The Effects of Maternal Risk Factors on Daughters' Health and Socioeconomic Outcomes in Adulthood: A Pseudo-Cohort Analysis of Demographic and Health Surveys Conducted in 50 Developing Countries 1986-2012

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Abstract

This analysis assesses life course impacts of maternal risk factors prevailing at the time of daughters' births on their subsequent adult health, reproductive and socioeconomic outcomes. Pseudo-cohorts are constructed using birth history and respondent reports from cross-sectional rounds of Demographic and Health Surveys (DHSs) conducted in 50 developing countries between 1986 and 2012. Of specific interest is whether a daughter born to a very young mother, at high birth order or close after the previous sibling increases the probability of experiencing child loss, having a low birthweight baby, being short, having low BMI, having more years of schooling, or having paid work in adulthood. Generalized linear models are estimated to test the relationships and simulate outcome probabilities with the systematic elimination of each and all three maternal risk factors. The results for 2,542 pseudo-cohorts across the 50 DHSs and a subsample of 1,386 pseudo-cohorts for 27 Sub-Saharan Africa surveys show that eliminating the three risk factors can reduce cohort mean proportions of adult women experiencing child mortality from 0.187 to 0.154, having low birthweight infants from 0.156 to 0.100, being of short stature from 0.052 to 0.048 or having poor body mass index from 0.103 to 0.094, and increase average years of schooling from 6.07 to 6.58 years. Adult daughters' experience of paid work increases only if the risk of high parity births is fully eliminated, with mean proportions rising from 0.335 to 0.413. Gains for Sub-Saharan African cohorts are even larger. The pseudo-cohort approach, while not without limitations, is promising and enables testing life course hypotheses in a longitudinal manner using large-scale, standardized, repeated cross-sectional data with considerable resource efficiency.

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Significance of maternal risk factors for health and socioeconomic wellbeing

Evidence is growing of the effects of maternal factors on fetal programming and consequences for perinatal, neonatal and infant outcomes and health and wellbeing in adulthood. Chronic health disease has been linked to fetal development deficits related to these maternal risk factors, i.e., the fetal origins of disease hypothesis. Fetal programming research shows that nutrients, e.g., protein, selenium, iron, zinc, Vitamin A, copper, choline, folate, affect gene expression during the development of the brain structure and other organs and tissues (Barker, 1994; 2000; Georgieff, 2007). Protein-caloric intake during pregnancy influences birth weight; and low and high birth weights have been linked to adult incidence of non-communicable diseases (Barker, 2000; Shetty and Schmidhuber, 2011), especially in high-income but increasingly in low and middle income countries (LMICs). From a demographic perspective, the quality of life tied to conditions at birth enlivens interpretation and the human development significance of the variations observed in life tables and life expectancies at birth across high to low income settings.

It is well accepted that a woman's reproductive history can influence the survival prospects of her fetus and newborn. The recurring incidence of fetal loss, pregnancies or infections to a mother can compromise the fetus' growth, organ development and survival. These intra-uterine conditions have been linked to poor maternal nutritional status, dietary intake or substance abuse behaviors. For developing countries, where 5.7 million or more births each year do not survive to their first birthday, serious infections during pregnancy, such as malaria and HIV and other sexually transmitted infections, introduce avoidable risks of maternal and infant mortality.

Demographic attention to risky childbearing patterns have focused on maternal indicators, such as birthing at young or old ages, having closely spaced births, and having a large number of births. A number of studies have examined co-variation between the incidence of infant and child mortality, as well as low birth weight, pre-term birth, and small-for-gestational age, with these maternal risk measures. Early childbearing places disproportionate demands on a girl's physiology to support her own growth and that of her fetus, as well as introduces complications during delivery. Pregnant older mothers carry higher risks for congenital anomalies and delivery and post-partum complications. Hypertension, diabetes and kidney or cardiovascular problems are also more common in older pregnant women and can retard fetal growth.

