When do parents bury a child? Uncertainty of offspring loss across the demographic transition

Diego Alburez-Gutierrez[1], Ugofilippo Basellini[1], and Emilio Zagheni[1]

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

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Abstract

Mortality decline in the context of the Demographic Transition (DT) 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 evaluate whether the demographic changes that characterise the DT (longer lifespans and lower fertility) do indeed make offspring loss more predictable for parents. For this, we document the development of the maternal age at offspring loss around the world in terms of its central value and variability. We find that the changes implied by the DT lead to offspring loss becoming more unpredictable for parents in the short term. Our findings have profound implications for population theory and for policy makers, especially in light of the radical demographic changes projected for the Global South.

Introduction

Studying demographic processes from the perspective of kin can help bridge the gap between macro-level change and the way in which individuals actually perceive this change (Murphy, 2011; Verdery, 2015). For example, the degree to which mothers experience offspring loss is not just the product of current mortality levels – it is influenced by historical mortality and fertility regimes (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 (DT) is a common framework for characterizing macro-level demographic change. At the heart of the DT is the belief that, by and large, global population change follows a predictable path that can be described in terms of changes in annualized mortality and fertility rates (Caldwell, 1978; Lesthaeghe, 2014; Reher, 2019). In an influential account, Livi Bacci (1997) portrayed the DT as a transition 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 (in theory, reducing the amount of 'untimely deaths' experienced by kin). There is some evidence to support this view. Studies have shown a robust correlation between life expectancy and lifespan equality, meaning that as individuals live longer, they are also more certain about the age at which they will die (Aburto et al., 2020; Aburto and van Raalte, 2018). However, the degree to which the DT 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 empirically.

In this paper, we explore the relationship between macro changes in fertility and mortality and the timing of offspring loss from the perspective of a mother. We consider whether the DT implies the transition from a disorderly world (in which the death of a child is highly unpredictable) to a more orderly world (in which offspring loss is more predictable). We ask: does offspring loss become an increasingly predictable event for mothers throughout the demographic transition? Concretely, how has the age at which mothers lose a child changed over time in terms of its central value and variability? We answer these questions by analyzing empirical demographic data for all world countries using a new methodology that combines established life-table and novel matrix kinship approaches (Caswell, 2019). 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 to population scholars because offspring survival sits at the very center of demographic theory. Increasing levels of child survival is often credited as a major driver of the fertility decline that characterizes the first demographic transition (Caldwell, 1978). However, child survival is often approximated using period infant and child mortality measures, which do not fully capture the experience of offspring loss for parents (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 surrounding offspring loss can help us better understand the drivers of global demographic change in the context of the DT. It can also shed light on how parents make important life decision. 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-vivo 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 empirical estimates for a selection of countries first and generalize the analysis to the entire world later. We conclude by discussing the implications of our findings for theory and policy.

Results

Our analyses contrast the historical and projected development of two measures related to women's experience of mortality. We report the median and interquartile range (IQR) for women's lifespan (i.e., 'age at own death'), and for the maternal age at child death (i.e., 'age at offspring loss'). For lifespan, we estimate the IQR and median values from a continuous density function of the $\boldsymbol{\ell}_x$ 'survivorship' life-table column obtained using spline interpolation. We obtain the IQR and median of the maternal age at offspring loss using a similar procedure, except that the relevant continuous density function ν is estimated by using a novel approach described in *Materials and Methods*. Estimates for women born after 1950 are based on mortality and fertility data from the 2019 Revision of the United Nations World Population Prospects (UNWPP). Estimates for earlier cohorts in Sweden come from the Human Mortality Database and Human Fertility Database.

We start by comparing the dynamics of lifespan and offspring loss in four countries that represent a variety of demographic trajectories. Sweden was chosen as a case of a country that has had relatively low mortality and fertility since the early 20^{th} century and has the longest and most reliable record of historical demographic data. Zimbabwe has comparatively high mortality and fertility and experienced an acute mortality surge starting in the late 20^{th} century as a result of the HIV/AIDS epidemic. India is a high-mortality and high-fertility country where total fertility is projected to decline from 5.9 in 1950-1955 to 1.71 in 2095-2100. Cuba underwent a very rapid mortality and fertility decline in the second half of the 20^{th} century, and now has one of the highest reported life expectancies at birth in the world.

