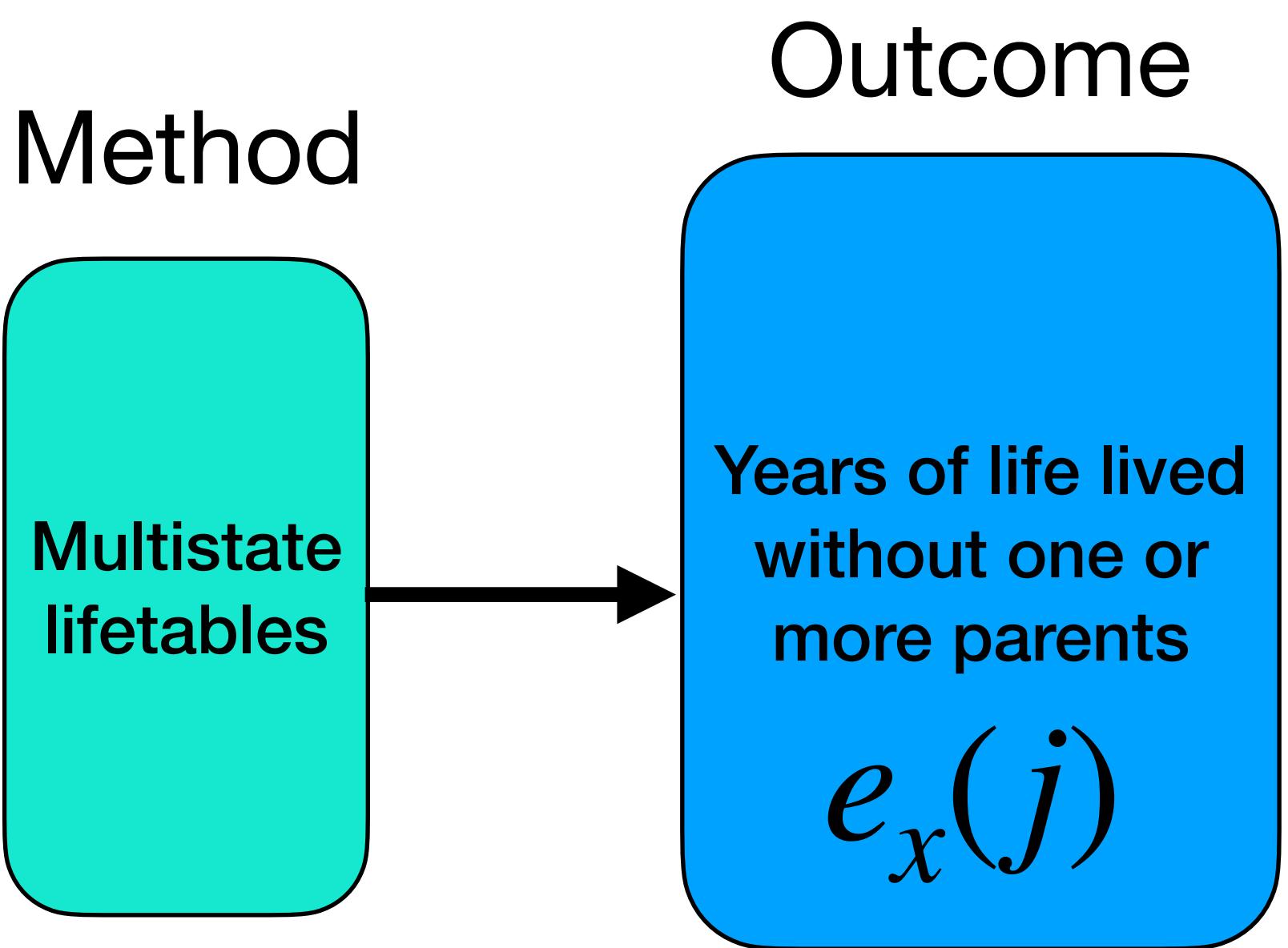
- Proportion of population in each state
- **Transition rates between states**

What info do we need?

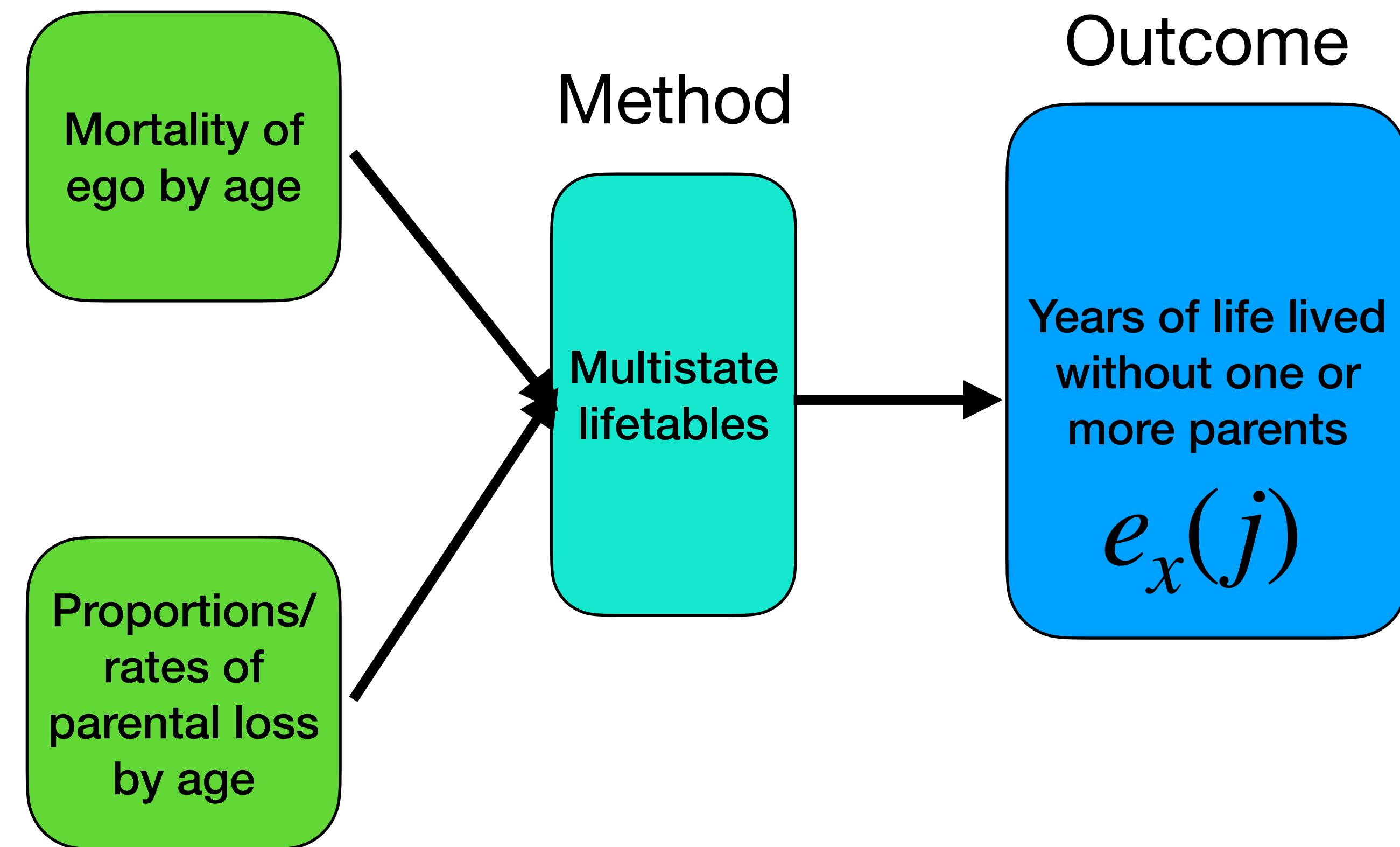
Outcome

Years of life lived
without one or
more parents

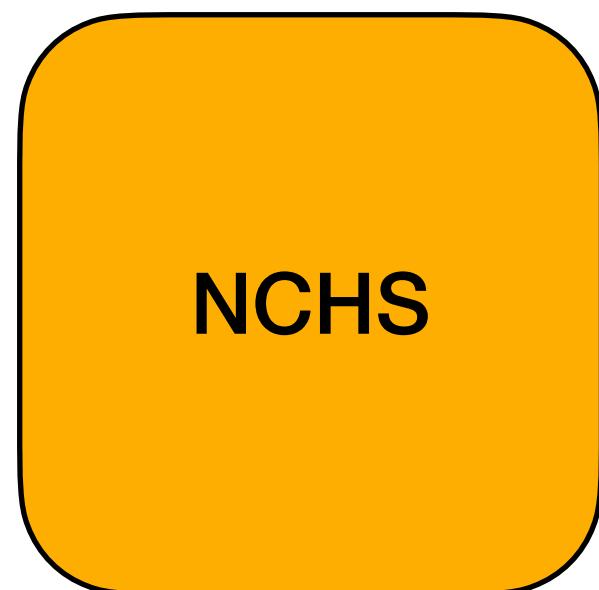
$$e_x(j)$$



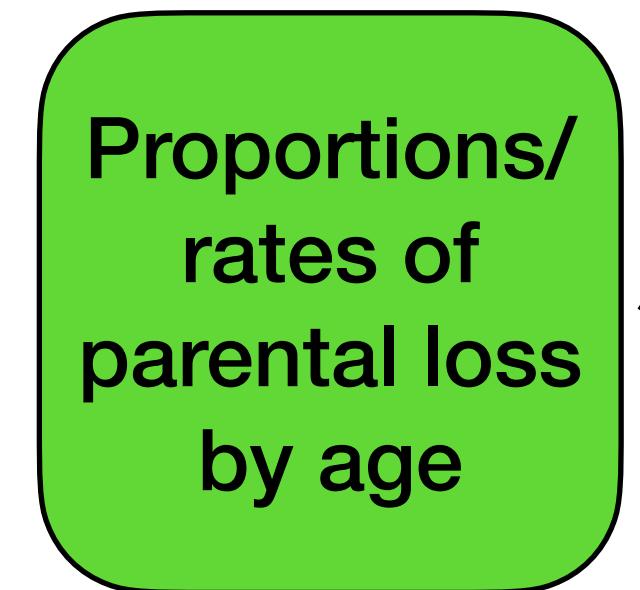
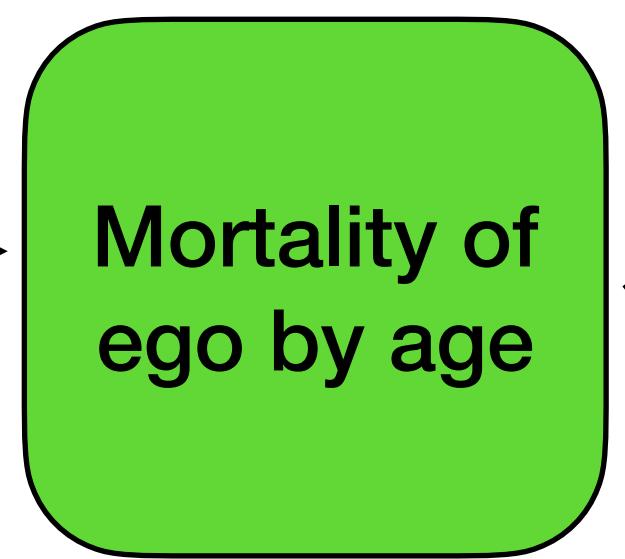
Inputs required



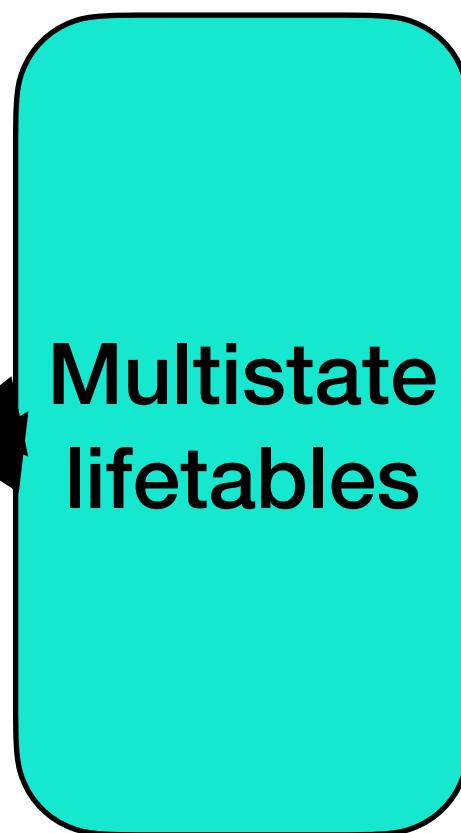
Data Sources



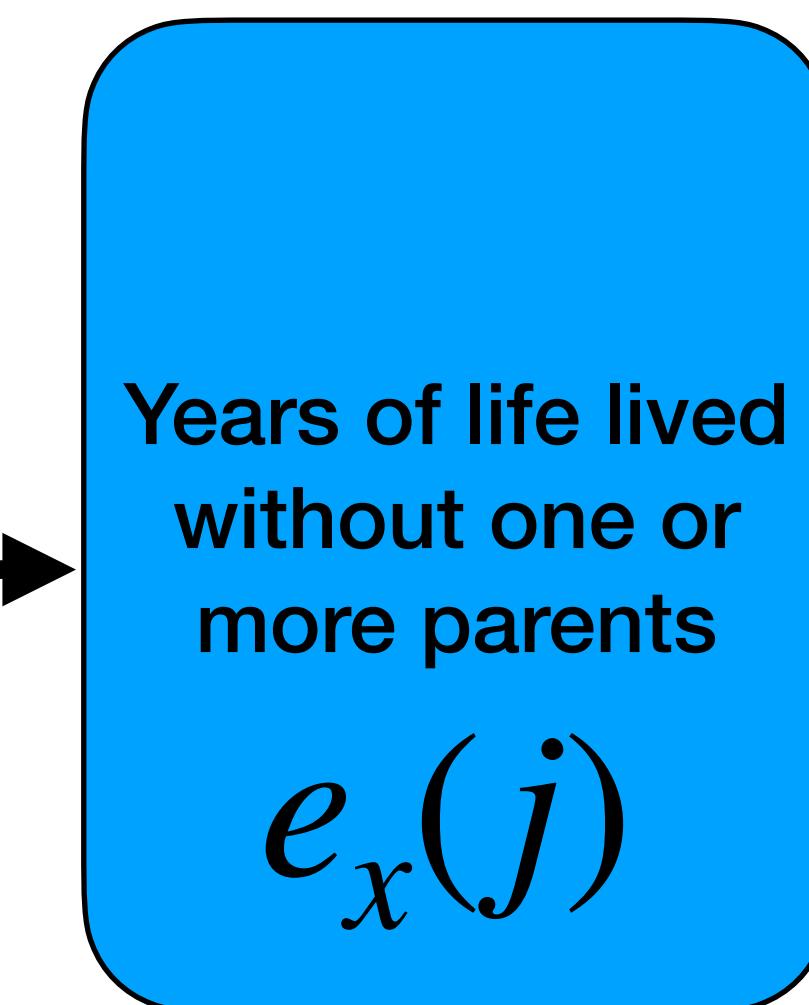
Inputs required



Method



Outcome



Data Sources

NCHS

Survey data

Inputs required

Mortality of
ego by age

Proportions/
rates of
parental loss
by age

Method

Multistate
lifetables

Outcome

Years of life lived
without one or
more parents

$e_x(j)$

Survey data on parental loss

- Survey of Income and Program Participation (2021)
- Run by US Census Bureau. Nationally representative longitudinal survey, on income, employment, household composition, and includes the family context of individuals
- Survey asked whether parents were alive or deceased as well as the participant's age at the time of losing each parent
- Sample size: 43,400 respondents (30,700 NHW; 8,300 Hispanic; 4,400 NHB)
- But many (10-15%) age-specific rates are missing

