New evidence about effects of reproductive variables on child mortality in sub-Saharan Africa

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Abstract

There is still considerable uncertainty about how reproductive factors affect child mortality. This study, based on Demographic and Health Survey data from 28 countries in sub-Saharan Africa, shows that mortality is highest for firstborn children with very young mothers. Other children with young mothers, or of high birth order, also experience high mortality. Net of maternal age and birth order, a short preceding birth interval is associated with above average mortality. These patterns change markedly, however, if time-invariant unobserved mother-level characteristics of importance for both mortality and fertility are controlled for in a multilevel–multiprocess model. Most importantly, there are smaller advantages associated with longer birth intervals and being older at first birth. The implications of alternative reproductive ‘strategies’ are discussed, taking into account that if the mother is older at birth, the child will also be born in a later calendar year, when mortality may be lower.

Keywords: birth interval; birth order; child mortality; fertility; maternal age; multilevel–multiprocess models

Background

A number of studies from less developed countries have shown that children born soon after an older brother or sister tend to experience poorer health and a higher chance of dying in infancy or childhood than children born after a longer birth interval (e.g., Hobcraft et al. 1983; Rutstein 2005; Kozuki and Walker 2013; Saha and van Soest 2013). A short subsequent birth interval has also been associated with poor child health (e.g., DaVanzo et al. 2008; Fotso et al. 2013). The evidence is more mixed when it comes to birth order and maternal age. Particular disadvantages for firstborn children and, to lesser extent, children of high birth orders have been reported in several studies (e.g., DaVanzo et al. 2008; Kozuki et al. 2013a; Ezeh et al. 2014), but some authors using more advanced methods to deal with selection have concluded that there is no effect of birth order on mortality (Bhalotra and van Soest 2008; Kozuki et al. 2013b) or even a favourable influence of higher birth order (reported, but not shown, by Kudamatsu 2012). Furthermore, whereas a very young maternal age at birth has been associated with high mortality (e.g., Finlay et al. 2011; Gibbs et al. 2012; Kozuki et al. 2013a; Ezeh et al. 2014), and some studies have shown a moderate increase in child mortality from age 35 or 40 (e.g., Kozuki et al. 2013a; Ezeh et al. 2014), other authors have observed an increase starting from around age 25 or 30 (Bhalotra and van Soest 2008; Finlay et al. 2011) or a generally adverse effect of higher age (undiscussed estimates in Saha and van Soest 2013). None of these reported patterns are theoretically implausible. As explained later, several counteracting mechanisms are probably involved, and the balance could tip in either direction.

Family planning programmes have been motivated to a large extent by the idea that such relationships between reproductive factors and child health are causal. In particular, attempts to help people avoid short birth intervals have been an important ingredient of these programmes. Furthermore, knowledge about causal effects (rather than statistical

associations) not only constitutes the ideal underpinning of family planning programmes and population policies; it is also what individuals need for their fertility decision-making, and it adds to our general insight into human physiology. For other purposes, identification of causal effects may not even be a goal. In particular, health personnel and health care planners may sometimes just be interested in knowing which groups of children are most vulnerable, in order to steer resources in that direction. This calls for a simple description of differences, for the relevant period and country (or within-country setting) in which these personnel operate.

In many earlier investigations that have aimed (perhaps implicitly) to identify a causal effect, many good attempts have been made to control for individual and societal characteristics that affect both a woman's reproduction and her children's health and mortality. However, there are always doubts about whether this has been done adequately. Besides, when assessing the importance of a reproductive variable, other reproductive variables must be controlled for, as they are closely linked with each other, and these controls have often been rather crude. The fact that the results have also been quite mixed—even those coming from the statistically most advanced investigations—adds to the motivation for further analysis based on good data and methods.

The aim of the study reported in this paper is to shed new light on the relationship between three main reproductive factors (birth order, maternal age, and length of preceding birth interval) and child mortality. It applies state-of-the-art methods to data from all 28 countries in sub-Saharan Africa where a Demographic and Health Survey (DHS) was conducted after 2010 and was readily available at the end of 2015. The focus is on the last ten years before each survey, for reasons to be explained later. The mortality effects of reproductive factors are a particularly pressing issue in this region, where infant mortality was as high as 64 per 1,000 births on average in the first part of the 2010s, under-five mortality was 83 per 1,000 births, and total fertility was 5.0 (Population Reference Bureau 2015).

Models for mortality up to age five are estimated in this study, since there is still a considerable proportion of children who die after the first year. Earlier studies have shown that associations with reproductive factors differ between infant and child mortality, and that there may also be variations within the infant period (e.g., DaVanzo et al. 2008), but for simplicity these differences are only very briefly addressed in this analysis.

The first step of the analysis is to describe the relationships between the reproductive variables and child mortality by means of a simple regression model that includes only a few control variables (but takes clustering of deaths within families into account). As mentioned, this simple model could be helpful for some purposes. In the next step, additional control variables—potentially affecting both fertility and child mortality—are added to this model. Finally, multilevel–multiprocess models are estimated; these control also for constant unobserved characteristics of the mother that affect both her fertility and her children’s death probabilities. The latter models include equations for both fertility and mortality, with random terms that are allowed to be correlated with each other.

Some of the models include the reproductive factors as separate variables, since this has been a very common approach. However, most of the models include a variable that combines maternal age and birth order. This is helpful when discussing the implications of the results, because a woman cannot have another child without also being older at that time, and certain combinations of birth order and maternal age are obviously impossible or highly unlikely. We could alternatively predict mortality for the possible combinations from the main effects, but using a combined variable also allows in a simple way for interactions between maternal age and birth order (although it turns out from a model with main and interaction terms that the latter are substantively unimportant; see details later).

Based on the estimates from the most complex model, four questions of high relevance to individual decision makers (and people who may provide them with guidance) are

answered. The first and very obvious one is: *what maternal age at birth will minimize the chance of losing the first child?* The second question is: *are there important long-term consequences of the age at first birth, in the sense that a relatively low age at first birth tends to lead to a low age at subsequent births, which may affect the mortality of those children?* This issue has not received much explicit attention in the literature. The third question is: *what are the implications of having a short interval to the next birth?* While this is also a very obvious concern, which has attracted much political and scholarly attention, a novel perspective is applied. This takes into account that a short next birth interval not only itself increases the chance that the next child dies; but given the mother's age at the most recent previous birth, a short interval to the next child also means that she will be younger when that child is born than she would have been with a long interval, and likely also relatively younger at subsequent births. The fourth question is: *will the next child experience a higher or lower mortality risk than the most recently born child?* This does not necessarily reflect how parents think about childbearing and mortality risks but, given the concerns that have been raised about children of high birth order, it is a relevant perspective to take.

The discussion rests, of course, on the assumption that the effects of the reproductive variables are persistent. Furthermore, it is taken into account that if a woman has a child at a younger age, the birth will necessarily take place in an earlier calendar year (Barclay and Myrskylä 2016). The latter is likely to have an impact because of continued general improvements in nutrition, sanitation, and healthcare. We cannot know how strong mortality improvement will be in the future; the predictions in this study are simply based on the estimated period effect. Readers who, for example, consider it likely that the improvement will be weaker over the coming years than during the study period, can make alternative predictions based on their own assumptions.