In medical terminology, parity is a woman's number of live births, and gravidity the number of times she has been pregnant. Nulliparous women are those who have not had a live birth (but may have been pregnant), primagravidas are those with their first pregnancy and primiparas are those who have had a first birth only. Grand multiparas have had at least five births. Birth complications, such as pre-eclampsia, prolonged or obstructed labor, uterine rupture, and hemorrhage, all are more likely to occur to nulliparous and grand multiparous women and threaten maternal and newborn survival. Maternal depletion syndrome, hypothesized to be the cumulative nutritional deficits experienced by mothers of high parity, has been linked to higher infant mortality.

The duration of time between pregnancies defines the interpregnancy interval. In settings where accurate reporting of a woman's dates of last menstrual periods or pregnancy termination is problematic, it is difficult to define conception dates or gestational age. Thus researchers often accept the interval between reported dates of live births as an alternative measure. The inter-birth interval (BI), however, masks the incidence of any fetal loss (miscarriages and induced abortions), and the empirical result is an artificial lengthening the interval. *Per se*, the interval between two births simply measures an exposure time or duration. It is in this period of time that events and behaviors, such as sexual abstinence, nutritional intake, physical activity, partner violence, and infection and other illnesses, occur which can affect maternal and newborn health. While a key demographic indicator, the birth interval is a fairly crude measure of exposure to the probability of a healthy conception.

Short birth intervals, usually defined as less than 18 months between live births, are indicative of conceptions occurring within 9 or fewer months since the preceding birth, assuming a normal gestation length of 9 months. Short BIs are associated with low birthweight and can reflect premature weaning of the preceding child, raising its risk of morbidity and mortality since its new sibling will be given priority at the breast. There are traditional practices of post-partum abstinence in some Sub-Saharan African settings, especially where polygamy is prevalent. Median durations of post-partum abstinence, based on the latest DHS esitmates, are as long as 11.8 months in Mozambique (2003), 12.2 months in Liberia (2007), and 21.3 months in Guinea (2005). While such customs appear to be weakening with earlier postpartum resumption of sex (Borda et al., 2010), an earlier resumption of unprotected sex increases the likelihood of conception and a short interpregnancy interval, with its attendant risks of low birth weight and premature mortality. At the other end of the distribution, long intervals, usually defined to be in excess of 60 months, have also been associated with increased infant mortality risk, possibly due to macrosomia or prolonged inactivity (physiological regression) of the reproductive system.

Young maternal age, high parity and short birth intervals have been accepted by the health and demographic research community as general indicators of infant and maternal morbidity and mortality risk. The three risk factors of maternal age, parity and birth intervals are inter-correlated. A high-parity birth usually means older maternal age and shorter intervals between births. A first birth carries its own exceptional risks especially for very young mothers. Efforts to model and isolate the individual effects of these three maternity factors can be confounded by the overlap in their distributions. An in-depth understanding of the underlying physiological and behavioral mechanisms and processes that affect these outcomes thus remains needed.

A healthy pregnancy is a strong determinant of health across the life span, where early life conditions – healthy fetal growth and development, nutrient intake, and sufficient time for maternal repletion through birth spacing – are accepted as protective of newborn health, particularly for females. Daughters born under optimal birth conditions are more likely to have strong immune systems and to develop physiologically to withstand the demands of single and repeated pregnancies and breastfeeding. In addition, girls with adequate nourishment through their teen years also enjoy improved fecundity and are less likely to experience adverse reproductive outcomes.

The early childhood research literature draws attention also to linkages between healthy fetal growth and the pace of cognitive development. Neuroscience studies identify the rapid pace of brain development in later gestation and the first three years of life. Maternal intake of key nutrients for brain development centers on consumption and absorption of protein, energy, certain fats, iron, zinc, copper, iodine, selenium, vitamin A, choline, and folate. These nutrients differentially affect neuronal cell growth and development of the central nervous system during late fetal and early neonatal periods. Cognitive abilities can be affected, including memory, reasoning, problem-solving and thinking. Neurodevelopment continues at an active pace through adolescence; and favorable learning environments, in family, community and schools, play important roles in reinforcing cognitive abilities and skills. In the arc of human development over the life span then--from birth to death--it is important to recognize the effects of healthy fetal origins on adult functioning and productivity. Cognitive abilities nurtured in childhood, but often compromised by conditions of poverty, are linked to school performance and educational attainment levels. In turn these are associated with economic advantages and gains in working adulthood.

