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Konrad-Zuse-Strasse 1 · D-18057 Rostock · Germany · Tel +49 (0) 3 81 20 81 - 0 · Fax +49 (0) 3 81 20 81 - 202 · www.demogr.mpg.de

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Diego Alburez-Gutierrez I alburezgutierrez@demogr.mpg.de
Ugofilippo Basellini I basellini@demogr.mpg.de
Emilio Zagheni I office-zagheni@demogr.mpg.de

When do parents bury a child? Quantifying uncertainty in the parental age at offspring loss

Diego Alburez-Gutierrez[*†1,2], Ugofilippo Basellini[†1,3], and Emilio Zagheni[1]

[1] *Laboratory of Digital and Computational Demography, Max Planck Institute for Demographic Research (MPIDR)*

[2] *Research Group on Kinship Inequalities, Max Planck Institute for Demographic Research (MPIDR)*

[3] *Institut national d'études démographiques (INED)*

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Abstract

Mortality decline in the context of the demographic transition is often portrayed as the harbinger of a progressively 'ordered' world in which deaths become more predictable. In this narrative, parents adjust their fertility because they are increasingly certain that their offspring will survive childhood. Here, we use formal demographic methods to evaluate whether the parental age at offspring loss does, indeed, become more predictable as a result of longer lifespans and lower fertility. Our study of 18 selected countries for the 1850-2000 birth cohorts finds that, while offspring loss will become increasingly uncommon and be experienced at older parental ages, there is

[*]Corresponding author: alburezgutierrez[at]demogr.mpg.de

[†]These authors contributed equally to this work.

no evidence of reduced variability in the age at offspring loss. These results advance fundamental population theory and have policy implications in terms of supporting bereaved parents over different stages of the life course.

Introduction

Studying demographic processes from the perspective of kin can help 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 rates—it is influenced by historical mortality and fertility rates at all ages (Alburez-Gutierrez et al., 2021). Goodman et al. (1974) outlined the fundamental mathematical relationships between fertility, mortality, and kin availability, but the precise mechanisms linking population-level demographic change to the lived experience of death 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, by and large, global population change follows a predictable path that can be described in terms of changes in mortality and fertility rates (Caldwell, 1978; Lesthaeghe, 2014; Reher, 2019). In an influential account, Livi Bacci (1997) portrayed the demographic transition as a progression from a state of 'disorder' to a state of 'order'. In the former state, deaths are 'random and chaotic' (Scheper-Hughes, 1992) and individuals are unable to predict how long they or their relatives will live. In the latter state, deaths fall into place along a 'chronological hierarchy' that allows individuals to be more certain about the timing of their deaths and the deaths of their relatives. This implies a reduced number of 'untimely deaths' experienced by kin. Here, we should distinguish between the *quantum* and the *timing* of kin loss. Quantum refers to the frequency of kin loss, while timing refers to the distribution of the losses over the lifecourse of bereaved kin. Alburez-Gutierrez et al. (2021) showed that the quantum of offspring loss declines across the demographic transition. However, the degree to which this also implies an ordering in the timing of kin death over an individual's life course, reducing the number of 'disorderly' or 'untimely' deaths, has not been studied extensively.

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 consider whether the demographic transition implies a progression from a disorderly world (in which the timing of offspring loss is highly unpredictable for parents) to a more orderly world (in which it is more predictable). We ask: does offspring loss become an increasingly predictable event for mothers throughout the demographic transition? We explore this question by analyzing changes in the central value and variability of the age at which mothers lose a child. For this, we propose a new methodology that combines established life-table and novel matrix kinship approaches (Caswell, 2019) and apply it to demographic data from 18 selected countries. 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 log-term consequences for bereaved parents and for women in particular (Hendrickson, 2009; Albuquerque et al., 2016; Espinosa and Evans, 2013). Child loss is projected to decline worldwide and to increasingly involve the death of an adult offspring, bringing about new challenges for bereaved older parents (Alburez-Gutierrez et al., 2021).

The degree to which parents can predict the timing of offspring loss matters because offspring survival sits at the very center 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; Freedman, 1962). 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 parents 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 uncertainty and heterogeneity surrounding offspring loss can help us better understand the drivers of global demographic change in the context of the demographic transition.