Data Sources

NCHS

Survey data

Inputs required

Mortality of ego by age

Proportions/ rates of parental loss by age

Method

Multistate lifetables

Outcome

Estimates of life lived without one or more parents

$e_x(j)$

Data Sources

NCHS

Survey data

Projection
model
estimates

Inputs required

Mortality of
ego by age

Proportions/
rates of
parental loss
by age

Method

Multistate
lifetables

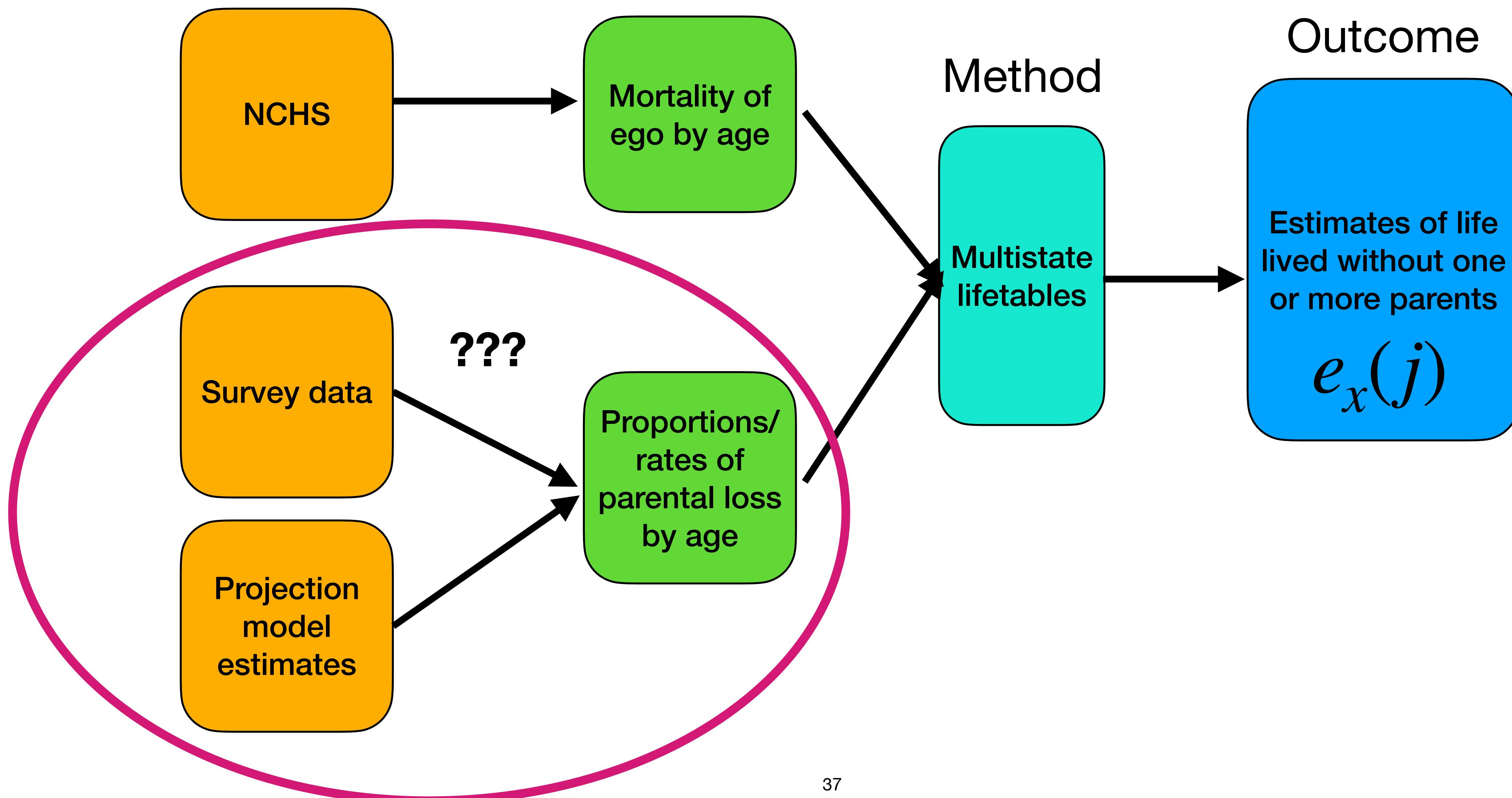
Outcome

Estimates of life
lived without one
or more parents

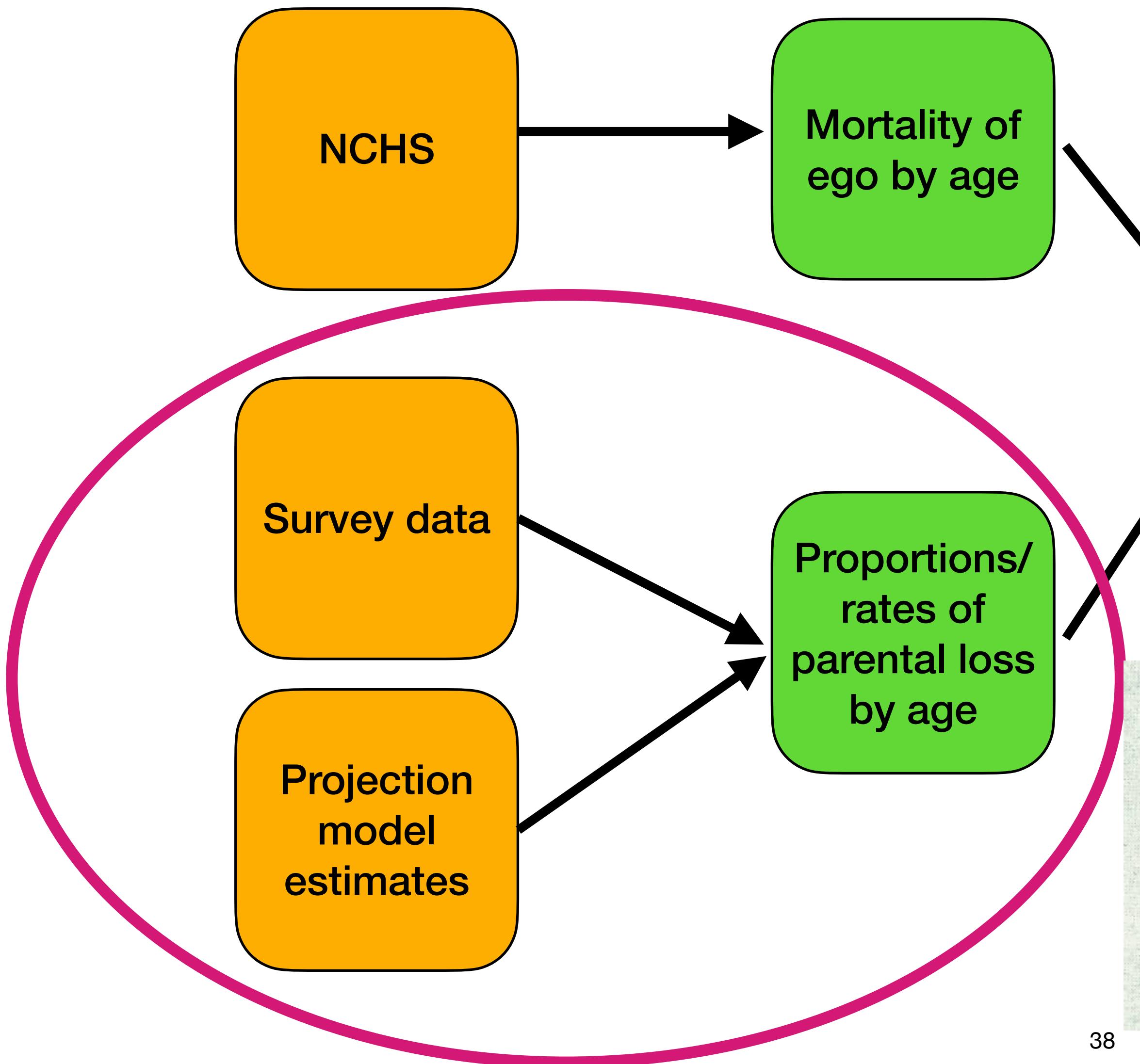
$e_x(j)$

Data Sources

Inputs required



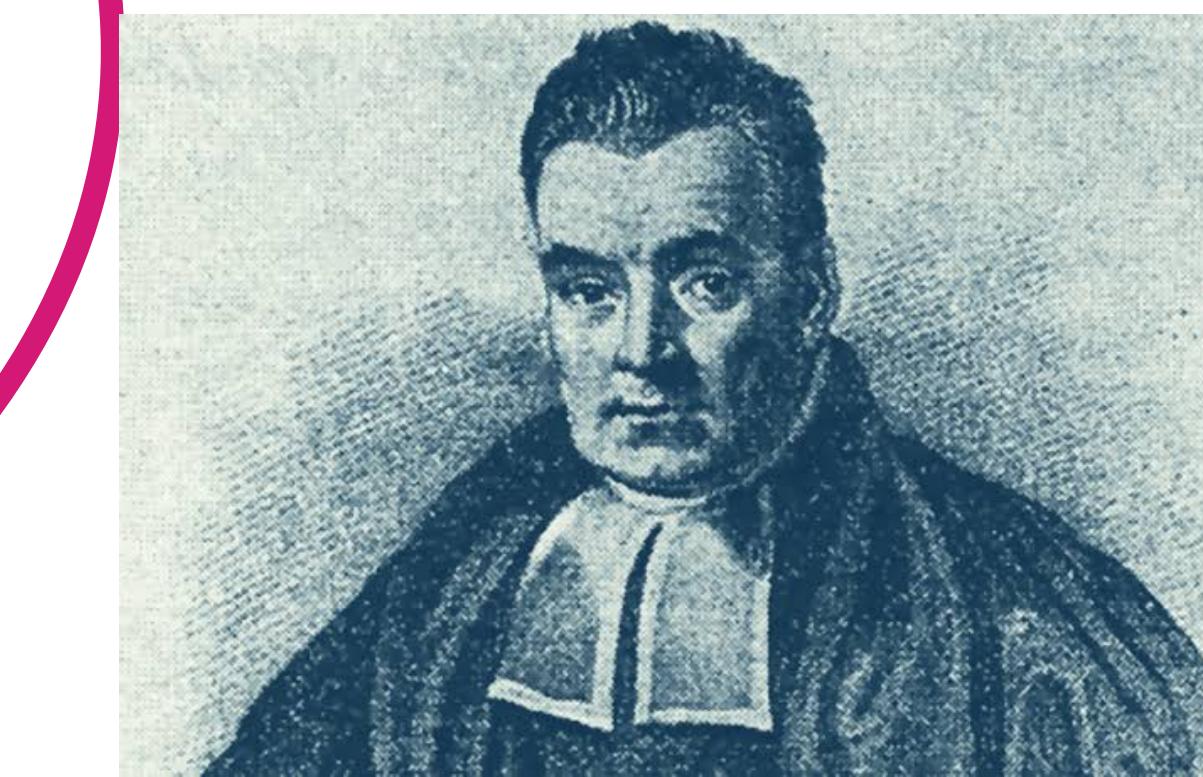
Data Sources



Inputs required

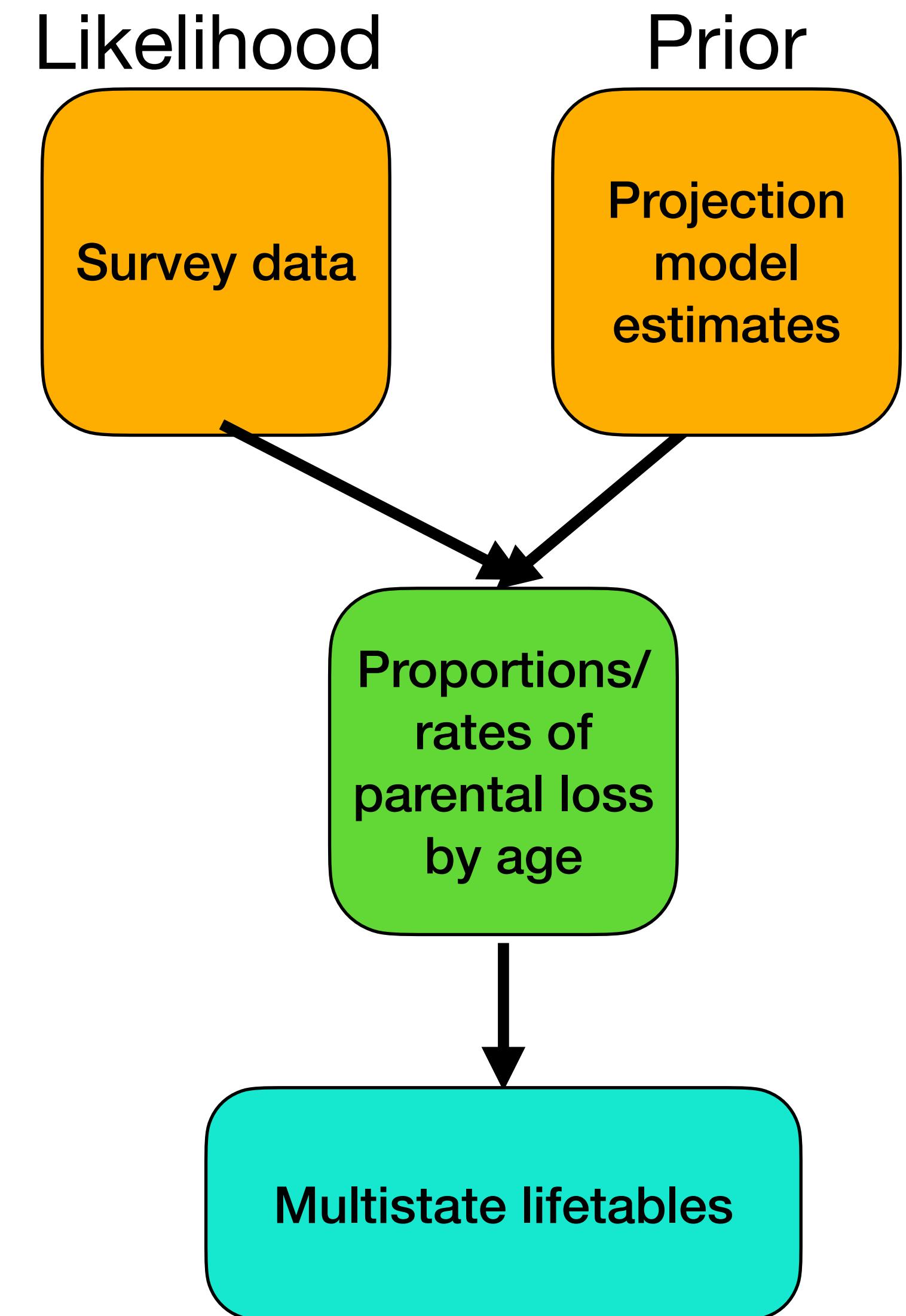
Method

Outcome



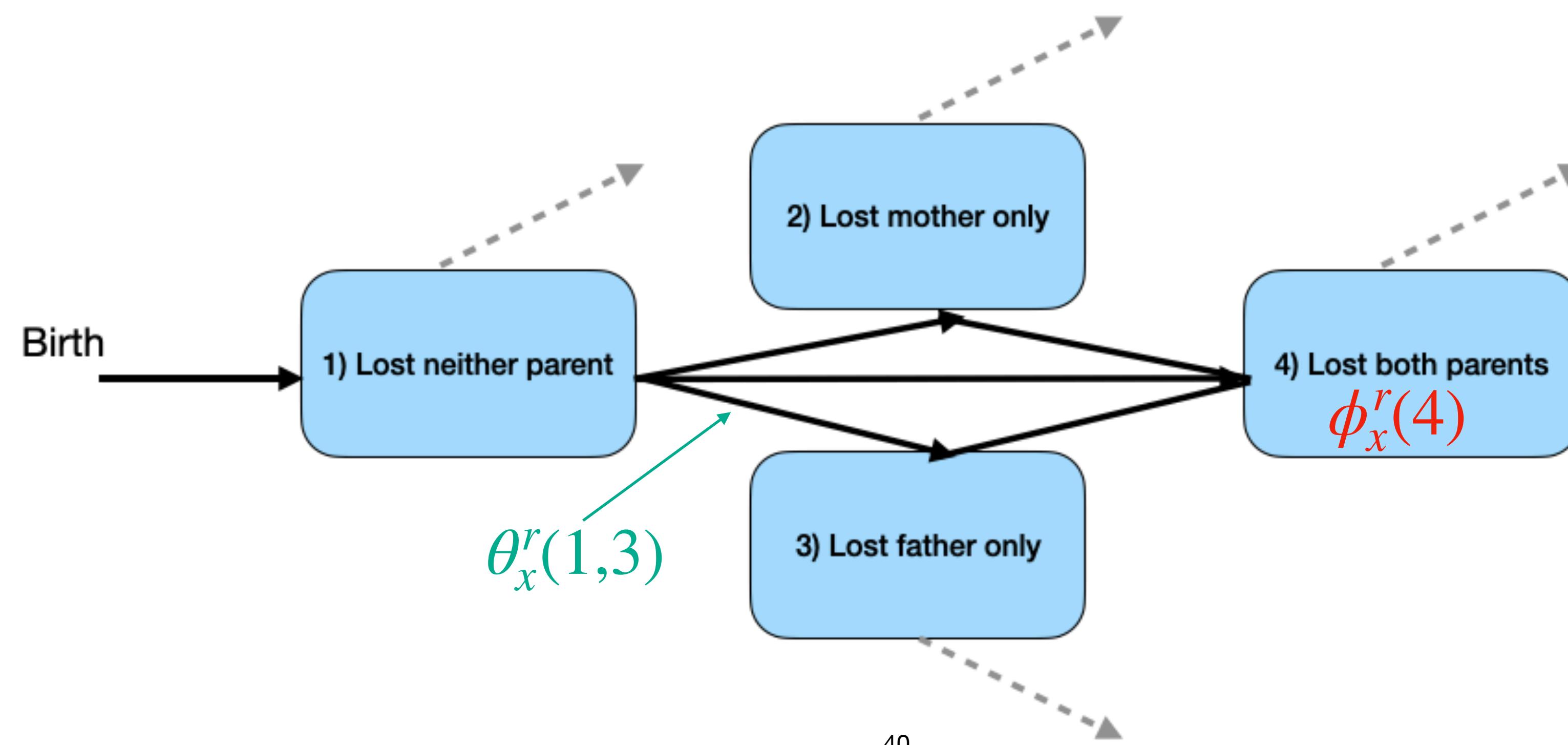
Bayesian estimation of the parental loss proportions

- In this case, we have some idea of the proportions in each parental loss state from the demographic projection model, even before we ‘see’ survey data (**prior**)
- Survey data is then put into the model through the **likelihood**
- The resulting **posterior** distribution of the proportions is informed by both sources
- These estimates (and their uncertainty) are then used to generate multistate lifetables (with uncertainty)



Model overview (transition rates)

- Denote $\theta_x^r(u, v)$ to be the **latent transition rate** at age x , race r , from state u to state v
- Also denote $\phi_x^r(l)$ as the proportion of the population in state l



Transition rates: likelihood

- The **observed transition rates** from the SIPP survey are denoted $m_x^r(u, v)$ and assumed to follow a Normal likelihood

$$m_x^r(u, v) | \theta_x^r(u, v) \sim N\left(\theta_x^r(u, v), \left(SE(m_x^r(u, v))\right)^2\right)$$

- Where $SE(m_x^r(u, v))$ are the sampling standard errors (calculated taking sampling design into account)

Transition rates: prior

- From the projection model we only know about the marginal transition rates. Denote these $\hat{m}_x^r(\cdot, v)$ (for $v = 2, 3$)
- Can express the latent marginal transitions as a function of θ_x^r and ϕ_x^r . e.g. for losing a mother:

$$\theta_x^r(\cdot, 2) = \frac{(\theta_x^r(1,2) + \theta_x^r(2,4)) \cdot \phi_x^r(1) + \theta_x^r(3,4) \cdot \phi_x^r(3)}{\phi_x^r(1) + \phi_x^r(3)}$$

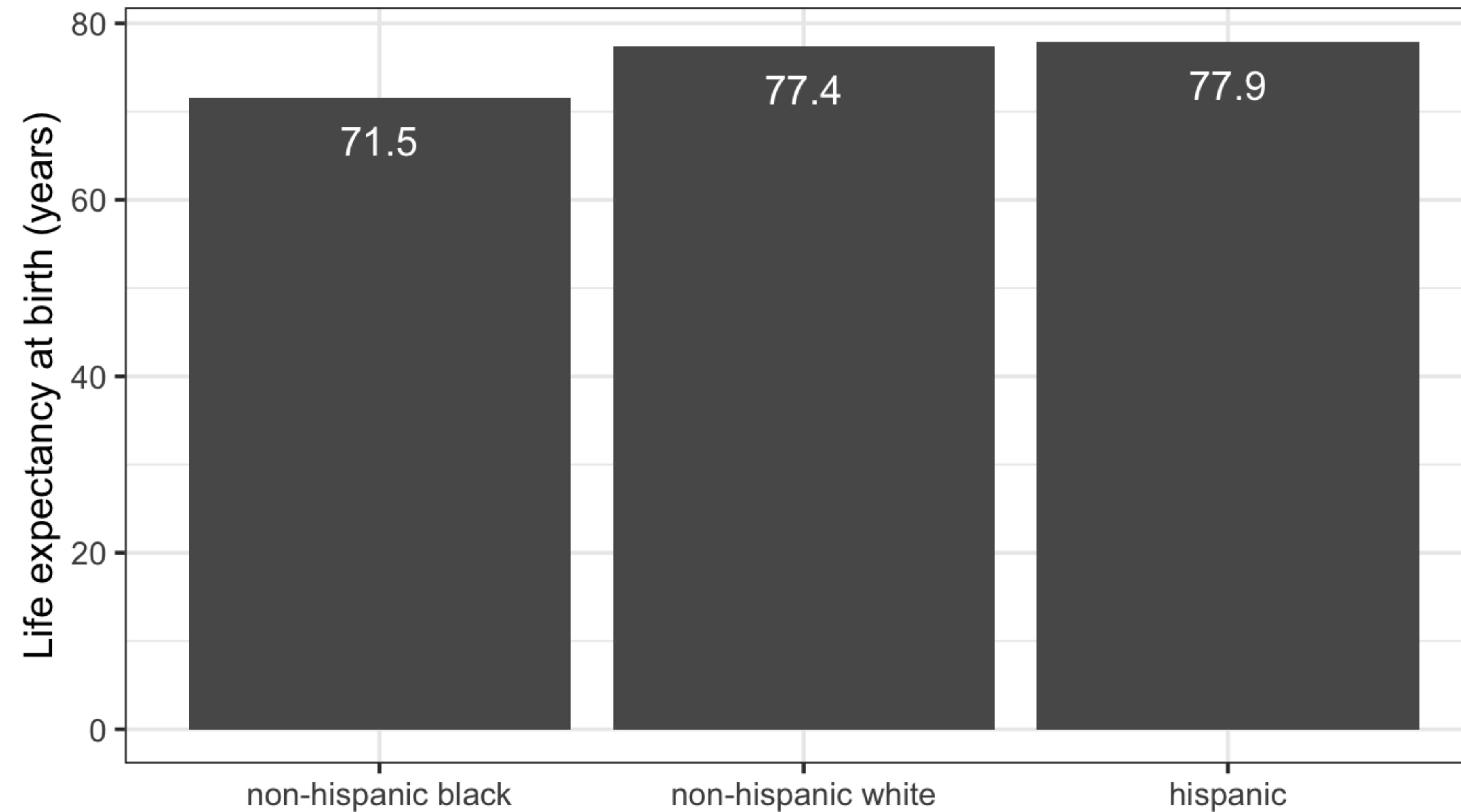
- The latent marginal rates then have prior distributions that are informed by the estimates from the projection model:

$$\theta_x^r(\cdot, v) | \sigma_v^2 \sim N(\hat{m}_x^r(\cdot, v), \sigma_v^2)$$

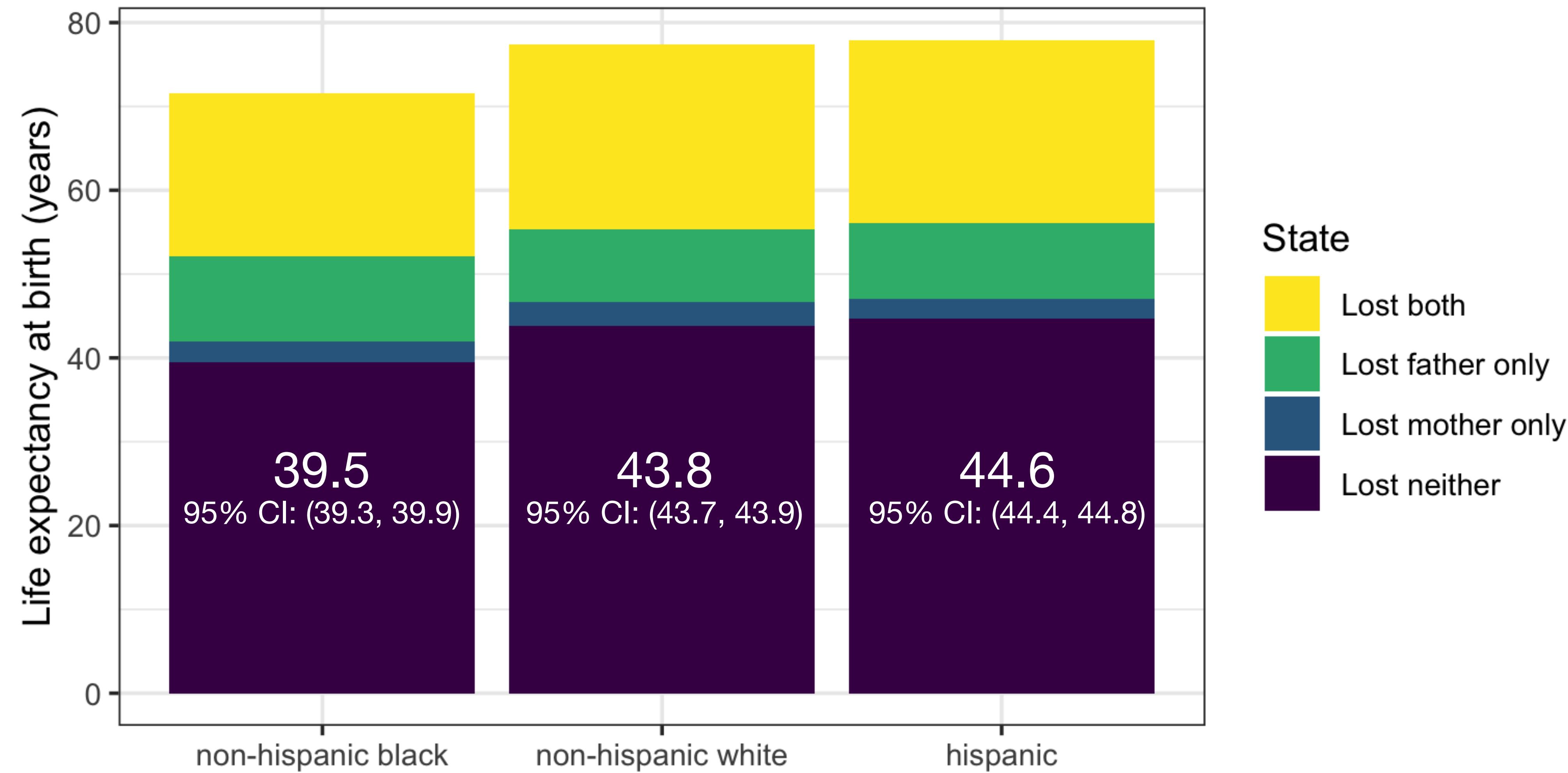
- The resulting posterior estimates for θ_x^r are thus informed by both survey data and the projection model