The models are estimated from pooled data, which means that we get a picture of the ‘overall’ relationship between the reproductive factors and child mortality across the 28 countries. We must, of course, keep in mind that the relationships are likely to vary between these countries, partly as a result of differences in policies and socio-economic resources. In principle, an obvious alternative would be to estimate country-specific models, with an eye to seeing how results differ between countries. However, effects may also vary considerably *within* a country, for example across social groups or between girls and boys (although the latter is a less important issue in Africa than in parts of Asia). In any case, introductory estimation showed that, for one-third of the countries, the iterative estimation procedure did not converge towards reasonable results. When models *could* be estimated, the standard errors of the key estimates were, of course, considerably larger than with the pooled sample. Fortunately, although the point estimates varied strongly between the countries, and some were suspiciously large, they all pointed in the same direction as those from the pooled analysis. In future, researchers might consider including potentially important country-level variables (as in e.g., Magadi and Desta 2011) and analysing how the effects of the reproductive factors are moderated by these. Alternatively, they might analyse whether the effects depend on variables at individual, household, or community level. Another possibility might be to add interactions between country and the reproductive variables, in parallel with what has been done in some other pooled analyses (e.g., Hatt and Waters 2006).

Theoretical issues

A brief review of social and physiological mechanisms

The three reproductive factors mentioned have been thought to affect children’s health and survival through many different, and partly counteracting, mechanisms. For example, low

maternal age may increase child mortality because of a particularly heavy nutritional burden during pregnancy (from feto-maternal competition), physiological immaturity (leading to preterm births or obstetric complications), and less health knowledge and fewer material resources among the parents (Chen et al. 2007; Finlay et al. 2011; Gibbs et al. 2012). On the other hand, the chance of chromosomal or congenital abnormalities increases as a woman approaches the end of her reproductive period, and the chance that she suffers from hypertension, diabetes, or other chronic diseases—with likely implications for the children’s health—increases with age throughout her reproductive period. The possibility of an adverse effect of higher maternal age because of deteriorating health has been referred to as the ‘weathering hypothesis’ (Geronimus 1992). In support of that idea, Powers (2013) found that the mortality of black infants in the United States (US) went up with increasing maternal age, and that there was a similar upturn among Mexican-origin children with mothers in their mid-20s or older. Furthermore, Love et al. (2010) reported that, among socially disadvantaged African-Americans (but not others in the US), the chance of having a child of low birth weight was 50 per cent higher if the mother was aged 30 or older than if she was under 20. Similarly, Goisis and Sigle-Rushton (2014) observed that, among black firstborn children in the United Kingdom (UK), the chance of low birth weight doubled when the mother’s age increased from around 25 to 40 (while the same pattern did not appear among disadvantaged white children).

It has been suggested that firstborn children experience particularly high mortality compared with those born later because the mother’s body is not adapted to pregnancy and childbirth, which increases the chance of complications during delivery (Lee et al. 2011). Besides, it is thought that children of high birth order are disadvantaged because of nutritional stress experienced by their mothers during previous pregnancies and lactation periods, and because of earlier reproductive injuries (Montgomery and Lloyd 1996). Also, there may be

fewer parental resources available when there are several older siblings (especially if these siblings are not old enough to help the younger ones or to contribute to the family income; Kravdal et al. 2013). Finally, having many siblings may increase the chance of disease transmission (although effects are not necessarily adverse, as relatively weak infections at young ages could confer immunity; Cardoso et al. 2004).

On the other hand, it is also possible that child mortality goes *down* with increasing birth order because mothers and fathers have accumulated more experience with childrearing. Such an effect of birth order could also arise if having many children affects the parents' health positively on the whole, in spite of the disadvantages just mentioned, so that they can care better for their children. In support of this idea, a negative relationship between number of children and mortality has been reported in many studies of middle-aged and older people in rich countries (e.g., Kravdal et al. 2012), which may in part reflect those who have children—and perhaps especially those who have many children—being less inclined to take health risks and having a more home-oriented lifestyle, which may give them health advantages in their reproductive years. However, there is no strong evidence for this particular causal pathway, and the situation may also be quite different in poorer settings. As mentioned, the idea of a protective effect of higher birth order was supported by Kudamatsu (2012), who carried out a within-mother analysis with control for maternal age and period dummies.

When it comes to the well-documented higher mortality after a short birth interval, several explanations have been suggested: (1) inadequate time to recover from the nutritional depletion caused by the previous pregnancy; (2) cervical insufficiency due to inadequate time to regain the strength of the muscles in the reproductive tissue; (3) breastfeeding of the preceding child during a substantial part of the pregnancy, with consequences for the intrauterine environment and later breastfeeding; (4) disease transmission of diseases from the very young sibling; and (5) fewer resources available from the parents because the previous

sibling, as well as older siblings, will tend to be younger than if the interval is longer (see elaboration in Conde-Agudelo et al. 2012).

Most of these arguments imply that mortality will continue to fall as preceding birth intervals increase, at least up to a certain length. However, it has also been suggested that mortality may go up again if the interval becomes very long. The idea is that the woman becomes primed for foetal growth during a pregnancy, which gives her advantages in later pregnancies, but that this benefit disappears if she waits too long (Zhu et al. 1999).

Selection

Child mortality is influenced by a number of individual and household characteristics, such as the parents' economic resources, knowledge, attitudes to care of children, trust in modern health services, and general health, and also the mother's autonomy. The socio-economic resources in the community are also important, for example, through the availability of healthcare and the quality of the sanitation system. And the natural environment has an impact above and beyond that, by affecting, for example, possibilities for microbial growth and survival of disease vectors. These factors also influence the need for children as labour and old-age security, the access to contraception, and other important determinants of fertility. If they are not controlled for, what appear to be effects of reproductive factors on mortality may actually be mortality effects of fertility determinants.

In general, some of these joint determinants of fertility and child mortality may be measured quite well in the data that are used, while others may be poorly measured or unmeasured, or may even be unmeasurable. The main approach taken in this study is to control for the unobserved characteristics of the mother and the environment she lives in that are constant over her reproductive career and affect her fertility throughout those years, and that also affect the mortality of all her children born within the relevant ten-year period before

the interview. Unfortunately, there is still a bias because of time-varying unobserved factors affecting both fertility and mortality. For example, while one family may be generally much richer than another family, with implications for fertility and mortality, there is also likely to be some variation in economic resources over time within each family. The latter is not taken into account by the model. Similarly, a mother and her partner's health, knowledge, attitudes, and access to health services may vary to some extent over the life course, as may the mother's breastfeeding practice. These time-varying components are likely to have an impact on the chance of having another child, how soon that child is born, and child mortality (see further discussion in the concluding section).

Data and methods

DHS surveys

The analysis was based on all 28 DHS surveys conducted in sub-Saharan Africa after 2010 and readily available at the end of 2015: Benin 2011, Burkina Faso 2010, Burundi 2010, Cameroon 2011, Congo (Brazzaville) 2011, Cote d'Ivoire 2011, Democratic Republic of Congo 2013, Ethiopia 2011, Gabon 2012, Gambia 2013, Ghana 2014, Guinea 2012, Lesotho 2009–10, Liberia 2013, Malawi 2010, Mali 2012, Mozambique 2011, Namibia 2013, Niger 2012, Nigeria 2013, Rwanda 2010, Senegal 2010, Sierra Leone 2013, Tanzania 2010, Togo 2010, Uganda 2011, Zambia 2013, and Zimbabwe 2010. For simplicity, women with one or more multiple births were left out, as in many earlier studies (DaVanzo et al. 2008; Saha and van Soest 2013). The focus was on the mortality of children born less than ten years before the interviews, as a compromise between including as many children as possible and analysing a recent period. The importance of the reproductive factors for child mortality may well vary over time—for example, because of changes in socio-economic resources, policies,

and (partly as a consequence) the types of disease that children tend to die from—and the results from a relatively recent period will be most useful for politicians, policymakers, and families making reproductive decisions. Furthermore, relatively recent births and deaths are more likely to be reported correctly, and the measurements at interview are more adequate indicators of the actual determinants of mortality in this period than of factors that have had a bearing on earlier deaths. As described later, however, including children born earlier as well gave quite similar results.

