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When do mothers bury a child? Heterogeneity in the maternal age at offspring loss

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The experience of losing a child is increasingly uncommon worldwide but is no less devastating for parents who experience it. An overlooked aspect of this phenomenon is its timing: at which age do bereft parents lose a child and how are these ages at loss distributed? We use demographic methods to explore the mean and variability of maternal age at child loss in 18 countries for the 1850–2000 birth cohorts. We find that the distribution of age of child loss is bimodal, with one component representing young offspring deaths and another representing adult offspring deaths. Offspring loss is transitioning from being a relatively common life event, mostly experienced by young mothers, to a rare one spread throughout the maternal life course. Moreover, there is no evidence of convergence in the variability of age at offspring loss. These results advance the formal demography of kinship and underline the need to support bereaved parents across the life course.

Keywords: mortality; kinship; bereavement; child loss; formal demography

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Introduction

Studying demographic processes from a kinship perspective can help to bridge the gap between macro-level change and the way in which individuals perceive this change (Murphy 2011; Verdery 2015). For example, the degree to which mothers experience offspring loss is not just the product of present infant and child mortality; it is influenced by historical mortality and fertility rates at all ages. Goodman et al. (1974) outlined the fundamental mathematical relationships between fertility, mortality, and kin availability, but the implications of demographic change for the lived experience of bereavement are not yet fully understood (Montgomery 2000).

The demographic transition theory is a common framework for characterizing macro-level demographic change. At the heart of this theory is the assumption that global population change, by and large, follows a predictable path that can be described in terms of changes in mortality and

fertility rates (Caldwell 1978; Lesthaeghe 2014; Reher 2021). Seen from the perspective of individuals living through it, the transition can be portrayed as a progression from a state of ‘disorder’ to a state of ‘order’ (Livi Bacci 1997). For mothers, it implies a shift from a world in which they can expect to experience the loss of a child (Scheper-Hughes 1992) to a world where offspring loss is relatively uncommon (Alburez-Gutierrez et al. 2021). The experience of losing a child, one of the most traumatic life events for parents, is surprisingly common around the world (Smith-Greenaway et al. 2021) and has been linked to detrimental short- and long-term consequences for bereaved parents and for mothers in particular (Reher 1995; Espinosa and Evans 2013; Albuquerque et al. 2016).

We distinguish between the *incidence* and the *timing* of offspring loss. Incidence refers to the frequency of offspring loss, while timing refers to the distribution of the losses over the life course of bereaved mothers. Whereas there has been some research on the incidence of offspring loss, less is

known about the timing of the event. Child loss is increasingly projected to involve the death of an adult offspring, bringing about new challenges for older bereaved mothers (Alburez-Gutierrez et al. 2021), but we know little about how the ages at which mothers lose a child will be affected. It is possible that falling infant and child mortality and rising ages at childbearing will act together to reduce the variability in age at child loss, meaning that the event will be more concentrated around certain ages. But it is also possible that the aforementioned processes will have the opposite effect, creating greater variability in the age at maternal bereavement and thus rendering child loss an event that is experienced across a larger range of maternal ages.

In this paper, we explore the relationship between macro changes in fertility and mortality and the timing of offspring loss from the perspective of mothers. We ask: how does maternal age at offspring loss vary in terms of its central value and variability throughout the demographic transition? Following the literature on lifespan inequalities (Vaupel et al. 2011; Aburto et al. 2020), we consider deaths to be more ‘predictable’ if the variability in their age distribution is lower. Predictability, in this context, refers to the variability of the distribution of ages at (offspring) death, not to the psychological process of anticipation. For this, we propose a method that combines established life-table and novel matrix approaches to modelling kinship (Caswell 2019) and apply it to demographic data from 18 selected countries.

The degree to which mothers can predict the timing of offspring loss matters, because offspring survival sits at the very centre of demographic theory. Increasing levels of child survival are often credited as a major driver of the fertility decline that characterizes the first demographic transition (Caldwell 1978). While the ‘old-age security’ motive considers children as a long-term investment, child survival is often approximated using period infant and child mortality measures, which do not fully capture the experience of offspring loss for mothers over their entire life course (Uhlenberg 1980, 1996). For example, there may be radical differences between current child mortality rates and the share of mothers in a population who have ever lost a young child (Smith-Greenaway and Trinitapoli 2020).

Studying the heterogeneity surrounding offspring loss can help us better understand the drivers of global demographic change in the context of the demographic transition. Changes in the variability

of age at maternal bereavement have consequences for mothers, who are less able to anticipate when, if at all, their child will die. Although the loss of a young child is associated with acute psychological distress, parents do not depend on young children financially, nor have they built their lives around the expectation that the children will provide support in old age. Examining changes in the timing of loss can shed light on how parents make important life decisions and plan for their own retirement. Parents may delay inter vivos transfers or think differently about their own retirement if they expect their offspring to survive to adulthood (especially if they themselves expect to reach very old age).

In the following sections, we use demographic methods to characterize maternal age at offspring loss. We present results for a selection of countries representing a range of mortality regimes, based on a combination of historical and projected demographic data. The findings show how the timing of offspring loss changes during the demographic transition. We conclude by discussing the implications of our findings for kinship demography and policy.

Methods

An intuitive overview of the methodological approach

We start with a schematic overview of our method, before providing a more technical description. Our analysis is implemented in three steps. First, we use kinship-matrix models to estimate offspring availability for an average woman in the population (who we call ‘Focal’). The kinship-matrix models we use, described in detail in Caswell (2019), are essentially demographic models that independently project the ‘population’ of Focal’s children, parents, siblings, etc. Our time-varying models (Caswell and Song 2021) take yearly age-specific fertility and mortality rates as inputs (see Data subsection) and return the distribution of kin for a randomly selected member of the population. The distribution of kin, in this case, refers to Focal’s expected number of offspring (sons and daughters), by Focal’s birth cohort and age, and also the age of her children. In other words, the method generates offspring who are alive at the start of the age interval and, as such, are at risk of dying.