Results

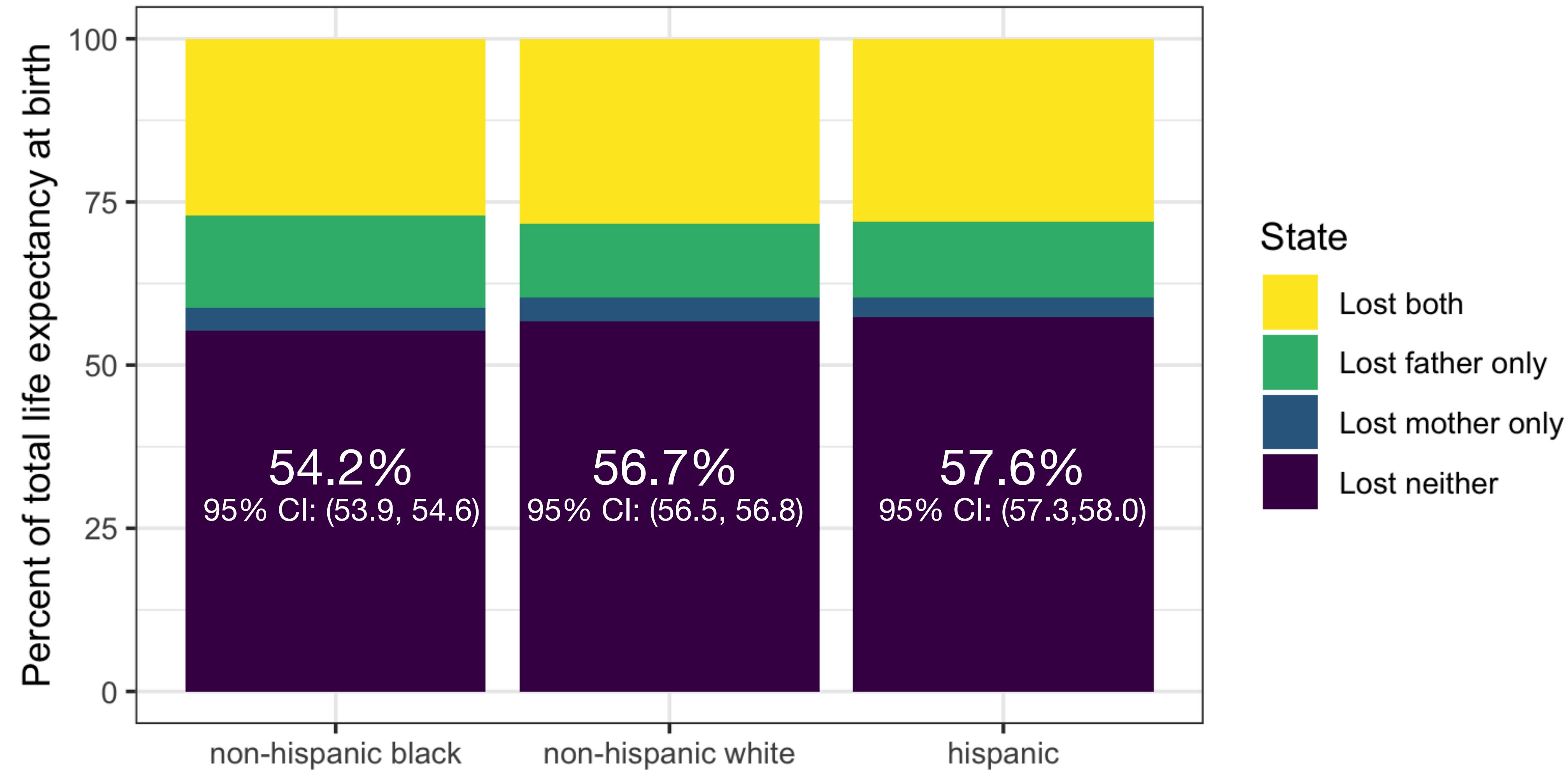
Life expectancy at birth



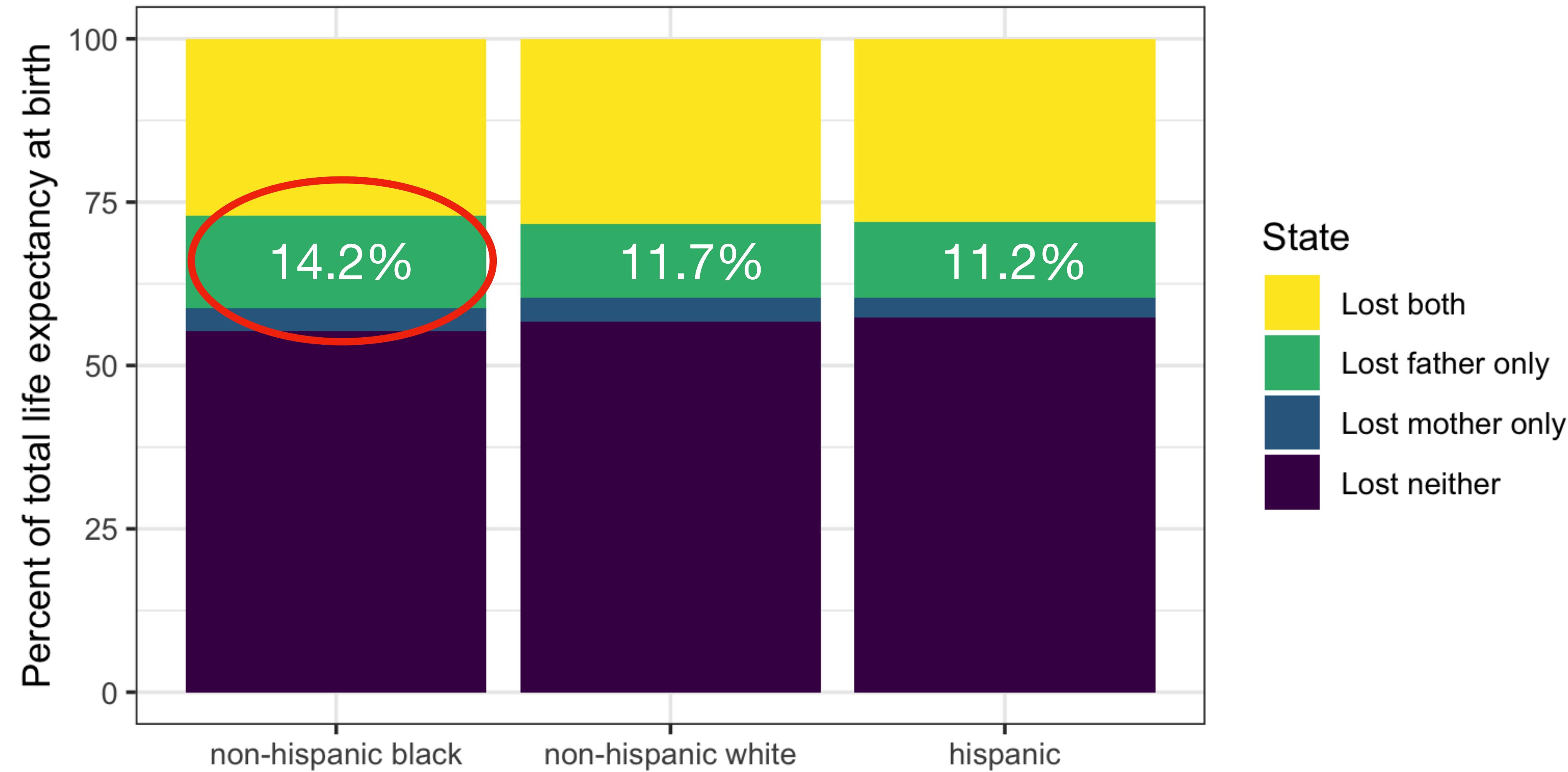
By parental loss state



Percent of total life expectancy

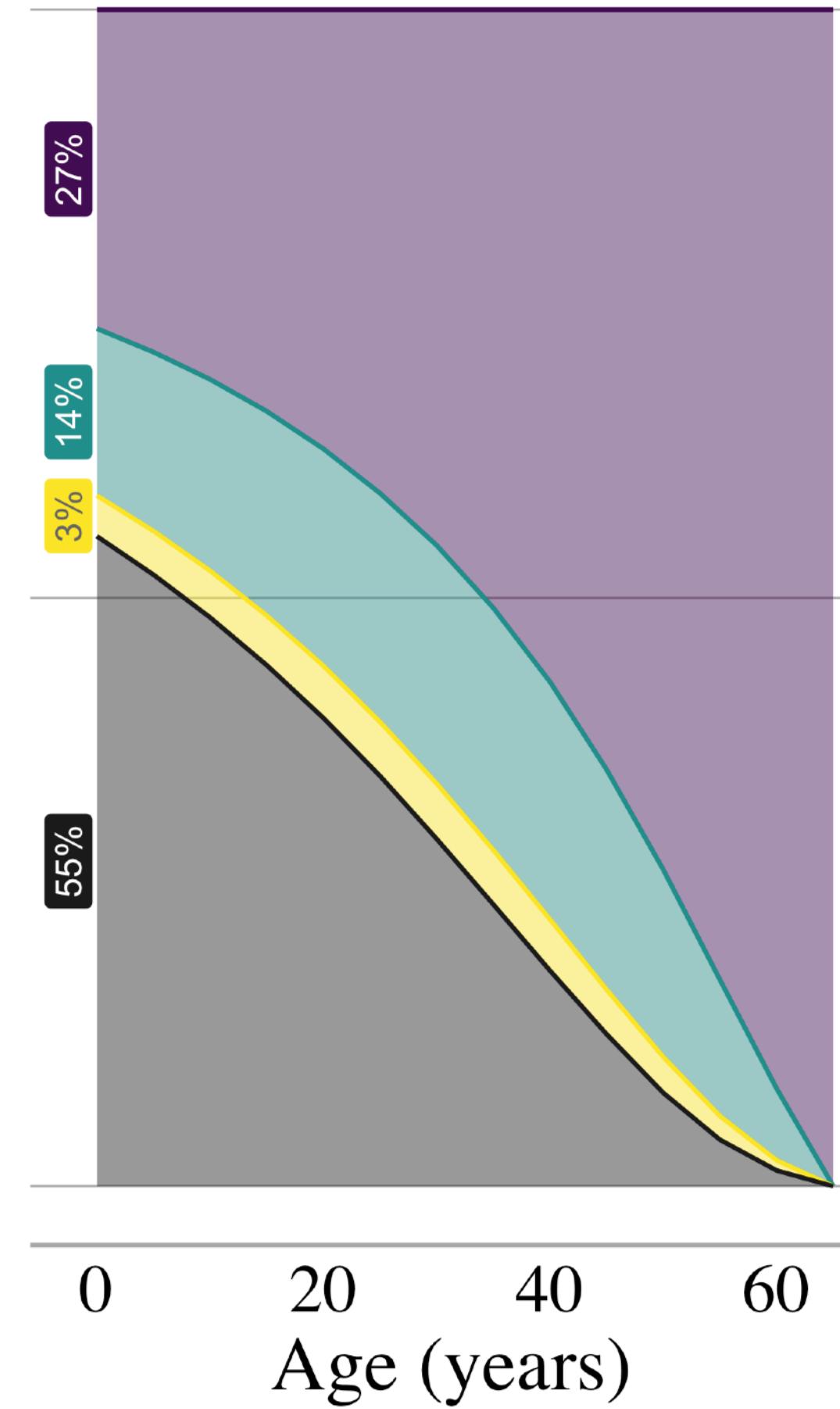


Percent of total life expectancy

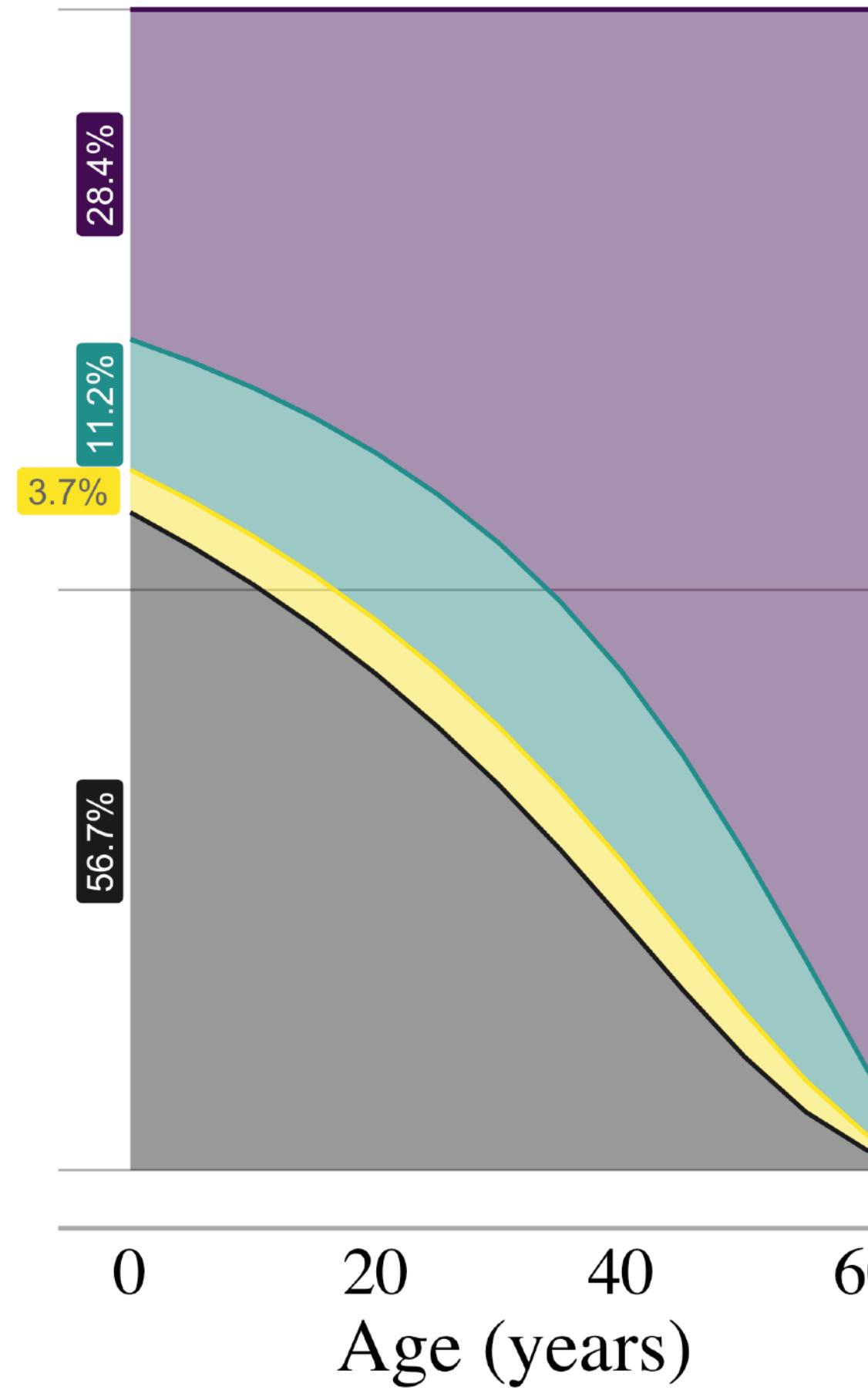


Over the life course

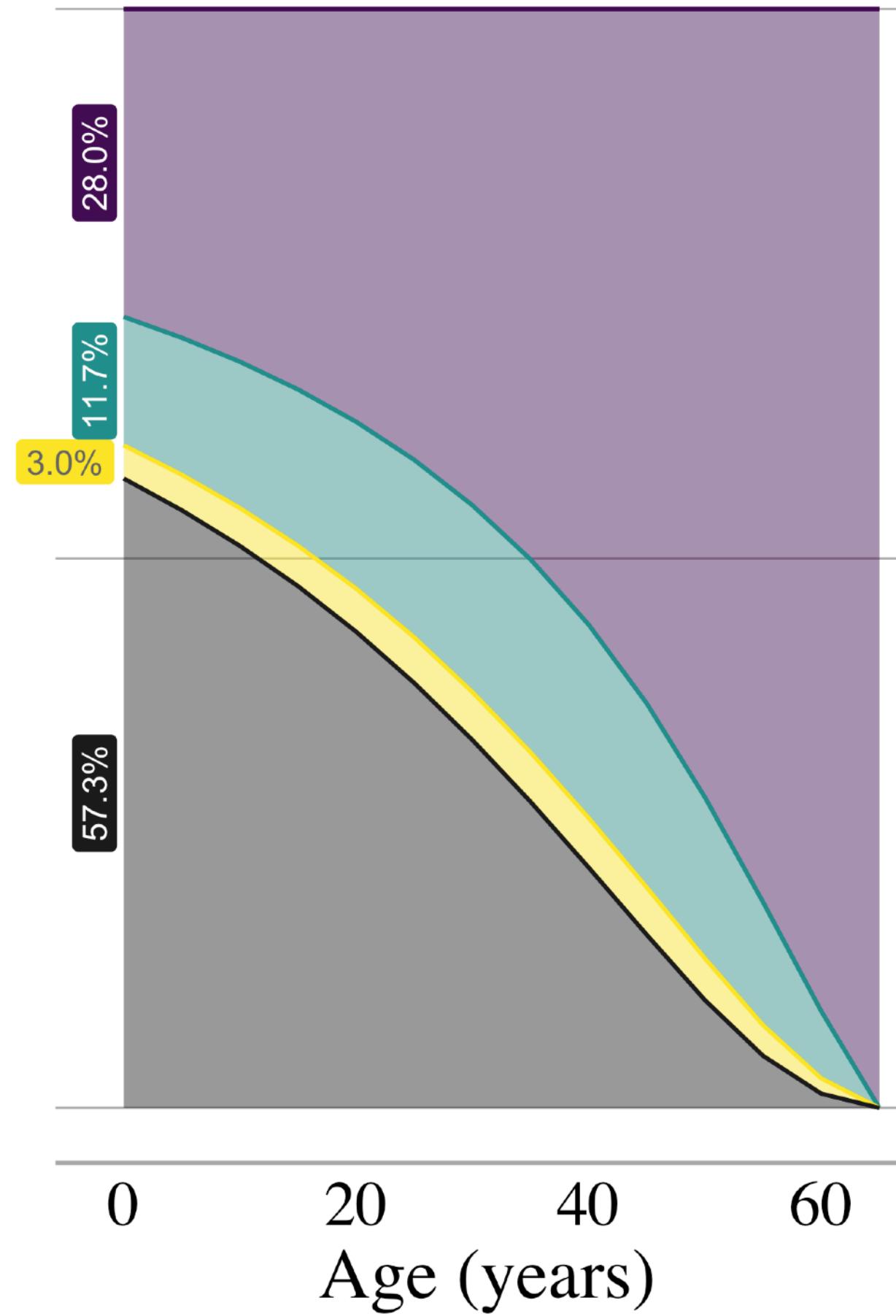
Proportion
of expected life remaining



a) Non-Hispanic black



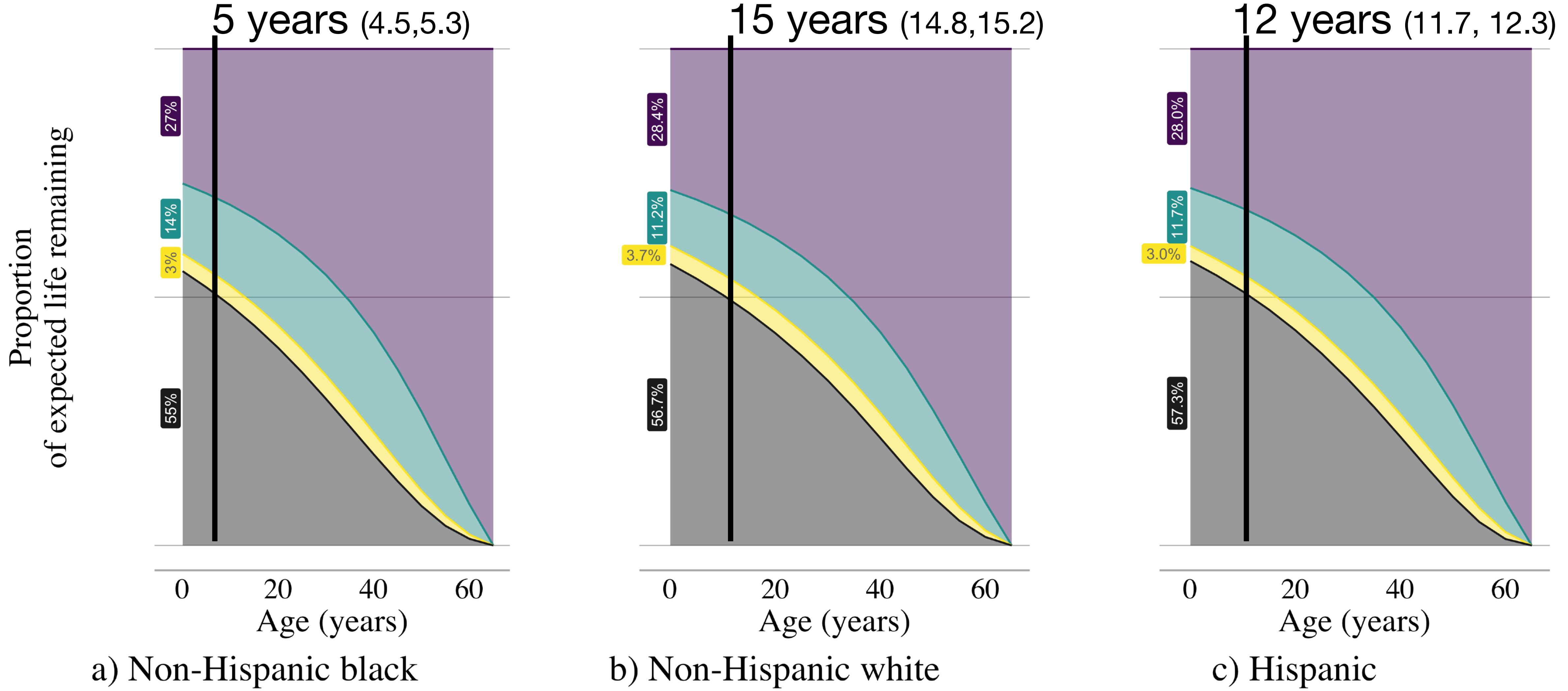
b) Non-Hispanic white



c) Hispanic

- Lost both
- Lost father only
- Lost mother only
- Lost none

Age at which majority of life is without both parents



a) Non-Hispanic black

b) Non-Hispanic white

c) Hispanic

- Lost both
- Lost father only
- Lost mother only
- Lost none

Takeaways

- At birth, can expect to live 42-46% of life without at least one parent
- Black children have less time with their parents but also are expected to lose a parent at a younger age
- Biggest difference across racial/ethnic lines is loss of father: Black children can expect to live 2 years longer without their father alive, even though overall life expectancy is ~6 years shorter
- Implications for life course outcomes and transitions
- Different consequences based on timing in life course: early loss versus sandwich generation

Summary and future work

Summary