The underlying physiological and cognitive changes during pregnancy and child growth and development are not explicitly measured in birth history data. However, birth histories collected in population surveys, particularly in low-income countries, can be used to study relationships between demographic markers, such as maternal risk factors, and reproductive, health and socioeconomic outcomes. The cross-national evidence base for national populations in low-income countries has been limited, though, with the cross-sectional design of DHSs and similar survey programs, such as the UNICEF Multiple Indicator Cluster Surveys. This paper applies a pseudo-cohort construction approach to link experiences at birth for females to those of their age counterparts in adulthood.

Study objective

In this study we assess the relationship between three key maternal risk factors present at the time of daughters' births and selected reproductive and socioeconomic outcomes in adulthood using cohorts as units of analysis. The three risk factors of interest are: 1) being born within a short interval of less than 18 months since the preceding sibling's birth; 2) being born to a mother who is young (under 18 years); and 3) being born at parity four or higher.

The reproductive outcomes of interest are: 1) short adult stature (<145 cms); 2) low adult body mass index (BMI <18.5); 3) delivery of low birth weight babies (reported by their mothers to be very small or small at birth); and 4) experience with child mortality.

The socioeconomic outcomes in adulthood of interest are: 1) female years of education and 2) female paid work status.[1]

Our hypotheses are tested at the cohort level, i.e., that cohorts of daughters born to mothers with these maternal risk factors will have proportionally worse outcome levels than cohorts of females born to mothers without these risks.

Source of data and measurement

[1] We will also explore as a socioeconomic outcome female adult's residence in a higher-wealth household.

Capitalizing on cross-sectional national survey data. For many developing countries, Demographic and Health Surveys (DHSs) are the only reliable sources of population-level information about maternal and child health. However, because of their cross-sectional nature, DHS data cannot be used to make causal inferences about life course effects. Our understanding about the influence of these risk factors at the population level has been based primarily on cross-sectional associations and some longitudinal analyses with sub-national data and limited generalizability. Meanwhile the volume of research on national cross-national surveys, like the DHS and MICS and the World Bank's Living Standard Measurement Surveys, continues to grow rapidly (Short et al., 2012). The ability to exploit multiple rounds of DHS data for longitudinal insights, though, has not been pursued with any frequency. (Hallett et al. (2010) who estimate HIV incidence between two DHS rounds, is one exception.) A panel investigation of the effects of maternal covariates on reproductive, child, or adult health and social outcomes can be informative, and the number of countries with an expanding time series of survey rounds increases every year. This raises the feasibility of linking aggregates of individuals sharing a common life event, such as birth or marriage year to track their health outcomes over time.

Constructing and linking birth cohorts. Unlike traditional panel data where individuals are followed and repeatedly measured, it is possible to construct a birth cohort by aggregating members born in the same year. Here we construct annual birth cohorts of daughters born in a given year in a 15-year period before the first available DHS survey in a given country.[2] These 15 birth cohorts are then linked to their 15 counterpart cohorts in each subsequent survey round for the same country. For example, daughters born in 1985 to female respondents in a country's

[2] We first used a ten-year period for births occurring before a DHS round because this is the same base of births used for infant mortality rates. We also tested cohorts constructed over a twenty-year period. To balance sample power and optimize on the age span for female adults, we have opted for births in the 15-year period prior to the DHS.

first DHS in 1990 are 5 years old. In a second survey round in 1995, the 1985 birth cohort from the 1990 survey is paired with the cohort of female births reported by 1995 survey female respondents to be born in 1985. For each subsequent survey, we can match the 1985 birth cohort from the base DHS to the same birth cohort of daughters reported by mothers in that round. In 1995, the 1985 cohort is age 10, and in 2000 they reach age 15, age 20 in 2005 and age 25 in 2010, assuming quinquennial survey rounds. In the 2000, 2005 and 2010 rounds, as females 15 years or older, they are eligible survey respondents and their height, weight and pregnancy experiences are collected. Their other adult health and socioeconomic outcomes can also be linked back to their birth cohort counterparts. We can also incorporate other covariates of the mothers from the base survey round for control variables. Further, we can replicate serially the pairing of cohort data constructed for daughters born in the 15 years prior to the following DHS round with their age counterparts in subsequent rounds, e.g., 15 single-year birth cohorts from 1990 paired to 15 cohorts of same-age female adult respondents interviewed in the 1995, 2000, 2005 and 2010 surveys and then for those daughters of 1995 survey respondents born in the 15 years prior paired to female respondents of the 2000, 2005 and 2010 surveys, and so on.