This study shows that while the overall likelihood of experiencing offspring death decreases over the demographic transition, the same cannot be said of the variability in the age at which mothers lose a child (conditional on ever having lost a child). We find that the transition from 'disorder' to 'order' theorized by demographers does not imply a higher level of predictability when it comes to the timing of offspring loss. Changes in the timing of loss can shed light on how parents make important life decisions and plan for their own retirement. Women may chose to reduce or delay their fertility if they are more certain that their offspring will survive past childhood. 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 next section, we use formal demographic methods to characterize inequalities in the age at which women experience offspring death. We present results for a selection of countries representing a range of mortality regimes, based on a combination of historical and projected demographic data. Our findings challenge the received wisdom that the timing of offspring loss becomes more predictable for mothers throughout the demographic transition. We conclude by discussing the implications of our findings for theory and policy.

Results

Quantum of offspring loss

Our analyses focus on the historical and projected development of the age at which mothers experience the death of a child. These results come from a novel approach that combines established life-table methods (Preston et al., 2001) and innovative matrix kinship models (Caswell and Song, 2021). We present results for 18 countries selected to represent a diverse range of life expectancy levels. We use mortality terciles to arrange the countries in 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).[1] We deliberately exclude populations that had experienced high excess mortality from the HIV/AIDS epidemic from our sample and purposefully included Sweden, which has the longest historical time series of demographic data. When presenting the results, we highlight one country in each group (in bold in the list above) as being indicative of the trend in their group.

We first consider trends in the quantum of offspring loss, or the incidence of maternal bereavement. As an example, consider the 61 thousand women born in Guatemala in the year 1950. We project that these women bore around 270 thousand offspring during their reproductive years (1965-2000) and that 30 thousand of these 'offspring'—i.e., 11% of all offspring—die before their mothers. We interpret this fraction of offspring that died before their mothers as a proxy for the fraction of mothers who experienced the death of (at least) one offspring.

Replicating this analysis for all countries and maternal cohorts, we document a sustained decline in the quantum of offspring loss over time. This is evidenced by the dwindling

[1] These terciles are based on levels of life expectancy at birth in 1980-1985, the middle of the 1950-2020 period for which the 2019 Revision of the United Nations World Population Prospects (UNWPP) provides empirical (i.e., not projected) life expectancy values.

percentage of offspring who will die before their mothers in Fig. 1 (we chose this measure to improve comparability across countries with very different fertility levels and population sizes). For example, 17% of the progeny of Angolan women born in 1950 will die before their mothers. This is equivalent to the value for Swedish women born one hundred years earlier. The values for women born in the year 2000 are 7% for Angola and $< 1\%$ for Sweden.

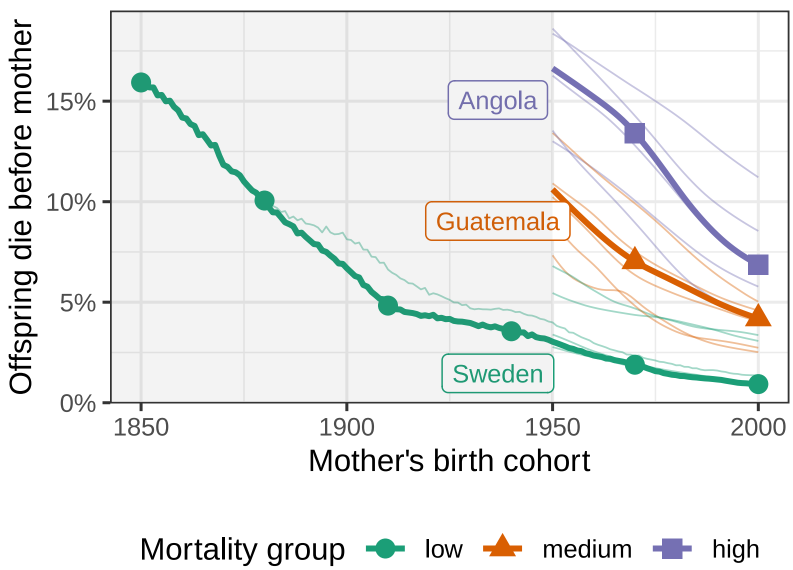

Figure 1: Share of a mother's progeny expected to die before her, by maternal birth cohort. Lower values indicate that a larger share of offspring will outlive their mothers, net of fertility levels. Angola, Guatemala, and Sweden are highlighted to represent the main trends in each group (high, medium and low mortality, respectively); other countries are faded lines in the background. The grey background shows estimates from 'historical' demographic data (see Materials and Methods).