Fig. 1 shows the documented negative relationship between lifespan duration (solid red lines) and lifespan inequality (dashed red lines): as individuals live (on average) longer, their length of life becomes more similar (Wilmoth and Horiuchi, 1999; Vaupel et al., 2011; Aburto et al., 2020). This trend can be observed more clearly for the case of Sweden, which has the longest series of high-quality historical demographic data. The Swedish case (top panel) exemplifies the growing divergence between lifespan and lifespan inequality that started for women born towards the end of the 19^{th} century. We observe this trend for the four chosen countries, although with perturbations for Zimbabwe derived from epidemic-induced mortality.

We now turn to the ages at which women can expect to lose a child. We find a sustained increase in the median maternal age at offspring loss (MAOL) over birth cohorts for the chosen countries (dashed blue lines in Fig. 1). This means that, as women (and children) live longer, they can expect to experience offspring loss at increasingly older ages.

We turn to Sweden for a long-term overview of the development of the IQR of the maternal age at offspring loss, which we use as a measure of the uncertainty surrounding

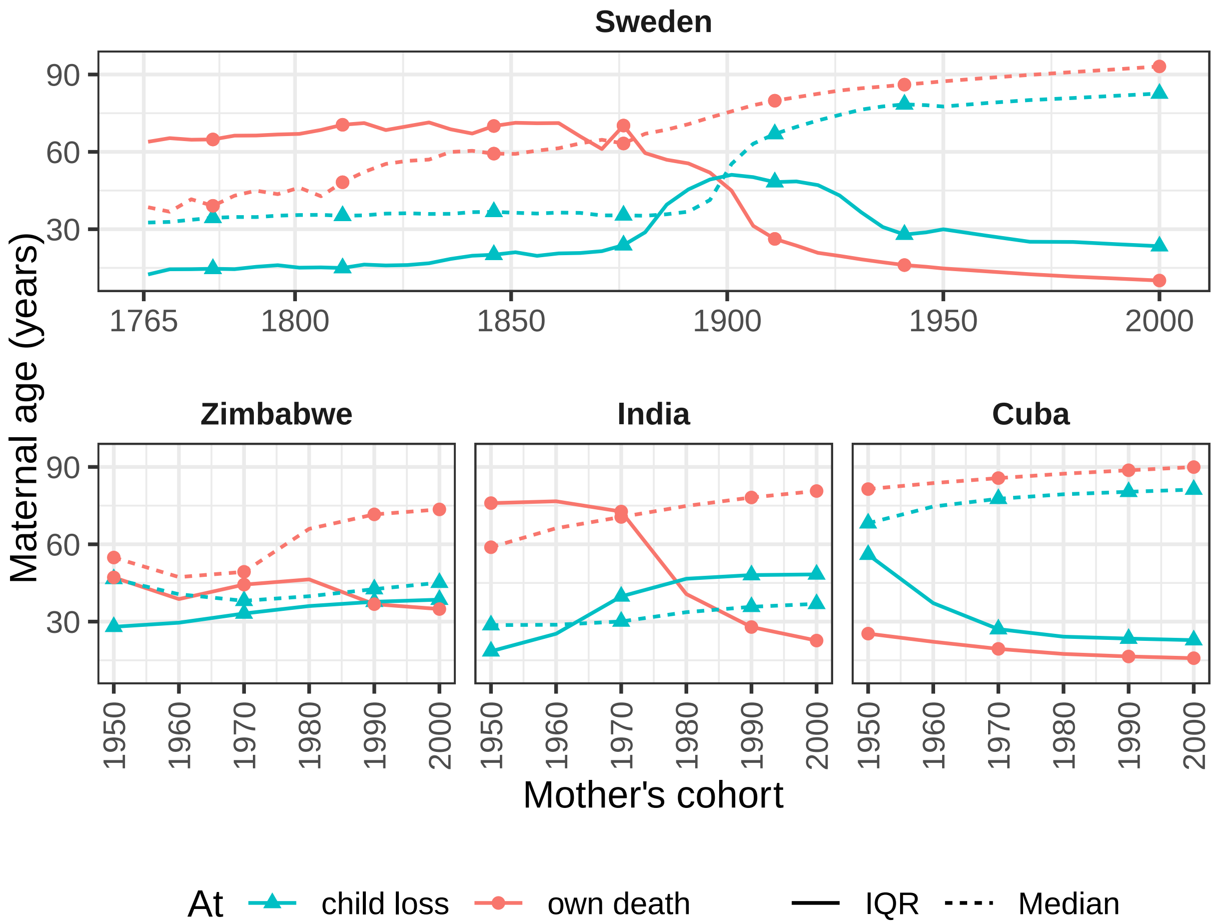

Figure 1: Timing of two key life events: woman's age at death (red), and maternal age at offspring loss (blue). Median ages and interquartile ranges in four countries representing different demographic trajectories. Sweden estimates (1756-2000 cohorts) use data from the Human Mortality and Human Fertility databases, Human Fertility Collection and demographic projections from the UNWPP. Estimates for the three other countries (1950-2000 cohorts) use empirical and projected data from the UNWPP.

the age at which mothers lose an offspring (i.e. uncertainty of offspring loss, UOL). The solid blue lines in Fig. 1 (panel A) show that UOL was low for most of 19^{th} century, when we observe a sustained increase in median lifespan (dotted red line). The UOL increased temporarily for mothers born between 1870 and 1950, who were caught in the macro-level demographic changes described by the DT before returning to almost pre-DT levels of UOL for women born after 1950. We observe a similar pattern in the other panels of Fig. 1 (which only show women born between 1950 and 2000). The trajectories of the three chosen countries are reminiscent of three different stages of Sweden's historical development, with

Zimbabwe corresponding to a first stage (slight increase in MAOL and constant UOL), India to a second stage (rising MAOL and UOL), and Cuba to a third stage (rising MAOL and declining UOL).