Figure 1 (right panel) illustrates the cohort linkage with four DHS rounds conducted in Kenya in 1988, 1993, 1998, 2003. The daughters aged 10 to 15 reported by mothers interviewed in 1998 are linked to their age counterparts aged 21 to 26 in the 2003 survey. Maternal risk and other individual covariates are measured at the time of their birth (1983 to 1988) while their outcomes are those subsequently reported by female survey respondents aged 21 to 26 in the 2003 survey round.

The left panel of Figure 1 shows daughters born between 1985 and 2000 are 0 to 15 years of age in an illustrative 2000 DHS round (green lines up to single blue line). The sample of those 10 to 15 years relates age-wise to the sample of 15 to 20 year old female respondents in the 2005 survey round (vertical red line). Thus these birth cohorts can be matched, aligning data on their conditions at birth (reported by the mothers who are female respondents in 2000) with data on their health status as young adult female respondents, age 15 to 20 year olds in 2005. (If a 2010 survey round occurred, the cohort data for 20 to 25 year olds is subsequently linked.)

This cohort, sometimes called a pseudo-cohort, approach has been used in labor economics and educational achievement studies (e.g., Deaton 1985; McIntosh, 2005) but only occasionally in public health investigations. Researchers (e.g., Verbeek and Nijman, 1992) have suggested that cross-sectional data constructed as cohorts can be treated as panel data, with some limitations. If these limitations can be addressed, analyses with constructed cohorts can enable insights into dynamic inter-generational relationships for child growth and development or event trajectories that otherwise are unavailable in LMICs given the paucity of large scale, longitudinal population data.

Cohorts are then the units of analysis and cohort-level means or averages are calculated from individual data of each survey round, connected as members, in our case, by the year of birth. Cohorts constructed from survey samples of individuals, however, are subject to measurement error. Whereas for individuals followed longitudinally their covariates and outcomes are observed repeatedly over time; with constructed cohorts we must rely on cohort means or averages. The accuracy of these summary statistics for aggregate units depends on the underlying coverage and size of the survey sample. For example, with longitudinal or panel data on individuals, each births and its birth order will be recorded. With cohort data, we can only calculate the average parity of members captured in the sample. The obtained cohort means are then consistent but potentially biased estimates of the true cohort values. Studies show that such measurement error, however, is negligible when the cohort size—number of members--is sufficiently large. In this paper, we are use means based on only cohorts with 100 or more members.

Another potential limitation of the pseudo-cohort approach for our analytic purposes is truncation bias. In our study, the upper age limit of 49 years for female respondents imposes such a constraint on observing long-term life outcomes. To track a female's reproductive history from birth through her reproductive lifespan requires countries have a long time series of DHSs, between the first and last round, for there to be sufficient exposure time to observe a cohort's reproductive behavior. Ten countries[3] allow observation of adult outcomes to ages 35 to 38 for daughters born in 15 years before the first survey. The average interval between first and last surveys is 10 years, allowing observation largely over the prime childbearing ages of 15 to 25 years. We tested this limitation by limiting the range of mean ages of the cohorts to 20 to 35 years and comparing the model coefficients from the two sets. The results were similar, suggesting that, for the time being, the effects of censoring are random. In general, truncation bias from a pseudo-cohort approach will be mitigated with future replications and as the time series of survey rounds and sample of countries increase.

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[3] Those countries with survey intervals of 20 years or more are: Burundi, Colombia, Dominican Republic, Ghana, Indonesia, Kenya, Liberia, Senegal, Uganda, and Zimbabwe.

Other limitations on using pseudo-cohorts as units of analysis include differential mortality and out-migration. Females who are acutely compromised in infancy may not survive to be represented by their age peers in subsequent surveys. If they are observed, these females may be selectively under-nourished and more likely to experience adverse pregnancy outcomes. The bias from unobservables associated with those who would have died, though, cannot be assessed.