Next, we explore how these bereavement events are distributed across the lifecourse of mothers. Fig. 2 shows the population-level number 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 over age, sex, and the current and previous levels of mortality and fertility. Alburez-Gutierrez et al. (2021) documented a decline in the quantum of offspring loss for subsequent birth cohorts. Here, we are chiefly interested in the relative distributions of offspring deaths over age. Offspring deaths in low mortality settings like Sweden are concentrated at higher maternal ages. In settings with higher mortality, such as Guatemala and Angola, offspring deaths happen mainly during women's reproductive ages, before age 50, when both mothers and offspring are young. The figure also shows the different composition of the offspring ages at death. In Sweden, more women live to older ages to experience the death of an adult offspring (who is often more than 50 years old). In Angola and Guatemala, women are more likely to experience the death of an offspring younger than 5 years old.

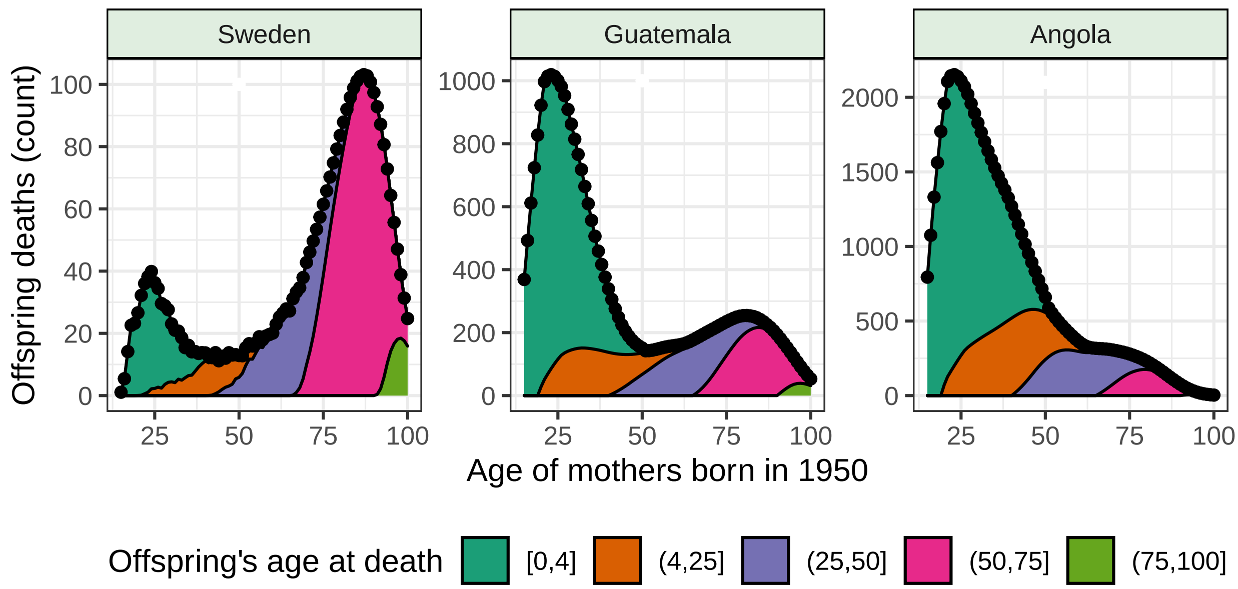

Figure 2: Expected number of offspring deaths over the maternal lifecourse for women born in 1950 in three selected countries (black dots, population-level non-cumulative counts). The colored areas show the offspring's age at death. Note the different y-axes in each panel.

General trends in the maternal age at offspring loss

We first explore trends in the maternal age at offspring loss over birth cohorts by considering the 'simple' mean and standard deviation (SD) of the age at which mothers lose a child based on the distributions showed in Fig. 2.[2] For convenience, we refer to these as the mean maternal age at offspring loss (MAOL) and the uncertainty of offspring loss (UOL). Fig. 3 (left) shows evidence of a sustained increase in MAOL over birth cohorts for all of the chosen countries. This means that, as women (and children) live longer, they can expect to experience offspring loss at increasingly older ages. This is true for all of the countries we consider, even if the projected increase in MAOL is less pronounced in low mortality countries.

Next, we examine the uncertainty surrounding the age at which mothers lose an offspring. The Swedish example in Fig. 3 (right) provides a long-term historical overview of this process. In Sweden, the UOL was low for most of 19^{th} 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 only narrower time-frames are available. High mortality countries (which are projected to undergo declines in mortality and fertility in the future) show growing UOL, while low mortality countries (where mortality and fertility is projected to remain relatively stable) show decreasing or no change in UOL. Medium mortality countries, which we assume to be in the middle of the demographic transition, show no evidence of change in the period observed.