As a second step, we use published life-table data to obtain the probability that these offspring will die in the next year. We match our kinship distributions

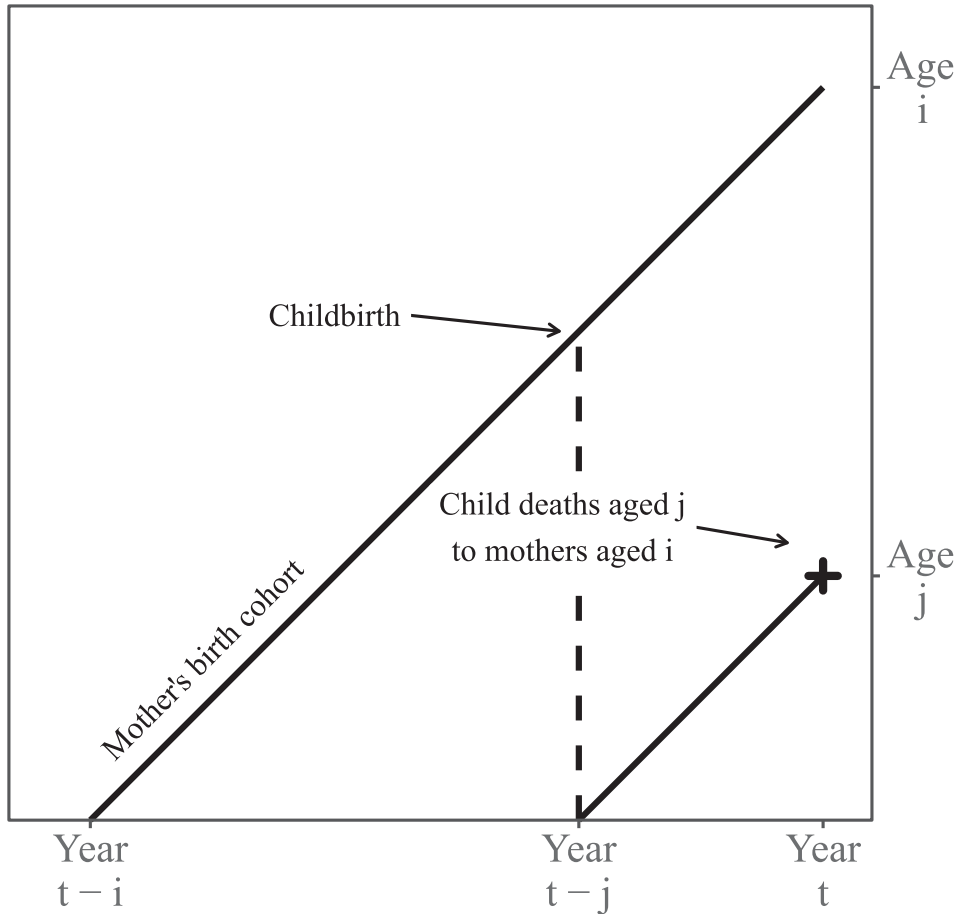


Figure 1 Lexis diagram showing the deaths of offspring aged j to mothers aged i

Note: An offspring death at time t and age j is indicated with a cross.

Source: Adapted from Keyfitz (1985).

with these probabilities of dying using the Lexis approach, as shown in Figure 1 and explained in detail in the next section. This yields the expected number of offspring deaths that Focal will experience. As a third step, we convert these individual-level distributions into population-level counts by weighting our estimates by a vector containing the number of women who are at risk of losing a child (i.e. the prospective mothers in our analysis). This produces population-level counts of offspring loss that capture all offspring deaths experienced by all women born in a given cohort over their entire life courses.

Distribution of offspring deaths over the maternal life course

We now provide a detailed description of how we implement the analysis. We use life-table methods and kinship-matrix models to compute $n_{i,j,t-i}$, the expected number of offspring deaths for women

born in year $(t-i)$, where $i = 15, \dots, 100+$ denotes the age of the mother and $j = 0, \dots, 85+$ the age of the child. If the present time is t , we can think of $(t-i)$ as the mother's birth cohort and $(t-j)$ as the mother's offspring's birth cohort (see Figure 1). We arrange the expected numbers of offspring deaths in a three-dimensional array $\mathbf{N} = (n_{i,j,t-i})$. For mothers, we consider ages $\alpha \leq i \leq 100+$, where $[\alpha, \beta] = [15, 49]$ are the limits of a woman's reproductive life. Offspring ages are restricted to $[\max(i - \beta, 0); (i - \alpha)]$, where $\max$ is a function that returns the maximum of two values. In other words, we restrict our analysis to offspring whose births occurred during their mother's reproductive period. We restrict the range of possible maternal and offspring ages (i, j) to avoid impossible cases (e.g. mothers aged 65 experiencing the death of a newborn or mothers aged 15 experiencing the death of a five-year-old).

We first compute the expected number of children who are alive at the start of the age interval j for an average woman aged i born in year $(t-i)$ (e.g. a

woman aged 20 might expect to have, on average, 0.2 five-year-old children). We obtain these values using the methods proposed by Caswell and Song (2021) and implemented in the R package DemoKin (Williams et al. 2023). We store them in the matrix $\mathbf{H} = (h_{i,j,t-i})$. Second, we determine how many of these offspring will die. For this, we use ${}_1q_{x=j,t-j}$, the life-table probability that an offspring born in year $(t-j)$ will die between ages j and $j+1$. We store these values in the vector $\mathbf{q} = (q_{j,t-j})$. Third, we compute the women's weighting vector $\mathbf{w} = (w_{i,t-i})$ by: (1) taking the initial number of women born in each cohort; and (2) computing the number left alive at age i by using standard life-table formulas (Preston et al. 2001). This accounts for changing age structure of the population of women over time. We combine these three quantities to obtain the expected number of offspring born to a mother herself born in year $(t-i)$ and aged i , who will die when they are j years old:

$$n_{i,j,t-i} = h_{i,j,t-i} \times q_{j,t-j} \times w_{i,t-i}.$$

The array $\mathbf{N}$ allows us to compute offspring loss by offspring's age at death. We obtain the values for any-age offspring loss as: $n_{i,t-i} = \sum_{j=0}^{100} n_{i,j,t-i}$, where $n_{i,j,t-i}$ is the entry in the $(i, j, t-i)$ position of the array $\mathbf{N}$.

Data

Data for the main analysis come from the United Nations' 2019 Revision of World Population Prospects (UNWPP; empirical data for the 1950–2020 period and medium-scenario projections for 2020–2100; <https://population.un.org/wpp2019/>). For Sweden and Denmark, historical mortality rates and population data come from the Human Mortality Database (www.mortality.org); fertility rates come from the Human Fertility Collection (www.fertilitydata.org for years up to 1890) and the Human Fertility Database (www.humanfertility.org for 1891–1950); and these websites provide more information on the primary data used by each source. To compute the maternal age at offspring loss for mothers born in a given cohort c , we need complete life-table data for the cohorts c through to $c+49$ (since the upper age bound of the reproductive age, β , is 49). We approximate cohort rates by drawing cohort profiles from period data (for a description, see e.g. van Raalte et al. 2023). This procedure may introduce a relatively small bias in the short term—less than 5 per cent deviation from observed cohort summary measures (van Raalte

et al. 2023)—but is unlikely to bias the estimates substantially in the long run.

