

The Role of Changing Education Composition in Growing Educational Mortality Inequalities in the US

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Wen Su ^{1,2,3}, Jesus Daniel Zazueta-Borboa ^{1,3}, and Jennifer B Dowd ^{1,3}

Abstract

Educational inequalities in mortality in the US have grown considerably over the past decades. Interpreting trends in educational inequalities in mortality over time is challenging because period trends cannot distinguish changes in access to each level of education from widening social disparities in underlying mortality risk. Building on previous work by Hendi et al. that assumes a monotonic association between relative education and mortality risk at each age, we propose a method that decomposes trends in education-specific life expectancy into 1) contributions from changes in age- and education-specific mortality rates, holding constant educational composition, and 2) contributions from changes in education composition holding constant mortality risk. We apply the method to US data on education and mortality from 2000-2019, finding that changes in composition contributed most to stagnating life expectancy among those with some college, while mortality improvements outpaced impacts of negative selection for those with a university education.

¹ Leverhulme Center for Demographic Science, Nuffield Department of Population Health, University of Oxford.

² School of Demography, College of Arts and Social Sciences, Australian National University.

³ Nuffield College, University of Oxford.

Background

In the US, educational inequalities in life expectancy were first documented by Kitagawa and Hauser (Kitagawa & Hauser, 1973), and have grown significantly over the last two decades (Brown et al., 2012; Case & Deaton, 2021; Halpern-Manners et al., 2020; Hendi, 2015; Meara et al., 2008; Montez & Bisesti, 2024; Sasson, 2016; Sylte et al., 2025). These widening educational inequalities are troubling, suggesting that Americans with less education are increasingly unable to attain the levels of health and longevity of more advantaged peers.

One significant challenge to interpreting trends in educational inequalities in mortality over time is that access to education has increased dramatically across time, and thus, the categories themselves are not comparable over time. For example, in the past, having less than a high school diploma or less was the norm; it is much less common today, and more strongly associated with socioeconomic disadvantage. Conversely, completing a college degree has become more common and less associated with family background compared to the past. In the extreme, changing educational composition means that educational inequalities could appear to increase even if the risk of dying doesn't change for any group (Dowd and Hamoudi 2014). The principal challenge to disentangling improvements in educational access from widening social disparities in mortality risk using period data is that it requires assumptions about the very association one is trying to characterize, namely, the underlying association between socioeconomic disadvantage and mortality.

Various attempts have been made to separate the impact of changes in the composition of educational groups from underlying changes in the mortality risk across educational categories. There are studies comparing mortality outcomes (e.g., life expectancy) by education level after statistically adjusting for the possible effect of changes in education composition (e.g. Cutler et al., 2011; Hendi, 2015). Some other studies make similar mortality rate comparisons but with respect to a fix point of a ranked (relative) education distribution (Bound et al., 2015; Goldring et al., 2016; Novosad et al., 2022). However, these studies do not explicitly quantify how compositional changes contribute to time changes in mortality across educational groups.

Most recently, Hendi et al. (2021) and Hendi (2024) proposed a “convex inequality regime”. Hendi shows this consistent log-linear pattern in the data from the US and Finland that assumes a constant diminishing returns between a latent relative education distribution and corresponding mortality risks. Hendi then compares life expectancy by education deciles which are assumed to be consistent and comparable across time. Using this approach, Hendi concludes that treating education as a homogeneous group across time might introduce bias towards the period comparison. The life expectancy comparisons under the convex inequality regime, adjusting for this bias, show a slightly smaller gradient of education-mortality relationship.

While Hendi’s approach was a great step forward in formalizing assumptions regarding educational selection and its impact on trends in educational inequalities, we extend this work with a formal decomposition of the contribution of changing educational composition to changes in educational inequalities over time and rely on a better-fitting non-parametric functional form for relative education and mortality.