We extend our analysis to all countries included in the UNWPP to determine whether the direction of change of the UOL can be predicted by a country's current mortality regime, which we use as a proxy for its position along a hypothetical DT. We expect countries that have low mortality to see declines in the UOL in the future, countries with high mortality to see increases, and countries somewhere in the middle to see little change between the 1950 and 2000 cohorts. In order to evaluate the general direction of change, we fit a set of country-level bivariate linear regressions to the UOL for the 1950-2000 female cohorts. We split the countries into terciles according to their life expectancy at birth in the year 2020. We refer to each of the resulting groups as 'low', 'medium' and 'high' mortality countries, but they can also be thought of as 'pre-transition', 'transitioning', and 'post-transition' countries.

Overall, this analysis confirms our previous findings that high-mortality countries (all which are expected 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 DT, show no evidence of change in the period observed. Similarly, we find a positive correlation between the median age at offspring loss and the variability of this measure for pre-transition countries, no correlation in transitioning countries, and a negative correlation in post-transition countries. The findings are robust to alternative definitions of a country's position along the DT, such as the population's median age (Dyson, 2013).

Fig. 2 shows the coefficients of the country-level linear regressions for 50 randomly chosen countries. Negative coefficients indicate an overall decrease in uncertainty for the timing of offspring loss (left panels) and own death (right panel) between the 1950 and 2000 birth cohorts. Positive coefficients represent growing uncertainty and coefficients not different from zero indicate no overall change (95% confidence intervals). We see that UOL is projected to increase in pre-transition countries, remain unchanged in transitioning countries and decline in post-transition countries. In contrast, lifespan uncertainty is projected to decline in most countries, with the largest gains projected for high-mortality countries.

Discussion

We set out to answer the question of whether the forces driving the DT (population-level declines of mortality and fertility rates) produce an 'ordering' of events over the life course, effectively ushering in a social world in which life courses are more orderly and predictable. Our focus on offspring loss showed that the DT does not necessarily imply a transition from demographic 'disorder' to 'order'. Instead, we found evidence of a transitional phenomenon whereby the DT results in a temporary *increase* in the uncertainty surrounding the maternal age at offspring loss. In high-mortality settings, offspring deaths are experienced early in life, whereas in low-mortality settings, they occur when mothers and offspring are older. This