Results

Incidence of offspring loss

Our analyses focus on the historical and projected trends in the ages at which mothers experience the death of a child. We present results for 18 countries, selected to represent a diverse range of life expectancy levels. We use mortality terciles to arrange the countries into three groups: low mortality (Australia, Cuba, Denmark, Japan, *Sweden*, and the United States), medium mortality (Algeria, China, El Salvador, *Guatemala*, India, and Myanmar), and high mortality (*Angola*, Burkina Faso, Chad, Ghana, Mali, and Senegal). When presenting the results, we highlight one country in each group (in *italic* in the list) as being indicative of the trend in their group. The terciles are based on life expectancy at birth in 1980–85, the middle of the 1950–2020 period for which the 2019 revision of UNWPP provides empirical (i.e. not projected) life expectancy values. We deliberately exclude populations that experienced high excess mortality during the HIV/AIDS epidemic around the 1980s from our sample, and we purposely include Sweden, which has the longest historical time series of demographic data.

We first consider trends in the incidence of offspring loss (maternal bereavement). As an example, consider the 61,000 women born in Guatemala in 1950. We estimate that these women bore around 260,000 offspring during their reproductive years (1965–2000) and that 30,000 of these offspring (i.e. 11 per cent of all offspring) are expected to die before their mothers (Figure 2). Replicating this analysis for a number of selected countries and maternal cohorts shows a sustained decline in the incidence of offspring loss over time. This is evidenced by the dwindling percentage of offspring who are expected to die before their mothers in Figure 2 (we chose this measure to improve comparability across countries with very different fertility levels and population sizes). For example, 17 per cent of the offspring of Angolan women born in 1950 are expected to die before their mothers. This is equivalent to the value for Swedish women born 100 years earlier. The values for women born in the year 2000 are 7 per cent for Angola and <1 per cent for Sweden.

Next, we explore how these bereavement events are distributed across the maternal life course.

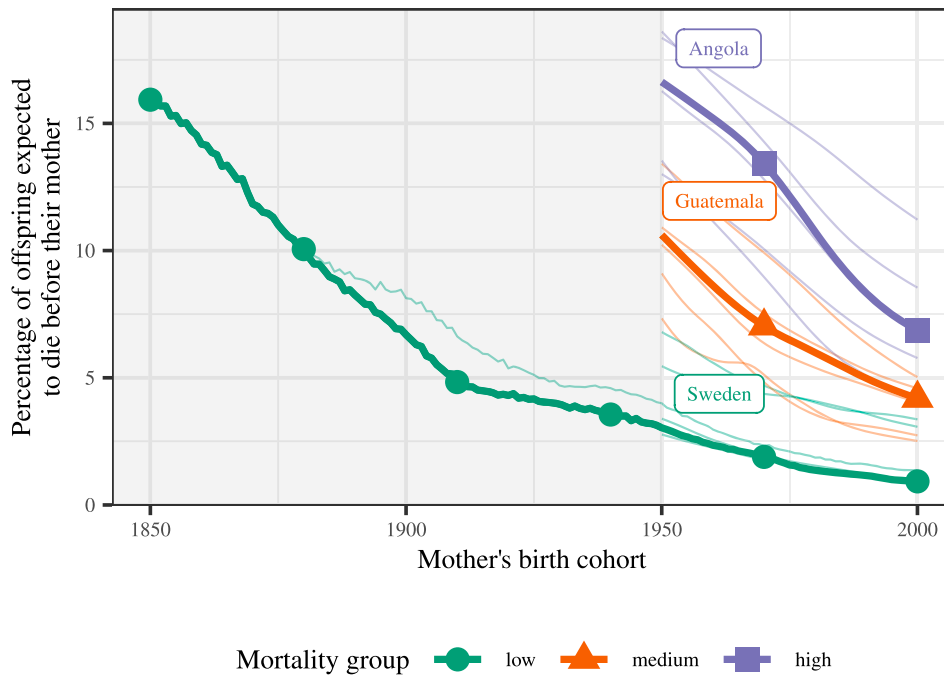


Figure 2 Share of a mother's offspring expected to die before her, by maternal birth cohort: 18 countries

Notes: Lower values indicate that a larger share of offspring are expected to outlive their mothers, net of fertility levels. Angola, Guatemala, and Sweden are highlighted to represent the main trends in each group (high, medium, and low mortality, respectively, according to life expectancy at birth); other countries are shown by faded lines in the background. The grey background shows estimates from historical demographic data (see Data subsection).

Source: Authors' analysis of data from UNWPP, Human Mortality Database, Human Fertility Collection, and Human Fertility Database (see Data subsection).

Figure 3(a)–(c) shows the population-level numbers of offspring deaths by maternal age. Note that the values vary greatly across the three selected countries, reflecting the influence of population size and distribution across age, sex, and current and previous levels of mortality and fertility. Here, we are interested chiefly in the relative distributions of offspring deaths across age, as shown by the rates in Figure 3(d)–(f). Offspring deaths in low-mortality settings such as Sweden are concentrated at higher maternal ages (75+). In settings with higher mortality, such as Guatemala and Angola, offspring deaths occur mainly during women's reproductive years (before age 50), when both mothers and offspring are young. Importantly, the upper panels highlight that the distributions of offspring deaths are bimodal. Figure 3 also shows the different compositions of offspring ages at death. In Sweden, more women live to older ages and can expect to experience the death of an adult offspring (who is often over 50 years old when they die). In contrast, women in Angola and Guatemala are more likely to experience the death of an offspring aged under five years than women in Sweden..

General trends in the maternal age at offspring loss

We first explore trends in maternal age at offspring loss across birth cohorts by considering the simple mean and standard deviation (SD) of the ages at which mothers lose a child, based on the distributions shown in Figure 3 (panels (a)–(c)). 'Simple', in this context, refers to summary measures of the general distribution, as opposed to the decomposed summary measures presented in the next subsection. For convenience, we refer to these as the mean maternal age at offspring loss (MAOL) and SD of offspring loss (SDOL). Figure 4 (left-hand panel) shows evidence of a sustained increase in MAOL across birth cohorts for all the chosen countries. This means that as women (and their children) live longer, they can expect to experience offspring loss at increasingly older ages. This is true for all the countries we consider, even if the projected increases in MAOL are less pronounced in low-mortality countries.