Our decomposition method attributes change in education-specific life expectancy to contributions from changes in age- and education-specific mortality rates, when relative education stays constant, and contributions from changes in education composition, as shifts in relative education, when their corresponding mortality is fixed across time. We demonstrate this new method using US data from 2000–2019.

Methodology

Data

We obtained death counts by single year of age and education level from 2000-2019 from the National Center of Health Statistics (NCHS, 2025) and population counts by single year of age and education level from the American Community Survey (ACS) (Ruggles et al., 2025). We categorised education into three mutually exclusive groups: high school (high school and below), some college (up to 3 years of college education), and university (4+ years of college). We subsequently apply shares of deaths and population by the three education groups at each age, calculated from NVSS and ACS, to the number of deaths and population exposure at the US national level extracted from the Human Mortality Database (HMD, 2025).

Methods

We propose a decomposition method based on the model of Hendi et al. (2021) and Hendi (2024). The method has two assumptions: there exists a monotonically decreasing relationship between relative education (from the lowest to the highest) and the associated mortality rates at each age; there are no other factors that could alter this relationship between education and mortality.

Life expectancy is calculated using age-specific mortality rates. We express the age-specific mortality rates, $\mu(x, t, i)$ for each education level i at time t , as a function (\mathbb{F}) of two independent variables: the mortality difference function $\Phi(x, t)$, which is a monotonically decreasing curve; the relative education function $\pi(x, t, i)$, as the range between the lower and upper bounds of relative education positions for any education group, with $\sum_i \pi(x, t, i) = 1$. This can be written as:

$$\mu(x, t, i) = \mathbb{F}[\Phi(x, t), \pi(x, t, i)]. \quad (1)$$

Education-specific mortality rates can be derived by averaging the area under the monotonically decreasing curve, namely the mortality difference function, based on their latent, relative education function $\pi(x, t, i)$. The age-specific mortality rates for the total population are derived as the total area under the curve.

We modelled the latent mortality difference function as a natural spline; other non-parametric alternatives (B-spline, spline interpolation, etc.) show a very similar fit (See

Supplementary Results). The spline is fit using the log age- and education-specific mortality rates as the dependent variable and the mid-point of the cumulative share of education levels as the independent predictor. The age- and education-specific mortality rates are binned mortality data by education level, with the upper and lower bounds of their relative education position as the cumulative share of education composition from the lowest to the highest education level.

Such a modelling procedure was previously proposed to graduate abridged life tables (Li, 2020), as well as smoothing binned population and death counts (Rizzi et al., 2016). The age- & education-specific mortality rates calculated under a spline model as the mortality difference functions return a very close fit to the underlying binned mortality rates by education (difference < 0.001 at older ages). National life expectancy and education-specific life expectancy calculated using these reconstructed age- & education-specific mortality rates show very small deviations from the original value (largest difference < 0.2 years).

Decomposition method

We can relate the two components of the age- & education-specific mortality rates to changes in education-specific period partial life expectancy between age 25 to 75 (${}_{75}e_{25}(t, i)$, hereafter used interchangeably with life expectancy) through:

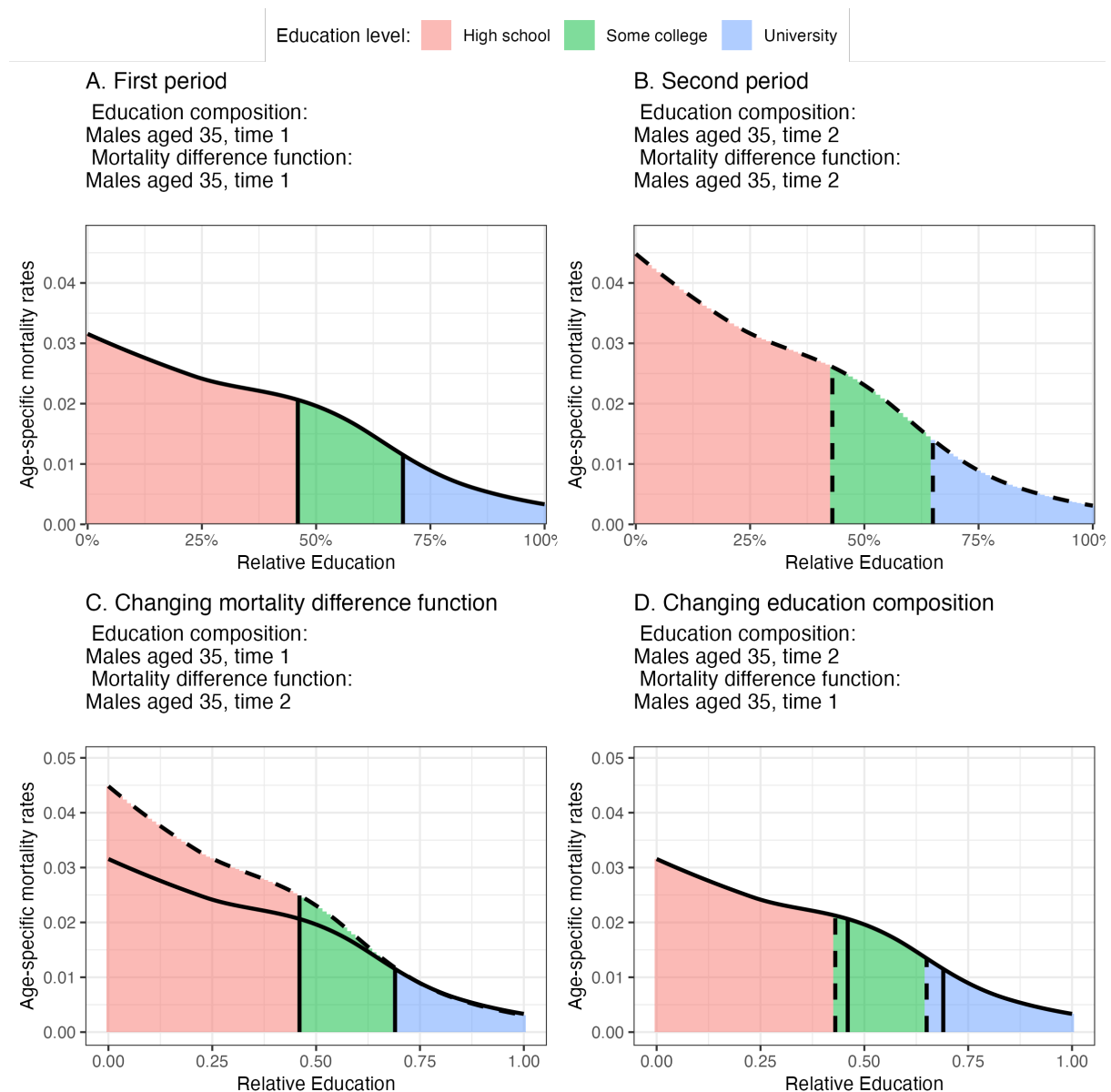
$$\begin{aligned}
 \frac{\partial {}_{75}e_{25}(t, i)}{\partial t} = & \\
 & \underbrace{-\ell(25, t) \int_{25}^{75} \ell(x, t) e_x(t) \left[\frac{\partial \mu(x, t, i)}{\partial \Phi(x, t)} \frac{\partial \Phi(x, t)}{\partial t} \right] dx}_{\text{Change due to mortality difference function}} \\
 & \underbrace{-\ell(25, t) \int_{25}^{75} \ell(x, t) e_x(t) \left[\frac{\partial \mu(x, t, i)}{\partial \pi(x, t, i)} \frac{\partial \pi(x, t, i)}{\partial t} \right] dx}_{\text{Change due to education composition}}.
 \end{aligned}
 \tag{2}$$

