# Education in sub-Saharan Africa: A New Look at the Effects of the Number of Siblings

**Abstract**

Studies examining the link between the number of siblings and children's education in Africa have given mixed results. Moreover, the potential for unobserved heterogeneity bias raises questions about how best to interpret any observed association. Using DHS data from 26 countries in sub-Saharan Africa and a multilevel multiprocess model that controls for time-invariant unobserved mother-level characteristics, we find indications that younger siblings increase the likelihood of entering primary school. However, once a child is enrolled, the number of pre-school aged siblings is negatively related to educational progression. The number of siblings older than 15 increases the chance of primary school entry and completion, but has no effect on subsequent transitions. There are also some positive effects of the number of siblings aged 6-15. On the whole, the number of siblings is not an important determinant of children's education. The results underscore the need to develop detailed measures of sibling groups which capture age variations in school participation and potential contributions to production.

## Introduction

Persistent population growth, which has been fueled by high fertility rates in poorer countries, has attracted a good deal of attention and concern. Its effects on the economy and the environment have been debated for decades, but another issue, more prominent in recent years, is that children living in large families may be disadvantaged relative to their counterparts with fewer siblings. Although the extant literature makes frequent reference to competition for resources and most investigations suggest adverse effects of sibship size on health and education, some studies report rather modest or no effects (see references below). Because the empirical evidence is inconsistent, we seek to re-evaluate and re-assess the consequences of sibsize, with a focus on educational outcomes in sub-Saharan Africa.

Identifying and explaining the relationship between sibsize and children's education is clearly policy relevant in the context of sub-Saharan Africa, where fertility remains high, economic development is slow, and in many countries educational enrollment is far from universal. A better understanding of how the number of siblings facilitates or obstructs participation in education could help development specialists and practitioners design programmes that are more successful in reducing the risk of non-enrollment or failure and so provide useful information as countries work towards meeting the education targets set out in the Millennium Development Goals. Nonetheless, interpreting associations between family size and educational attainment is far from straightforward: a number of characteristics of the mother and father and the social and physical environment in which they live influence both fertility and educational attainment (also elaborated on below). To address this issue, some researchers have attempted to control for as many potentially confounding variables as possible (e.g. Anh et al. 1998), though the possibility of residual unobserved heterogeneity bias makes the interpretation of parameter estimates tentative. For this reason, instrumental variable and fixed effects approaches have been utilized to more rigorously control for sources of bias linked to differential selection into larger and smaller families. Multiple births (Black et al. 2005; Cáceres-Delpiano 2006; de Haan 2010; Li et al. 2008), the sex composition of older siblings (Angrist et al. 2010; Conley and Glaber 2006; de Haan 2010; Goux and Maurin 2005; Lee 2008), miscarriages (Maralani 2008), the introduction of the one-child policy in China (Qian 2005) or parents' sibship size (Jaeger 2008) - each interpreted as involving random shocks to fertility - have been used as instrumental variables. Although a case can be made to justify the use of each of these measures, they all have their limitations (see Rosenzweig and Zhang 2009 for a critique of twinning and Åslund and Grönqvist 2007 for a critique of sex composition). Other authors have used fixed effects at the household-level (Dammert 2010; Eloundou-Enyegue and Williams 2006), child-level (Schmeer 2009) or both (Guo and Van Wey 1999). This method controls for time-invariant unobserved factors but identification requires variation at the level of the fixed effect. Because measures of the total number of siblings do not vary for children in the same family or for the same child, other more detailed measures, such as the number of siblings below a certain age at a certain relevant point in the child's life must be introduced. Although effects of the presence and age of siblings at the time of a particular transition are likely to be meangingful, there may be additional effects of time-invariant sibsize measures, which would be absorbed into the fixed effect. Besides, there is a risk that the estimates depend heavily on the exact definition of the sibling variable. Some researchers have found that the use of one of these relatively advanced techniques does not change the conclusions appreciably (Eloundou-Enyegue and Williams 2006; Maralani 2008), whereas others have drawn the opposite conclusion (Angrist et al. 2010; Åslund and Grönqvist 2007; Black et al. 2005; Cáceres-Delpiano 2006; de Haan 2010; Lee 2008).

In this study, we use another type of statistical approach to handle the selection problem. We estimate multilevel, multiprocess models that include equations for both children's education and their mothers' fertility, with (potentially) correlated unobserved factors. This modelling strategy has a number of advantages. As with fixed effects models, we require some families with more than one child and some within family variation in the outcome variable. In contrast to fixed effects models, however, we can include variables that do not necessarily vary across children with the same mother. Further, unlike instrumental variable approaches, we need not find a variable that affects fertility but not education, conditional on fertility. Although this approach has become increasingly common in the demographic literature in recent years (see, for example, Makepeace and Pal 2008; Steele et al. 2009; Upchurch et al. 2002), it has not been used to examine the relationship between mothers' fertility and their children's education.