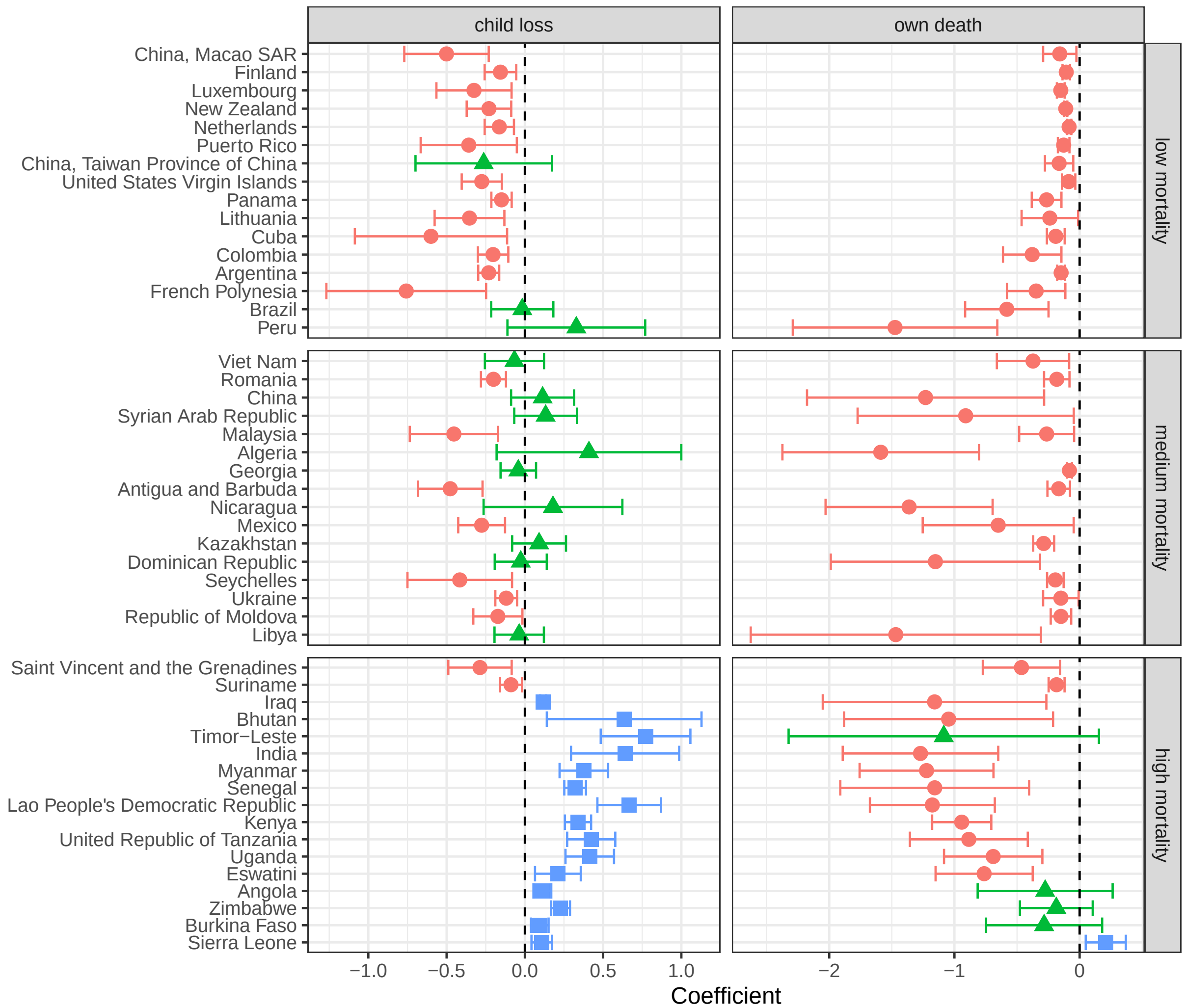

Figure 2: Slope of linear regression fitted to the IQR of the maternal age at offspring loss for the 1950-2000 female birth cohorts in 50 randomly selected countries ordered by their life expectancy at birth in the year 2020 (any-age offspring, β and 95% CI). Red circles are negative βs, blue squares are positive βs, and green triangles are βs that are not different from zero.

equilibrium is disrupted as countries transition from high to low levels of mortality.

These findings have implications for demographic theory. Rising uncertainty surrounding the timing of offspring loss may be a trigger for fertility decline. The DT postulates that fertility preferences depend on parents' beliefs about whether their children will survive childhood. At the same time, it is widely acknowledged that parents do not experience population-level mortality change directly (Montgomery, 2000). Here, we advocate for a focus on the lived experience of kin loss instead. Growing inequality in the experience of child loss may signal to parents the coming of a new demographic era in which child death is uncommon and offspring can be generally expected to survive the dangerous period of childhood.