- Demographic processes link the individual to the aggregate, and back again
- Transitions in demographic rates have implications for the availability of different types of kin, which impacts individual level outcomes
- Patterns of parental loss in the United States are not constant
- Increase in premature parental loss due to traumatic causes
- Loss of a parent is racially patterned in both magnitude and timing

Estimates here help to quantify and reframe, but it's just one piece

Future work

- Extending methods to investigate heterogeneity in fertility and mortality
- Compare / integrate concepts of non-biological parents, one parent households, same-sex parents
- Estimation and understanding in low- and middle-income countries
- Extension of statistical models to more complex kin structures



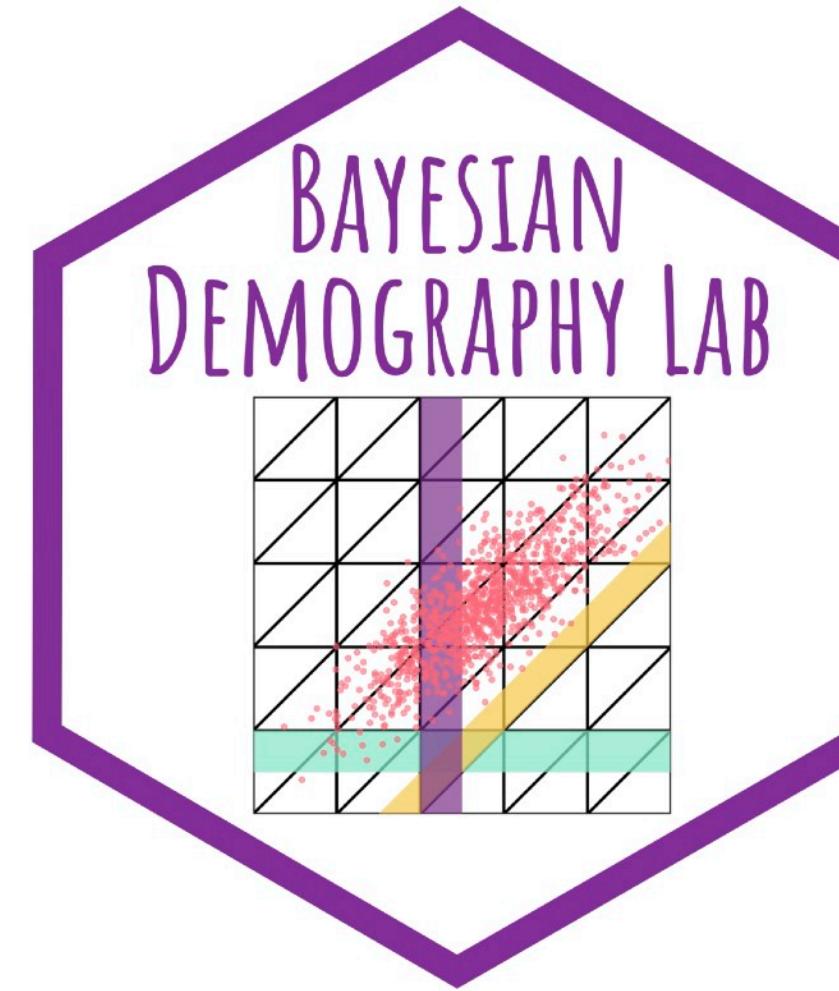
World Health Organization



Team



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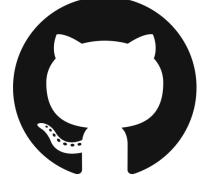
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Thanks!

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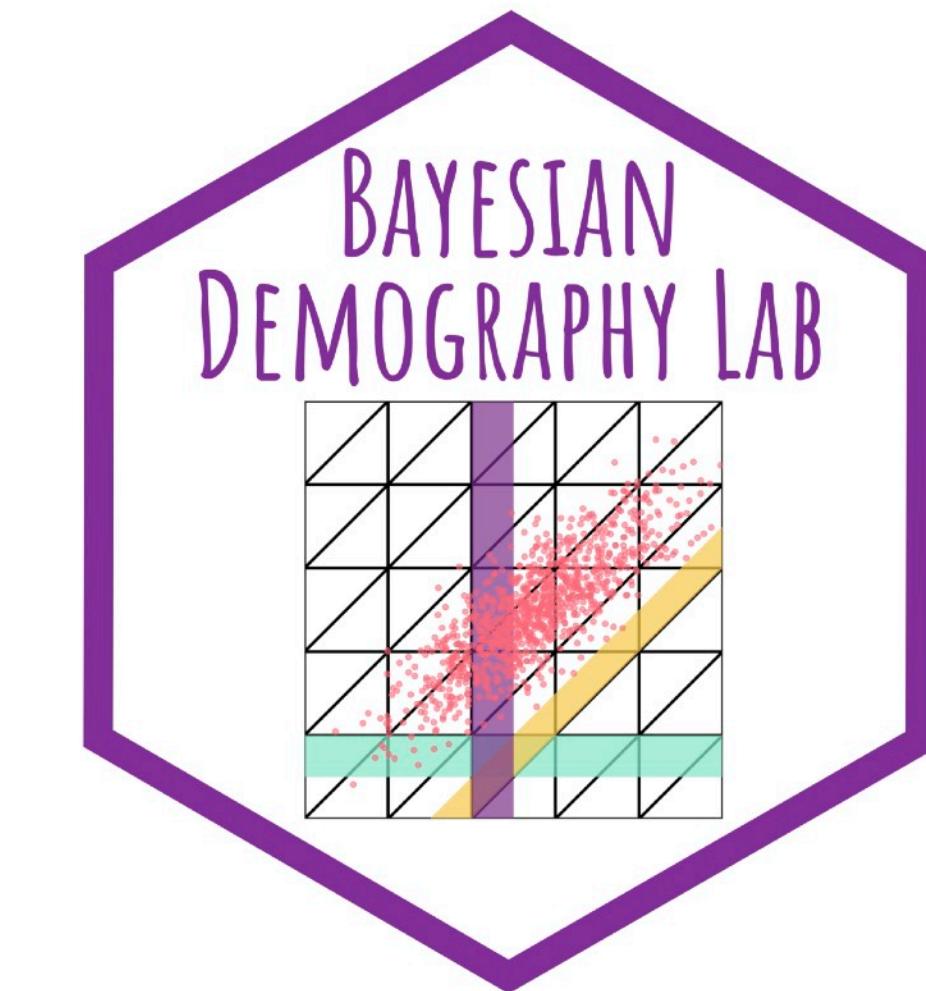
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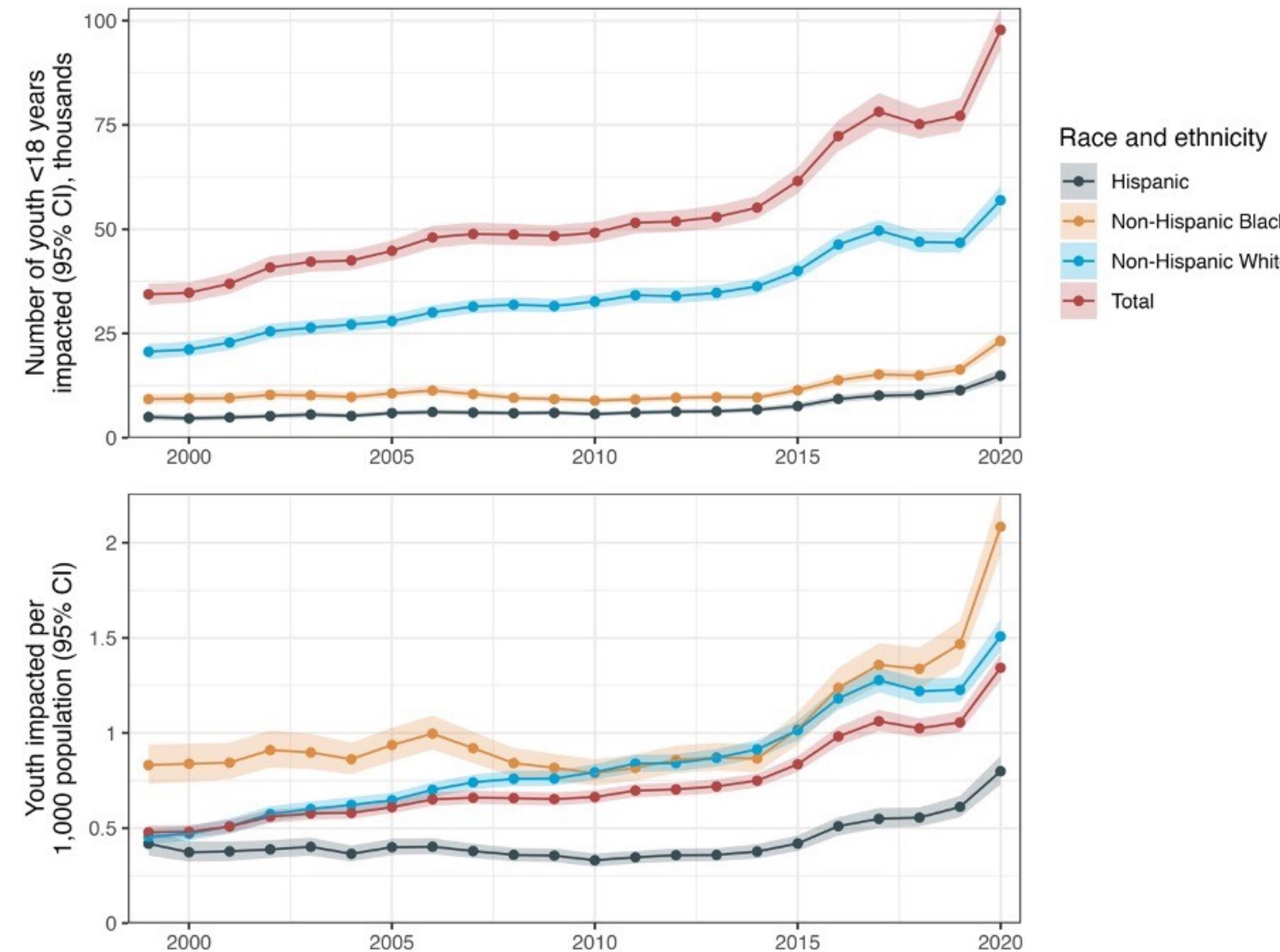
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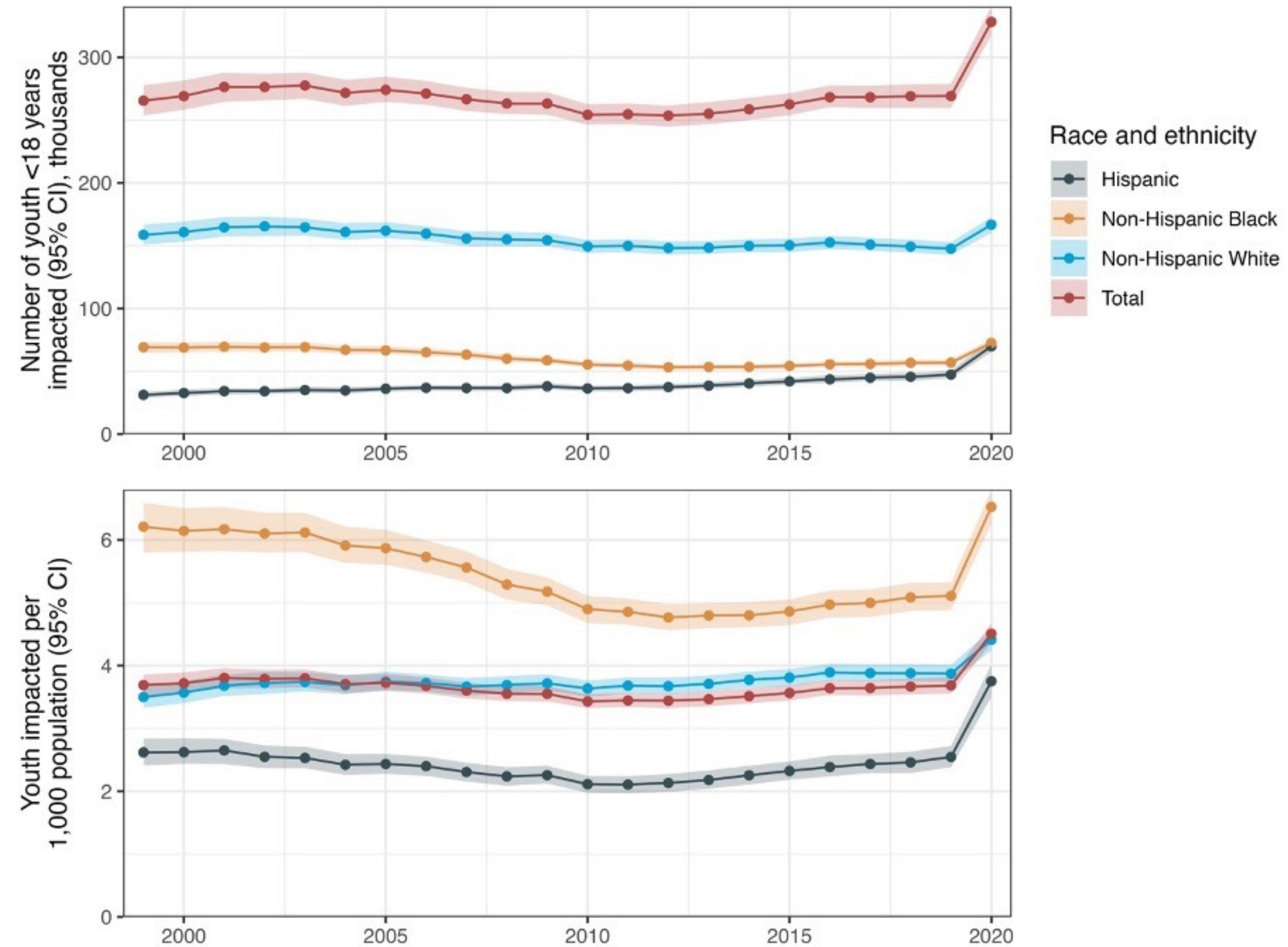
Extra