A graphical illustration underlying the idea of the decomposition can be found in Figure 1. Panel A and Panel B illustrate the underlying mortality difference function and the education composition for time 1 and time 2, respectively. The first term in equation (2) attributes the changes in education-specific life expectancy to changes due to the mortality difference function at each age. This term is essentially measuring how much the mortality difference function changed across time, and in turn the age- & education-

specific mortality rates, while the composition for each education level (as relative education position) stays constant. This is also illustrated as panel C. Positive contributions from this term signify a contribution to an increase in education-specific life expectancy due to decreased mortality risks because of the changing mortality difference function. Meanwhile, the second term in equation (2) quantifies changes due to education composition. This is illustrated as panel D, and we are seeing how compositional change, while holding the mortality difference function constant across time, would result in changes in mortality for each education level at each age. Positive contributions from this term represent a decrease in age- and education-specific mortality, and therefore life expectancy increases, from compositional changes. Composition changes in this context could be a result of a shrinking population size for the lowest education level (high school) or an expanding population size for highest education level (university). Negative contributions for both terms represent contributions to decrease in life expectancy from changes in mortality difference function and education composition, respectively.

We quantify partial life expectancy between 25 and 75 here to minimize the effect of pre-existing mortality selection, which we cannot observe without longitudinal cohort data. Decomposition methods with a similar structure of mathematical expressions can be found in Su et al. (2024), Torres et al. (2019), and Shkolnikov et al. (2006) for decomposing mortality and composition components towards life expectancy changes among national populations.

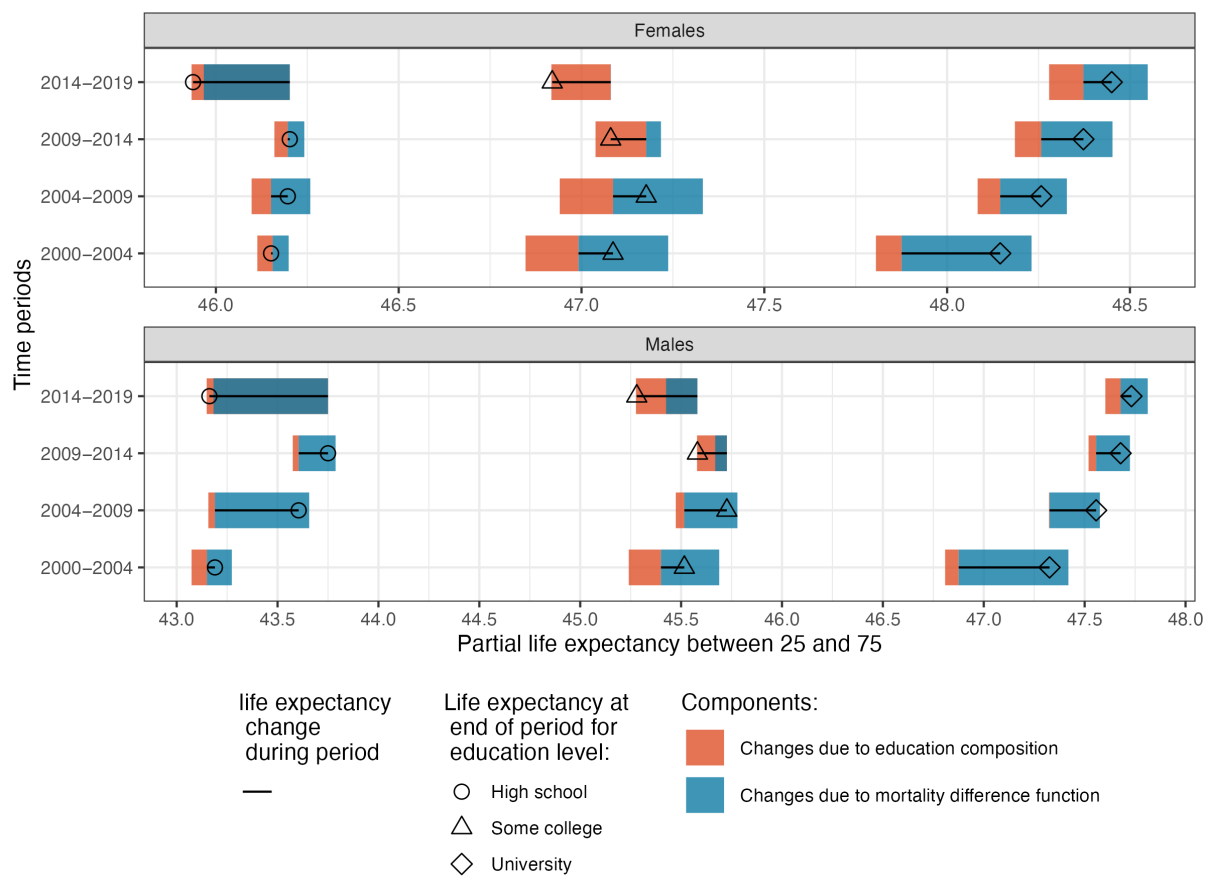
Figure 1. Illustration of the idea underlying the decomposition method