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. An obvious limitation of this proposition is that societies might come to regard any long-term trend as 'natural', making it hard 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. One is left to wonder, along with Scheper-Hughes (1992), whether this worldview reflects 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). We showed that the DT implies the replacement of a long-standing order, after a period of heightened uncertainty, with a new demographic order. It is possible that the shared understanding of what constitutes an untimely death may also change in the process.

It is generally acknowledged that lifespan equality is preferable to lifespan inequality (van Raalte et al., 2018), but the same may not be true for offspring death. Lifespan equality means that more people are in a position to make informed decisions related to saving, 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 a shift towards a regime in which offspring loss happens later in life, if at all. A recent study projected that the global burden of maternal bereavement will be 1.6 times lower for women born in 2000 compared to women born in 1955 (Alburez-Gutierrez et al., 2021). 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 can be beneficial for mothers given the known negative effects of parental bereavement. It may also have unintended consequences. If offspring loss happens late in a woman's life, she may not be able to have another child to achieve her desired family size. In addition to this, parents often organize their lives around the expectation of having children around when they are old. This may lead to negative outcomes for mothers if their children pass away when the mothers reach old age, a likely outcome for mothers with a single child.

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 (Smith-Greenaway et al., 2021). 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 comes 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. A previous study of offspring loss using the same data found that this assumption is less important than the choice of future mortality trajectories (Alburez-Gutierrez et al., 2021).

We identify a great potential for more research in the direction outlined in this article. Future studies can consider how rapid demographic change, e.g., mortality crises or 'baby-booms', affects the timing of offspring loss for parents. Individuals experience kin loss beyond offspring death. Future studies can document how demographic change affects the ordering and timing of other kin deaths over an individual's life course. A kinship lens can provide a much-needed complement to our understanding of the DT and of population change more broadly.

Conclusion

We investigate the widely-held belief that the demographic transition (DT) leads to a more 'ordered' social world in which kin loss is more predictable. Concretely, we explore whether the DT reduces the uncertainty surrounding the timing of offspring loss for mothers around the world. We find that the DT implies (i) a sustained increase in the median maternal age at offspring loss, and (ii) a temporary increase in the uncertainty surrounding the age at which a mother can expect to lose a child. The consecutive declines in mortality and birth rates that characterize the DT produce a shift from one ordered state (in which offspring routinely die as children) to another ordered state (in which offspring mainly die as adults). We project that women in settings where mortality is currently high will be increasingly uncertain about the timing of the death of their offspring even as they are more certain about the timing of their own deaths (as lifespan equality increases). 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.

Future work

We are currently exploring alternative methodologies to summarise the central value and variability of the maternal age at offspring loss. In particular, we are exploring using mixture models considering that the distribution of ages at offspring loss is bimodal (with a first peak corresponding to young-offspring deaths and a second peak corresponding to adult-offspring deaths). We are also working on showing results disaggregated by the offspring's age at death (as opposed to any-age offspring deaths, as currently shown in the paper).

Materials and Methods

Maternal age at offspring loss in a stable population

For simplicity, we first present the estimation procedure for a stable population, in which mortality and fertility rates remain fixed. We use life table methods and matrix kinship models to estimate $n_{i,j}$, the expected number of offspring deaths, where $i = 15, \ldots, 100+$ denotes the age of the mother and $j = 0, \ldots, 85+$ the age of the child. We arrange the expected number of offspring deaths in the matrix $\boldsymbol{N} = (n_{i,j})$, restricting 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. Such cases are denoted with "*na*" in the corresponding matrix. 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:

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

In order to obtain $\boldsymbol{N}$, we first estimate the average number of surviving children aged j for an average woman aged i (e.g., a woman aged 20 can expect to have, on average, 0.2 five-year-old children). We estimate these values using an extension of Caswell (2019) implemented in the R package 'DemoKin' and store them in the matrix $\boldsymbol{H} = (h_{i,j})$ (see *Supplementary Materials*). Second, we estimate how many of these offspring will die. For this, we use ${}_1q_{x=j}$, the probability of dying between (offspring) ages j and $j + 1$ in a cohort life table (LT). We store these values in the vector $\boldsymbol{q} = (q_j)$. Third, we account for the age distribution of mothers by storing the number of women aged i in the weighting vector $\boldsymbol{w} = (w_i)$. We combine these three quantities to estimate the expected number of offspring of a mother aged i who die when they are j years old: $n_{i,j} = h_{i,j} \times q_j \times w_i$.