Project 1

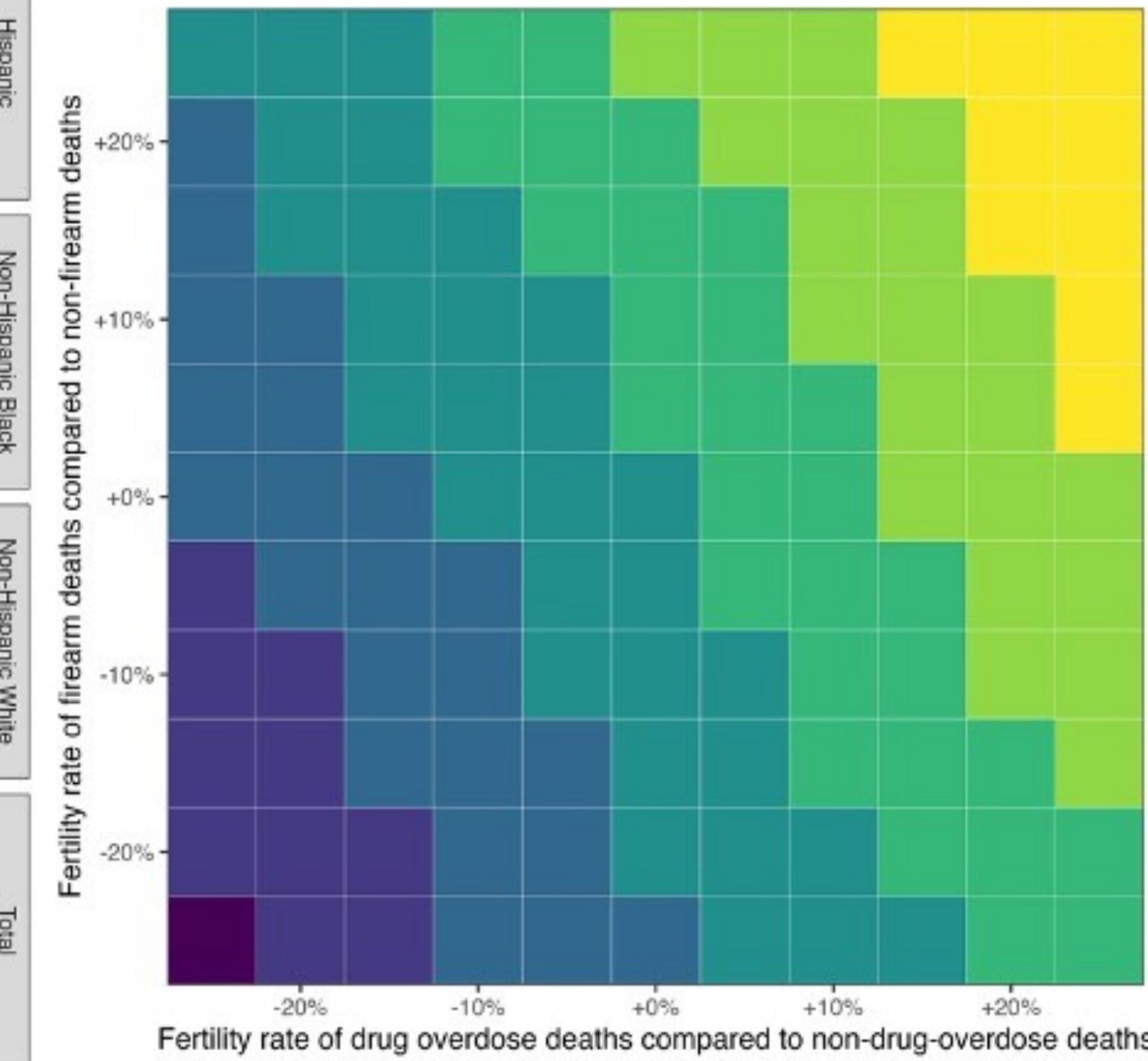
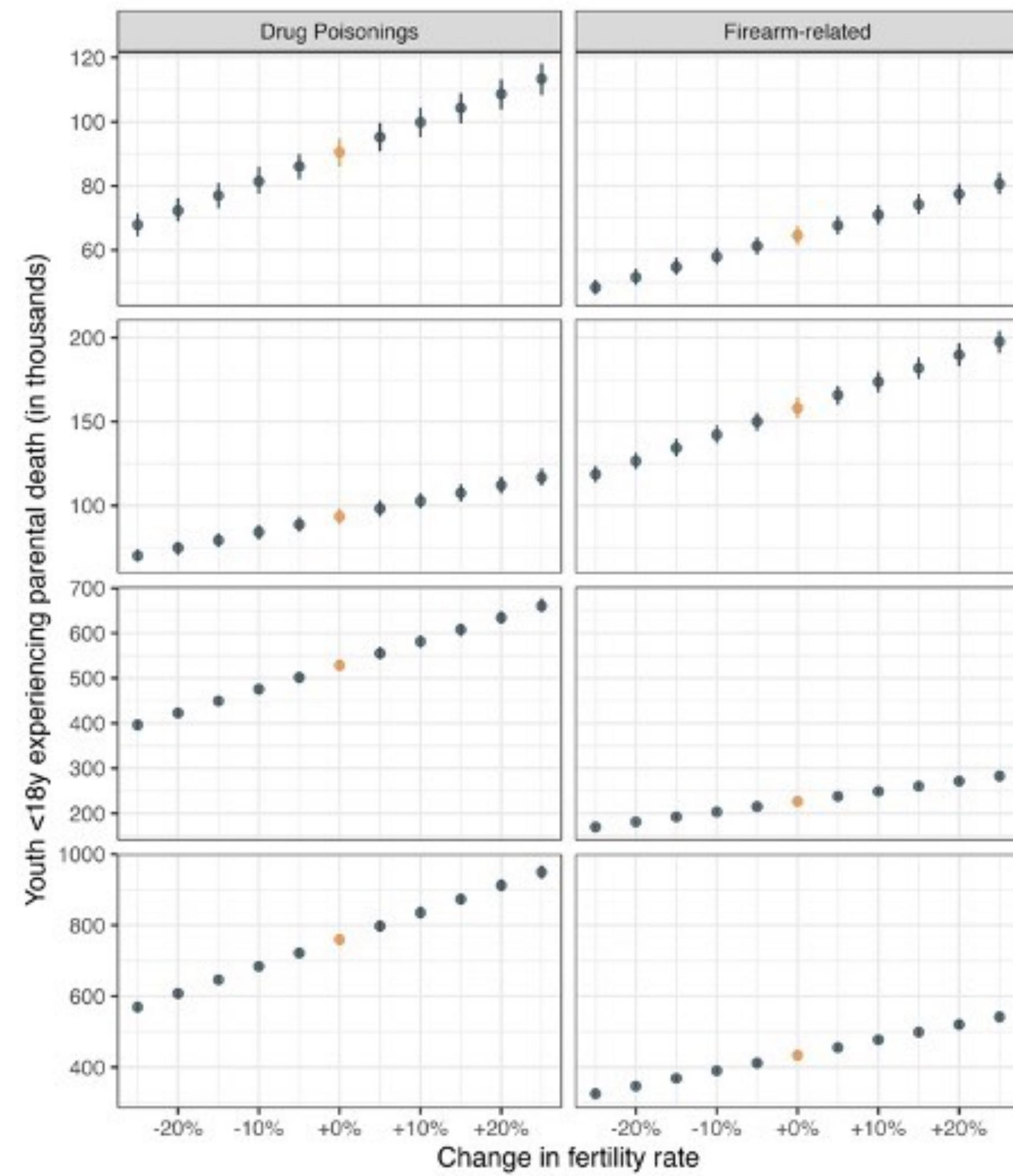
Both causes combined



All causes



Sensitivity



Youth <18y experiencing
parental death (in thousands)

Expected number of living children

$$\begin{pmatrix} a^f \\ a^m \end{pmatrix}(x+1, t+1) = \begin{pmatrix} U_t^f & 0 \\ 0 & U_t^m \end{pmatrix} \begin{pmatrix} a^f \\ a^m \end{pmatrix}(x, t) + \begin{pmatrix} \bar{\alpha}F_t^f & \bar{\alpha}F_t^m \\ \alpha F_t^f & \alpha F_t^m \end{pmatrix} \begin{pmatrix} \phi^f \\ \phi^m \end{pmatrix}(x, t)$$

Quantities of interest

First, we only consider the first 18 entries of $a^f(x, t)$ and $a^m(x, t)$ reflecting the expected number of living children less than 18 years old of an individual aged x in year t , and sum these entries over both child sexes. Define this quantity to $a_{<18}(x, t)$. In any given year, we can estimate the number of children losing a parent as

$$\text{Number of children } < 18 \text{ yo experiencing parental death} = \sum_{x=0}^{\omega} a_{<18}(x, t) \times D(x, t) \quad (4)$$

where $D(x, t)$ reflects the death counts of individuals aged x , in year t , from a given cause. This term can be computed by sex, giving the number of children who lost a mother (father). The probability for youth aged less than 18 years old experiencing a parental death by cause in year t , can be expressed as the ratio

$$p^g(t) = \frac{\text{Number of children } < 18 \text{ yo experiencing parental death}}{\text{Number of children } < 18 \text{ yo}} = \frac{\sum_{x=0}^{\omega} a_{<18}(x, t) \times D(x, t)}{\sum_{x=0}^{\omega} a_{<18}(x, t) \times N(x, t)}$$

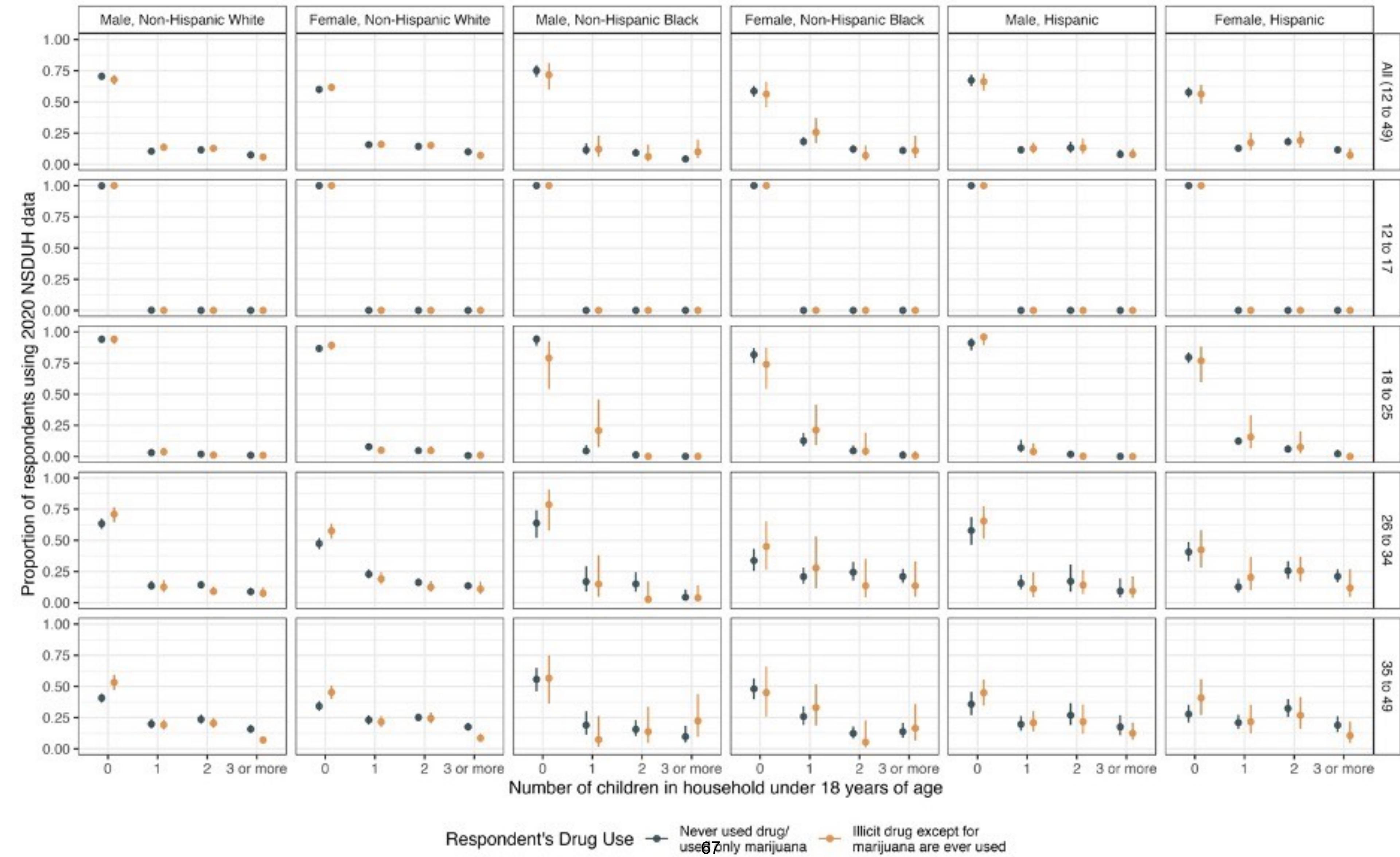
Male fertility

- Model ratio of race/ethnicity fertility to national fertility over time
- Male race/ethnicity specific fertility is:

Ratio x male national fertility x race-specific female national fertility x (male/female national fertility)

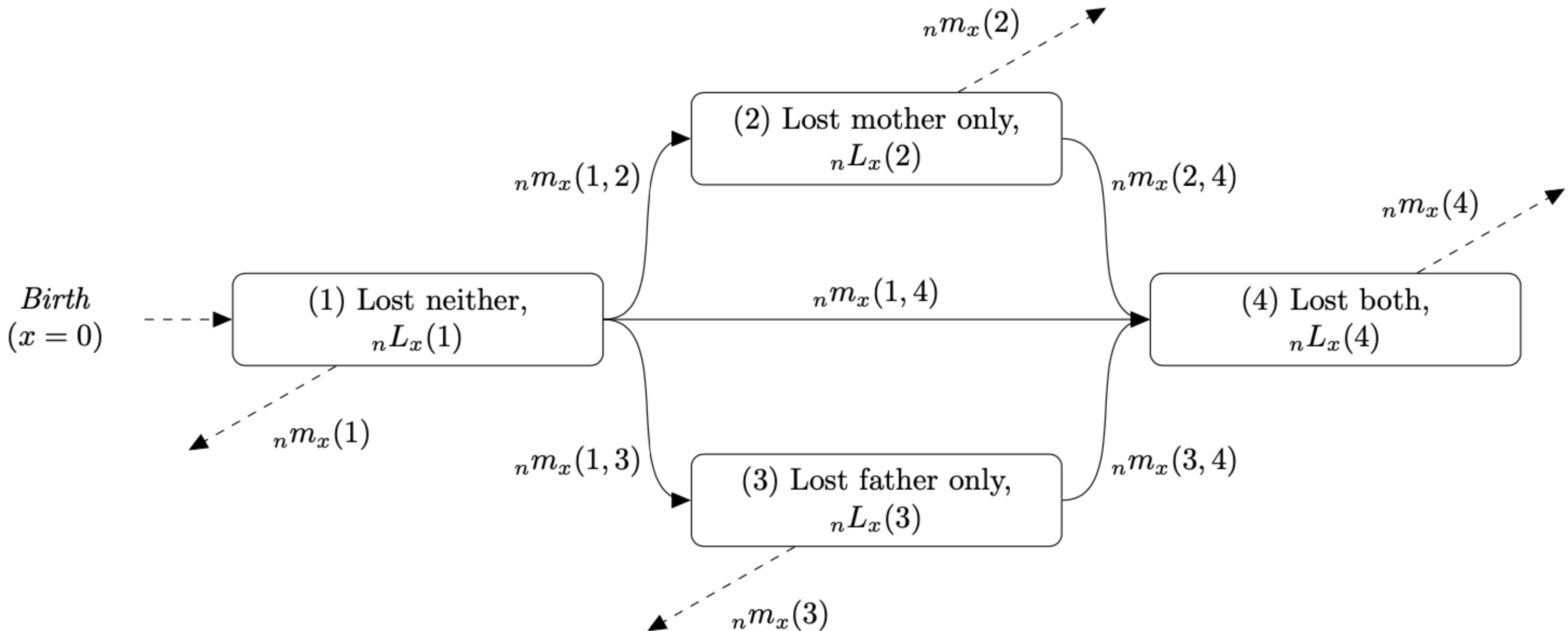
$$\hat{f}_{r,a,t} = (\widehat{\alpha_{a,r}} + \hat{\beta}_{a,r} t) \times F_{a,t} \times TFR_{r,,t} \times \frac{TFR_{M,t}}{TFR_{F,t}}$$

NSDUH



Project 2

States of parental loss



Multistate lifetable for parental loss

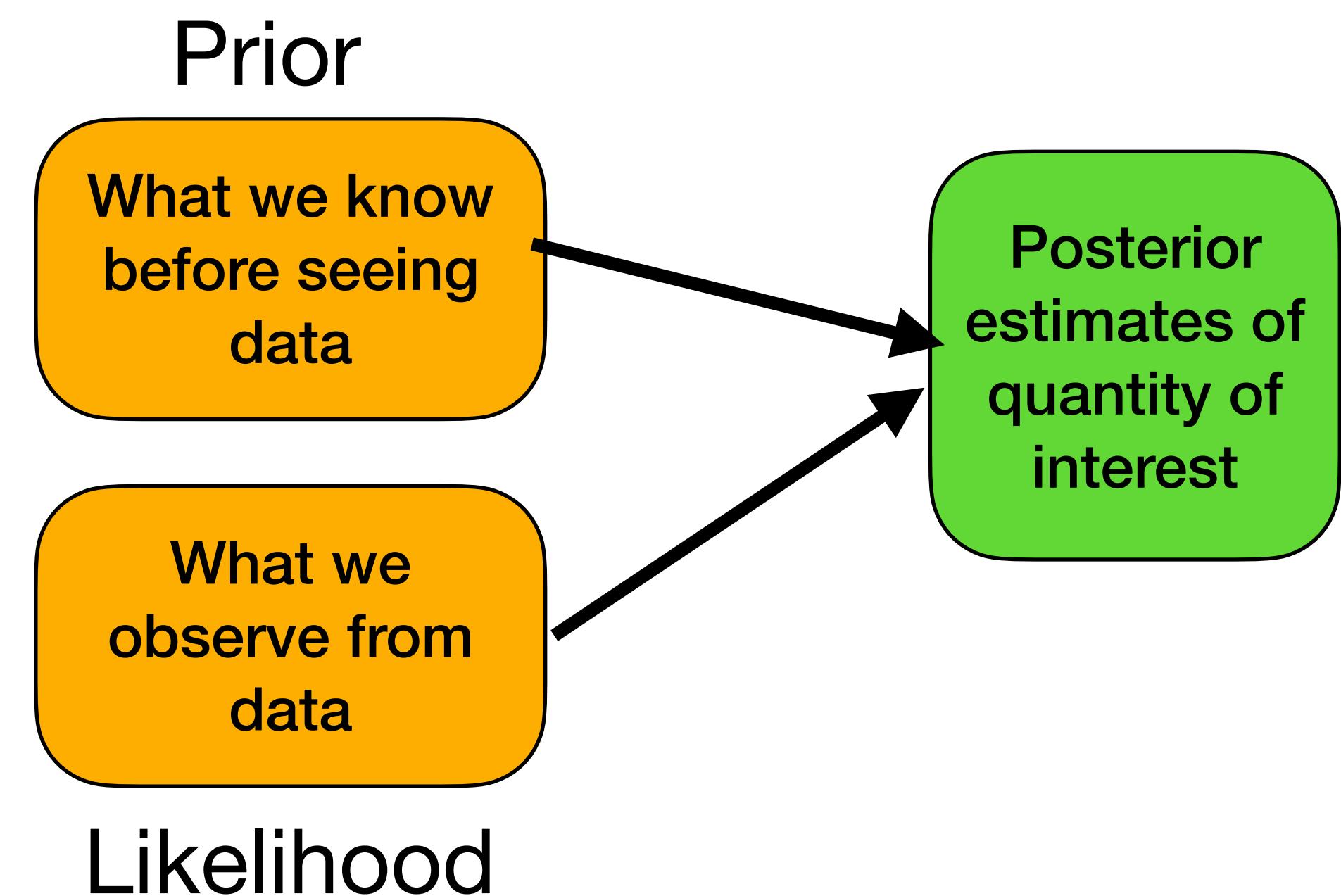
- Interested in four different states over age (lost none, lost mother, lost father, lost both)
- Partition person-years lived in each age group into person-years in each state
- Calculate the life expectancy lived in each state i for each age x

$$e_x(i) = \frac{\sum_{k=0}^{\infty} L_{(x+k \cdot n)}(i)}{\ell_x} \quad \text{for } i = 1, 2, 3, 4$$

- E.g. $e_0(1)$ is the expected number of years lived with both parents at age 0.