In our models, which are estimated using DHS data for 26 countries in sub-Saharan Africa, we consider the age of the siblings and allow for sibsize effects to vary across educational transitions. Earlier studies have provided mixed evidence about such variations. Some have found the sharpest effects at the secondary level (Anh et al. 1998; Maralani 2008), while others have reported no such differences (Eloundou-Enyegue and Williams 2006). We consider four different educational transitions, and take into account the number of siblings and their ages at the time decisions about entering or remaining in school are likely to have taken place. No earlier investigation has both made a distinction between educational transitions and included multiple, time-varying age-specific measures of the number of siblings.[1]

[1] The studies that come closest are those by Connelly and Zheng (2003) and Sudha (1997), where a few different educational transitions were considered and number of younger and older siblings were included in the models. At the time when the first educational transitions are made, the 'older' siblings may of course be rather young. Conversely, at the time of secondary school transitions, the 'younger' may be rather old.

## Theoretical Considerations

A number of mechanisms may contribute to a relationship between sibsize and a child's education. We first discuss some pathways through which sibsize may affect education. This discussion motivates our own operationalization, which is presented briefly. We then consider the possible confounding factors and review the empirical evidence.

### Possible Causal Effects of Sibsize

While education may benefit the child greatly in the long run and also increase the value of the contribution a child can make to the household, severe credit constraints may force parents in poor settings to downplay such arguments and take a short-term perspective. More specifically, in any given period, the direct costs of education for children (costs of school fees, books and uniforms, possibly set off against free meals at school), expenditures on basic necessities for everyone, plus any consumption beyond that may not be allowed to exceed the total income that can be earned by each household member. Because there are also obvious time constraints, this income depends on whether he or she goes to school or helps a child with school work (i.e. there are opportunity costs of schooling), supervises young children, or is responsible for some of the housework that needs to be done in the household. For example, children above a certain age may contribute to the income generation, but to a lesser extent if they go to school or help with housework. Similarly, assisting children with school work and doing housework reduces parents' earning capacity. On the other hand, when very young children are enrolled in school, time that older siblings or parents would otherwise spend supervising them can be allocated to other tasks. Another implication of the time contraints is, of course, that housework and other responsibilities reduce the time available to a child for school participation.

According to the so-called 'resource dilution argument', which in its simplest form posits that parents with many children will have less to spend on each (e.g. Blake 1989), one might expect that the presence of many siblings reduces a child's chance of taking further education. However, given the general ideas just presented, this perspective would benefit from some additional nuance and refinement. Above all, as the previous literature illustrates, a distinction should to be made between siblings in different age groups, to reflect variations in the set of alternative activities.

The situation is relatively simple for the youngest siblings, and the theoretical prediction is in line with the resource-dilution argument: having a relatively large number of young (preschool aged) siblings, whose net contribution to the household economy is negative, should reduce the likelihood of educational progression. The effect of older siblings who have already completed their education is more ambiguous. To the extent that they are able to make a relatively large net contribution to the household economy, the income effect should increase the likelihood that their younger sibling enters and remains in school. If these older children do some of the housework that otherwise would have been allocated to the younger sibling, there may be an additional positive substitution effect. In line with these hypotheses, a number of studies have shown beneficial effects of relatively old siblings, while having young siblings is more clearly a disadvantage (Chernichovsky 1985; Lloyd and Blanc 1996; Schmeer 2009).[2] However, any positive effect of having older siblings may be partly offset by a substitution effect working in the other direction: it is possible that the younger children have to do more housework when they have older siblings, because it is important to free up the latter's time for paid work.

[2] However, DeGraff, Bilsborrow and Herrin (1996) did not find such differences according to age in their analysis of children's education.

The predicted effect of having a large number of school-age siblings, who are both costly to send to school and able to contribute substantially to production is not straightforward either. Moreover, it has received relatively little attention thus far in the literature. Let us assume that each child in this age group is a net cost to the parents if he or she attends school (i.e. the work contribution from the child is outweighed by expenses). If, in a particular year, the parents have a small number of school-aged children, they may (with possible support from older children) afford to enroll all of them. If, however, they have a large number of school-aged children,  they may only be able to afford to send some of them to school. Decisions about the number of children to send to school will likely depend on whether children who do not attend school  are able to make a net contribution to the household and on the extent to which the costs of enrolling more children in school increases at a decreasing rate. To elaborate on this, some inputs of importance for education may be more or less non-rivalrous (Downey 1995). For example, uniforms may be handed down to younger siblings,  school supplies such as text books may  be shared, and it may be possible to organize common transportation to school. Thus, the additional expenses associated with education will not increase proportionally with number of children in school. Anyway, the chance that all children are sent to school will be lower in the family which, at any given time, has many school-aged children than in an otherwise similar family with a small number of school-aged children. If education must be rationed, the chance of (continued) enrollment for any particular child depends on what sort of principles  parents employ when prioritizing between their children.

In principle, it is also possible that that there is a *positive* contribution to the effect of the number of school-aged siblings, though it may not necessarily be dominating: in circumstances where (a) school-aged children have limited paid work opportunities (b) some types of housework are carried out primarily by the school-age children and (c) the demand for this type of housework is relatively fixed or does not increase proportionally with family size, the presence of many school-aged siblings may mean less time per child is required for housework, and more time is available for at least some children to attend school.

Other types of effects of the number of siblings are also possible. For example, a child's chance of getting an infectious disease, or a particular severe version of the disease, may be particularly high when there are many siblings and a more crowded home environment. Such effects have been suggested especially for measles and some respiratory infections, though there are also examples of beneficial effects, possibly because of immune mechanisms (Aaby 1988; Burström et al. 1999; Cardoso et al. 2004). Repeated occurrences of infectious diseases may lead to stunting, poorer cognitive development, and eventually reduce the chance of educational success. Further, additional young children may have an adverse effect by lowering the overall intellectual environment in the family. This so-called confluence theory has not received much empirical support, however (Steelman et al. 2002).