Notes: The solid line and the dotted line correspond to the mortality difference and education composition at times 1 and 2, respectively. The figure is for illustrative purposes. In our calculation, we use the mid-point between times 1 and 2, instead of time 1, to calculate the decomposition.

Results

Figure 2. Decomposition of education-specific life expectancy changes into components of the mortality difference function and education composition.



Note: The x-axis is not up to scale between females and males. On average, females have a higher life expectancy at each education level, as well as smaller differences across education levels.

Figure 2 shows the contributions to trends in education-specific life expectancy from changes due to the mortality difference function and education composition by each education level. We observe a diverging trend in life expectancy across different education levels, especially during the last (2014–2019) period. While life expectancy continued to increase for those with a university education, the population with some college or high school education experienced a rise in life expectancy during the period 2000–2009, followed by a decrease during 2009–2019.

For both females and males during the first decade of the 21st century (2000–2009), we observed an increase in life expectancy for some college and university-educated populations. This is a result of a positive contribution (increase in life expectancy) from

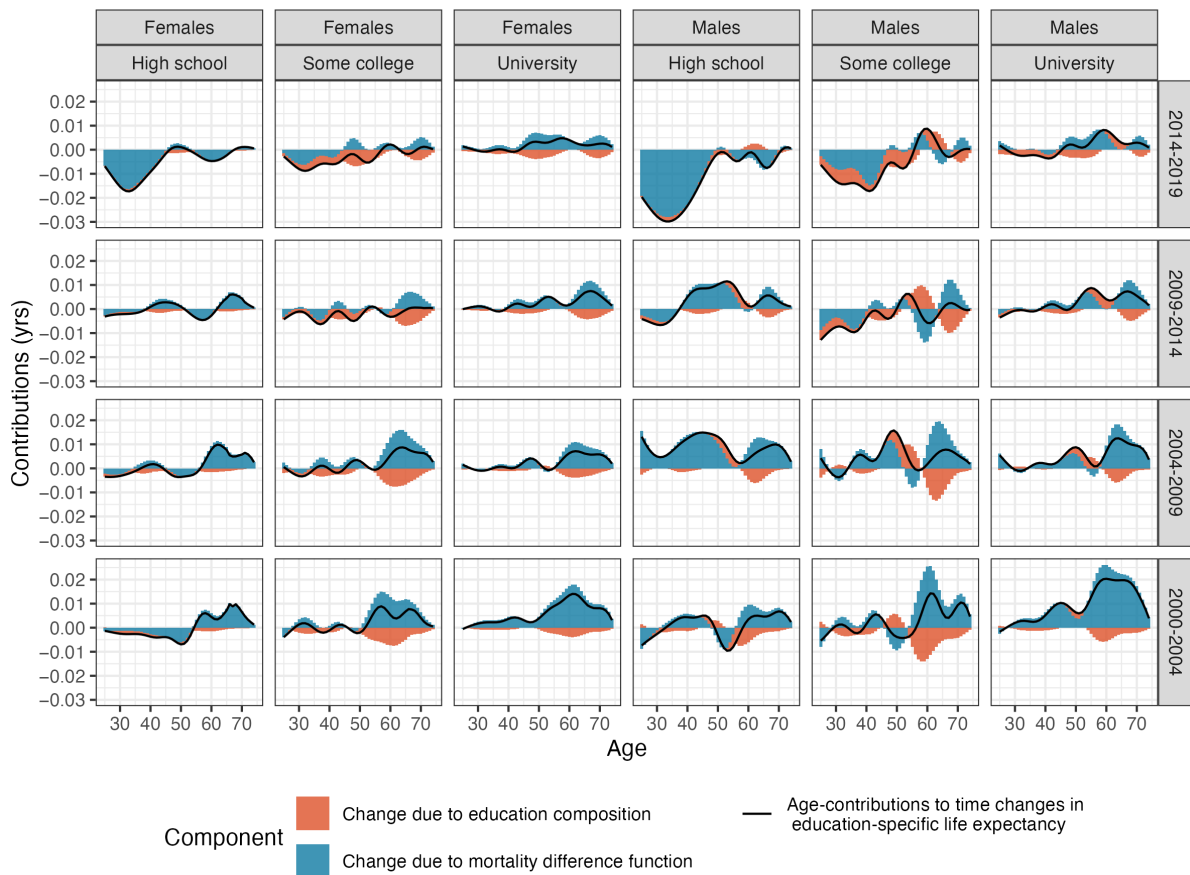
lower mortality risks for these education levels, offset by a small negative contribution (decrease in life expectancy) due to changes in education composition. The composition effect reflects more people obtaining a university degree and fewer people getting a high school degree or less. For those with a high school or less education, the life expectancy gains from a reduction in mortality risk is almost entirely offset by the negative contribution from compositional changes. This results in life expectancy stagnation for females with a high school education during 2000–2014, and males during 2000–2004.