The DHS surveys include region-specific weights that should be used when calculating country-level descriptive statistics. However, it is less obvious that these weights are needed in the estimation of statistical models, especially when selection into the sample is not linked to the outcome variable, as in this study. For example, Solon et al. (2013) have argued that, in such a situation, weighting may actually reduce the precision of the estimates, and if the effects under study vary across subgroups, weighting by subgroup size may not even help us get closer to effects that are representative of the whole population. Their recommended strategy is to estimate models both with and without weights, and to compare the results. In the final estimation in this study, weights were not included. Introductory estimation showed that inclusion of region-specific weights, or weights that also took into account the size of each country's population relative to the number of observations in the respective survey, had very little impact on the estimates.

Simple outline of the ideas behind the multilevel–multiprocess model

The analysis was based on a model that includes two equations for a woman's fertility and one for the mortality of all her children born within the relevant period (usually ten years). The mortality equation reflects the idea that a child's chance of dying within a certain period is influenced by a number of observed characteristics relating to the child, the mother, the

household, and the community in which the mother lives. Furthermore, it is assumed that there is a contribution to mortality that is the same for all siblings and is normally distributed across mothers (with zero mean). This contribution reflects additional characteristics of the mother, household, and community that are unobserved, in the sense that they are not included in the model.

This idea that siblings share some unobserved mortality determinants (i.e., that deaths tend to be clustered in certain families) has influenced the research area for several years. For example, it has been shown that inclusion of a mother-level random term gives a weaker relationship between a child's chance of dying and the deaths of older siblings (Arulampalam and Bhalotra 2008; Omariba et al. 2008). In principle, point estimates of all other effects can also be somewhat different if such a random term is added, provided that the model is logistic or has another non-linear structure (Snijders and Bosker 2012, p. 309). Furthermore, in both linear and non-linear models, standard errors of effects of observed characteristics shared by siblings typically become larger (i.e., the significance of such effects is overstated if the random term is not included in the model). Similarly, the fertility equations in the model (one for first births and one for higher-order births) reflect the impact of observed characteristics, as well as factors that are unobserved and that are assumed to add a constant positive or negative contribution to a woman's first and higher-order birth rates from age 15 and throughout her reproductive period. These unobserved fertility determinants are represented by a mother-level normally distributed random term. (It is reasonable to refer to this as a mother-level random term, because although the model includes an equation for first births, and women who are childless at interview contribute in the estimation of this, they do not contribute to the estimation of the variance of the random term.)

When the model includes both fertility and mortality equations, and the respective random terms are allowed to be correlated, it takes into account that certain constant

characteristics of mothers (or the households or communities in which they live) that are not captured by the included variables affect both fertility and mortality. Most unobserved factors that tend to give high mortality (see examples earlier) are probably linked to factors producing high fertility. In other words, we would expect the correlation to be positive, and that we would estimate, for example, a less adverse effect of a short previous birth interval if this correlation is taken into account. Note that the simpler models that are estimated are just special cases of this general model, where the fertility equation is left out or the correlation forced to be zero. These are referred to as ‘standard’ models in the paper, while the models where a non-zero correlation is allowed are referred to as multilevel–multiprocess models.

Multilevel–multiprocess models of this type have been estimated in earlier investigations of strongly interlinked socio-demographic processes (Upchurch et al. 2002; Steele et al. 2009; Kravdal et al. 2013). Furthermore, models with correlated random terms for fertility and mortality have been estimated in studies of the importance of reproductive factors for child mortality in South Asia (Makepeace and Pal 2008; Bhalotra and van Soest 2008; Saha and van Soest 2013). However, fertility was modelled very differently in the latter studies, with equations for birth intervals after the first birth. Furthermore, Makepeace and Pal (2008), who focused on middle-order births, did not consider the importance of maternal age or birth order, and in the other studies these effects were captured by second-degree polynomials, while in the analysis reported in this paper categorical variables were used.

We could also consider estimating sibling fixed effects mortality models to control for unobserved factors shared by siblings (as done, for example, by Kozuki and Walker (2013) in their analysis of effects of the birth interval length). As with such fixed effects models, the multilevel–multiprocess approach requires at least some mothers with two or more children. In contrast to fixed effects models, however, we can include variables that are bound to be constant across children with the same mother, and mothers who have only one child

contribute in the estimation of some of the parameters of interest (although not the parameters that characterize the distribution of the random effects).

Detailed model specifications

The multilevel–multiprocess model used in the analysis included the following mortality equation:

$$\log (p_{ijt}/(1-p_{ijt})) = \gamma_0 + \gamma_1 \mathbf{Y}_{ijt} + \tau_i$$

where p_{ijt} is the probability that child j of mother i dies within their t 'th year, given survival up to the beginning of the year. Each child contributed to the estimation with one-year observations from birth ($t=1$) until their fifth year ($t=5$), death, or interview, whichever came first. The notation $\mathbf{Y}_{ijt}$ represents a vector of characteristics of the child (including the child's age -1 in one-year categories), the mother, and the household, plus calendar year at the beginning of year t , and some characteristics of the primary sampling unit (PSU) the mother lived in at interview (see detailed description in the 'Variables' subsection). The corresponding coefficients are denoted by γ_1 , while γ_0 is an intercept. Only those children whose mother was 15 years or older at birth and (in most models) who were born less than ten years before interview contributed in the estimation of the mortality equation. Finally, τ_i is a mother-specific term that represents unobserved time-invariant characteristics. It is assumed to be drawn at random from a normal distribution with mean zero and a variance to be estimated, and to affect the mortality of all the mother's children born within the ten-year window. The estimation was based on about 1.5 million one-year observations.

The models also included the following fertility equations; for the first birth rate, $h_{it}^{(1)}$, and the higher-order birth rates, $h_{it}^{(2)}$, for woman i at time t :

$$\log h_{it}^{(1)} = \beta_0^{(1)} + \beta_1^{(1)} \mathbf{A}_{it}^{(1)} + \beta_3^{(1)} \mathbf{X}_{it}^{(1)} + \delta_i$$

$$\log h_{it}^{(2)} = \beta_0^{(2)} + \beta_1^{(2)} \mathbf{A}_{it}^{(2)} + \beta_2^{(2)} \mathbf{D}_{it} + \beta_3^{(2)} \mathbf{X}_{it}^{(2)} + \beta_4^{(2)} \mathbf{M}_{it} + \delta_i$$

In the respective equations, $\beta_0^{(1)}$ and $\beta_0^{(2)}$ are intercepts, while in the equation for first births, $\mathbf{A}_{it}^{(1)}$ is a piecewise linear spline transformation of the woman's age and $\beta_1^{(1)}$ is the corresponding vector of coefficients. Each woman contributed to the estimation from the beginning of the year when she turned 15 until the end of the year when she turned 44 or until her interview, if sooner. In the equation for second and higher-order births, $\mathbf{A}_{it}^{(2)}$ is an age spline and $\mathbf{D}_{it}$ is a spline transformation of duration since last birth. In the respective equations, $\mathbf{X}_{it}^{(1)}$ and $\mathbf{X}_{it}^{(2)}$ include calendar year and characteristics of the mother, household, and community in which she lived; $\mathbf{X}_{it}^{(2)}$ also includes the number of older children who have died, counted nine months before the time under consideration (see further details in the next subsection). Taking into account the fact that earlier deaths affect fertility had considerable implications for the size of the effects of the reproductive variables on child mortality, although not their direction. Parity dummies are denoted by $\mathbf{M}_{it}$. Eleventh and later births were not considered.