Our Operationalization

To summarize, educational investments are likely to depend in complex ways on the number of siblings at different ages at various stages of the child's life when the various educational transitions under study are particularly relevant. It is far from obvious how this should be operationalized in a statistical model, in terms of age categorization and definition of 'sibling', not least when we consider the institutional and cultural variations that characterize the countries of Africa. In much of our analysis we consider three age groups (see details below). The mid group is relatively broad (6-15) and may include what is referred to above as 'school-aged' siblings, having presumably a negative but not necessarily *strongly* negative effect, as well as siblings for whom schooling is no longer a realistic option and therefore fit within the ‘older’ category above, and that more likely contribute to a positive effect. Following common practice, we define ‘siblings’ as children with the same mother. Some of these siblings may live outside the household, but may still present competing demands on the family resources, and they may contribute financially. There may also be children in the household who instead have the same father (Lloyd and Gage-Brandon 1994), and some may be fostered in. These two groups of ‘siblings’ may have similar effects on a child’s education.

Birth order has been included in some studies of the association between education and number of siblings (e.g. Åslund and Grönqvist 2007; Black et al. 2005; Li et al. 2008), in part because it is related to the siblings’ ages. For example, children who are born first have little competition from young siblings early in life, but may be expected to support younger siblings later (e.g. Tenikue and Verheyden 2010), while those born late face competition from siblings at the outset which gradually tapers off. These mechanisms are captured by our measures of siblings in different age groups (while studies including birth order have typically used the total number of children ever born to the mother). One might also consider including birth order because the parents are likely to benefit longer from the education of children born early, or because they may have a higher income when they have their last-born children, but these arguments are actually about parents’ age, which is indicated in our analysis by mother’s age when the educational transitions are made. In other words, adding birth order would make interpretation difficult because it would capture some of these effects of parents’ and sibling’s age, but not all. We have therefore excluded it from our models. That said, there may also be more ‘pure’ birth order effects: in some countries the first-born (son) or last born (daughter) may have special obligations and rights regardless of number of siblings, and the parents’ experience with childcare and -raising improves with birth order. We may pick up some, but not all, of these effects with our sibsize variable.

Possible Variations in Effects

It is widely acknowledged that sibsize effects may vary across educational transitions (see references above). To the extent that primary school is mandatory and compliance is strictly enforced, any effect of household characteristics, including the number of siblings, will be weakened. In contrast, effects on the higher educational transitions may be relatively strong because of higher tuition fees. An additional argument is that these higher transitions depend on having already obtained a rather high educational level. In that case it is likely that any siblings either have had or will have rather long school careers as well (because of parental views about fairness across siblings and persistence in parents' attitude to education) and that they therefore remain competitors rather than potential sources of support for many more years. Thus, the effects of the number of siblings in our two oldest age groups would be less positive or more adverse at higher transitions.

There are probably also variations in the sibsize effect across social settings, depending for example on differences in ideas about children's work as an alternative to schooling, the level of tuitions fees, and the extent to which a broader kin network can be relied on for support (Anh et al. 1998; Eloundou-Enyegue and Williams 2006; Knodel and Wingsith 1991; Li et al. 2008; Maralani 2008; Parish and Willis,1993; Schmeer 2009). However, we do not address such variations in this study.

Other Contributions to the Sibsize-Education Relationship

In addition to the causal effects addressed above, an observed relationship between sibsize and a child's education may be, to some extent, spurious. First, even amongst people with the same economic resources and education, preferences for investments in education will vary. If parents with strong preferences for education also prefer small families, perhaps partly because they anticipate having to meet the costs of their preferred level of investment in education (the so-called quantity-quality tradeoff considerations (Becker 1991; Becker and Lewis 1973)), the relationship between sibsize and children's education will be more negative than the causal effect of sibsize on childen's education.

Second, a correlation between fertility and children's education may be due to other factors that influence both fertility and education decision-making. For example, a lack of trust in government institutions may reduce demand for (state sponsored) education and increase demand for children (substitutes for government support in old age).

Alternatively, high fertility may be the result of unwanted births. Characteristics associated with inadequate contraceptive use, such as individual values or household or community socio-economic resources (given the socio-economic indicators included in the model), may affect a child's education as well. In addition, common factors may well underlie norms and attitudes about the importance of adherence to traditional patterns of post-partum abstinence and prolonged breastfeeding (and so affect fecundability) and of investing in children's education.

In this study, we control for some observed characteristics that may affect both fertility and children's schooling, such as mother's education. Educated women typically value children's education highly, and may for that and various other reasons aim to have few children, while the fact that they tend to be relatively rich may push their fertility desires up (assuming that childbearing expenses do not rise in step with the higher purchasing power). We also control for unobserved factors at the mother level that are constant over time and thus influence all her fertility transitions as well as the educational outcomes for all her children. This approach comes closer to identifying a causal effect than what has been estimated in many other studies. In other words, we provide a better assessment of how children may benefit in terms of education if unwanted fertility diminishes exogenously through, for example, the introduction or expansion of efficient family planning programs, or if childbearing desires are reduced for reasons unrelated to plans about children's education.