Next, we examine the variability in age at which mothers lose offspring. The Swedish example in

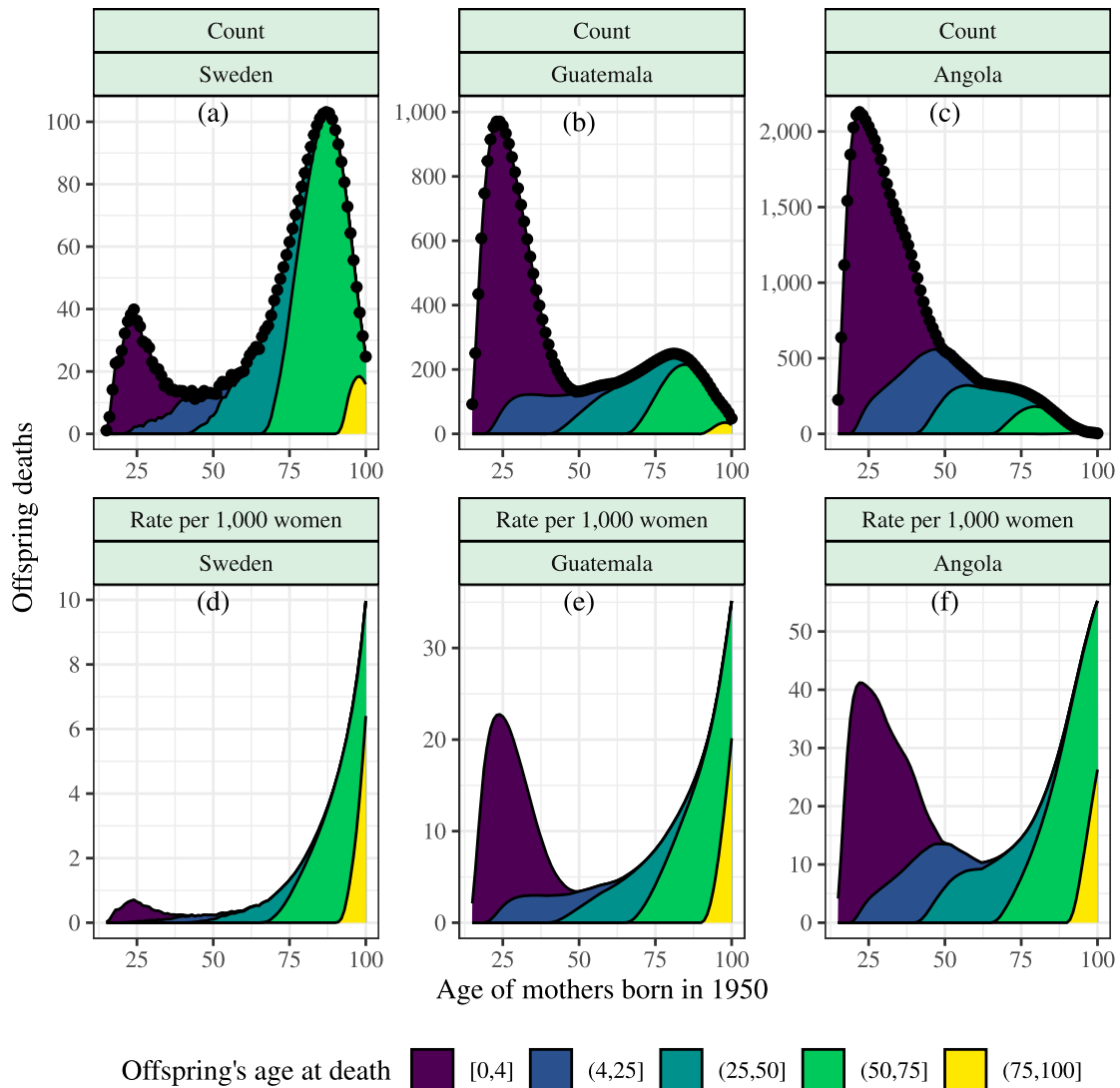


Figure 3 Expected numbers and rates of offspring deaths over the maternal life course for women born in 1950: three selected countries

Notes: The shaded areas show the offspring's age at death. Panels (a)–(c) show population-level, non-cumulative counts (black dots). Panels (d)–(f) show population-level, non-cumulative counts per 1,000 women in each population. Note the different y-axes on each panel.

Source: As for Figure 2.

Figure 4 (right-hand panel) provides a long-term historical overview of this process. In Sweden, SDOL was low for mothers born in the mid-nineteenth century and increased temporarily for mothers born between 1870 and 1950, before returning to relatively low levels. We observe a similar pattern for the other countries, for which much shorter time frames are available. High-mortality countries (which are projected to undergo declines in mortality and fertility in future) show growing SDOL, whereas low-mortality countries (where mortality and fertility are projected to remain relatively stable) show decreasing SDOL. Medium-mortality countries, which we assume to be in the

middle of the demographic transition, show either increasing SDOL or no change in the period observed.

Timing of offspring loss: Young and adult components

Figure 3 shows that the distribution of offspring deaths over the maternal life course is bimodal, meaning that conventional measures of central tendency and dispersion may be inadequate to summarize them (Castro Torres et al. 2022). This particular shape of the distribution can be explained

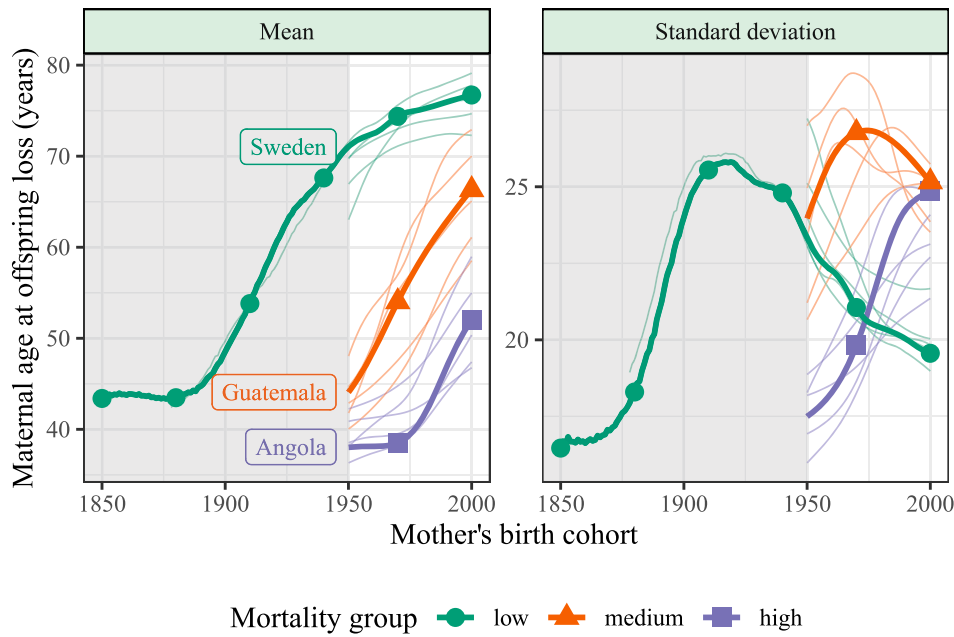


Figure 4 Simple mean and standard deviation of the maternal age at offspring loss (MAOL and SDOL): 18 countries

Notes: Countries are categorized into low-, medium-, and high-mortality groups according to their life expectancy at birth. The grey background shows estimates from historical demographic data (see Data subsection).