After 2009, life expectancy increases slowed down even for the university-educated population. This is a result of the slowing down in reductions in mortality, accompanied by continued negative impacts of composition - more people reaching this level of education with higher underlying mortality risks. For those in some college category, we see negative contributions from both the mortality difference function and education composition, leading to a decrease in life expectancy. A similar dynamic is observed for those with a high school or less education during 2014–2019, although the negative contribution due to composition changes is smaller than that observed for some college category.

Figure 3 illustrates the age contributions for the dynamics observed in Figure 2. Compositional changes generally contribute a smaller proportion across all ages compared to changes in underlying mortality differences across all education levels. Cohort patterns are clearly visible for the contributions from changes due to composition, especially for populations with university education and some college education. For example, from 2000–2004, negative contributions from composition changes concentrate at ages 55+ (corresponding to cohorts born before 1955) in the university category. By 2014–2019, the negative compositional contributions for this group were more concentrated below age 55 (cohorts born after 1970s). Smaller positive contributions in reducing mortality at older ages, accompanied by increasing negative contributions from composition changes at younger ages, shaped the slowing down of the life expectancy increase across different education levels.

In the full paper, we will incorporate confidence intervals to quantify uncertainties in our decomposition method, describe the full range of results and put them in the context of the broader literature on widening educational inequalities in the US.

Figure 3. Decomposition by age of education-specific life expectancy changes into components of the mortality difference function and education composition.



Notes: The sum of age contributions across all ages equals the changes in education-specific life expectancy shown in Figure 2. The sum of contributions due to changes in education composition or mortality difference function across all ages also equals their respective components in Figure 2.