There is a mother-specific random term, δ_i , in both fertility equations, just as in the mortality equation. It represents unobserved time-invariant characteristics and is assumed to be drawn at an early age and to stay with the mother throughout her reproductive period, thus affecting all her birth rates. A non-zero correlation between δ_i and τ_i was allowed.

The models were estimated via maximum likelihood, using the software package aML (Lillard and Panis 2003). See the supplementary material (Appendix 1) for a fuller account of model specifications and estimation.

Variables

As mentioned earlier, the mortality equations in the different models included either separate variables for maternal age and birth order or a variable combining these two factors. In both cases, the previous birth interval was also included, with 30–41 months as the reference category. The reference category was chosen to match the three-year categories for maternal age, which facilitates the presentation and discussion of the results. For firstborn children, the birth interval dummies representing the five categories other than the reference category were set to zero.

The numbers of deaths in the different categories of these reproductive variables are shown in Table 1. Parentheses around a number mean that the group is so small that it was left out of the estimation. This limit was set quite arbitrarily at 0.5 per cent of the total number of deaths.

(Table 1 about here)

As already pointed out, the three reproductive variables, plus calendar year and child's age were included in the mortality equation, while woman's age, duration since previous birth, parity, mortality of older children, and calendar year were included in one or both of the fertility equations. In addition, the following variables were included in both the fertility and mortality equations: the woman's education (grouped into 0–2, 3–6, 7–8, 9–10, and 11+ years and interacted with a grouped age variable in the equation for first birth); the woman's

religion (Christian, Muslim, other/no religion); the standard DHS indicator of household wealth (based on household amenities); averages of women's education (in years completed) and household wealth calculated for the community (DHS PSU) the woman lived in at interview; and whether that community was urban or rural. The mortality equation also included the child's sex. Furthermore, country dummies were included in both the fertility and mortality equations to capture differences between countries in other characteristics (see the supplementary material, Appendix 1, for a fuller account of these variables).

Some of these socio-economic variables measured at interview may not adequately reflect the earlier situation that influenced fertility and child mortality, because changes may have taken place between that time and the interview. In principle, variables measured at interview may even capture factors that are *consequences* of fertility or child mortality (Cohen et al. 2011). However, many of the factors measured at interview are likely to be fairly stable over the relevant period, and to the extent that there is a reverse causality problem, it is reassuring that these factors have rather modest importance as controls in the multilevel–multiprocess models (not shown in tables).

Calendar year was entered as a continuous variable, with a linear effect in all models. Almost the same results appeared when it was included as a categorical variable instead. Allowing the year effects to differ across countries did not change the results either.

'Standard' mortality models

For reasons explained earlier, simpler models were estimated in the first steps of the analysis. These models included just the mortality equation, with its mother-specific random term, although omitting that term had hardly any impact on the effects of the key variables (not shown in tables). They are referred to here as 'standard' mortality models (although some may consider models without a random term as more 'standard'). Obviously, we would get

the same results if the fertility equation had been kept in and the correlation between the fertility and mortality random term forced to be zero (which would be more computationally intensive).

In some of these models, only calendar year and country were included in addition to the reproductive variables and child's age. Other models, referred to hereafter as 'augmented standard' models, included all the control variables. Inclusion of these additional variables had more impact on the key estimates in these 'standard' models than in the multilevel–multiprocess models (where the effects of constant joint determinants of fertility and mortality are already largely captured through the correlated constant and normally distributed fertility and mortality random terms).

Results

This section presents the effects of the reproductive factors on the log-odds of dying within a year (among children younger than five years old), according to three different models: (1) the 'standard' model including only calendar year and country as control variables; (2) the 'augmented standard' model; and (3) the multilevel–multiprocess model where the fertility and mortality random terms are allowed to be correlated. Then, the implications of the results from the latter model are spelt out. There are two versions of each of the models: one where maternal age and birth order are included as separate variables (results presented very briefly) and one where these two variables are combined.

'Standard' mortality models with few control variables

According to the 'standard' mortality model with only year and country included as control variables, mortality decreases with increasing maternal age until the mid-30s, after which there is an upturn (Table 2, first column of estimates). It also increases with birth order,

except that mortality is higher for firstborn than second-born children. Note that the coefficient for firstborn children reflects the difference between being a first child and being a second child born 30–41 months after the first child (the reference category for birth interval length). Furthermore, mortality falls with increasing interval length until 42–53 months; there is no further decline after that. These estimates accord with the patterns reported in several earlier analyses based on relatively simple statistical models (see ‘Background’ section).

(Table 2 about here)

The general decline in mortality over time, estimated from this multicountry sample without weighting, is quite sharp: an annual reduction of 0.058 in the log-odds of dying (i.e., approximately a 5.8 per cent drop in the death probabilities every year). This figure is reasonably comparable with published numbers. For example, Demombynes and Trommlerová (2012) reported that more than half of the countries in the region that had a DHS survey between 2005 and 2012 experienced an annual decline of under-five mortality that was larger than the Millennium Development Goal of 4.4 per cent. Similarly, a graph produced by You et al. (2015) showed an annual decline of more than 4 per cent from 2000 to 2015, after slower improvement in the previous decade.

The combined ‘effects’ (a word used hereafter for simplicity and without claim of causality) of maternal age and birth order are shown in Table 3, in the form of log-odds of dying for children with various combinations of maternal age and birth order, compared with the reference category (second-born children with a mother aged 21–23).

(Table 3 about here)

Firstborn children with mothers younger than 18 experience the highest mortality. Relatively high mortality is also seen among second-born children with a mother in that age group, firstborn children with a mother who is 18–20, children of birth order seven who have a relatively young mother, and most of the children of birth order eight or higher (log-odds > 0.30 above the reference category). Additionally, mortality is elevated, but less markedly, among most other children who are firstborn, who are of high birth order (6+), or who have a relatively young mother (for their birth order). Mortality is lowest among children of birth order two or three with a relatively old mother.

Firstborn children do not experience the same disadvantage after their first year as when they are infants. This is seen by specifying a logistic equation for infant mortality and a discrete-time hazard equation for mortality at ages 1–4 instead of ages 0–4 (see supplementary material: Panel A of Table A1 in Appendix 2). In fact, child mortality at ages 1–4 is rather low for firstborn children with mothers in their 20s and is only moderately elevated if the mother is very young. Furthermore, children of birth orders two to five who do not have particularly young mothers experience a clearer advantage after their first year than earlier. Finally, short intervals have less adverse impact after the first year, while there is a clearer protective effect of longer intervals at this age. This accords with earlier studies of birth intervals and may partly reflect the stronger relative importance of biological pathways compared with social pathways among the youngest children (Manda 1999; Rutstein 2005; DaVanzo et al. 2008; Fotso et al. 2013).