Empirical Evidence

Several studies have shown a negative association between sibize and children's education in Western countries (Blake 1989; Booth and Key 2009; Conley and Glauber 2006; Downey 1995; Goux and Maurin 2005; Hauser and Sewell 1985; Jæger 2008; Kuo and Hauser 1997; Steelman and Powell 1989). However, many of the more recent investigations, some of which have used twin births as an instrument, have reported little or no effect (Angrist et al. 2006a; Åslund and Grönqvist 2007; Black et al. 2005; Caceres-Delpiano 2006; de Haan 2010). Studies from Asia seem to be more consistent in suggesting adverse effects (Anh et al. 1998; Connelly and Zheng 2003; Knodel and Wongsith 1991; Lee 2008; Li et al. 2008; Lillard and Willis 1994; Maralani 2008; Parish and Willis 1993; Pong 1997; Post 2001; Schmeer 2009), though some studies concluded that the effects were not very large (DeGraff, Bilsborrow and Herrin 1996; Rosenzweig and Zhang 2009).

Fewer analyses have been undertaken with African data, and the findings are mixed. In the 1980s, Gomes (1984) reported a positive effect of the total number of children in the family, though that was actually a result of a combination of a positive effect of time since first birth, and therefore high birth orders, and no effect (for medium birth-order children) of having younger siblings. Chernichovsky (1985) found positive effects of the number of siblings at age 7 to 14 and a negative effect of the presence of an infant sibling. Later studies have shown adverse effects, especially among girls (Lloyd and Gage-Brandon 1994) and in urban areas, as opposed to beneficial effects in rural areas (Montgomery et al. 1995). In a particularly thorough analysis with data from Cameroon, Eloundou-Enyegue and Williams (2006) found rather weak adverse effects. Lloyd and Blanc (1996) showed moderately adverse effects of young siblings in 4 out of 7 countries in sub-Saharan Africa.

## Data

Our study uses data from Demographic and Health Surveys (DHS) – a set of nationally representative and largely comparable surveys which have been conducted in a number of less economically developed countries with the aim of providing researchers and policy makers with information about, in particular, reproductive behaviour and children's and adults' health. We use data from from the most recent African surveys that included information on the educational attainment of each of the women's children who were co-residing with them at the time of interview. More precisely, in the surveys that we used there is a reference to a line in a household roster for each of these children, and the educational level is reported in this roster. Other recent DHS surveys in sub-Saharan Africa include no such link, which means that one has to search through the roster to find the person that resembles the child the most. Our analytic sample comprises data from 26 surveys conducted between 2003 and 2009 in: Benin (2006), Burkina Faso (2003), Cameroon (2005), Congo-Brazaville (2005), Congo-DR (2007), Ethiopia (2005), Ghana (2008), Guinea (2005), Kenya (2009), Lesotho (2010), Liberia (2007), Madagascar (2009), Malawi (2004), Mali (2006), Mozambique (2003), Namibia (2007), Niger (2006), Nigeria (2008), Rwanda (2005), Senegal (2005), Sierra Leone (2008), Swaziland (2007), Tanzania (2005), Uganda (2006), Zambia (2007), and Zimbabwe (2006).[3]

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[3] The surveys have used a stratified cluster sample design. Within each province, a number of primary sampling units (PSUs) have been selected. These uints typically encompass one or a few villages or part of a town. On

Because information on educational attainment is only collected for children who are currently co-resident, we are faced with a potential sample selection problem. Children who have died or left home[4] may have various unobserved characteristics that are linked with unobserved determinants of fertility, education or both. The effect of fertility on education in our sample may therefore be different from what it would be for a child randomly drawn from the entire population. There has been a similar limitation in earlier studies, with a few exceptions, such as that by Ahn et al. (1998) and Black et al. (2005), where there was information also about children not living at home. Our solution is to include an additional process in the multiprocess system that links the likelihood of survival and co-residence to the other equations through unobserved factors at the mother level that are allowed to be correlated. This approach does not, however, take into account that there may be unobserved child-specific determinants which affect the process of leaving home. The main concern is, of course, that some children have left home in order to take education – which is especially relevant at the secondary level. We return to the implications of that below.

For each educational transition, we only consider children that fall within the relevant age range. For example, only children 7 and older are considered in our equation for low primary education, while only children who are 18 or older are included when we consider transitions to upper secondary education. In either case, the upper limit is 20 because many children who are older than 20 will have already left home. Increasing the cut-off to age 25 led to somewhat less adverse effects of number of siblings.

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average, about 25 households have been randomly selected within each primary sampling unit, and women of reproductive age in the household have been interviewed

[4] The proportion who have died or left home in the age group that we consider is 41%, increasing from 29% at age 7 to 68% at age 20.