[2]'Simple,' in this context, refers to summary measures of the general distribution, as opposed to the decomposed summary measured presented in section *Timing of offspring loss for young and adult components.*

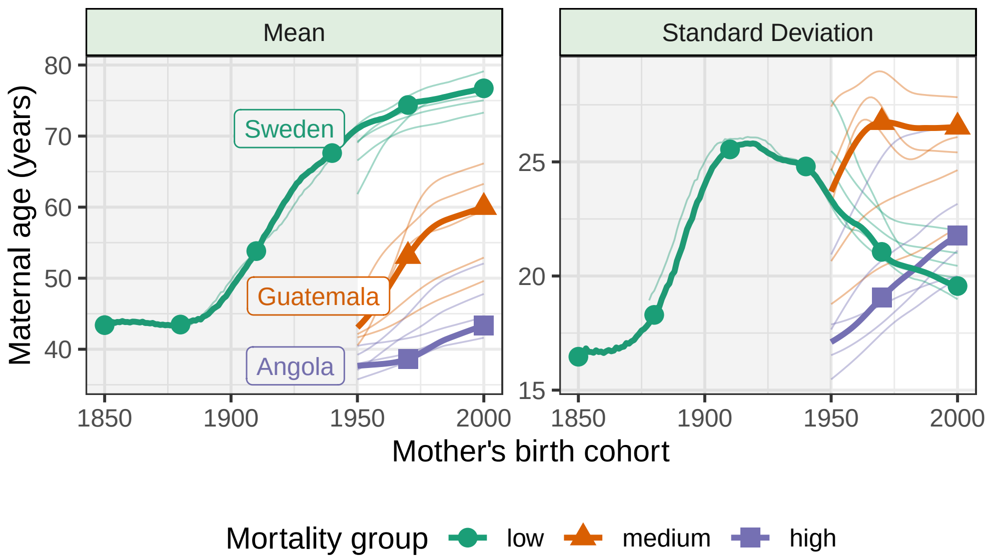

Figure 3: Simple mean and standard deviation of the maternal age at offspring loss in 18 countries, grouped into low, medium, and high mortality groups according to their life expectancy at birth.

Timing of offspring loss for young and adult components

Fig. 2 showed that the distribution of offspring deaths over the maternal lifecourse is bimodal, meaning that conventional measures of central tendency and dispersion may be inadequate to summarise them (Castro Torres et al., 2022). We use a non-parametric approach (see *Materials and Methods*) to decompose the distribution of offspring deaths into two components. The first, 'young component,' captures the deaths of offspring that mainly happen during women's reproductive years, when both mothers and children are young. The second, 'adult component,' captures offspring deaths that happen mainly outside of women's reproductive age, when both children and mothers are older (e.g., some older mothers in low mortality settings will lose adult offspring older than 50 years old).

Fig. 4 shows the results of our decomposition analysis for women born in 1950 in the three representative countries. The values inside each component (shaded area) indicate the proportion of the overall distribution that is explained by each component, or the 'relative importance' of that component. This weight is derived from the decomposition analysis and, for any given birth cohort, sums to unity between the young and adult component. For example, for Swedish women born in 1950, 80% of the overall distribution of offspring loss is captured by the adult component, whereas only 20% 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 child death (i.e., the relative importance of the young component is 86%). The uppermost panel of Fig. 5 shows how these values changed over time, with young-offspring deaths constituting a progressively smaller proportion of all the offspring deaths experienced by women over time.

The decomposition analysis provides a more nuanced picture of the development of the maternal age at offspring loss by distinguishing between the loss of young and adult offspring. Fig. 5 shows that the rapid increase in the simple mean shown in Fig. 3 stems from two overlapping processes: a slow but steady increase in the mean age for the adult component,