The life course experiences of females who permanently migrate for work out of country or other reasons will also not be captured by their age peers in later survey rounds. The potential bias from out-migration for most countries is likely to be small while that from differential mortality may be more substantial. Our regression approach, however, will yield conservative estimates of risk factors' influences by measuring them only among surviving females who transition to motherhood.

Linked cohort data does offer at least two advantages over panel data. First, the cost of repeated cross-sectional surveys with standardized content that allow construction of cohort panels is much lower than for longitudinal surveys of comparable sample size. Second, cohort panels are not subject to bias from sample attrition the same way longitudinal surveys are; therefore they can cover a longer period of time. As long as the cross-sectional data are based on a representative sample of the population of interest and differential mortality or mortality is not a major issue, cohort data can provide consistent estimates of the parameters of interest.

Cohort measures of maternal risks. Measurement of risk factors at a daughter's birth is based on each live birth reported by the female respondent in each survey round in a given country. The latter's personal covariates, such as education level and place of residence at the time of the survey, are also incorporated for analysis. Nutritional and reproductive outcomes of interest are obtained from the cohort-linked female respondents in later surveys. For example, a 39-year old female respondent in a 1998 survey may report her fifth child to be a daughter born in 1984, at a calculated 30-month interval since the last older sibling and maternal age of 25 years. In 1998, the index daughter is 14 years old and we classify her as at risk as a high-parity birth but not at risk due to young maternal age or short birth interval. The daughter's birth year of 1984 is then aligned with female respondents in the 2003 DHS born in the same year who are age 19. At the cohort level, by aggregating across all daughters born in 1984 in the 1998 survey and all 2003 female respondents born in 1984, we can then associate risk factors at birth with adult reproductive experiences and socioeconomic status.

The cohort linkage as described above is carried out between all pairs of DHSs in the time series available for a given country. In Kenya, for example, we have 1993, 1998, 2003, and 2008 survey rounds, enabling us to link cohorts in the 1993-1998, 1998-2003, and 2003-2008 pairs of surveys. After limiting the sample of pseudo-cohorts to those with at least 100 members, we arrive at an analysis sample of 2,542 single-year birth cohorts across 200 DHSs for 50 countries.

Analytic framework and approach. The study's analytic framework is shown in Figure 2. There are noticeably few predictors for adult daughters, e.g., her maternal age at first birth or parity. In our effort here to focus on early life factors, we have deferred pursuing intergenerational effects on the daughters' reproductive experiences in adulthood. We are also constrained by the number of continuously measured variables across DHSs, which, for example, household wealth is not.

We estimate generalized linear regression models (GLM) for each of the reproductive and socioeconomic outcomes. The models include regions as dummy variables with robust variance estimation to adjust for correlated observations within. We estimate the outcomes models for the full sample of cohorts (2,542) and for those from the Sub-Saharan African region (1,386). The six reproductive and three socioeconomic outcomes are defined in Table 1. After the model estimations, we conducted a post-estimation simulation to predict the cohort proportions for each outcome by manipulating each of the three maternal risk factors. We predict the outcome proportions if no daughters are born to mothers at young maternal age, at high parity (4 plus) or within 18 months of the preceding birth. We also predict the outcome proportions if all three risk factors were eliminated. Finally, because anthropometry-based outcomes, such as short stature and BMI are not available from the earliest surveys, the analytic samples for these models is reduced to 1,985 cohorts across all countries and 1,153 cohorts for the SSA sample. The cohort sample size with birth size information is also smaller than the overall one, with 1,052 for all countries and 607 for sub-Saharan Africa.

For paid work, female and partner education outcomes, the cohort sample is reduced due to the late introduction of data collection on payment for work. Thus for this outcome, the cohort sample is 1,054 cohorts overall and 484 cohorts for Sub-Saharan Africa.

To assess bias from missingness, we carried out simulations on the samples of all cohorts and non-missing cohorts and found little difference. The results presented here are based on all cohorts.