**Methods**

Statistical Approach

We have estimated a model that includes equations for parity-specific birth (hazard) rates for each woman *i*, a logistic equation for the chance that each of her children (*j*) is alive and co-resident at the time of the interview, and a series of educational-level-specific attainment equations for each co-resident child *j*. The equation for the first-birth rate is:

$$\log h_i^{(1)} = \beta_0^{(1)} + \boldsymbol{\beta}_1^{(1)} \mathbf{A}_i^{(1)}(a, v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8) + \boldsymbol{\beta}_3^{(1)} \mathbf{X}_i + \delta_i$$

and the equation for the higher-order birth rates is

$$\log h_i^{(2)} = \beta_0^{(2)} + \boldsymbol{\beta}_1^{(2)} \mathbf{A}_i^{(2)}(a, v_1', v_2', v_3', v_4', v_5') + \boldsymbol{\beta}_2^{(2)} \mathbf{D}_i (d, z_1, z_2, z_3, z_4) + \boldsymbol{\beta}_3^{(2)} \mathbf{X'}_i + \boldsymbol{\beta}_4^{(2)} \mathbf{M}_i + \delta_i$$

We have only considered 2nd to 8th births. Including higher order births ( 9th and 10th) did not change our results. $\beta_0^{(1)}$ is a constant, and $\mathbf{A}_i^{(1)}$ is a piecewise linear spline transformation of age (a), with nodes $v_1$ - $v_8$ at the end of the years when the woman turned 16, 18, 20, 22, 24, 29, 34, and 39, respectively. The process starts at the end of the year when the woman turned 14 and ends at the end of the year when she turned 44 or at interview. $\boldsymbol{\beta}_1$ is the corresponding vector of coefficients. Also $\mathbf{A}_i^{(2)}$, which is included for second and higher-order births, is an age spline, with nodes at 19, 24, 29, 34, and 39 years, and $\mathbf{D}_i$ is a spline transformation of duration (d) with four nodes at 2, 4, 6 and 8 years. $\mathbf{X}_i$ and $\mathbf{X'}_i$ are vectors of characteristics of the mother and the household and some aggregate-level factors (see specification below). The only difference between them is that **X** includes an interaction between age and the educational level, reflecting delayed transitions to first birth amongst the better educated. (Inclusion of this interaction turned out not to be important for the key estimates, though.) $\mathbf{M}_i$ are parity dummies (3-7, with 2 as the reference category).

A restriction implied by the equations above is that effects of **A**, **D** and **X'** are the same for all second and higher order births. However, we also estimated models with specific equations for each of the birth orders between 2 and 8 (with only the relevant nodes included in the various age splines). The results were similar but suggested slightly more adverse effects of sibsize on education.

The woman-specific heterogeneity term, $\delta_{i,}$ represents the value of a collection of unobserved time-invariant characteristics drawn at random (from a normal distribution with mean zero and variance $\sigma^2_\delta$ ) at an early age, staying with her throughout her reproductive period, and affecting all her birth rates.

The second equation, for the probability *s* that child *j* lives at home at interview (i.e. is not dead, has not been fostered out and has not left home for other reasons), is:

$$\log (s_{ij}/(1-s_{ij})) = \eta_0+\boldsymbol{\eta}_1\mathbf{Z}_{ij} + \lambda_i$$

where $\mathbf{Z}_{ij}$ is a vector of characteristics of the child and the household and some aggregate-level factors, $\boldsymbol{\eta}_1^{(1)}$ are the corresponding coefficients, and $\eta_0$ is a constant term. $\lambda_i$ is a woman-specific random effect that is constant and affects the probability of staying home and remaining alive for all her children. It is assumed to be normally distributed with mean zero and variance $\sigma^2_\lambda$.

Education was categorized into 5 levels according to the number of years of completed schooling: 0, 1-5 (corresponds in most countries to some but not completed primary education), 6-8 (completed primary and some secondary; referred to as completed primary below for simplicity), 9-11 (some secondary), 12+ (completed secondary). We refer to these as levels n=0,1,2,3 and 4, respectively. The following equation is included for children who were 7-20 years old at interview and lived at home (children in this age group could have completed one year of schooling if they started at age 6, which is the lowest among the common school-starting ages in the region):

$$\log (p_{ij}^{(1)}/(1-p_{ij}^{(1)})) = \gamma_0^{(1)}+\boldsymbol{\gamma}_1^{(1)}\mathbf{Y}_{ij} + \tau_i$$

where $p^{(1)}$ is the probability of having reached level 1, $\mathbf{Y}_{ij}$ is a vector of characteristics of the child and the household and some aggregate-level factors, $\boldsymbol{\gamma}_1^{(1)}$ are the corresponding coefficients, and $\gamma_0^{(1)}$ is a constant term. Similarly, the following equation is included for children who had reached level 1 and were 12-20 years old at interview, and who therefore could have proceeded from level 1 to level 2:

$$\log (p_{ij}^{(2)}/(1-p_{ij}^{(2)})) = \gamma_0^{(2)}+\boldsymbol{\gamma}_1^{(2)}\mathbf{Y}_{ij} + \tau_i$$

For children who were 15-20 years old and had at least reached level 2, we included the equation

$$\log (p_{ij}^{(3)}/(1-p_{ij}^{(3)})) = \gamma_0^{(3)}+\boldsymbol{\gamma}_1^{(3)}\mathbf{Y}_{ij} + \tau_i,$$

and for those who were 18-20 years old and had at least reached level 3, we included the equation

$$\log (p_{ij}^{(4)}/(1-p_{ij}^{(4)})) = \gamma_0^{(4)}+\boldsymbol{\gamma}_1^{(4)}\mathbf{Y}_{ij} + \tau_i.$$

$\tau_i$ is a woman-specific random effect that is time- and child-invariant (but see elaboration below) and assumed to be normally distributed with mean zero and variance $\sigma^2_\tau$.