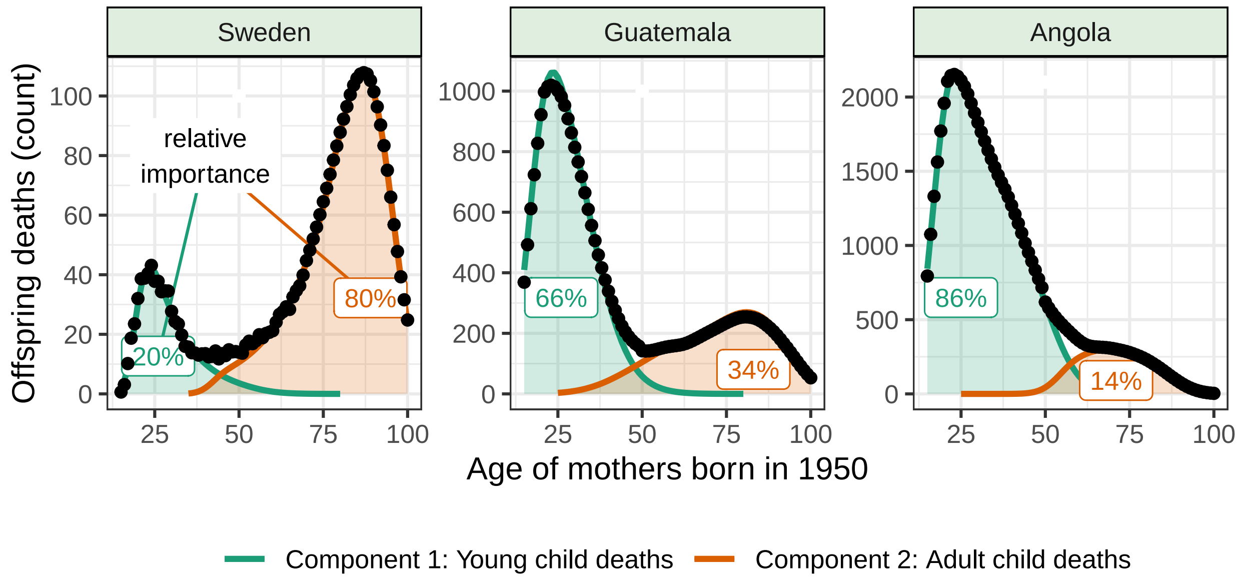

Figure 4: Young and adult components resulting from the decomposition analysis (shaded areas) in three selected countries. The fitted values for the two components (coloured lines) sum up to the expected number of offspring deaths (black dots) for each cohort. 'Relative importance' refers to the proportion of the overall distribution captured by each component. Note the different y-axes in each panel.

and a rapid decrease in the relative importance of the young component. The difference in the MAOL for the young component within mortality groups is relatively small (although the overall levels vary widely between groups). Differences in the ages at which mothers experience the death of an adult child are considerably higher both within and between groups.

We now consider the uncertainty of offspring loss, UOL, by focusing on changes in the SD of each component. Our previous analysis of the simple SD (Fig. 3) suggested a consistent trend, where the UOL would temporarily increase from relatively low levels to relatively high levels in 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 (Fig. 5, bottom-left) shows a growing tendency in medium- and low mortality settings. In the context of falling infant mortality rates, offspring are more likely to survive early childhood. This leads to a wider spread of maternal ages 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 the SD of the maternal age at young offspring loss (from 7.6 years in 1850 to 11.5 years in 2000). This is consistent with a scenario where the death of a young offspring becomes increasingly uncommon and less concentrated in the 0-5 offspring ages. This contrasts with Angola, which shows a decline in UOL 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 SD of the adult component (Fig. 5, bottom-right) 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, the ages at which mothers can expect to lose a child are spread more widely across the maternal lifecourse (as are the ages at death of the offspring themselves—see Fig.2). This contrasts with Sweden, where most adult deaths are concentrated at relatively high maternal ages. It also contrasts with Angola, where offspring deaths are mostly clustered around young maternal ages. Here, the (slow) growth of the UOL for the adult component points to an increasingly heterogeneous composition of the maternal age at offspring loss.