‘Augmented standard’ model

When a range of socio-economic variables are added to the ‘standard’ model (see Table 2, second column of estimates), a less protective effect of higher maternal age up to the mid-30s and a less adverse effect of higher birth order after the second child appear, while the effect of

birth interval changes very little. The combined effects of maternal age and birth order are shown in Table 4. Mortality among first and second-born (and to lesser extent third-born) children with relatively old mothers is higher (relative to the reference category) according to this ‘augmented standard’ model than according to the simpler model. A less clear difference in the opposite direction appears for children with relatively young mothers (of any birth order) and those of birth order eight or higher.

(Table 4 about here)

Multilevel–multiprocess model

When joint unobserved constant determinants of fertility and mortality are also taken into account by allowing the random terms to be correlated (see Table 2, third column of estimates), there is a further change away from the protective effect of higher maternal age up to the mid-30s and from the adverse effect of higher birth order after the second-born that appears with the simplest model. These changes fit well with the correlation between the random terms, which is positive as expected (0.47 and highly significant). In fact, according to this model, where maternal age and birth order are included as separate variables, there is a quite sharp *adverse* effect of higher maternal age, at least from the late teens, and mortality *declines* quite strongly with birth order. The effect of calendar year is essentially the same as estimated from the simpler models, while the effect of the birth interval length is slightly weaker.

Suspensions may arise when effects are so strong, but it is important to keep in mind that high birth order goes hand in hand with high maternal age. For example, if birth intervals are 30–41 months, a prediction from these separate effects of maternal age and birth order in

Table 2 is that, if a woman starts childbearing at age 18–20 and proceeds with three-year intervals between births, the log-odds of dying within a year compared with those for a second child will be 0.07 lower ($-0.16+0.09$) for a third child, 0.06 lower ($-0.33+0.27$) for a fifth child, and 0.10 higher ($-0.50+0.60$) for a child of birth order eight or higher.

Values of almost the same size can be found shaded in grey in Panel A of Table 5, which shows effects of the variable combining maternal age and birth order. (The differences between these estimates and predictions from the main effects in the third column of estimates in Table 2 reflect variations in the importance of maternal age across birth order. These interactions are strongly significant as judged from a likelihood ratio test, but there is no clear pattern in the point estimates.) In reality, intervals tend to be shorter than three years, especially among women who have large families, so for a woman who starts childbearing at age 18–20, an average child of birth order eight will have log-odds of dying that are closer to the value to the left of the grey diagonal (which is -0.02 , rather than 0.12). If a woman has a child at a considerably lower age than the one shown on the diagonal, however, the mortality of that child will be quite low. Conversely, mortality will be high at higher maternal ages. In fact, absolute values as high as 0.2–0.3 appear at some of the highest and lowest ages for birth orders above one, but there are few children in these categories.

(Table 5 about here)

There are some differences in the patterns over the first five years of a child's life. In particular, being a firstborn child and being born after a short birth interval have less adverse effects for children aged 1–4 than for infants, and there is also a clearer protective effect of a long interval (see supplementary material: Panel B of Table A1 in Appendix 2). The effects

on infant mortality are almost the same if the model only includes an equation for infant mortality and not also one for mortality at age 1–4 (not shown in tables).

As should be clear from earlier comments and the more detailed account in the supplementary material, the results are robust to a number of alternative model specifications. Larger differences appear when the mortality equation is no longer restricted to children born in the most recent ten years. In such an analysis, effects of maternal age and birth order are somewhat weaker, and the general mortality decline is also weaker (see supplementary material: Table A2 in Appendix 2). However, the overall conclusions are similar.

The message to individual women according to the multilevel–multiprocess model

This section explains in detail how various reproductive ‘strategies’ affect child mortality, according to the estimates from the main specification of the multilevel–multiprocess model.

The chance of losing the first child. While the conclusion from the ‘standard’ models is that a woman who wants to minimize the chance of losing her first child should avoid early childbearing (assuming that future effects will be just as those estimated), the conclusion from the multilevel–multiprocess model is different: the advice is to become a mother in the late teens or early 20s. According to predictions from the models (shown in the supplementary material: Table A3 in Appendix 2), the under-five death probability will be 12 rather than 10 per cent if the woman waits until she is 27–29 years old, assuming that the child’s characteristics are otherwise average. However, if the general decline in mortality continues with the same force, the mortality of the first child will also decline with increasing maternal age after 18, although quite moderately. The latter conclusion comes from adding the estimated period effect to the combined effect of maternal age and birth order (see Panel B of Table 5). The period contribution is set to zero for the age group 21–23, and as a woman

‘moves’ into a higher three-year age group, child mortality is reduced by 0.17, because the childhood period up to age five will then be experienced three years later and the estimated period effect (see note to Table 5) is -0.057 per year ($-0.057 \times 3 = -0.17$).

Long-term implications of first birth timing. There are also long-term implications of first birth timing, because if the woman is relatively old when she has her first child, she will also be relatively old when she has her subsequent children, unless she ‘compensates’ by having particularly short birth intervals. For example, if a woman has her first child when she is 18–20 years old and has another child after a three-year interval, she will then be 21–23; if the next interval is also three years, she will be 24–26 when that child is born, and so on. Thus, she will, so to speak, move along the diagonal shaded in grey in Table 5. If she instead starts three years later and proceeds with three-year intervals, she will move along the diagonal to the right of the one that is shaded. We can shed light on the long-term implications of having an age at first birth that is one category higher by, for each birth order above one, comparing mortality for each maternal age category with that in the higher maternal age category (i.e., inspecting the birth order specific effects of maternal age). Let us start by ignoring the possibility of a continued general mortality decline (Panel A, Table 5). In this case, the conclusion is quite clear: except for second births at very low ages, a higher maternal age increases child mortality. (All point estimates go in this direction, and one-third of the differences are actually significant at the 5 per cent level according to Wald tests based on the variances and covariances of the estimates. One-half are significant if we use a 10 per cent significance level.) Thus, while postponing the first birth from age 15–17 to age 18–20 will reduce the mortality of that child, and having the first birth at age 21–23 rather than at age 18–20 will have no impact, there will be adverse long-term effects of both these postponement steps. Postponement beyond age 23 increases the mortality of the first child slightly, and is

also a disadvantage for younger siblings. In other words, it is not quite so helpful after all to avoid a very early first birth, and we could say that there is a double benefit of not postponing motherhood further after reaching age 23. Note that these conclusions about the longer-term implications of age at first birth are not a result of a variation in the effect of maternal age across birth orders; as mentioned, there is no clear pattern in this interaction. The key point is that child mortality increases with maternal age except at the very lowest ages, and higher-order births do not occur at these low ages.

If it is assumed instead that the general mortality decline continues with the same pace, the conclusion is that a higher maternal age at subsequent births reduces child mortality moderately (see Panel B, Table 5). The only exception is that there is no clear trend after age 33 at the highest birth orders. To summarize, with unabated further decline in general mortality, it is a disadvantage for the first child if the mother is younger than 18, and such early motherhood is also a disadvantage for children she might have later. Further postponement of motherhood beyond age 18–20 reduces both the mortality of the first child and that of younger siblings moderately.

Net, 'secondary', and long-term effects of birth intervals. When discussing which length of next birth interval would be ideal, given a woman's current age, two types of effects are relevant in the short run. First, and most importantly, a short birth interval will itself increase the mortality of the next child. As mentioned, this net effect is slightly weaker according to the multilevel–multiprocess model than according to the 'standard' models. Second, if the interval is short, the mother will be slightly younger at next birth than she would otherwise have been, which may have an additional impact. This is referred to as a 'secondary' effect. Besides, there is a longer-term effect: if she is younger at next birth, she will also tend to be younger at later births.