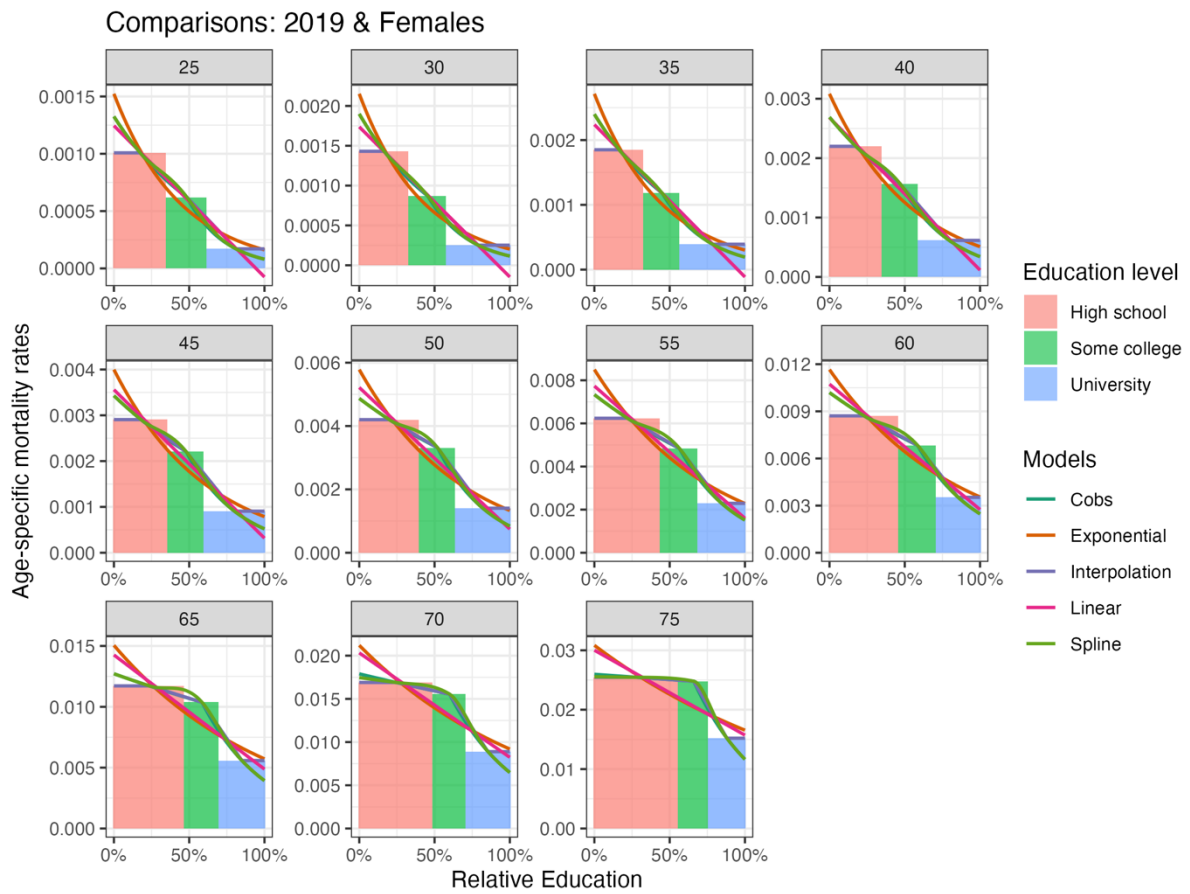
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Supplementary Materials

Supplement Results



Notes: Coloured bars represent the binned education-specific mortality rates with respect to their relative education position. Cobs stands for linear constrained B-splines in the model's section. Exponential represents the log-linear model. Interpolation is a spline interpolation. Linear stands for a linear model, which is also the slope of inequality. Spline is referring to spline which monotonically declines.