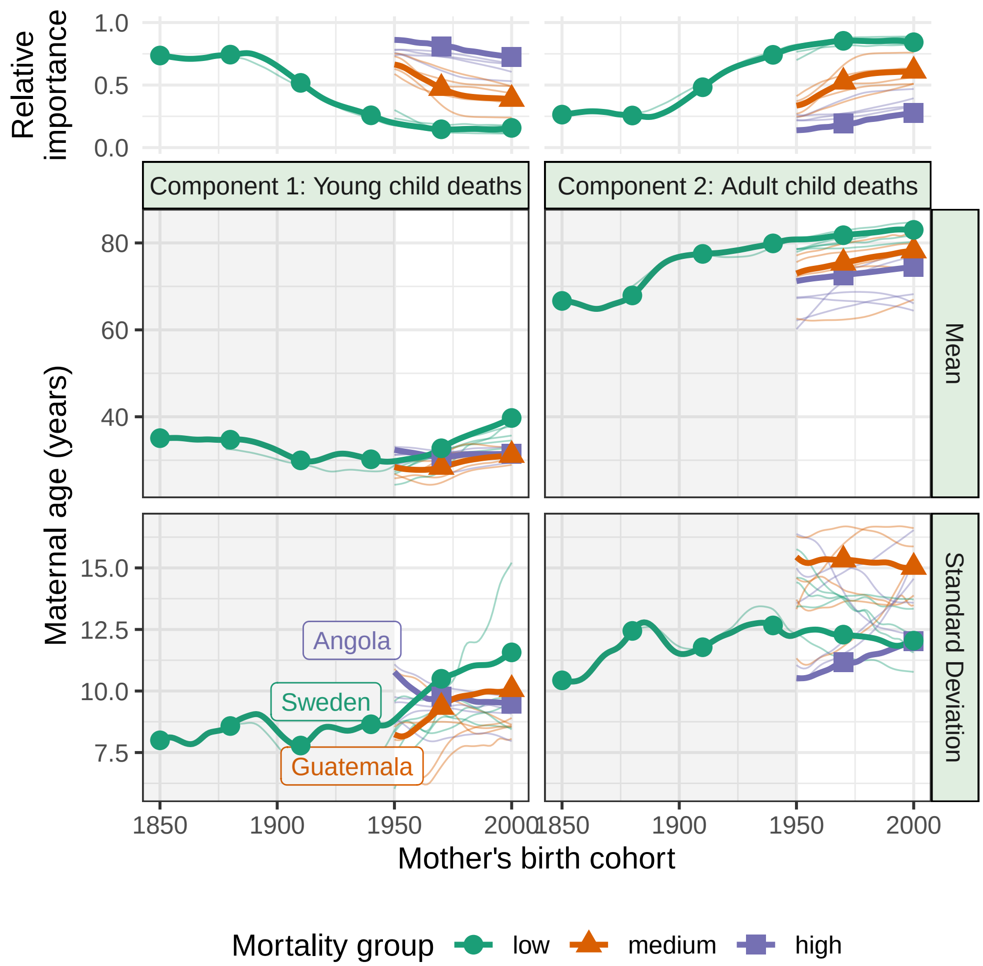

Figure 5: Decomposed mean and standard deviation of the maternal age at offspring loss (18 countries, Angola, Guatemala, and Sweden highlighted). The top two panels represent the weights of each component, with higher values implying that a component explains a larger proportion of the variability of the data (weights sum to unity within each birth cohort).

Discussion

We set out to answer the question of whether the forces driving the demographic transition (population-level declines of mortality and fertility rates) invariably produce an 'ordering' of events over the life course, effectively ushering in a social world in which life courses are more predictable. Our focus on the *timing* of offspring loss found no evidence of declining variability of the ages at which mothers lose a (young or adult) offspring. We find that the average mother's uncertainty about the age at which she may lose a *young offspring* tends to increase as offspring deaths become less concentrated at very young ages. This happens against the backdrop of an overall declining *quantum* (i.e., incidence) of offspring loss, especially at young ages. We also find little evidence of a decline in the variability in the age at which mothers may expect to lose an *adult offspring*, even as the offspring's age at death becomes more heterogeneous over time (given lower and later fertility). 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.

Livi Bacci (1997) predicted that, as a result of the demographic transition, the experience of kin loss would come to resemble a 'natural chronological hierarchy of death' in which untimely deaths are uncommon. A shortcoming of this proposition is that societies might come to regard any long-term trend as 'natural,' making it difficult to distinguish between 'timely' and 'untimely.' The notion that a 'natural order' represents a state in which members of older genealogical generations invariably die before members of younger generations may reflect a particular historical and class vantage point rather than a timeless universal truth. In words of Scheper-Hughes (1992), this worldview may reflect the experience of the 'modern, bourgeois, nuclear family' in the Global North more than the experiences of those leading 'short, violent, and hungry lives' elsewhere. Indeed, child death has been extremely common for most of human history (Volk and Atkinson, 2013) and parents routinely face offspring loss in many parts of the world (Doyle, 2008; Cannon and Cook, 2015).