Results

The description of the covariates and outcome variables of interest and values for their means, standard deviations and ranges are provided in Table 2. Exploratory data analysis did not raise any concerns about nonlinear distributions of the outcomes or covariates as potential violations of assumptions required for ordinary least squares regression. Nonetheless, GLM regression models were estimated and the results for all 2,542 cohorts and 1,386 in the Sub-Saharan African region are reported separately. Two child-related outcomes (mortality and low birthweight) are measured with different denominators, one based on all children born to mothers in the cohort and one based on the cohort mothers. We illustrate our findings using these two child loss measures--the cohort proportion of births dying before age 5 and the cohort proportion of mothers with a recent birth (3 to 5 years before the survey) dying before age 5.

Overall, our findings support our hypothesis that the proportion of risk factors present at the time of a daughter's birth increases the cohort proportion experiencing adverse health outcomes and decreases the cohort proportions experiencing socioeconomic wellbeing in adulthood. The coefficients and standard errors from the GLM models of cohort proportions are shown in Table 3.1 for all regions and in Table 3.2 for the Sub-Saharan Africa region. The effect sizes are sizeable, largely in the expected direction and often statistically different from 0. The strength of the effects tend to be weaker for socioeconomic, as opposed to health, outcomes.

For example, as seen in Table 3.1, for each percentage point increase in a female cohort born to mothers under 18 years old, that cohort's subsequent probability as mothers of ever experiencing child loss increases by 2.022 points. Similarly cohorts with high proportions born at parity 4 or higher, have an increase of 0.938 points in the proportion experiencing child loss. The counterpart increases for the SSA cohorts are 2.760 and 1.233 points, larger than the full sample's estimates. This is borne out by the SSA region's fixed effect of +0.552. The observed and simulated proportions are illustrated in Figure 3.

The effect of short birth intervals on child loss, while not statistically significant, is in the expected direction, indicating that the higher the proportion of short intervals in the cohort, the higher the proportion experiencing child loss. In the SSA sample, the coefficient (1.509) is similarly positive and large, although not statistically significant.

The effects for most risk factors in Sub-Saharan African cohorts are larger than those for all countries combined and more often statistically significant. Cohorts with high proportions of daughters born to mothers with any education are observed to have better reproductive and nutritional status outcomes. Being born to mothers residing in urban areas at the time of the base survey does not show any consistent pattern of effects.

Regarding the socioeconomic outcomes, for the full sample of cohorts, the effect of being born to a young mother (<age 18) is significantly negative on the daughter's paid work status in adulthood (coeff = -4.315, $p<.10$) and on her years of schooling (coeff = -2.194) although not significantly. Being born at high parity also shows a negative coefficient (-0.983, ns) associated with the proportion of adult daughters currently with paid work, while a short birth interval shows a positive effect (+1.014, ns). A similar pattern with coefficients having higher values is observed for SSA cohorts.

For the full cohort sample, two of the three maternity risk factors lower the cohorts' average number of years of education—young maternal age (coeff=-2.194, ns) and short birth intervals (coeff=-3.630, ns) while high parity increases it (+1.585 years, p<.10). Among the SSA cohorts, higher proportions in all three maternity risk factors are associated with lower years of schooling, particularly those reflecting large families, i.e., high parity and short birth intervals.

A strong intergenerational relationship between maternal education and daughters' schooling is observed. The higher the proportion of daughters born to mothers with any schooling the greater the increase in average number of daughters' years of schooling (coeff=+7.426, p<.01). The relationship is similarly strong for SSA cohorts (coeff=7.401, p<.01).

The post-estimation predicted proportions are given in Table 4 and selectively illustrated in Figures 3 and 4. The post-estimation simulation shows that eliminating high risk births reduces the observed cohort of children dying before age 5 from 0.084 (equivalent to 84 deaths by age 5 per 1000 births) to as low as 0.062 if all high parity births were eliminated. For the proportion of mothers ever reporting a child dying before age 5, the observed proportion of 0.187 declines to 0.154 if all three maternal risk factors are eliminated, while the largest reduction is to 0.12 with the elimination of parity 4-plus births. In Sub-Saharan Africa, the observed proportion of mothers reporting child loss is higher, at 0.231 with the elimination of all three factors having the potential to reduce it to 0.061.