Source: As for Figure 2.

in part by the U-shape of the mortality rate curve; indeed, if we assumed a constant probability of death for all offspring independent of age, the distributions in Figure 3 would become unimodal.

We use a non-parametric approach to decompose the distribution of offspring deaths into two components. Specifically, we decompose the distribution of offspring deaths using the sums of smooth exponentials model (Camarda et al. 2016), a powerful and flexible approach for modelling complex series of counts. The model assumes that counts are realizations of a Poisson process, whose expected value is modelled as an additive decomposition of smooth components. We decompose the observed pattern of offspring deaths into two components using a two-dimensional decomposition that provides smooth results over ages and cohorts. We compute starting values for the estimation procedure using the R package *MortalitySmooth* (Camarda 2012) and enforce concavity constraints to ensure that the observed patterns are decomposed into two distributions. This approach can be interpreted as fitting a non-parametric, two-component mixture model to the observed data.

The resulting first component, the *young* component, captures the deaths of offspring that occur mainly during women's reproductive years, when both mothers and children are young. The second

component, the *adult* component, captures offspring deaths that occur mainly outside women's reproductive ages, when both children and mothers are older (e.g. some older mothers in low-mortality settings will lose adult offspring who are themselves aged over 50 years).

Figure 5 shows the results of our decomposition analysis for women born in 1950, for the three representative countries. The shaded areas indicate the proportions of the overall distribution that are due to each component, that is, the relative importance of each component. This weight is derived from the decomposition analysis and, for any given birth cohort, the weights of the young and adult components sum to unity. For example, for Swedish women born in 1950, 81 per cent of the overall distribution of offspring loss is captured by the adult component, whereas only 19 per cent is captured by the young component. Things are radically different for Angolan women born that year, for whom young child deaths are overwhelmingly more important than adult offspring deaths: the relative importance of the young component is 86 per cent. Figure 6 shows how these values have changed and are projected to change across cohorts, with young offspring deaths constituting a progressively smaller proportion of all offspring deaths experienced by women over time in all three country groups.

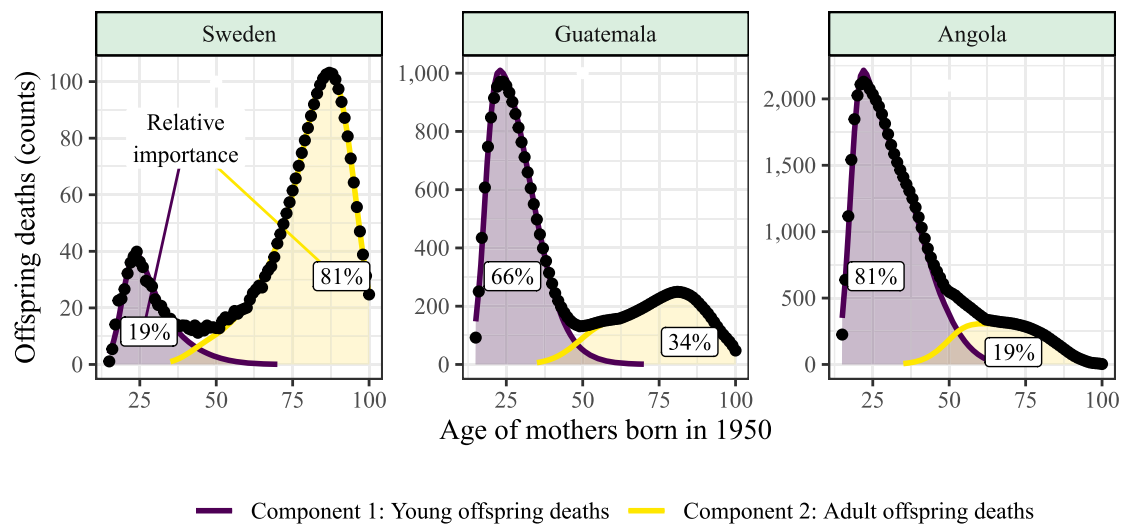


Figure 5 Young and adult components (shaded areas) resulting from the decomposition analysis: women born in 1950, three selected countries

Notes: The fitted values for the two components (solid lines) sum to the total expected number of offspring deaths (black dots) for each cohort. 'Relative importance' refers to the proportion of the overall distribution captured by each component. Note the different y-axes on each panel.

Source: As for Figure 2.

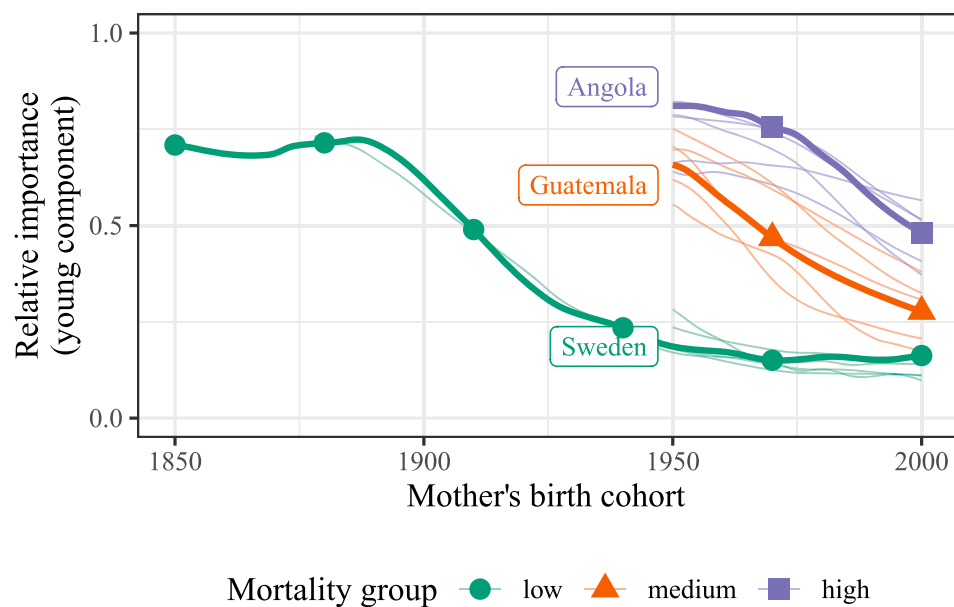


Figure 6 Relative importance of the young component across birth cohorts, as derived from the decomposition analysis: 18 countries, with Angola, Guatemala, and Sweden highlighted

Notes: Higher values imply that the young component (i.e. young offspring deaths) explains a larger proportion of the variability in the data, whereas lower values imply that the adult component (i.e. adult offspring deaths) is more important for a given birth cohort. The weights of the young and adult components sum to unity within each birth cohort.