Using Bayesian methods to combine data sources

- Estimates of quantity of interest are a combination of the **prior** knowledge and evidence we see from data, encoded in the **likelihood**
- The **posterior** combines both of these types of evidence to give estimates of the quantity of interest
- Bayesian inference is very useful in a wide range of demographic settings:
 - Dealing with multiple data sources
 - Different types of uncertainty
 - Hierarchical structures

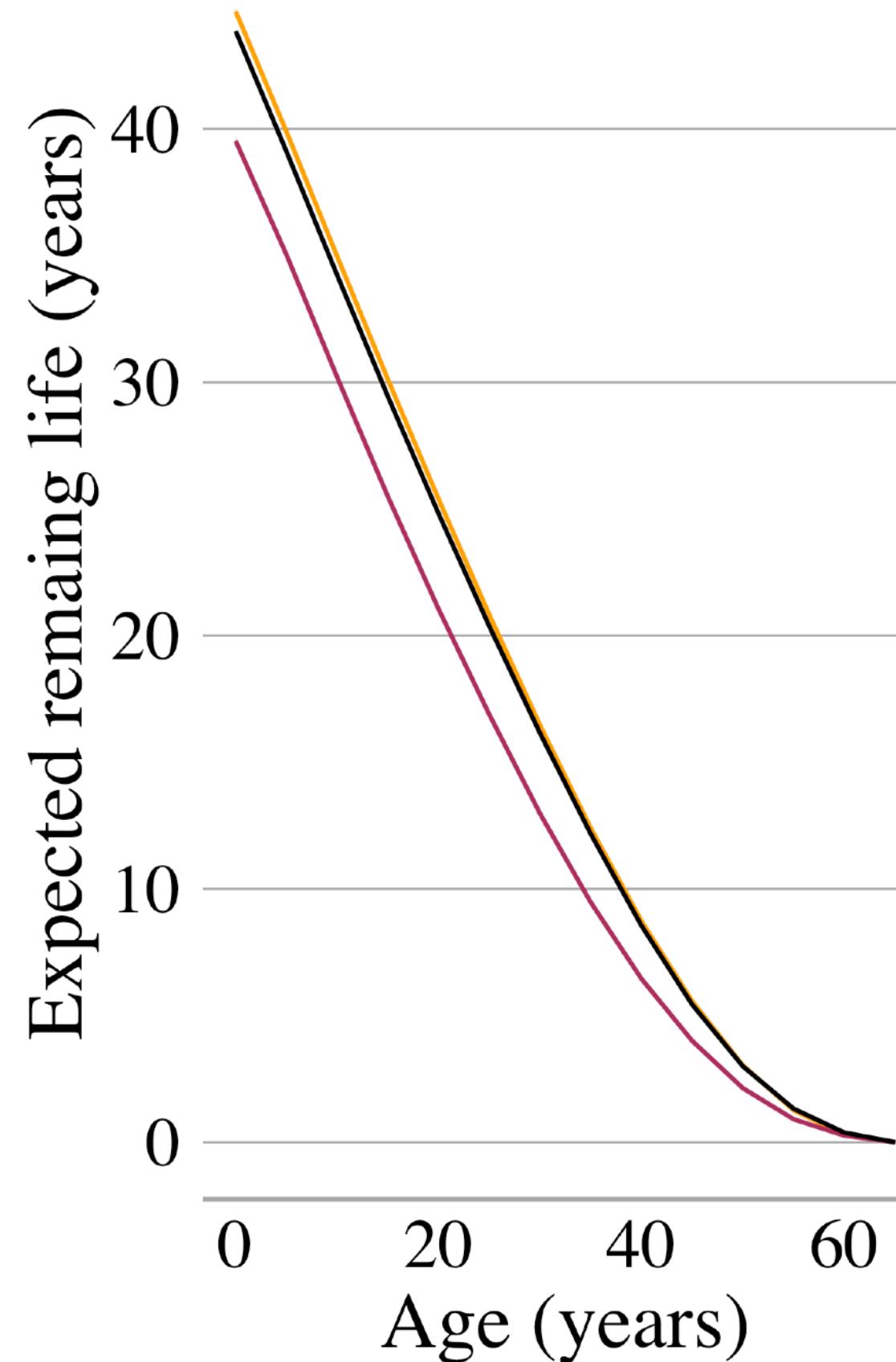


Computation

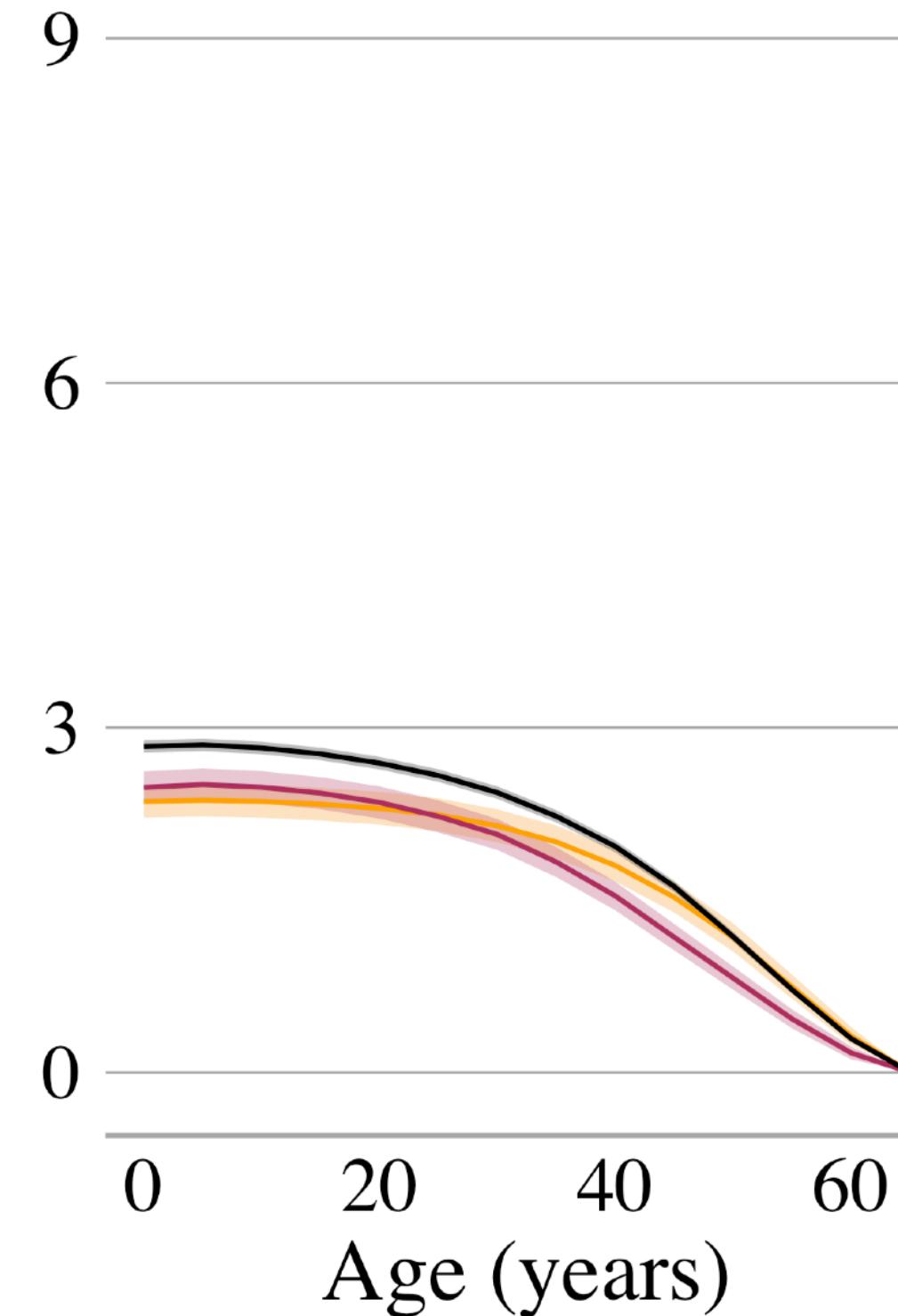
- Samples from the posterior distribution for the transition rates (and proportions) are obtained using a Markov Chain Monte Carlo (MCMC) algorithm (using Stan in R)
- Posterior samples for rates and proportions are then used to calculate posterior samples of multistate lifetables by parental mortality status
- 95% credible intervals are calculated based on the 2.5th and 97.5th percentiles