Discussion

Our analysis of data from low-income countries aimed to assess life course impacts of maternal risk factors at daughters' birth on their adult reproductive and socioeconomic outcomes. Pseudo-cohorts were constructed using birth history and respondent reports from cross-sectional rounds of Demographic and Health Surveys conducted in 50 developing countries between 1986 and 2012. National longitudinal surveys of health and development are rare in low resource settings and the expansive series and sample sizes of DHSs enable linking summary measures for birth cohorts over time. The limited number of economic variables such as household wealth can only be assessed as an outcome and is limited to a smaller number of countries with recent surveys. We endeavored to proxy socioeconomic welfare using school attainment of the adult daughter and observe a strong intergenerational relationship between maternal and daughters' schooling. This may reflect physical health advantages conferred on daughters as a result of their mothers' healthy patterns of childbearing.

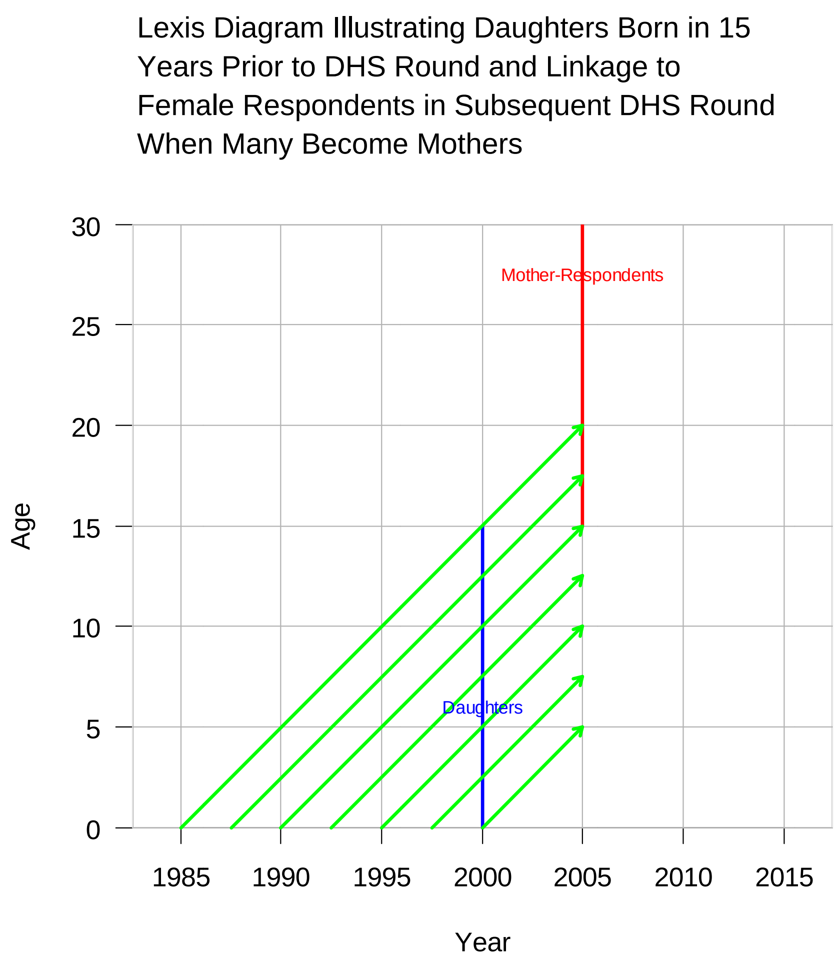
With the exception of paid work in adulthood, the simulated proportions uniformly show that elimination of all maternal risk factors lowers the observed level of adverse reproductive health outcomes and increases average years of schooling for adult daughters, both in the overall and SSA cohort samples. The proportion experiencing paid work increases only if high parity births are eliminated (from 0.335 to 0.413) and only in the full sample of cohorts.