Source: As for Figure 2.

The decomposition analysis provides a more nuanced picture of trends in MAOL and SDOL by distinguishing between the loss of young and adult offspring. Figure 7 (upper panels) shows that the

rapid increase in the simple mean shown in Figure 4 stems from two overlapping processes: a slow but steady increase in the mean age for the adult component and a rapid decrease in the relative

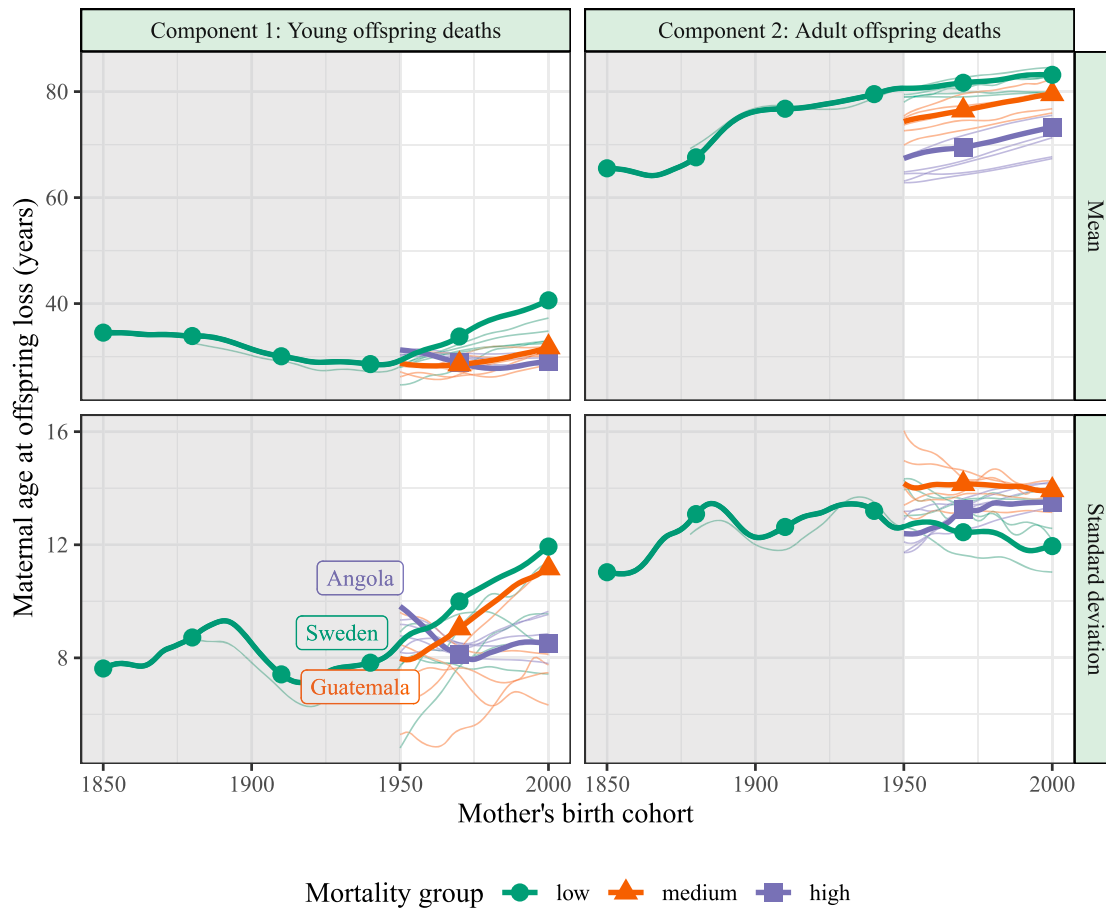


Figure 7 Decomposed mean (upper panels) and standard deviation (lower panels) of young and adult components of maternal age at offspring loss: 18 countries, with Angola, Guatemala, and Sweden highlighted
Source: As for Figure 2.

importance of the young component (the latter portrayed in Figure 6). The differences in MAOL for the young component within mortality groups are relatively small (although the overall levels vary widely between groups). Differences in the ages at which mothers experience the death of an adult offspring are considerably higher both within and between groups. (Note that the values in Figure 4 are the sum of the values in Figure 7 for each component weighted by the ‘relative importance’ parameter produced by the decomposition analysis and shown in Figure 6).

We now consider the variability in maternal age at offspring loss, by focusing on changes in the SD of each component. Our previous analysis of the simple SD (Figure 4) suggested a consistent trend, where SDOL would temporarily increase from relatively low levels to relatively high levels during the course of the demographic transition before returning to pre-transition levels. We exemplified this trend with reference to the historical experience of Sweden. The decomposition analysis shows that

this temporary increase in the simple SD is, in fact, the result of changing variability in the decomposed distributions.

Overall, the SD of the young component (Figure 7, lower left panel) shows an increasing trend in medium- and low-mortality settings. In the context of falling infant mortality, offspring are more likely to survive early childhood. This leads to a wider variability in maternal age at offspring loss, even if women give birth during a shorter period of their lives as a result of declining fertility rates. In Sweden, we find a progressive increase in SDOL for the young component (from 7.6 years for those born in 1850 to 11.9 years for those born in 2000). This is consistent with a scenario where the death of a young offspring becomes increasingly uncommon and less concentrated at ages 0–5 across cohorts. This contrasts with Angola, which shows a decline in SDOL for the young component between the 1950 and 2000 maternal cohorts, driven by a sustained concentration of offspring deaths at young maternal ages stemming

from the persistently high fertility and child mortality rates projected for the country. It is worth keeping in mind that these processes coincide with a decline in the relative importance of the young component (the importance of which varies considerably between low- and high-mortality countries).

SDOL for the adult component (Figure 7, lower right panel) is lowest when most adult offspring die either at very old ages (low-mortality countries) or at relatively young ages (high-mortality countries). In Guatemala (and other medium-mortality countries), the ages at which mothers can expect to lose a child are spread more widely across the maternal life course (as are the ages at death of offspring themselves; see Figure 3). This contrasts with Sweden, where most adult deaths are concentrated at relatively high maternal ages. It also contrasts with Angola, where offspring deaths are clustered mostly around young maternal ages. For high-mortality countries, the (slow) growth of SDOL for the adult component points to an increasingly heterogeneous composition of MAOL.