In order to remove mother-specific sources of unobserved heterogeneity bias, we allow for the possibility of nonzero correlations between $\delta_i$, $\lambda_i$ and $\tau_i$ . Specifically, $\delta_i$, $\lambda_i$ and $\tau_i$

are assumed to follow a trivariate normal distribution with correlations $\rho_{\delta\lambda}$, $\rho_{\delta\tau}$, and $\rho_{\lambda\tau}$.[5] We estimate the model via maximum likelihood using the software package aML (Lillard and Panis 2003). The distributions are approximated by 5 support points. The results do not change appreciably when the number of points is increased. As further described below, only the correlation between the education heterogeneity term and the fertility heterogeneity term turned out to be important. Because determinants of educational transitions may differ between the primary and secondary level, in additional calculations, we included one random effect for the first two educational transitions and another for subsequent transitions. In this more complex specification, where all four unobserved factors were allowed to be correlated with each other, the sibsize effects were almost identical.

Variables

In addition to the woman's age and the duration since her previous birth, the fertility equations include controls for (in the $\mathbf{X}_i$ and $\mathbf{X'}_i$ vector) the woman's education level, her religion, and country of residence. The country dummies capture unobserved country-level factors of importance for fertility. Education was grouped into five categories: 0, 1-5, 6-8, 9-11, and 12+ years. Religion was grouped into three categories: Christian, Muslim, and other or no religion. In addition, the equation for first births includes (in $\mathbf{X}_i$) an interaction between the educational level and an age variable grouped into <20, 20-24, 25-29, 30-34, and >34.

The equation for the probability of being alive and living at home includes: the child's age and birth order, the mother's age, education and religion, and country dummies.

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[5] One might argue that there is something 'special' with children who are included in the analysis of higher educational transitions in spite of having many siblings or other potential disadvantages and thus be likely to leave school earlier. This kind of selection is also taken into account through our approach.

The education equations include the mother's education, religion and age (continuous) when the educational transition was most relevant, the child's age at interview (one-year categories), country dummies, and the number of siblings.[6]

We used two different operationalizations of the number of siblings. In the first part of the analysis, we included the number of siblings younger than 10 and alive when the child had reached the age when s/he, in principle, should have made the progression under consideration (i.e. age 7 for the progression to level 1, age 12 for the progression to level 2, age 15 for the progression to level 3, and age 18 for the progression to level 4). With this simple specification of the sibsize effect, we tested whether it was acceptable to assume a linear effect, and we assessed the importance of allowing for a correlation between the unobservables. In the next step, we used our main operationalization of sibsize: the number of siblings aged 0-5 at the relevant points in time, the number of siblings aged 6-15, and the number of siblings aged 16 or more.

A woman's birth rate at a given age is presumably influenced by the characteristics of the community in which she lived at that time, such as the average level of education (Kravdal 2002). Her children's education is also likely to be influenced by such aggregate factors. However, the DHS surveys only provide information about the place of residence at the time of the interview. This is particularly problematic if the choice of residence is influenced by fertility (with for example the low-fertility women being more likely to move to or remain in urban and relatively modernized areas). In additional calculations, we included the average education among women in the PSU where the woman lived at interview and whether that

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[6] In additional models, we included the calendar year when the child was 'under risk' for the educational transition. There is much variation at the lowest educational transition, where the analysis includes children who were quite young at interview as well as the older (who made these transitions many years earlier). Because there have been changes in fertility over time as well as changes in education for other reasons, we suspected that estimates might be different with year included as a control variable. They were not.

PSU was urban. In those specifications, the parameter for the number of siblings younger than 10 was slightly less negative.

We decided not to include indicators of wealth as measured by household amenities and/or ownership of certain consumer durables at the time of interview (Bollen, Glanville and Stecklov 2007; Filmer and Pritchett 2001; Rutstein and Johnson 2004). While these, to some extent, reflect earlier living standards with importance for fertility and children's education, they can also be influenced by the timing and level of fertility. In principle, the woman's educational level at interview may also have been affected by her childbearing history, and especially by whether she has had a very early birth, but because average educational levels are rather low, this is probably less of a problem than it would be in analyses of women living in wealthier countries (Cohen et al. 2011).

**Results**

Table 1 presents estimates of the effect of an additional sibling under the age of 10 on the likelihood of progression from first to second (ages 7-11), second to third (ages 12-14), third to fourth (ages 15-17), and fourth to the fifth (around age 18) educational level (the full set of estimates for this model is shown in Supplementary table S1). With this simple operationalization, we see the adverse effect that has been reported in a number of other studies from different parts of the world. Further, the results suggest that the presence of siblings of this age inhibits education most substantially at higher levels of attainment: an additional sibling reduces the odds of making the first transition by only 3%, but by about 10% for the two highest transitions.

(Table 1 about here)

Allowing correlations between the unobserved factor in the equation for the chance that the child lives at home at interview and those in the two other equations is not important: constraining these correlations to zero had essentially no impact on the effects of the number of siblings on the four educational transitions. The negative correlation between the unobserved variable in the fertility equation and the unobserved variable in the education equation, however, has far greater impact. When the correlation was set to zero (which presumes there are no common constant determinants that bias the relationship between the two processes) the parameter estimates suggested far more adverse effects of additional siblings: -0.127, -0.168, -0.188, and -0.206 (not shown in tables).