Let us, for example, consider a woman who has her first child when she is 18–20 years old and ignore the effect of the general decline in mortality. The mortality of that child, when measured as the log-odds difference from the reference category, is 0.41 (Panel A, Table 5). If the woman has another child after a three-year interval, the mortality of that child will be zero (recall that 30–41 months is the reference category for birth intervals), and if she proceeds with this spacing (i.e., moves along the grey shaded diagonal), the mortality of her third child will be –0.07. If she instead had her second child after an interval of less than 18 months, she would be younger at that time, which would decrease mortality to somewhere between 0.00 and –0.06 (the number to the left of the diagonal), thus offsetting slightly the net adverse effect of the short birth interval (0.91 for intervals of <18 months). If she had another child after an interval of less than 18 months, she would be aged about 21–23 at third birth (rather than the age 24–26 she would have been if she had had two three-year intervals). That would give her child a mortality advantage (–0.14 as opposed to –0.07) because of her lower age, which counteracts some of the adverse interval effect. If she then continued with three-year intervals, each of her next children would experience lower mortality than they would have done, had she started with two three-year intervals (the figures along this diagonal being –0.20, –0.17, –0.10, –0.12, and –0.02, as opposed to the grey shaded diagonal figures of –0.09, –0.09, –0.10, 0.07, and 0.12). More generally, shifting towards a maternal age category that is one category younger because of a couple of short earlier birth intervals reduces the log-odds of dying by up to 0.19, and by about 0.10 on average (across ages and birth orders above two). Moving to a more informative metric, the corresponding average difference in the under-five death probability from moving down by one maternal age category is about 0.6 of a percentage point according to the predictions shown in the supplementary material (Table A3 in Appendix 2).

To summarize, short intervals are themselves detrimental for child mortality, but this is to some extent offset against a maternal age advantage, so there may be long-term advantages for younger siblings. Again, the picture is different if there is a general mortality decline (Panel B, Table 5). In that case, there are secondary or long-term *disadvantages* from short birth intervals.

Mortality of next versus previous child. While concerns about children of high birth orders have been voiced, and the estimates from the ‘standard’ models show that these children do indeed experience relatively high mortality, it is not obvious how individual families and those guiding them should think about this issue. It may be relevant for them to ask whether the mortality of the *next* child will be higher than that of the child most recently born. Obviously, that will depend much on birth interval lengths. Assuming first that both the previous and the next child are born after an interval of three years (the reference category), the answer can be found by comparing the mortality for each birth order and maternal age group with the mortality in the cell one step below and to the right in Table 5, that is, down along a diagonal. Ignoring first the general mortality trend, the conclusion is that, among women with two children, the mortality of the next child is in most cases significantly lower (see underlined estimates in Table 5, Panel A). In addition, a second child born after a three-year interval has lower mortality than the first child (also shown with underlining). The pattern is more mixed at third and higher birth orders, where there is one example of significantly *higher* mortality for the next child (shown with dashed underlining), and also two differences in this direction and two in the opposite that are significant at the 10 per cent level (not shown in the table). Additionally, there are some weaker indications of differences (p-values around 0.1–0.3), and they all suggest higher mortality for the next child. Thus, we can say that, on the whole, after the third child, the next child experiences a mortality risk that

is either quite similar to that of the one most recently born or perhaps somewhat higher. In comparison, the ‘augmented standard’ model (Table 4) points more strongly towards higher mortality for the next child, primarily at relatively high maternal ages and birth orders.

If both the preceding and subsequent birth intervals are rather short, it is more relevant to compare the mortality of the most recently born child with a value between the one that is lower along the diagonal and the one that is one step to the left of that (i.e., directly below it in Panel A), because a shorter interval means the mother will be younger at next birth. In that case, it is less clear that the next child will experience higher mortality. Conversely, if intervals are generally long, it is clearer that the next child will have higher mortality.

However, if mortality decline continues as in the study period, it is much more reasonable to conclude that the next child will tend to have lower mortality, and especially if intervals are relatively long (still assuming, of course, that the interval lengths are the same for both children). This can be seen from the numbers in Panel B.

Summary and conclusion

The importance of reproductive factors for infant and child mortality has received much attention over many years, and the issue is still highly relevant in many parts of the world, not least in sub-Saharan Africa. However, whereas adverse effects of short birth intervals have been reported consistently, there is much uncertainty about the effects of maternal age and birth order. A number of individual and societal characteristics that are hard to measure affect both fertility and mortality, so conclusions from earlier investigations may be questionable. Also, results from studies that have dealt with selection in the most advanced way have given divergent results.

For some purposes, identification of causal effects may not even be a goal. Therefore, in the study reported here, a model that controls only for period and country was estimated,

using DHS data from sub-Saharan Africa. This analysis showed that firstborn children with a mother younger than 18 and those born after very short intervals have the highest mortality. High mortality was also observed among second-born children with a mother aged under 18, firstborn children with a mother aged 18–20, children of birth order seven with a relatively young mother, and most children of birth order eight or higher. Mortality was lowest among children of birth order two or three with a relatively old mother.

Adding a number of socio-economic control variables changed the picture, but not very strongly. There was only a moderate weakening of the protective effect of higher maternal age and the adverse effect of higher birth order. However, moving to a multilevel–multiprocess model that had not previously been used in this research area led to very strong further change in the same direction, actually reversing the effects. Thus, higher maternal age has an adverse effect, except at the lowest ages, while higher birth order reduces mortality. With this approach, we took into account that constant unobserved characteristics of the mother may affect both her fertility and her children’s mortality. Indeed, the strong positive correlation that is estimated between the fertility and mortality random terms means that unobserved factors that increase (or decrease) fertility also increase (or decrease) child mortality to a large extent.

There are three messages from the multilevel–multiprocess analysis. First, while postponing the first birth from age 15–17 to age 18–20 will reduce the mortality of that child, and having the first birth at age 21–23 rather than at age 18–20 will have no impact, there will be adverse long-term effects of both these postponement steps (because the older the mother is at first birth, the older she will tend to be at later births). Postponement beyond age 23 increases the mortality of the first child slightly and is a disadvantage also for younger siblings. However, if the general decline in mortality continues with the same strength as in the study period, it is a disadvantage for the first child if the mother is younger than 18, and

such early motherhood is also a disadvantage for children she might have later. Further postponement of motherhood beyond age 18–20 reduces both the mortality of the first child and that of younger siblings moderately. It is, of course, difficult to give advice in this situation. Mortality fell more sharply during the study period than in preceding years, and it is far from clear whether this favourable development will continue.

Second, there is a beneficial net effect of avoiding a short birth interval, as also found in numerous earlier studies. As mentioned, however, the secondary or long-term effects operating through a slightly higher maternal age at next and later births are adverse, unless the secular mortality decline continues, in which case a higher maternal age will reduce mortality moderately. Stated differently, if a woman has one or more children after short birth intervals, those children will have relatively high mortality, but later children will—in the absence of further mortality decline—benefit from her lower age at their birth. This has not been mentioned as a possibility in earlier studies.