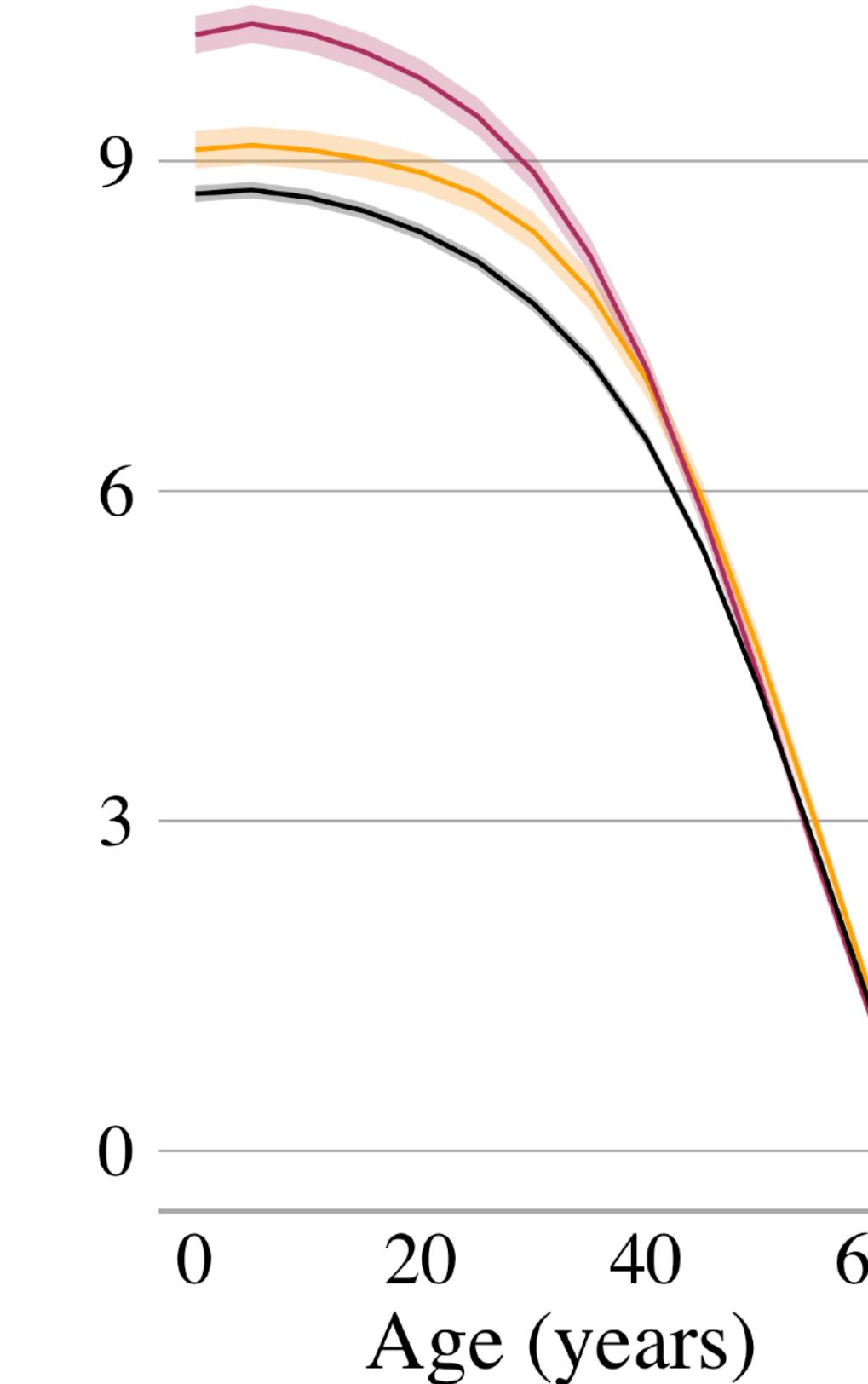
Remaining life expectancy



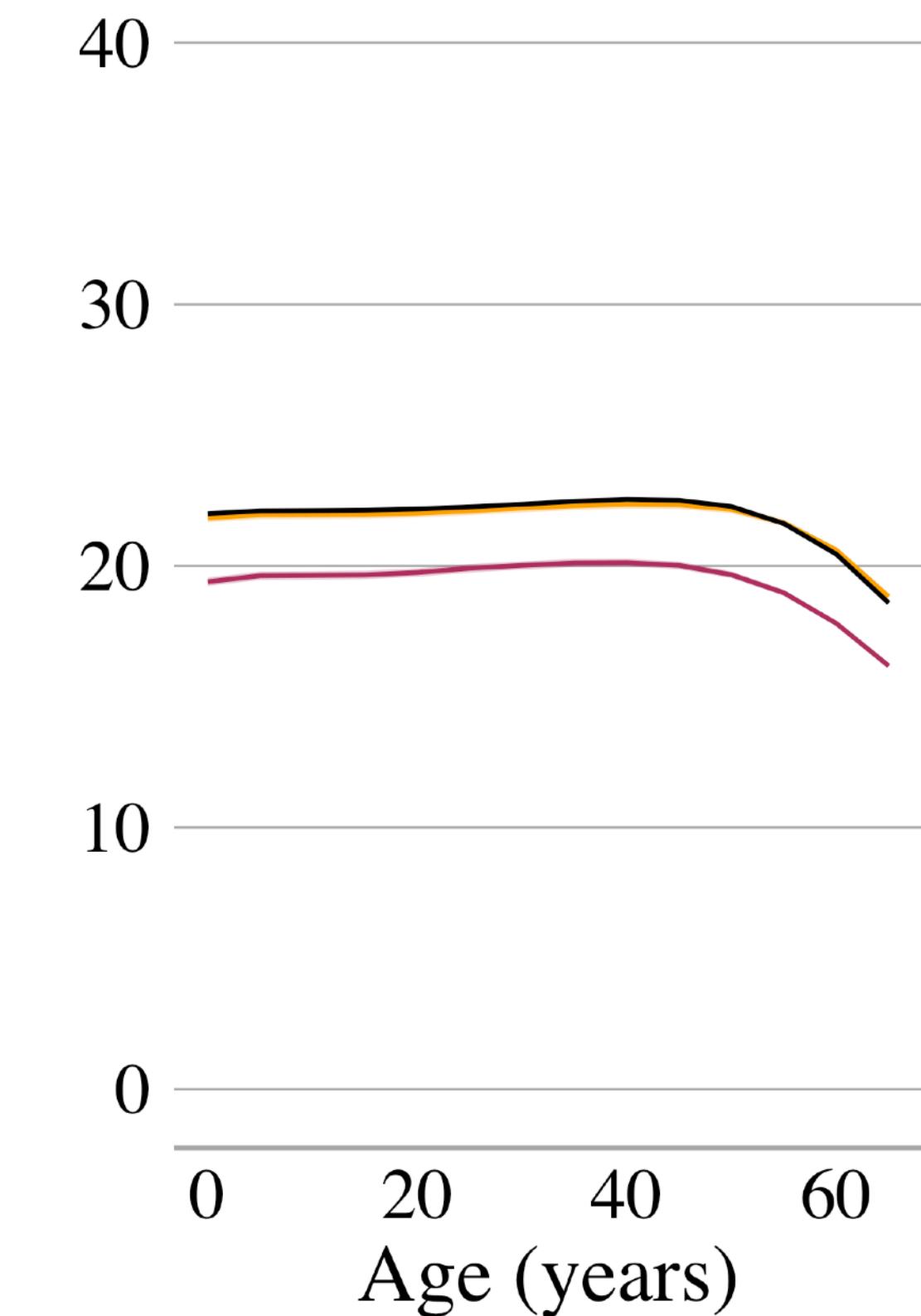
a) Lost none



b) Lost mother only



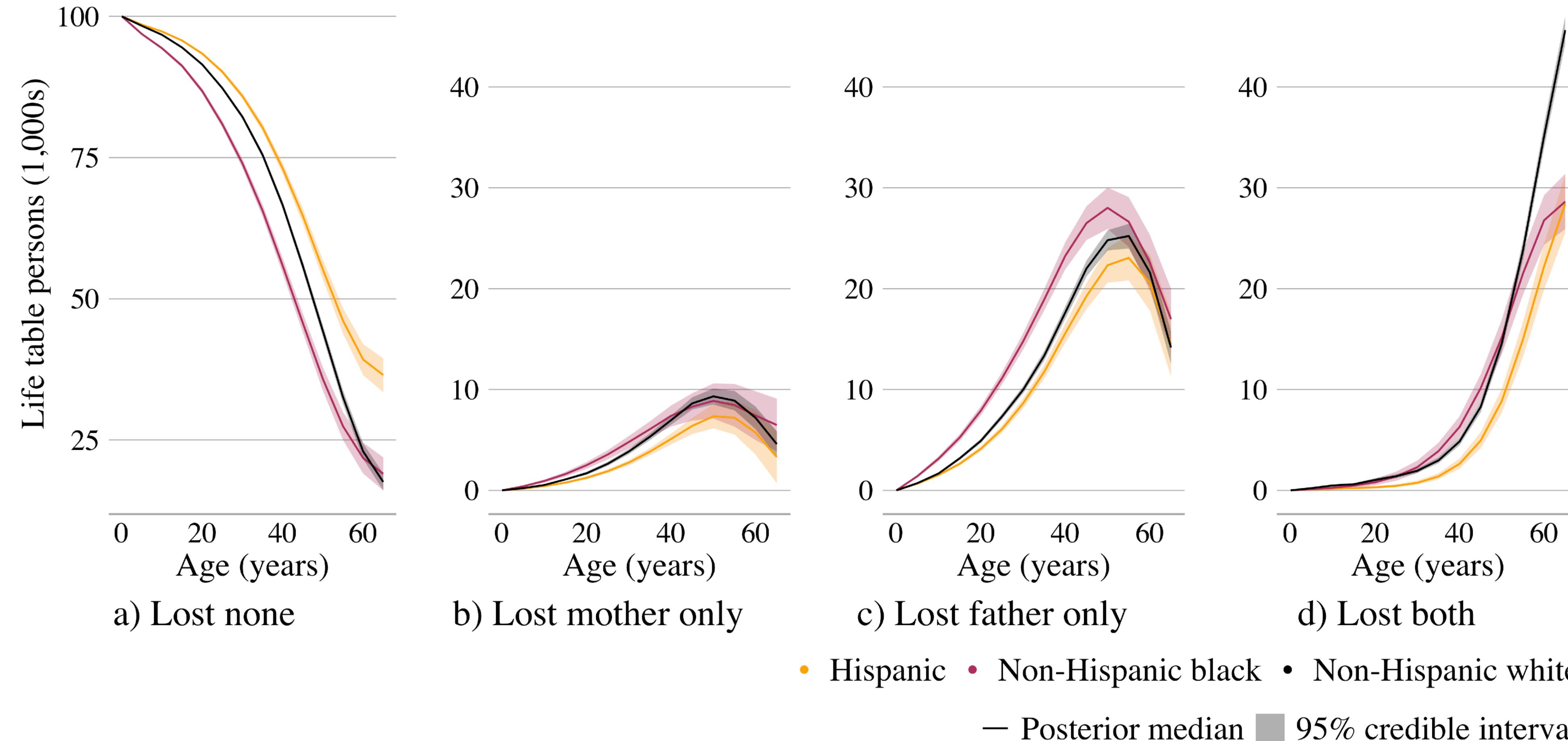
c) Lost father only

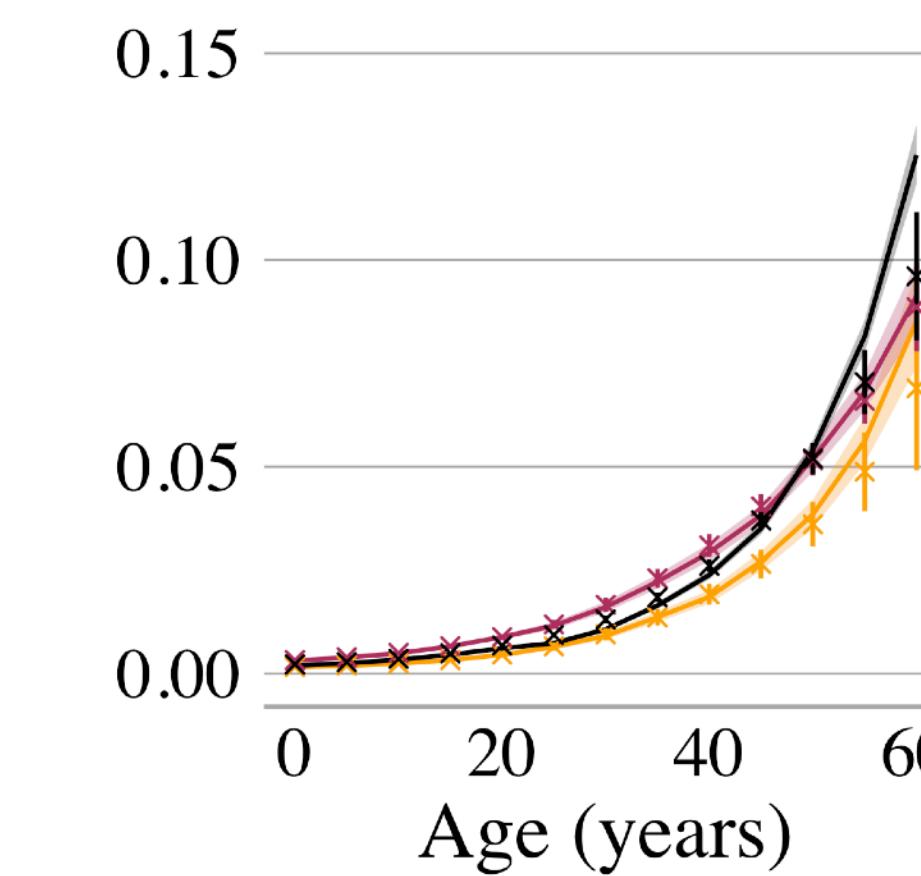
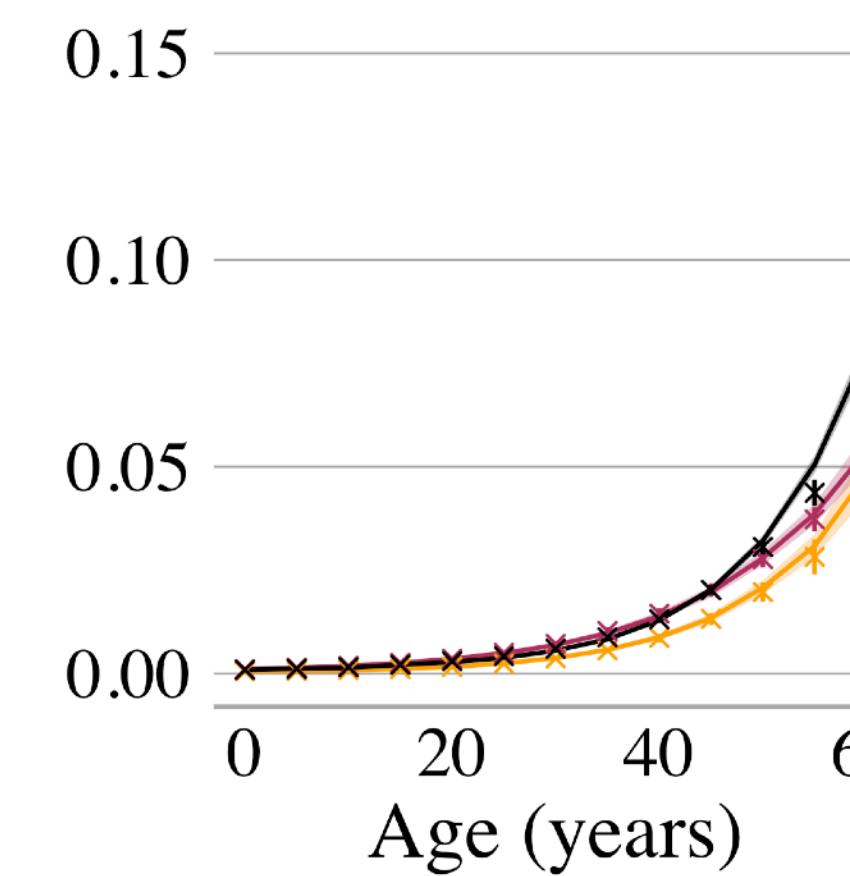
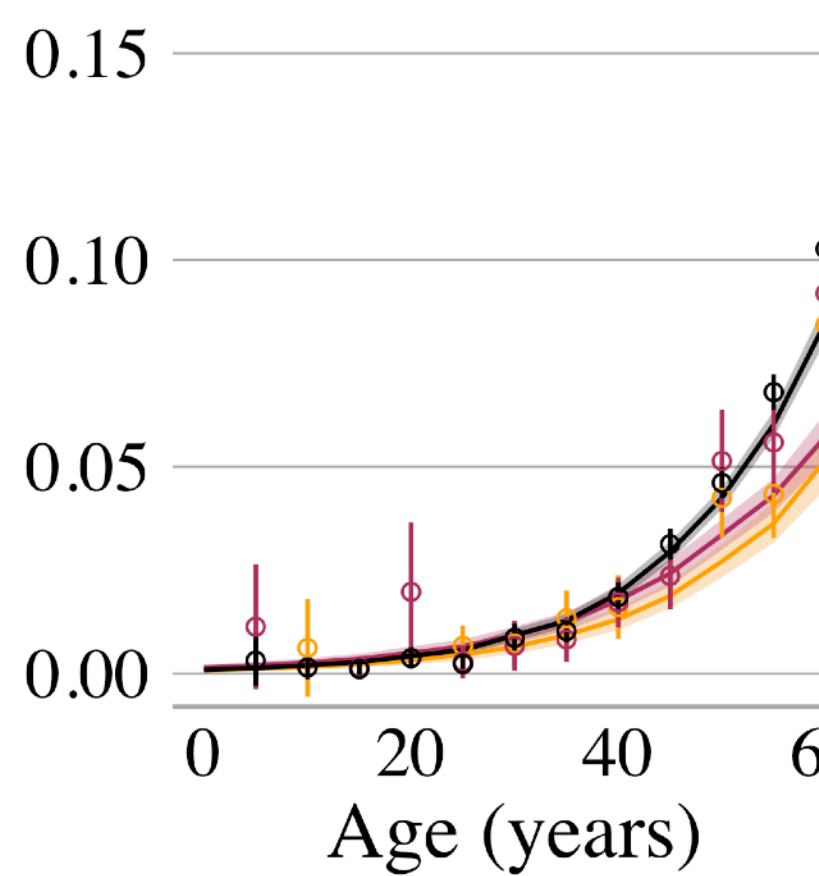
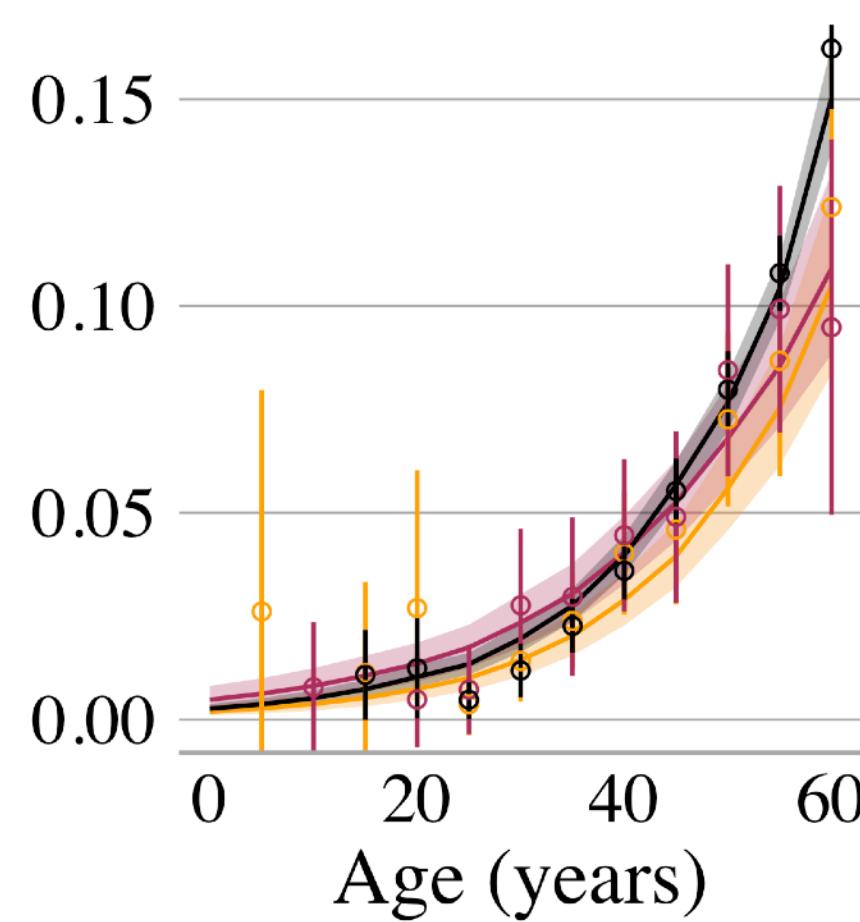
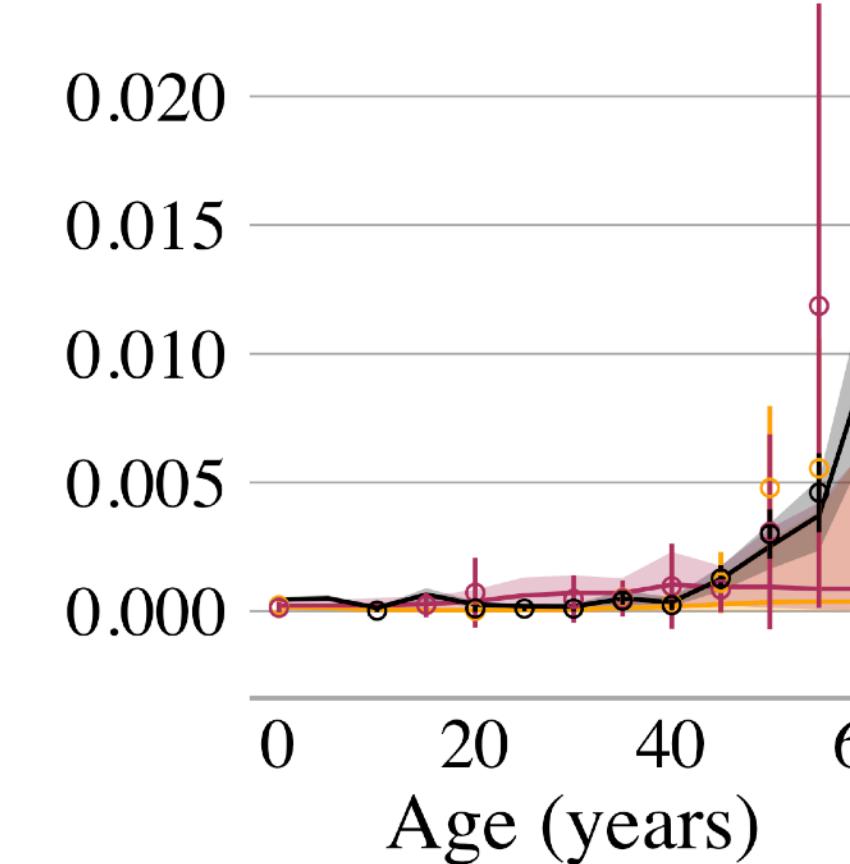
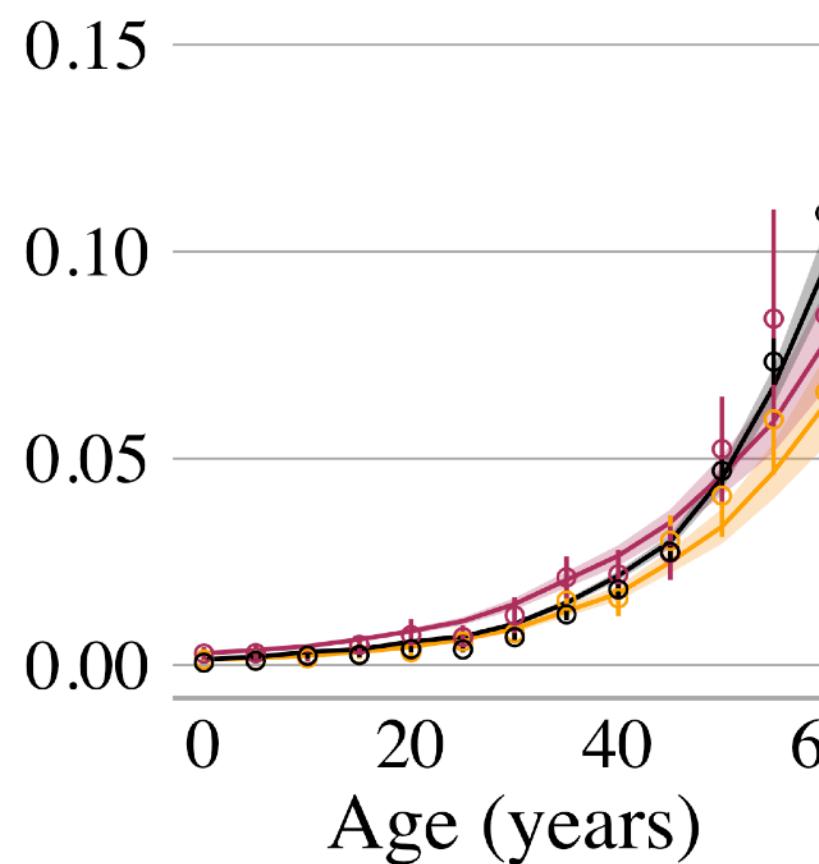
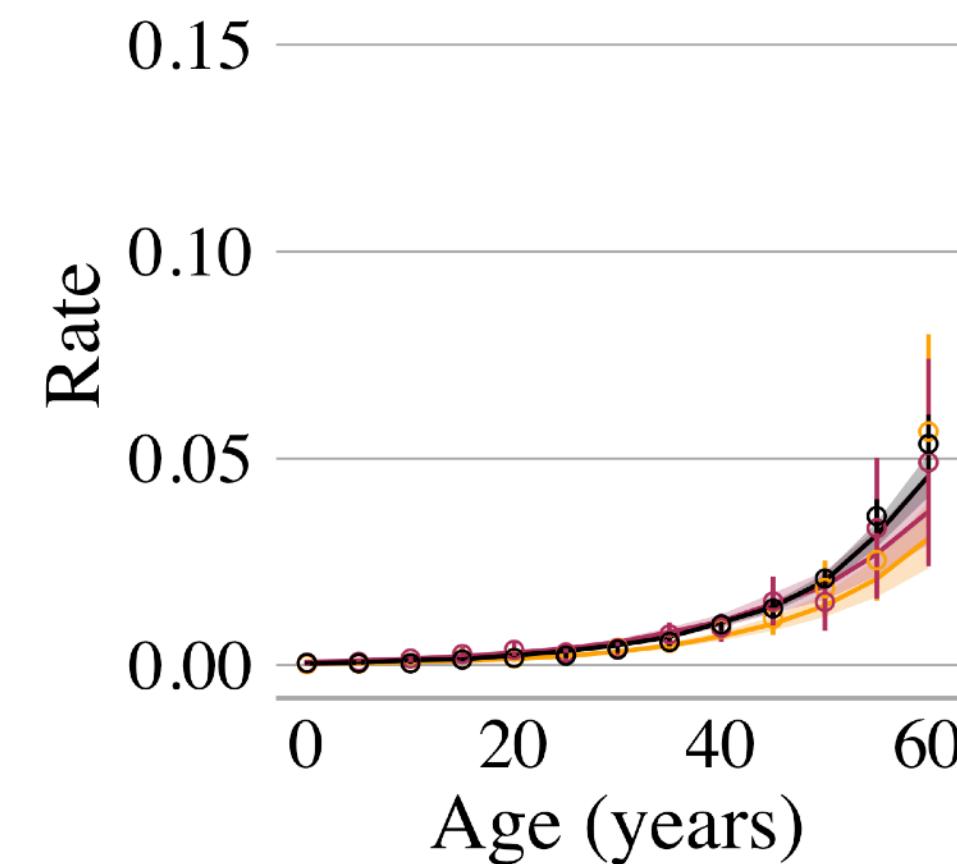


d) Lost both

- Hispanic
- Non-Hispanic black
- Non-Hispanic white
- Posterior median
- 95% credible interval

Survivors by age

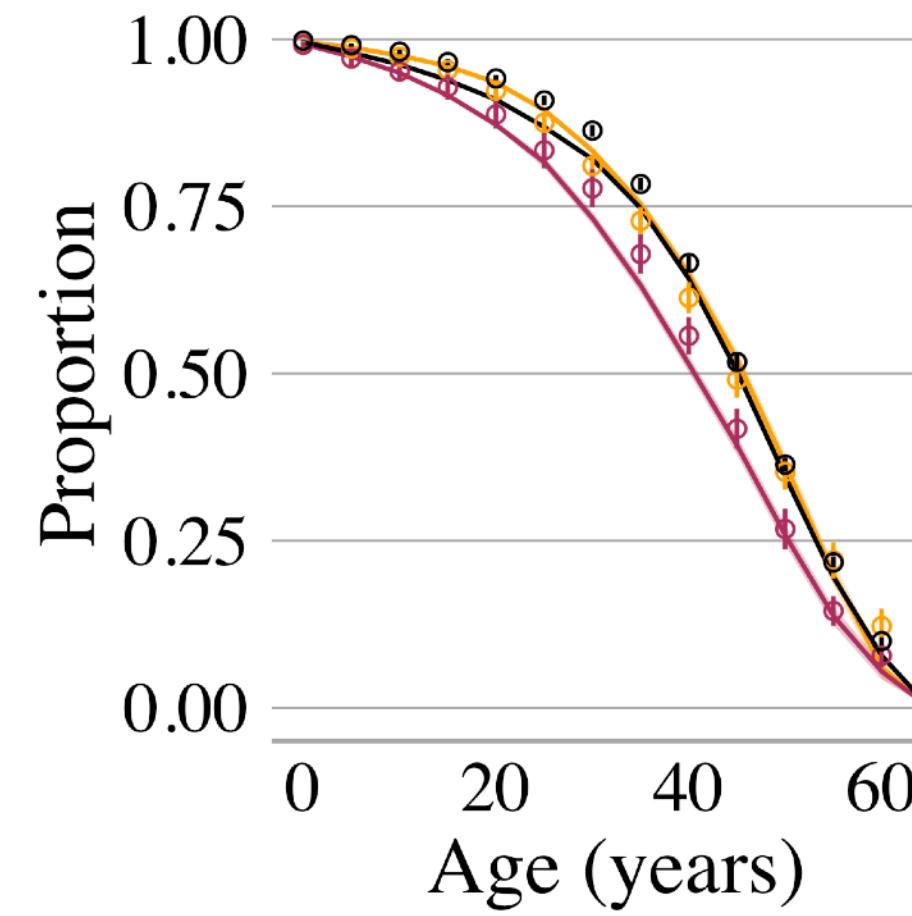




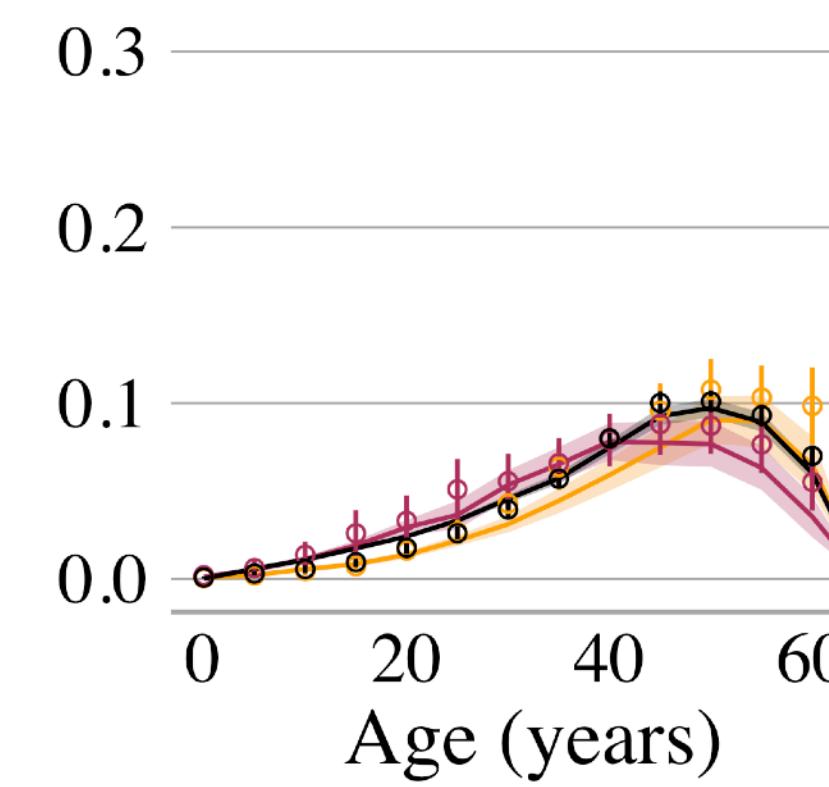
◦ SIPP estimates × Projection matrix estimates