It is generally acknowledged that lifespan equality is preferable to lifespan inequality (van Raalte et al., 2018). The same may be true for offspring loss. Lifespan equality means that more people are in a position to make informed decisions related to savings, pension, inter-generational transfers, fertility, and other important life decisions. As we have shown, an increase in the uncertainty surrounding the timing of offspring loss reflects, on the whole, a shift towards a regime in which offspring loss happens later in life, if at all. Postponing the age at offspring loss means that mothers spend, on average, fewer years and a smaller share of their lifetimes in a potential state of bereavement, after having experienced the death of a child. This is a positive development that can benefit mothers, given the known negative effects of parental bereavement. At the same time, the lingering variability in the age at child death is experienced by mothers as heterogeneity in the timing of offspring loss. This has potentially negative outcomes for mothers who organized their lives around the expectation of having children around when they reach old age. The situation is particularly worrying for mothers with a single child, an increasingly common family configuration (Kohler et al., 2002; Verdery, 2019).

Our study has three main limitations. First, our reliance on country-level rates ignores substantial sub-national heterogeneity derived from social and economic inequalities. Studies using individual-level data could test for sub-national variability in the timing of offspring loss. Nevertheless, this study could not be fully replicated using survey data, which are restricted to women's reproductive life, do not project future developments, and fail to capture offspring loss in settings where it is uncommon. Second, our interpretation of greater variability as 'uncertainty' assumes that mothers are aware of the population-level trends. This is consistent with the idea that mother-centered approaches come closer to the actual lived experience of parents than traditional child mortality rates (Smith-Greenaway and Trinitapoli, 2020). Third, our analyses for younger cohorts rely on demographic projections made by the UNWPP, which may make them especially sensitive to the assumption of convergence to replacement fertility levels built into the medium projection scenario.

We identify a great potential for more research in the direction outlined in this article. Future work can 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. What are the implications of rising lifespan inequality, or of changing parity-specific fertility, for the timing of maternal bereavement? Further studies can consider how rapid demographic change—e.g., mortality crises such as the Covid-19 pandemic or 'baby-booms'—affects the timing of offspring loss.

Individuals experience kin loss beyond offspring death. Future studies may 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 changes in the the timing of offspring loss for mothers to investigate the widely-held belief that the demographic transition leads to a more 'ordered' social world in which offspring loss is more predictable. We find no evidence of reduced uncertainty 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 *quantum* of offspring loss) is projected to decline for subsequent 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 uncertainty of the age at which mothers will lose a child. This contrasts with known trends in lifespan inequality, which suggest that as individuals live longer, they tend to be increasingly certain about the age at which they will die (Aburto et al., 2020; Smits and Monden, 2009; Vaupel et al., 2011). The degree to which parents can predict the timing of offspring loss is likely to affect fertility decisions, retirement plans, and the timing of inter-generational bequests, among other key life choices that have wide implications for demographic theory and for social policy.

Acknowledgments

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Materials and Methods

Distribution of offspring deaths over the maternal lifecourse

We use life table methods and matrix kinship models to compute $n_{i,j,t-i}$, the expected number of offspring deaths for women born in year $(t-i)$, where $i = 15, \ldots, 100+$ denotes the age of the mother and $j = 0, \ldots, 85+$ 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 Fig. 6). We arrange the expected number of offspring deaths in a three-dimensional array $\boldsymbol{N} = (n_{i,j,t-i})$. For mothers, we consider ages $\alpha \leq i \leq 100+$, where $[\alpha, \beta] = [15, 49]$ are the limits of female 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. We restrict the range of possible maternal and offspring ages (i, j) to avoid impossible cases (such as mothers aged 65 experiencing the death of a newborn, or mothers aged 15 experiencing the death of a five year old). These cases are denoted with "na" in Eq. (1), which shows the matrix $\boldsymbol{N} = (n_{i,j})$ for a given birth cohort $(t-i)$:

$$\boldsymbol{N} = (n_{i,j}) = \begin{bmatrix} n_{15,0} & na & \dots & \dots & \dots & na \\ n_{16,0} & n_{16,1} & na & \dots & \dots & na \\ \vdots & \vdots & \ddots & \ddots & \ddots & \vdots \\ n_{49,0} & n_{49,1} & n_{49,2} & \dots & \ddots & na \\ na & n_{50,1} & n_{50,2} & \ddots & \dots & na \\ na & na & n_{51,2} & \ddots & \dots & na \\ \vdots & \vdots & \ddots & \ddots & \ddots & \vdots \\ na & na & na & \dots & n_{99,84} & na \\ na & na & na & \dots & n_{100+,84} & n_{100+,85+} \end{bmatrix} \tag{1}$$