Third, in the absence of a continued mortality decline, and assuming that birth intervals are generally three years, a woman's second or third child will have a lower chance of dying than the child born most recently. At higher birth orders, the picture is less clear but, on the whole, the evidence tilts very weakly towards the opposite pattern, that is, the next child having higher mortality than the most recently born child. If birth intervals are generally shorter than three years or the recent mortality decline continues, it is clearer that the next child will have lower mortality. However, although a woman may not need to be particularly concerned about the five-year survival of higher-order children, a high birth order might weaken the child's health in the longer term or cause socio-economic disadvantages for other reasons. That is beyond the scope of this analysis.

The conclusions from the 'standard' models were different. Those estimates suggested more adverse short- and long-term effects of low maternal age at first birth and short birth

intervals, partly because of the slightly stronger net birth interval effect and the effect of maternal age for the firstborn, and partly because of the negative or U-shaped relationship between maternal age and child mortality at second and higher birth orders. These models also suggested more clearly that, at the highest birth orders, the mortality of the next child will be higher than that of the previous child.

The adverse effect of a higher maternal age and the protective effect of higher birth order in the multilevel–multiprocess models may be considered surprising or, at least, surprisingly strong. However, while it has been common to assume that higher maternal age is favourable over much of the relevant age span, adverse effects of maternal age from a quite low age or over the entire age span have been reported elsewhere: in some earlier studies of child mortality in a generally poor population (Saha and van Soest 2013) and in a disadvantaged subgroup in a rich setting (Powers 2013). Such effects have also appeared in studies of birth weight among minority groups in the US (Love et al. 2010) and the UK (Goisis and Sigle-Rushton 2014). In addition, a protective effect of higher birth order—which can be seen as counteracting the maternal age effect so that a next child does not have markedly higher mortality than the child born previously—has been reported in earlier studies (Kudamatsu 2012). Furthermore, effects in these directions are theoretically plausible. In particular, there may be an accumulation of maternal health problems over age (Geronimus 1992), which outweighs the various physiological and social advantages that have attracted more attention in this literature. As regards the birth order effect, a possible explanation is that parents have accumulated experience with childrearing, although it may seem unlikely that this benefit is so large. Another possibility, relevant at least for the highest birth orders, is that siblings above a certain age may help so much at home and with income generation that this outweighs the burden associated with children who are not much older than the one under study. In line with this idea about assistance from older children, a recent study based on the

same type of method showed that, whereas the number of preschool-aged siblings was inversely related to a child's educational progression, having older siblings was an advantage (Kravdal et al. 2013). Moreover, in addition to being plausible and in accordance with some earlier studies, the findings reported here are robust to many alternative model specifications.

Unfortunately, the multilevel–multiprocess model does not control perfectly for selection, as factors that vary over time within a family are not accounted for. For example, in theory, a mother may not be particularly 'childbearing prone' when she has her third child at age 25, but because of changes in her health or economic situation, or for other reasons, she may revise her ideas some years later about the value of children and the possibility of raising another child. Thus, she may continue childbearing beyond her original intentions, perhaps even at a faster pace. Furthermore, her access to health services and her breastfeeding pattern may have changed over time, with implications for her 'natural fertility' and her chance of avoiding unwanted births. Such factors can obviously also affect the mortality of her children (although some studies have shown that controlling for breastfeeding does not matter much; Rutstein 2005; DaVanzo et al. 2008).

Another limitation of the analysis is that the models are estimated from a pool of survey observations from several countries, while in reality there may be considerable variation in the effects between countries or between subgroups within a country. Therefore, the estimates should be viewed as reflecting some sort of 'overall' effects across the countries.

Despite these limitations, the results may be seen as a challenge to common beliefs about the importance of reproductive factors for child mortality, or as support for challenging evidence that already exists. Given the importance of the subject, it would be very valuable to see the effects confirmed and explored further in future research based on similar or even better methods and preferably carried out in a less diverse setting.

Notes and acknowledgements

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Table 1 Number of deaths by birth order, maternal age, and length of preceding birth interval among children aged under five years and born less than ten years before DHS interviews in 28 countries in sub-Saharan Africa

Birth order	Maternal age (years)										Sum
	15–17	18–20	21–23	24–26	27–29	30–32	33–35	36–38	39–41	42+	
1	3,001	3,574	1,721	728	294	(163)	(55)	(24)	(8)	(1)	9,569
2	434	2,242	2,420	1,205	557	257	(119)	(49)	(18)	(5)	7,306
3	(9)	627	1,856	1,665	898	425	200	(95)	(45)	(12)	5,832
4	–	(78)	799	1,369	1,214	742	371	(148)	(69)	(26)	4,816
5	–	(13)	(183)	707	1,051	889	520	269	(129)	(39)	3,800
6	–	(1)	(19)	227	635	833	596	375	203	(69)	2,958
7	–	–	(7)	(38)	268	526	556	454	276	(93)	2,218
8+	–	–	(1)	(22)	(86)	360	630	945	914	474	3,432
Sum	3,444	6,535	7,006	5,961	5,003	4,195	3,047	2,059	1,662	719	39,931

Preceding interval (months), second and higher-order births only

≤17	5,563
18–23	6,427
24–29	6,720
30–41	6,577
42–53	2,492
54+	2,583

Note: Numbers in parentheses represent less than 0.5 per cent of the total number of deaths.

Source: Author's calculations based on DHS data.

Table 2 Effects (log-odds, with standard errors in parentheses) of maternal age, birth order, length of preceding birth interval, and calendar year on mortality among children aged under five years and born less than ten years before DHS interviews in 28 countries in sub-Saharan Africa, according to three different models

	‘Standard’ mortality model ¹	‘Augmented standard’ mortality model ²	Multilevel–multiprocess model ³
Maternal			
age (years)			
15–17	0.41*** (0.02)	0.31*** (0.03)	0.12*** (0.03)
18–20	0.12*** (0.02)	0.07*** (0.02)	–0.04* (0.02)
21–23 ⁴	0	0	0
24–26	–0.07*** (0.02)	–0.02 (0.02)	0.09*** (0.02)
27–29	–0.13*** (0.02)	–0.05** (0.02)	0.17*** (0.02)
30–32	–0.15*** (0.02)	–0.05* (0.02)	0.27*** (0.03)
33–35	–0.23*** (0.03)	–0.11*** (0.03)	0.31*** (0.03)
36–38	–0.17*** (0.03)	–0.05 (0.03)	0.45*** (0.04)
39–41	–0.08** (0.04)	0.04 (0.04)	0.60*** (0.04)
42+	0.00 (0.05)	0.11** (0.05)	0.73*** (0.06)
Birth order			
1	0.27*** (0.02)	0.33*** (0.02)	0.45*** (0.02)
2 ⁴	0	0	0
3	0.01 (0.02)	–0.04* (0.02)	–0.16*** (0.02)
4	0.09*** (0.02)	–0.01 (0.02)	–0.25*** (0.02)
5	0.16*** (0.02)	0.03 (0.03)	–0.33*** (0.03)
6	0.26*** (0.03)	0.10*** (0.03)	–0.38*** (0.03)
7	0.37*** (0.03)	0.19*** (0.03)	–0.40*** (0.03)
8+	0.49*** (0.03)	0.29*** (0.03)	–0.50*** (0.04)

Preceding interval (months), second and higher-order births only⁵

≤17	0.94*** (0.02)	0.95*** (0.02)	0.91*** (0.02)
18–23	0.59*** (0.02)	0.58*** (0.02)	0.54*** (0.02)
24–29	0.32*** (0.02)	0.32*** (0.02)	0.28*** (0.02)
30–41 ⁴	0	0	0
42–53	–0.21*** (0.03)	–0.19*** (0.02)	–0.17*** (0.02)
54+	–0.21*** (0.03)	–0.17*** (0.03)	–0.14*** (0.03)
Year	–0.058*** (0.002)	–0.057*** (0.002)	–0.055*** (0.002)
Standard deviation			
of δ			0.44*** (0.00)
Standard deviation			
of τ	0.79*** (0.01)	0.78*** (0.01)	0.83*** (0.01)
Correlation between			
δ and τ			0.47*** (0.01)

Notes:

¹‘Standard’ mortality model also includes child’s age and country.