Discussion

We set out to answer the question of whether the forces driving the demographic transition (population-level declines in mortality and fertility rates) are leading to greater variability in the ages at which mothers experience the death of a child. We find that while the overall likelihood of experiencing offspring death decreases over the demographic transition, the same cannot be said of the SD in the age at which mothers lose a child (conditional on ever having lost a child). Our focus on the *timing* of offspring loss reveals no clear evidence of declining variability in the ages at which mothers lose an offspring. The variability in ages at which bereaved mothers lose a *young* offspring tends to increase as offspring deaths become less concentrated at very young ages. Qualitatively, we interpret a higher variability in MAOL as an indication of the event being less ‘predictable’ for mothers. This is occurring against the backdrop of an overall declining *incidence* of offspring loss, especially at young ages. We find a persistently high variability in the age at which mothers can expect to lose an *adult* offspring. Nevertheless, we document a sustained increase in the mean age at which mothers can expect to lose an offspring in general, and an adult offspring in particular, with substantive heterogeneity in patterns and trajectories across countries.

We contribute to the growing field of kinship demography by presenting distributions of maternal age at child loss (conditional on ever having lost a child). Our study of the population of bereaved mothers shows that an increase in the variability surrounding the timing of offspring loss reflects, on the whole, a shift towards a regime in which offspring loss occurs later in life, if at all. Nonetheless, a relative decline in frequency of offspring loss does not imply that the event is any less detrimental for bereaved mothers. Postponement of offspring loss means that mothers spend, on average, fewer years and a smaller share of their lifetimes in a potential state of bereavement after experiencing the death of a child. This is a positive development that should benefit mothers, given the known negative effects of parental bereavement. At the same time, the lingering variability in age at child death means that the group of mothers who experience the death of a child is very heterogeneous.

Bereavement may affect subgroups of mothers, and their families, in different ways. For example, losing a child in old age potentially leads to more negative outcomes for mothers who have organized their lives around the expectation of having children around when they reach old age. The situation is particularly worrying for mothers with one child, an increasingly common family configuration (Kohler et al. 2002; Verdery 2019). At the same time, it is possible that mothers who lose a child later in the life course will have developed a stronger capacity to cope with adverse events and will have more economic and social resources to deal with them. Our study provides novel evidence on the age distribution of maternal bereavement in the context of population ageing. More research is needed to understand how the same event affects women differently across age, socio-economic status, ethnicity, and other socio-demographic characteristics. This body of evidence could help to inform policies aimed at supporting bereaved parents, with a particular focus on older parents and parents in disadvantaged conditions.

Some of the limitations of our study are related to data availability. First, our reliance on country-level rates ignores the substantial heterogeneity between subgroups resulting from geographic, social, and economic disparities. Subgroup distributions could, in principle, be computed if the disaggregated demographic rate data existed. However, this would likely involve challenges in modelling internal migration or transitions between educational or socio-economic states. Second, our use of simple life tables and age-specific fertility rates results in a model where a

woman's fertility rate at a given age does not depend on her past reproduction. This introduces a bias in the computation of the distribution of offspring loss. The bias could be partly remedied by using multistate kinship models that incorporate data on parity progression ratios (Caswell 2020), but the necessary input data are not available for all the populations we study. Third, our analyses for younger cohorts rely on the UNWPP demographic projections, making them especially sensitive to the assumption of convergence to replacement fertility levels built into the medium-scenario projection.

A fourth limitation is that we model fertility and mortality processes separately. As a result, we ignore intergenerational demographic correlations and any potential dependence between fertility and mortality. For example, our models do not account for the fact that risks of infant mortality may be higher for very young and very old women. Relaxing this long-standing assumption in kinship demography (Ruggles 1993) would require not just better data but considerable methodological development. Lastly, on a more substantive level, our interpretation of the model outcomes refers to events with a smaller variability in age (e.g. maternal bereavement) as being more predictable for mothers. This is an anthropological interpretation and should not be confused with the mathematical concept of predictability (the probability of an event being close to zero or one).

We identify great potential for more research in the direction outlined in this paper. Future work could use demographic methods or simulations to explore the mechanisms that link changes in the distribution of fertility and mortality to the timing of offspring loss. Indeed, given recent developments in theoretical kinship demography, it is now possible to produce exact results relating survival and fertility curves with expected bereavement and its timing and spread. For example, we could investigate the implications of rising lifespan inequality or changing parity-specific fertility for the timing of maternal bereavement. Further studies could consider how rapid demographic changes (e.g. a mortality crisis, such as the Covid-19 pandemic, or a baby boom) affect the timing of offspring loss.

Individuals experience kin loss beyond offspring death. Future studies could also document how demographic change affects the ordering and timing of other kin deaths over an individual's life course. A kinship lens provides a much-needed complement to our understanding of the demographic transition and of population change more broadly.

Conclusion

We explore the influence of macro-level population change on the predictability of offspring loss. Our analysis shows that the distribution of maternal ages at child loss is bimodal. We examine trends in offspring loss for two components: one capturing the deaths of young offspring and the other capturing the deaths of adult offspring. The analysis of the two components finds no evidence of reduced variability in the *timing* of offspring loss for mothers in a selection of low-, medium-, and high-mortality countries. The likelihood that a mother will ever lose a child (the *incidence* of offspring loss) is projected to decline in more recent birth cohorts, and mothers who do lose an offspring will do so at increasingly older ages. But this will not be accompanied by a corresponding reduction in the variability of ages at which mothers lose a child. The degree to which mothers can predict the timing of offspring loss is likely to affect key life choices (e.g. fertility decisions, retirement plans, and the timing of intergenerational bequests), with wide implications for kinship demography and social policy.

Notes and acknowledgments

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- 5 Data availability: All data and codes needed to reproduce the results of this paper are accessible via the following link: <https://osf.io/6n8d3/>. All analyses were conducted in R (R Core Team 2022) using the DemoKin package (Williams et al. 2023).

Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

- Aburto, José Manuel, Francisco Villavicencio, Ugo Filippo Basellini, Søren Kjærgaard, and James W. Vaupel. 2020. Dynamics of life expectancy and life span equality, *Proceedings of the National Academy of Sciences* 117(10): 5250–5259. <https://doi.org/10.1073/pnas.1915884117>
- Albuquerque, Sara, Marco Pereira, and Isabel Narciso. 2016. Couple's relationship after the death of a child: A systematic review, *Journal of Child and Family Studies* 25(1): 30–53. <https://doi.org/10.1007/s10826-015-0219-2>
- Alburez-Gutierrez, Diego, Martin Kolk, and Emilio Zagheni. 2021. Women's experience of child death over the life course: A global demographic perspective, *Demography* 58(5): 1715–1735. <https://doi.org/10.1215/00703370-9420770>
- Caldwell, John C. 1978. A theory of fertility: From high plateau to destabilization, *Population and Development Review* 4(4): 553–577. <https://doi.org/10.2307/1971727>
- Camarda, Carlo G. 2012. Mortalitysmooth: An R package for smoothing Poisson counts with P-splines, *Journal of Statistical Software* 50: 1–24. <https://doi.org/10.18637/jss.v050.i01>
- Camarda, Carlo G., Paul H. C. Eilers, and Jutta Gampe. 2016. Sums of smooth exponentials to decompose complex series of counts, *Statistical Modelling* 16(4): 279–296. <https://doi.org/10.1177/1471082x16641796>
- Castro Torres, Andrés F., Ewa Batyra, and Mikko Myrskylä. 2022. Income inequality and increasing dispersion of the transition to first birth in the Global South, *Population and Development Review* 48(1): 189–215. <https://doi.org/10.1111/padr.12451>
- Caswell, Hal. 2019. The formal demography of kinship: A matrix formulation, *Demographic Research* 41: 679–712. <https://doi.org/10.4054/DemRes.2019.41.24>
- Caswell, Hal. 2020. The formal demography of kinship II: Multistate models, parity, and sibship, *Demographic Research* 42: 1097–1146. <https://doi.org/10.4054/DemRes.2020.42.38>
- Caswell, Hal and Xi Song. 2021. The formal demography of kinship III: Kinship dynamics with time-varying demographic rates, *Demographic Research* 45: 517–546. <https://doi.org/10.4054/DemRes.2021.45.16>
- Espinosa, Javier and William N. Evans. 2013. Maternal bereavement: The heightened mortality of mothers after the death of a child, *Economics & Human Biology* 11(3): 371–381. <https://doi.org/10.1016/j.ehb.2012.06.002>
- Goodman, Leo A., Nathan Keyfitz, and Thomas W. Pullum. 1974. Family formation and the frequency of various kinship relationships, *Theoretical Population Biology* 5(1): 1–27. [https://doi.org/10.1016/0040-5809\(74\)90049-5](https://doi.org/10.1016/0040-5809(74)90049-5)
- Keyfitz, Nathan. 1985. *Applied Mathematical Demography*. New York: Springer. <http://public.eblib.com/choice/publicfullrecord.aspx?p=3084208>
- Kohler, Hans-Peter, Francesco C. Billari, and José Antonio Ortega. 2002. The emergence of lowest-low fertility in Europe during the 1990s, *Population and Development Review* 28(4): 641–680. <https://doi.org/10.1111/j.1728-4457.2002.00641.x>
- Lesthaeghe, Ron. 2014. The second demographic transition: A concise overview of its development, *Proceedings of the National Academy of Sciences* 111(51): 18112–5. <https://doi.org/10.1073/pnas.1420441111>
- Livi Bacci, Massimo. 1997. *A Concise History of World Population*, 2nd ed. Cambridge, MA: Blackwell.
- Montgomery, Mark R. 2000. Perceiving mortality decline, *Population and Development Review* 26(4): 795–819. <https://doi.org/10.1111/j.1728-4457.2000.00795.x>
- Murphy, Michael. 2011. Long-term effects of the demographic transition on family and kinship networks in Britain, *Population and Development Review* 37: 55–80. <https://doi.org/10.1111/j.1728-4457.2011.00378.x>
- Preston, Samuel H., Patrick Heuveline, and Michel Guillot. 2001. *Demography: Measuring and Modeling Population Processes*. Malden, MA: Blackwell Publishers.
- R Core Team. 2022. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. <https://www.R-project.org/>
- Reher, David. 1995. Wasted investments: Some economic implications of childhood mortality patterns, *Population Studies* 49(3): 519–536. <https://doi.org/10.1080/0032472031000148806>
- Reher, David S. 2021. The aftermath of the demographic transition in the developed world: Interpreting enduring disparities in reproductive behavior, *Population and Development Review* 47(2): 475–503. <https://doi.org/10.1111/padr.12266>
- Ruggles, Steven. 1993. Confessions of a microsimulator: Problems in modeling the demography of kinship, *Historical Methods: A Journal of Quantitative and Interdisciplinary History* 26(4): 161–169. <https://doi.org/10.1080/01615440.1993.9956352>
- Scheper-Hughes, Nancy. 1992. *Death Without Weeping: The Violence of Everyday Life in Brazil*. Berkeley: University of California Press.

- Smith-Greenaway, Emily, Diego Alburez-Gutierrez, Jenny Trinitapoli, and Emilio Zagheni. 2021. Global burden of maternal bereavement: Indicators of the cumulative prevalence of child loss, *BMJ Global Health* 6(4): e004837. <https://doi.org/10.1136/bmjgh-2020-004837>
- Smith-Greenaway, Emily and Jenny Trinitapoli. 2020. *Maternal Cumulative Prevalence Measures of Child Mortality Show Heavy Burden in Sub-Saharan Africa*, Proceedings of the National Academy of Sciences, February, 201907343. <https://doi.org/10.1073/pnas.1907343117>
- Uhlenberg, Peter. 1980. Death and the family, *Journal of Family History* 5(3): 313–320. <https://doi.org/10.1177/036319908000500304>
- Uhlenberg, Peter. 1996. Mortality decline in the twentieth century and supply of kin over the life course, *The Gerontologist* 36(5): 681–685. <https://doi.org/10.1093/geront/36.5.681>
- van Raalte, Alyson, Ugofilippo Basellini, Carlo Giovanni Camarda, Marília Nepomuceno, and Mikko Myrskylä. 2023. The dangers of drawing cohort profiles from period data: A research note, *Demography* 60(6): 1689–1698. <https://doi.org/10.1215/00703370-11067917>
- Vaupel, James W., Zhen Zhang, and Alyson A. van Raalte. 2011. Life expectancy and disparity: An international comparison of life table data, *BMJ Open* 1(1): e000128. <https://doi.org/10.1136/bmjopen-2011-000128>
- Verdery, Ashton M. 2015. Links between demographic and kinship transitions, *Population and Development Review* 41(3): 465–484. <https://doi.org/10.1111/j.1728-4457.2015.00068.x>
- Verdery, Ashton M. 2019. Modeling the future of China’s changing family structure to 2100, in *China’s Changing Family Structure: Dimensions and Implications*. American Enterprise Institute, pp. 23–78. <https://doi.org/10.2307/resrep24663.4>
- Williams, Iván, Diego Alburez-Gutierrez, Hal Caswell, and Xi Song. 2023. DemoKin: An R package to implement demographic matrix kinship models. <https://CRAN.R-project.org/package=DemoKin>