Assuming a linear effect of number of siblings seems justified. When we measured the number of siblings categorically (with indicators for 1, 2 and 3 or more siblings below age 10), a rather linear pattern obtained for the second and third educational transitions. For the first, the step from 0 to 1 had the largest effect, and for the fourth, the step from 1 to 2 had the largest effect, but the odds of progression at least decreased monotonically with number of siblings (Table 2).

(Table 2 about here)

Our next step was to include the number of children in three different age groups – our most detailed and preferred operationalization. As expected, the parameter estimates for the number of siblings aged 0-5 are generally negative. For the first educational transition, which involves enrolling in school and completing some primary education, the relationship is positive but only borderline significant ($p<0.10$). While one might expect less adverse effects for transitions at the primary school level (because primary school is less costly and usually mandatory), it is hard to explain why having many young siblings would increase rather than decrease attainment. Perhaps a child who has many younger siblings also is more likely to have at least one sibling who is nearly old enough to attend school and who might provide substitute labour or help with housework (i.e. those we have defined as young children may contribute more positively than we have assumed, while at the same time not having school participation as an alternative, such as our mid-group). The relationship could also reflect that women who at that time in the child's life course had relatively many young and surviving children tended to live in wealthier households (though such a positive effect of wealth on fertility is not obvious), which could have a simulating effect on the child's education as well.

(Table 3 about here)

The presence of siblings older than 15 increases the likelihood of making the first two educational progressions (at about age 7 and age 12). The positive effect could be due to the net contributions older children are able to make to the household. A similar beneficial effect is not seen at the secondary level, however. One possible explanation may be that in families where a child is supported through 8 years of education, siblings older than 15 – who may have had the same opportunities - may not contribute to the family income by working, but may be enrolled in school themselves.

The effects of number of siblings aged 6-15 are positive or essentially zero. This is quite reasonable in light of the other estimates and the theoretical discussion above, which suggested a variety of countervailing effects. The effect of the number of children in the lower part of this age segment might go in either direction, though a negative effect perhaps on the whole seems most likely, while the oldest may have completed school and make a net contribution to the family.

Although many of the coefficients for the number of siblings are significantly different from zero, their substantive effect is rather modest. To illustrate, we set the remaining covariates to their average values in the sample used to analyse the first educational transition, and predicted the probability that a 20-year old child who has entered school also has made the second transition. If we considered children who have 0, 2, 4 or 6 younger and/or older siblings, all born at two year intervals, the predicted probabilities varied between 75% and 82%. (Similarly, the chances of making the third transition varied between 39% and 45 %.) Even in the rather extreme and unlikely situation where the child has 5 siblings born 7, 8, 9, 10 and 11 years after his or her own birth (i.e. younger than 6 when it was relevant to make the second transition), the predicted transition probability is no lower than 66%.

**Summary and Conclusion**

Using data from 26 countries in sub-Saharan Africa, we have revisited the association between sibsize and educational outcomes. Ideally one would like to know how children may benefit in terms of education if unwanted fertility declines through, for example, efficient family planning programs, or if childbearing desires are reduced for reasons that are unrelated to concerns about financing children's education. However, as widely recognized, estimates of such an effect may well be biased – and most likely overstated – when unobserved joint determinants of mothers' fertility and their children's education are not controlled. Some researchers have tried to mitigate bias by including a large number of relevant control variables, while others have used instrumental-variable or fixed-effects approaches. Despite having been used in investigations of other socio-demographic processes that are highly interlinked (see, for example, Steele et al (2009)), thus far, no study has used a multilevel multiprocess model as we do to address this particular question. This approach allows us to control for unobserved characteristics of the mother that are time-invariant and that affect both her birth rates and her children's education. As we anticipated, our results confirm that had we not controlled for time-invariant unobserved mother-level factors, we would have overstated the adverse effects of the number of siblings.

Our findings suggest that the effect of siblings depends on their age and the particular educational transition being considered. In general younger siblings tend to reduce educational attainment (at least above primary school). In contrast, the effects of having siblings aged 16 or older are non-negative or even positive, and the effects of having school-aged (6-15) siblings are also sometimes positive. These patterns lend support to our argument that the underlying causal mechanisms are more complex than a straightforward dilution of resources perspective would suggest. Future work should give higher priority to developing and testing theoretically informed operationalizations of number of siblings – specific to each educational transition - that to a larger extent reflect the various mechanisms that drive the relationship between sibship size and investments in children's education. It is important to emphasize, however, that the number and age of siblings seem to have a rather small impact on the likelihood of continued enrollment and progression. Predictions based on various possible sibling groups showed a variation of no more than 6-7 percentage points in a child's probability of completing primary school or a few years of secondary school, and sibship size appears to be an even less important determinant for the other transitions. (In comparison, predictions using the same values of the other covariates showed that the chance of taking some years of secondary education is more than 50 percentage points higher for children whose mother has at least completed primary education than for those with less educated mothers.)

While the methodology is rather innovative in dealing with a longstanding difficult statistical problem, this study also has some limitations (both in terms of methods and the data we analyze). Like fixed effects models, our approach only controls for time-invariant unobserved factors. This could be a problem if, for example, mothers gradually develop a more modern outlook, leading to a more positive attitude towards both education and modern methods of contraception – the latter resulting in longer birth intervals at the end of her reproductive period and thus less apparent competition for the children born then. Conversely, during periods when she enjoys a particularly high household income, she may have many children (though such a positive income effect is not obvious) and be able to provide them with a good education. To the extent that there really is a positive effect of young siblings on the chance of school entry, as only weakly indicated by our results, the latter could be one explanation. However, the other relatively advanced methods that have been used are not without their limitations either (as mentioned above), and our approach provides a valuable and, in some ways less restrictive, alternative.