• Hispanic • Non-Hispanic black • Non-Hispanic white

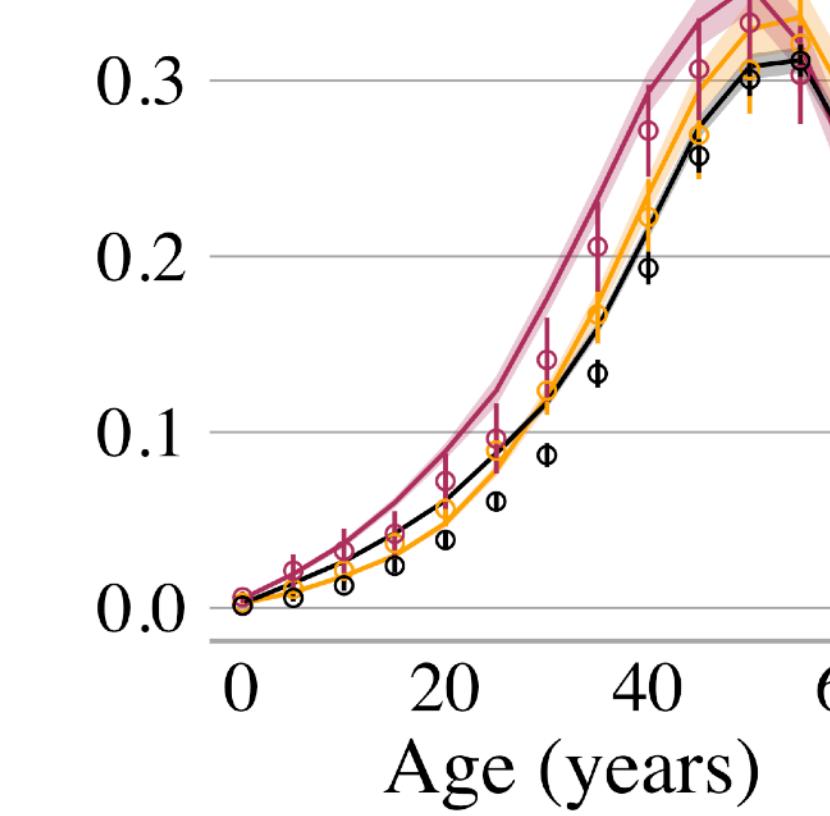
— Posterior median ■ 95% credible interval



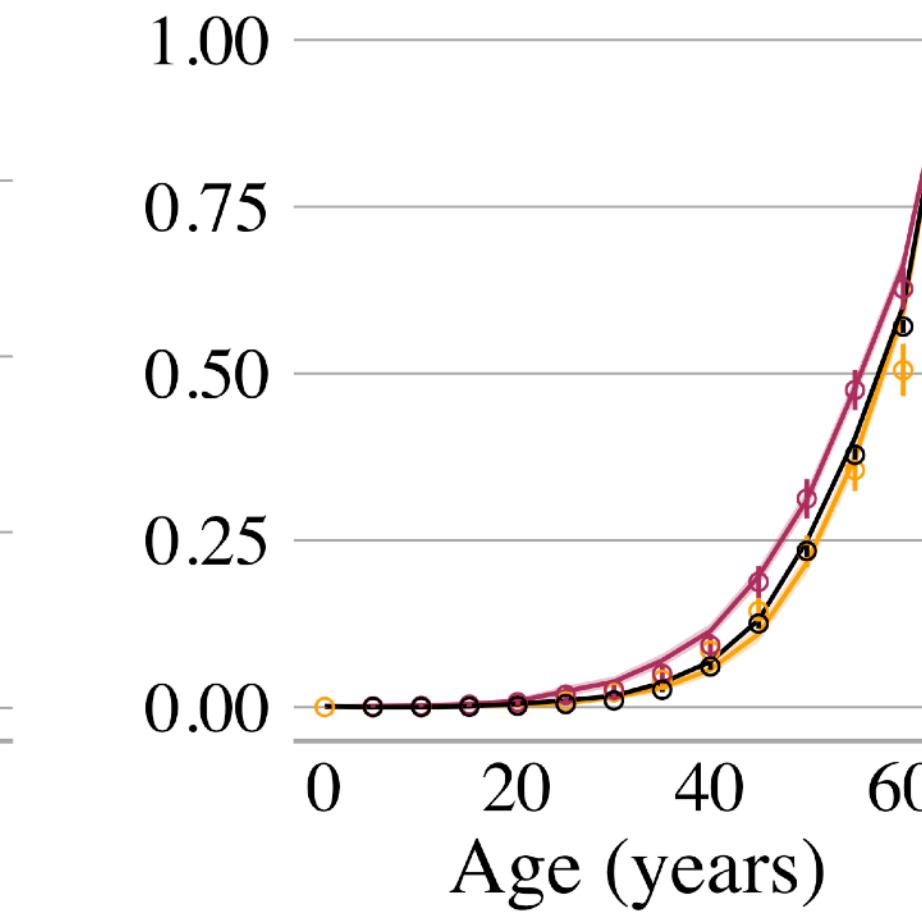
a) Lost none



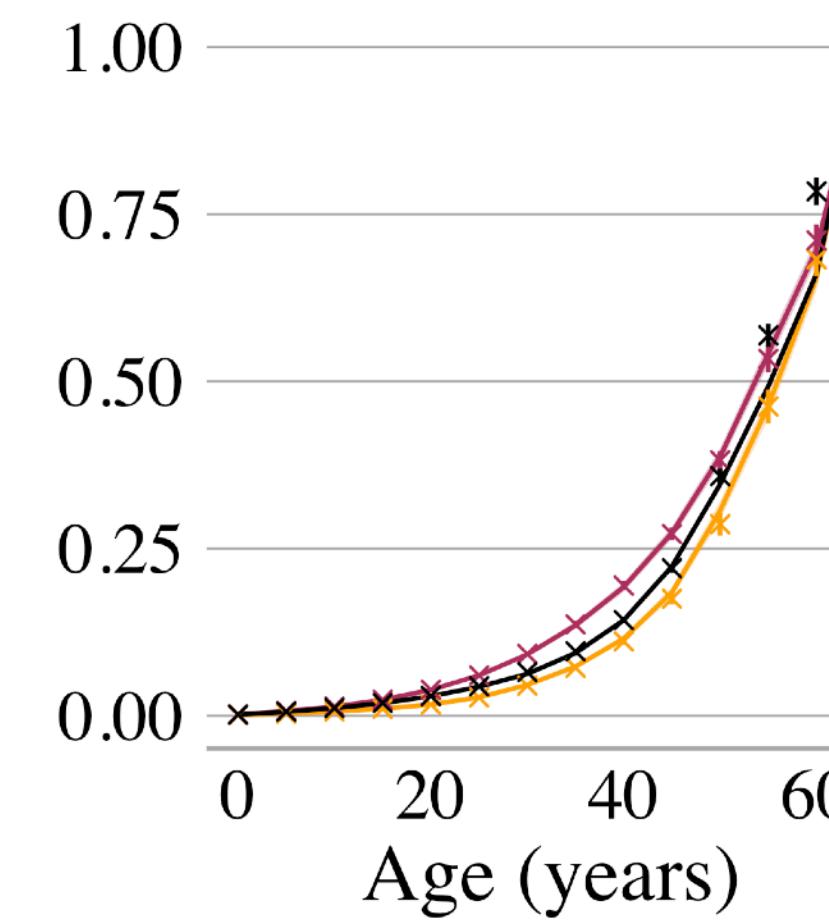
b) Lost mother only



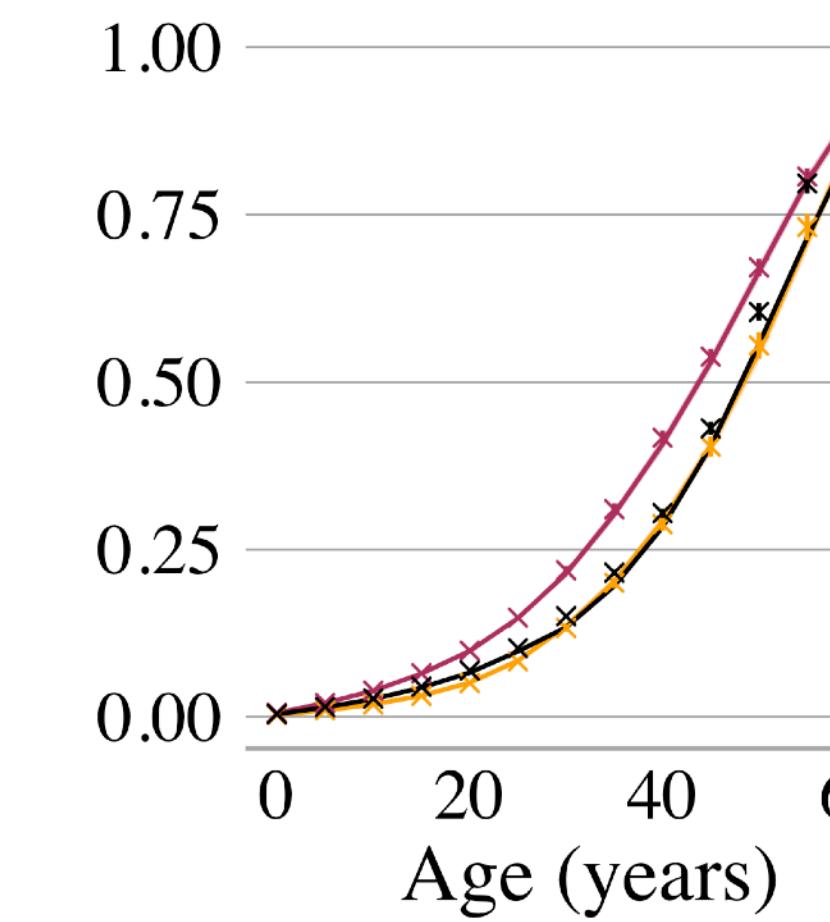
c) Lost father only



d) Lost both



e) Lost mother or both

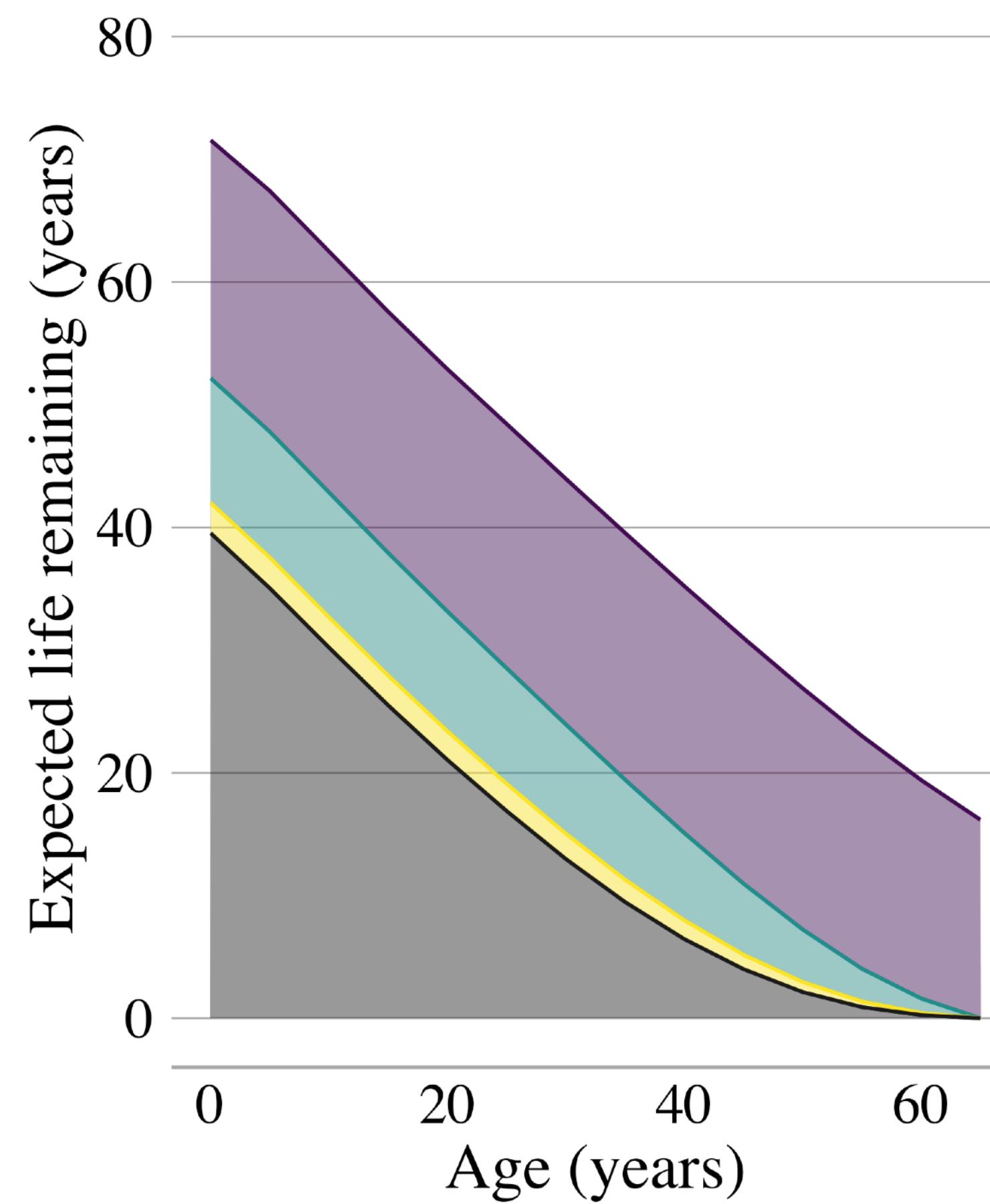


f) Lost father or both

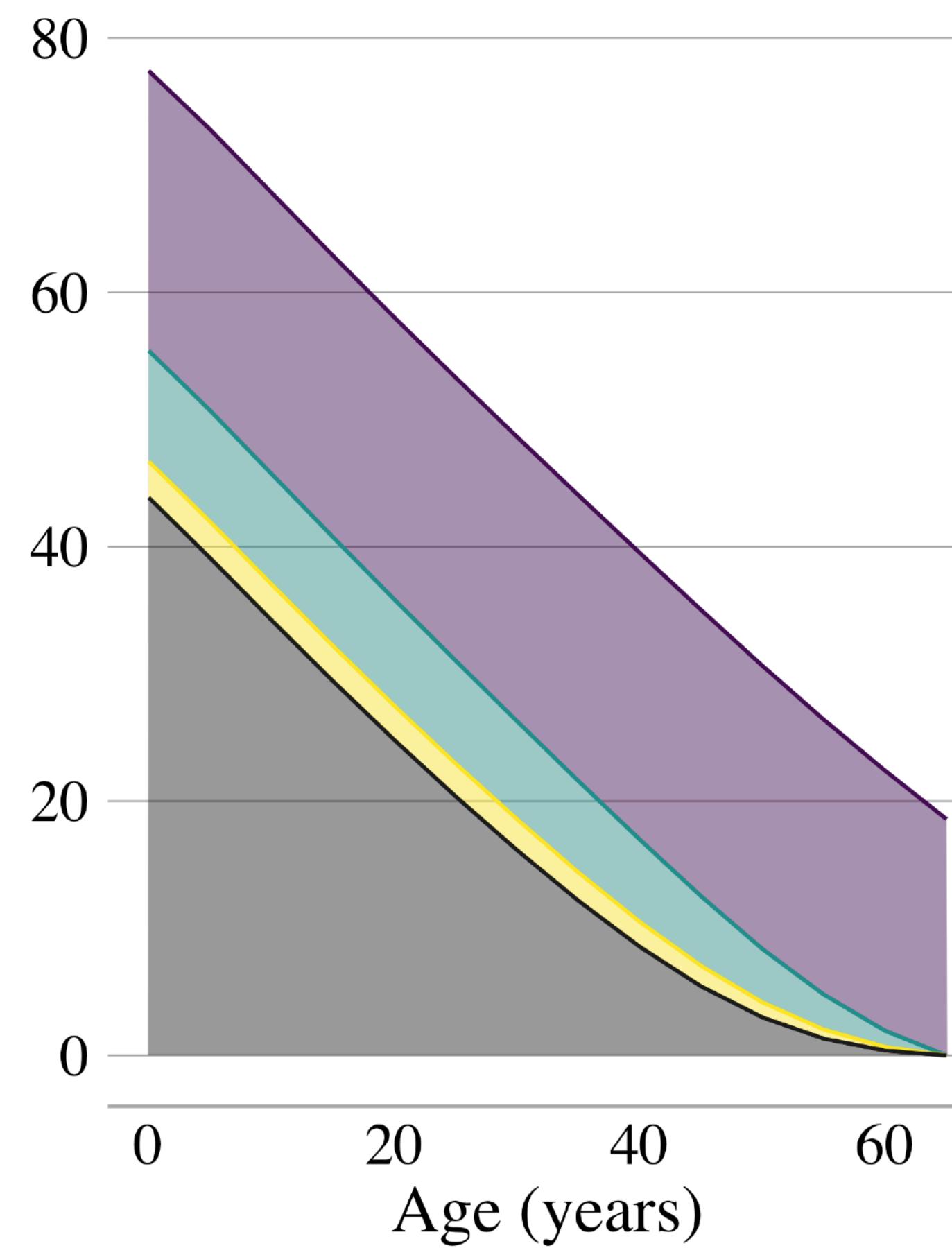
◦ SIPP estimates × Projection matrix estimates

• Hispanic • Non-Hispanic black • Non-Hispanic white

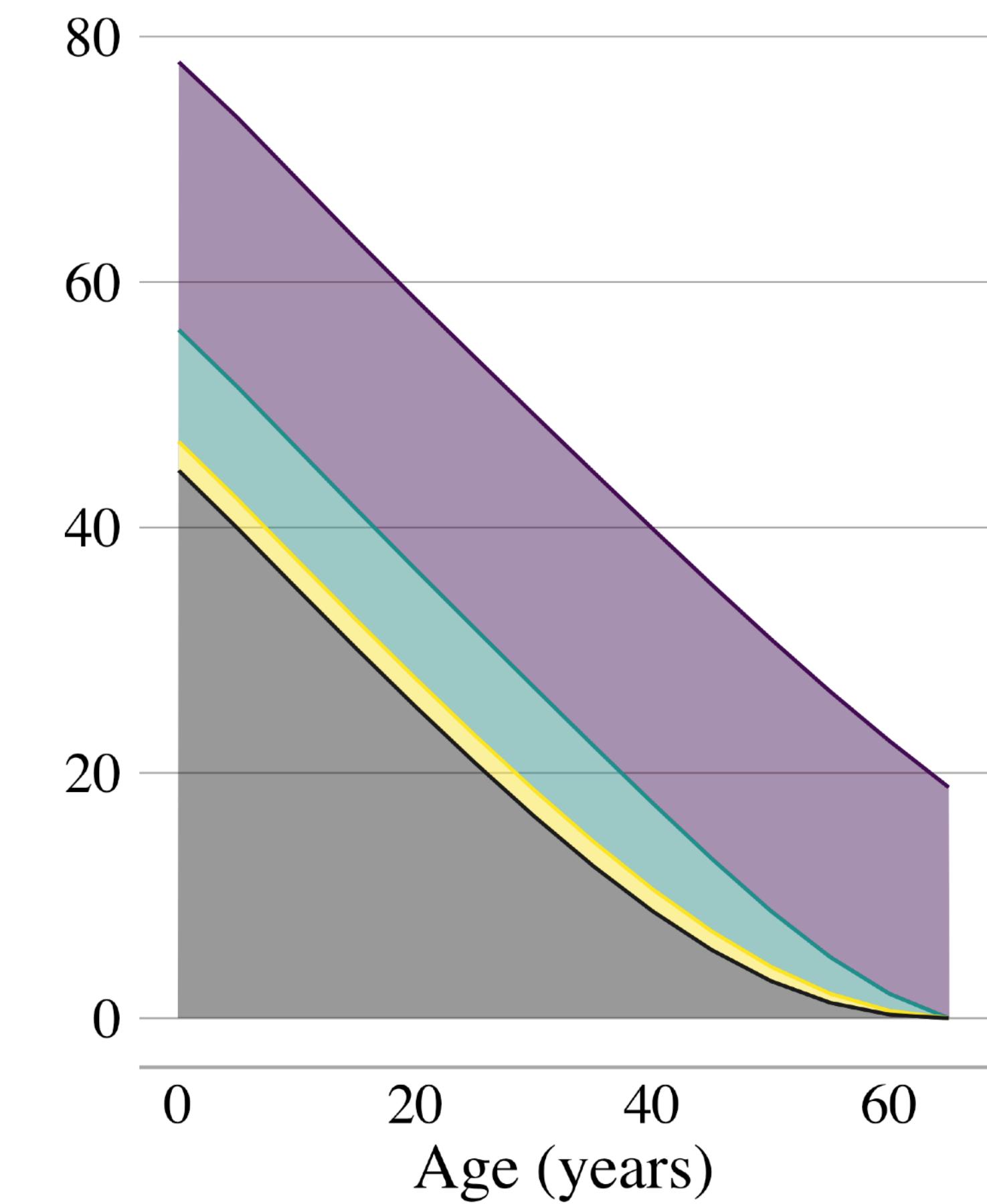
— Posterior median ■ 95% credible interval



a) Non-Hispanic black



b) Non-Hispanic white



c) Hispanic

- Lost both
- Lost father only
- Lost mother only
- Lost none