We first compute the expected number of surviving children aged j for an average woman aged i born in year $(t-i)$ (e.g., a woman aged 20 can 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`.[3] We store them in the matrix $\boldsymbol{H} = (h_{i,j,t-i})$. 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 $\boldsymbol{q} = (q_{j,t-j})$. Third, we account for the age distribution of mothers by storing the number of women born in year $(t-i)$, alive at age i, in the weighting vector $\boldsymbol{w} = (w_{i,t-i})$. We combine these three quantities to obtain the expected number of offspring, to a mother born in year $(t-i)$ and aged i, who die when they are j years old:

$$n_{\mathrm{i,j,t-i}} = h_{\mathrm{i,j,t-i}} \times q_{\mathrm{j,t-j}} \times w_{\mathrm{i,t-i}}. \tag{2}$$

The array $\boldsymbol{N}$ allows us to compute offspring loss by the 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

[3] https://github.com/IvanWilli/DemoKin.

entry in the $(i, j, t - i)$ position of the array $\boldsymbol{N}$.

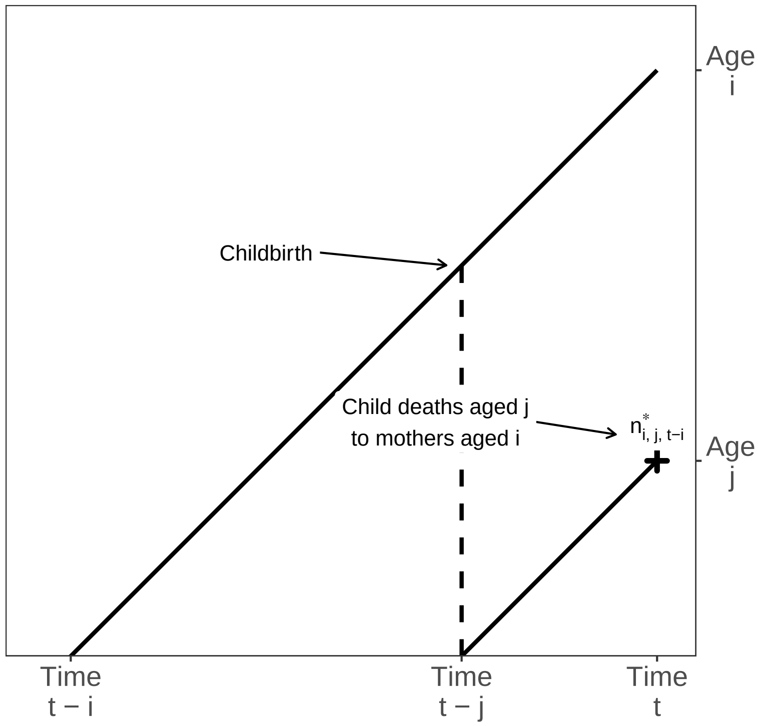

Figure 6: Lexis diagram showing the expected number of offspring dying at age j to mothers aged i. The offspring's death at time t and age j is indicated with a cross.

Data

Data for the main analysis come from the 2019 Revision of the United Nations World Population Prospects (UNWPP, empirical data for the 1950-2020 period and median-scenario projections for 2020-2100). Historical mortality rates and population data for Sweden and Denmark come from the Human Mortality Database.[4] Fertility rates come from the Human Fertility Collection (up to 1890) and from the Human Fertility Database (1891-1950).[5] We approximate cohort rates from period rates by taking the values along the diagonals.

[4] https://www.mortality.org/.

[5] https://www.fertilitydata.org and https://www.humanfertility.org/.

This procedure may introduce a relatively small bias in the short-term—less than 5% deviation from observed cohort summary measures (van Raalte et al., 2022)—but is unlikely to substantially bias the estimates in the long run. In order 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 obtain these by assuming that the 2100-2150 rates remain stable at the levels projected by the UNWPP for 2100.

Decomposition analysis

We decompose the distribution of offspring deaths using the Sum of Smooth Exponentials model (Camarda et al., 2016), a powerful and flexible approach to model 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 `MortalitySmooth` package (Camarda, 2012) and enforce concavity constrains 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.

Data availability

All data and codes needed to reproduce the results of this paper are available in an open-access OSF repository (Basellini and Alburez-Gutierrez, 2022). All analyses were conducted in `R` (R Core Team, 2022).

Author contributions

D.A.-G., U.B., and E.Z. designed research; D.A.-G. and U.B. performed research; U.B. contributed new analytic tools; D.A.-G. and U.B. analyzed data; D.A.-G. created the data visualizations; D.A.-G., U.B., and E.Z. wrote the paper.

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