²‘Augmented standard’ mortality model also includes child’s age, country, and several other variables (see ‘Variables’ subsection).

³Multilevel–multiprocess model also includes child’s age, country, and several other variables in the mortality equation (see ‘Variables’ subsection) plus fertility equations.

⁴Reference categories.

⁵The dummies for all categories are set to zero for firstborn children.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

Source: Author’s estimations based on DHS data.

Table 3 Effects (log-odds) of maternal age and birth order on mortality among children aged under five years and born less than ten years before DHS interviews in 28 countries in sub-Saharan Africa, according to the ‘standard’ mortality model¹

Birth order	Maternal age (years)									
	15–17	18–20	21–23	24–26	27–29	30–32	33–35	36–38	39–41	42+
1	0.68***	0.39***	0.20***	0.18***	0.07	–	–	–	–	–
2	0.30***	0.10***	0 ²	–0.07*	–0.13***	–0.14**	–	–	–	–
3	–	0.11**	0.04	–0.05	–0.16***	–0.23***	–0.22***	–	–	–
4	–	–	0.12***	–0.01	–0.05	–0.05	–0.09	–	–	–
5	–	–	–	0.09*	0.04	–0.03	–0.03	–0.06	–	–
6	–	–	–	0.19***	0.08***	0.11***	–0.02	0.08	0.13*	–
7	–	–	–	–	0.33***	0.20***	0.11**	0.19***	0.28***	–
8+	–	–	–	–	–	0.34***	0.17***	0.34***	0.43***	0.50***

Notes:

¹‘Standard’ mortality model also includes length of preceding birth interval, calendar year, country dummies, and child’s age. Standard errors of the combined effects of maternal age and birth order are between 0.03 and 0.08 (largest in the smallest groups, see Table 1). Effects of birth interval are 0.95, 0.59, 0.32, 0, –0.20, and –0.22 for each of the six length categories, respectively, and the effect of calendar year is –0.059, with standard errors as in the first column of estimates in Table 2. The standard deviation of the random term is 0.78.

²Reference category.

***p<0.01; ** p<0.05; * p<0.10

Source: As for Table 2.

Table 4 Effects (log-odds) of maternal age and birth order on mortality of children aged under five years and born less than ten years before DHS interviews in 28 countries in sub-Saharan Africa, according to the ‘augmented standard’ model¹

Birth order	Maternal age (years)									
	15–17	18–20	21–23	24–26	27–29	30–32	33–35	36–38	39–41	42+
1	0.65***	0.41***	0.27***	0.32***	0.27***	–	–	–	–	–
2	0.23***	0.06*	0 ²	–0.03	–0.03	–0.01	–	–	–	–
3	–	0.05	–0.01	–0.05	–0.13***	–0.17***	–0.14*	–	–	–
4	–	–	0.04	–0.05	–0.07*	–0.04	–0.07	–	–	–
5	–	–	–	0.01	–0.01	–0.05	–0.03	–0.06	–	–
6	–	–	–	0.09	0.08	0.06	–0.06	0.05	0.10	–
7	–	–	–	–	0.22***	0.12**	0.05	0.14***	0.23***	–
8+	–	–	–	–	–	0.24***	0.09*	0.26***	0.35***	0.42***

Notes:

¹‘Augmented standard’ mortality model also includes length of preceding birth interval, calendar year, country dummies, child’s age, and several other variables (see ‘Variables’ subsection). Standard errors of the combined effects of maternal and birth order are between 0.03 and 0.08 (largest in the smallest groups, see Table 1). Effects of birth interval are 0.95, 0.58, 0.31, 0, –0.19, and –0.19 for each of the six length categories, respectively, and the effect of calendar year is –0.058, with standard errors as in the second column of estimates in Table 2. The standard deviation of the random term is 0.76.

²Reference category.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

Source: As for Table 2.

Table 5 Effects (log-odds) of maternal age and birth order on mortality of children aged under five years and born less than ten years before DHS interviews in 28 countries in sub-Saharan Africa, according to the multilevel–multiprocess model¹

Panel A: Model estimates²

Birth order	Maternal age (years)									
	15–17	18–20	21–23	24–26	27–29	30–32	33–35	36–38	39–41	42+
1	0.57***	0.41***	0.39***	0.54***	0.57***	–	–	–	–	–
2	0.04	–0.06*	0 ³	0.09**	0.18***	0.28***	–	–	–	–
3	–	–0.21***	–0.14***	–0.07**	–0.02	0.03	0.13**	–	–	–
4	–	–	–0.23***	–0.20***	–0.09**	0.05	0.11*	–	–	–
5	–	–	–	–0.27***	–0.17***	–0.09**	0.03	0.08	–	–
6	–	–	–	–0.31***	–0.21***	–0.10**	–0.10**	0.10*	0.20**	–
7	–	–	–	–	–0.19***	–0.16***	–0.12**	0.07	0.23***	–
8+	–	–	–	–	–	–0.23***	–0.28***	–0.02	0.12***	0.24***

Panel B: Sum of the period effect (set to zero at age 21–23) and the combined effect of maternal age and birth order shown in Panel A.

Birth order	Maternal age (years)									
	15–17	18–20	21–23	24–26	27–29	30–32	33–35	36–38	39–41	42+
1	0.91	0.58	0.39	0.37	0.23	–	–	–	–	–
2	0.38	0.11	0 ³	–0.08	–0.16	–0.23	–	–	–	–
3	–	–0.04	–0.14	–0.24	–0.36	–0.48	–0.55	–	–	–
4	–	–	–0.23	–0.37	–0.43	–0.46	–0.57	–	–	–
5	–	–	–	–0.44	–0.51	–0.60	–0.65	–0.77	–	–
6	–	–	–	–0.48	–0.55	–0.61	–0.78	–0.75	–0.82	–

7	–	–	–	–	–0.53	–0.67	–0.80	<u>–0.78</u>	–0.79	–
8+	–	–	–	–	–	–0.74	–0.96	–0.87	<u>–0.90</u>	–0.95

Notes:

¹Multilevel–multiprocess model also includes length of preceding birth interval, calendar year, country dummies, child’s age, and several other variables in the mortality equation (see ‘Variables’ subsection) plus fertility equations.

²Standard errors of the combined effects of maternal age and birth order are between 0.03 and 0.08 (largest in the smallest groups, see Table 1). The effects of preceding birth interval are 0.91, 0.54, 0.28, 0, –0.16, and –0.15 for each of the six length categories, respectively, and the effect of calendar year is –0.057, with standard errors as in the third column of estimates in Table 2. The standard deviations of the random terms are 0.44 and 0.81, and the correlation between them is 0.47. Where pairs of estimates along diagonals are underlined, the estimate that is lower on the diagonal is significantly smaller than the one that is higher ($p < 0.05$). Dashed underlining indicates a significant difference in the opposite direction. The grey shaded diagonal illustrates a possible trajectory assuming three-year birth intervals, as discussed in the ‘Results’ section.

³Reference category.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

Source: As for Table 2.