Maternal age at offspring loss in non-stable populations

The stable model introduced above does not allow demographic rates to vary over time. We introduce chronological time to obtain a three-dimensional array $\boldsymbol{N}^* = (n^*_{i,j,t-i})$ containing the expected number of offspring deaths for women born in year $(t - i)$ by maternal age i and offspring age at death j (the superscript * identifies a non-stable object). The logic of the estimation is the same as for stable populations, except that we use a Lexis-diagram approach (Goodman et al., 1974) to adjust the subscripts for each of the constituent elements of Eq. (2) in order to retrieve the appropriate age-cohort combinations from each array or matrix. Fig. 3 clarifies how the different subscripts enter the calculation.

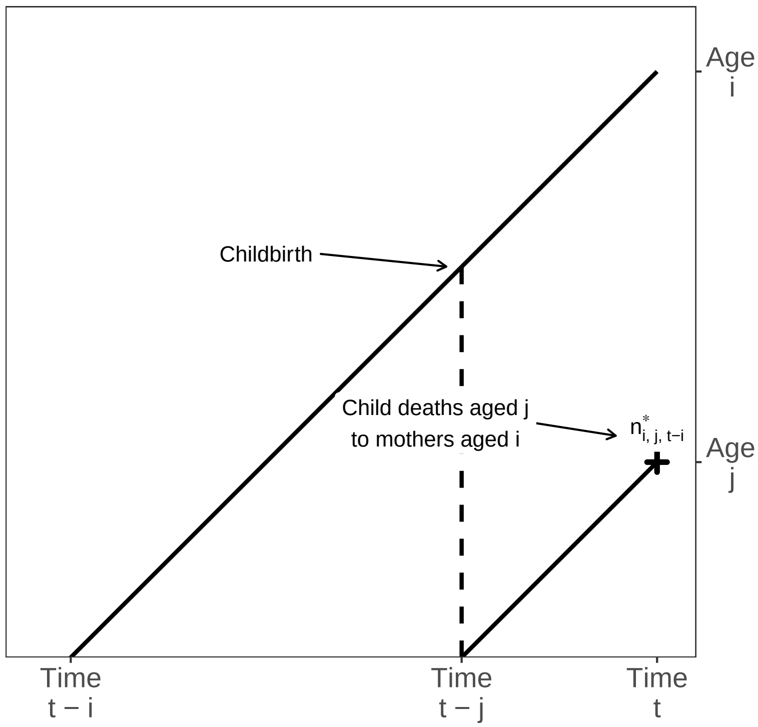

Figure 3: Lexis diagram showing the estimation of the expected number of offspring dying at age j to mothers aged i. The offspring's death at time t and age j is indicated with a cross.

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. 3). Each element of the array $\boldsymbol{N^*}$ is computed as follows:

$$n^*_{\mathrm{i,j,t-i}} = h^*_{\mathrm{i,j,t-i}} \times q^*_{\mathrm{j,t-j}} \times w^*_{\mathrm{i,t-i}} \quad (2)$$

where $h^*_{\mathrm{i,j,t-i}}$ is the expected number of surviving children aged j for a mother aged between i and $i+1$; $q^*_{\mathrm{j,t-j}}$ is the probability of dying at age j for an offspring born in year $t-j$; and $w^*_{\mathrm{i,t-i}}$ is the number of women born in $t-i$ ages between i and $i+1$.

The array $\boldsymbol{N^*}$ allows us to estimate offspring loss by the offspring's age at death. We compute 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 $\boldsymbol{N^*}$. Finally, we derive the density function of Eq. 2 using spline interpolation to obtain a smooth curve $\nu_{i,t-i}$ which sums to unity.

Data

Data for the main analysis come 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 from Sweden come from the Human Mortality Database (1765-1950). Fertility rates come from the Human Fertility Collection (1765-1890) and from the Human Fertility Database (1891-1950). We approximate cohort rates from period rates by taking the values along the diagonals. In order to estimate 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). These data can be obtained from the HMD historical data for Sweden, but not from the UNWPP data for all the cohorts of interest, which is why we assume that the 2100-2150 rates remain stable at the levels projected by the UNWPP for 2100.

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