Another limitation of our study, as well as in most others, is that we do not have information on the educational attainment of children who have left the household. We handled this potential selection problem by including an equation for the chance that the child is alive and co-resident with the mother, and adding a constant mother-level random term to this equation that was allowed to be correlated with the corresponding random terms in the fertility and education equations. Our results suggest that this data limitation results in little if any sample selection bias, assuming, of course, that the relevant factors do not change over time or differ across children with the same mother. In reality, however, some children may have left home because they have a particularly strong preference for education, which is relevant especially at the secondary level (though the child may return later and therefore be included in the analysis). If the strategy of leaving home to take education is more frequently used by children with many siblings – which the literature on child fostering suggests is likely in some of the countries in our sample (Isiugo-Abanihe 1985; Lloyd and Desai 1992) – we will underestimate the educational attainment for this group of children and thus overestimate the adverse effect of sibsize. In addition, the women interviewed in our data are no more than 50 years old. This arbitrary cut-off could compromise the representativeness of the sample, particularly when we focus on older children. However, robustness tests suggested this was not an issue.

Finally, we have made certain choices about which control variables to include that could be criticized. In addition to leaving out measures of wealth and birth order (for reasons we set out in more detail above), we have ignored variations by sex. Earlier studies have taken both the number and the sex-composition of siblings into account (Connelly and Zheng 2003; Dammert 2010; Lillard and Willis 1994; Parish and Willis 1993; Sudha 1997). Others have included interactions between sibsize and the child's sex (Ahn et al. 1998; Dammert 2010; Li et al. 2008; Lloyd and Gage-Brandon 1994, Lloyd and Blanc 1996; Schmeer 2009; Sudha 1997), with mixed results. We thought consideration of such issues would make an already rather complex analysis too intricate, and we were also concerned that patterns of gender inequality may differ greatly across (and potentially within) the countries included in the analysis.

To sum up, the study has its limitations but also many advantages compared to earlier contributions to this literature: a large data set from many countries is used; the statistical method is both original and appropriate given our aims and objectives; and we have taken into account both that the siblings' age matters and that there may be variations across educational transitions. Finally, the focus on Africa should be very valuable, given the socioeconomic and demographic characteristics of this region. Our results suggest that (exogeneous) declines in fertility will not, on their own, translate into far greater educational enrollment or attainment.

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**Table 1.** Effects of number of siblings younger than 10 on the chance (log odds) of making four educational transitions.

| Educational Transition (Minimum age for transition) | Estimate (SE) |
|---|---|
| From level 0 to level 1, i.e. from no education to some primary (age 7) | -0.035*** (0.008) |
| From level 1 to level 2, i.e. from some primary to completed primary (age 12) | -0.079*** (0.010) |
| From level 2 to level 3, i.e. from completed primary to some secondary (age 15) | -0.095*** (0.016) |
| From level 3 to level 4, i.e. from some secondary to completed secondary (age 18) | -0.111*** (0.037) |

*Notes*: The model is described in the text. A full list of parameter estimates is shown in Supplementary table S1.

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

**Table 2.** Effects of number of siblings younger than 10 (categorized) on the chance (log odds) of making four educational transitions.

| Educational Transition (Minimum age for transition) | 0 sibling | 1 sibling Estimate (SE) | 2 siblings Estimate (SE) | 3+ siblings Estimate (SE) |
|---|---|---|---|---|
| From level 0 to level 1, i.e. from no education to some primary (age 7) | 0 | -0.091*** (0.028) | -0.125***(0.028) | -0.142*** (0.030) |
| From level 1 to level 2, i.e. from some primary to completed primary (age 12) | 0 | -0.184*** (0.041) | -0.286***(0.041) | -0.368*** (0.041) |
| From level 2 to level 3, i.e. from completed primary to some secondary (age 15) | 0 | -0.150*** (0.055) | -0.323*** (0.058) | -0.367*** (0.060) |
| From level 3 to level 4, i.e. from some secondary to completed secondary (age 18) | 0 | 0.034 (0.101) | -0.237** (0.119) | -0.382*** (0.138) |

*Notes*: The model is described in the text.

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

**Table 3.** Effects of number of siblings in different age groups on the chance (log odds) of making four educational transitions.

| Educational Transition (Minimum age for transition) | Number of siblings of age 0-5 Estimate (SE) | 6-15 Estimate (SE) | 16+ Estimate (SE) |
|---|---|---|---|
| From level 0 to level 1, i.e. from no education to some primary (age 7) | 0.018* (0.010) | 0.010 (0.008) | 0.123*** (0.010) |
| From level 1 to level 2, i.e. from some primary to completed primary (age 12) | -0.115*** (0.014) | 0.060*** (0.012) | 0.042*** (0.013) |
| From level 2 to level 3, i.e. from completed primary to some secondary (age 15) | -0.102*** (0.023) | 0.065*** (0.018) | 0.014 (0.018) |
| From level 3 to level 4, i.e. from some secondary to completed secondary (age 18) | -0.131** (0.060) | 0.008 (0.036) | 0.037 (0.035) |

*Notes*: The model is described in the text.

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