Our analysis is not without limitations, some of which are methodological and accompany the application of the pseudo-cohort approach, e.g., truncation bias, differential mortality and respondent loss due to out-migration. Truncation bias can be mitigated over time with the growing number of DHS surveys, particularly extending the time series in sub-Saharan African countries. We have also tested restricting the age range for cohort members and found little difference in the regression results. Selective mortality, particularly due to unobservable factors, is not a bias easily addressed by this cohort approach. Out-migration bias, on the other hand, is likely to have small statistical impact on our findings. There is likely empirical heterogeneity in the reproductive and socioeconomic experiences of the cohort members both at birth and in adulthood. The covariance in cohort proportions will be more constrained and larger standard errors will result in less statistical significance. However, the direction and magnitude of the effects observed are in the expected directions and interpreted as acceptable support for the study hypothesis and methodological approach.

While a more comprehensive understanding of the reproductive and biological pathways that connects gestational and newborn health with growth and development over the life course is much needed, findings from this analysis give some credence to the linkages between demographic indicators of healthy childbearing and adult health and socioeconomic wellbeing. The results support findings in the research literature related to birthspacing, maternal age and parity and levels of risk for infant and child mortality. Such risks are preventable. Direct and indirect interventions exist that can eliminate compromising factors at birth, such as through adequate birth spacing with prolonged breastfeeding, improved girl and maternal nutrition, contraceptive practice, and extended schooling to delay early childbearing. These have the potential to prevent adverse birth outcomes over long run and in an enduring manner.

This analysis has aimed to generate knowledge of selected risk factors' influences in mediating the relationships between maternal health and pregnancy conditions and adult reproductive health and socioeconomic outcomes. Such knowledge can reinforce the design and provision of interventions to alleviate the adverse impacts of risk factors at birth and reducing infant and child mortality. A final contribution of this study is methodological by expanding the set of statistical tools available to test hypotheses using large-scale, standardized, repeated cross-sectional survey data in a longitudinal manner. The approach also confers considerable resource efficiency to future panel analyses.

Figure 1. Illustration of Birth Cohort Construction and Linkage across DHS Rounds



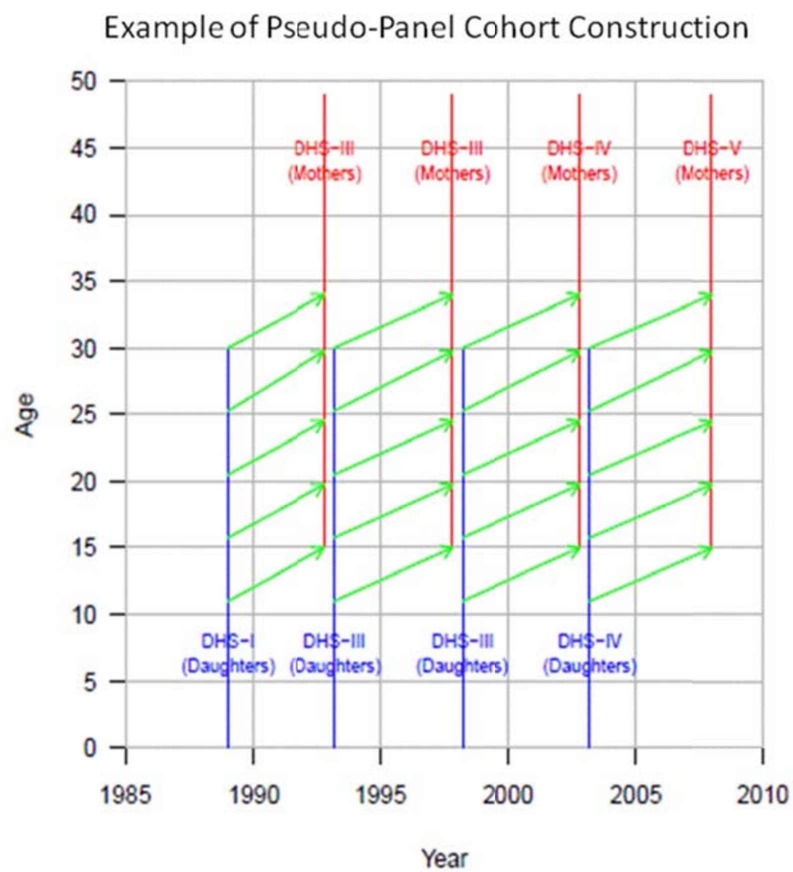


Figure 2. Analytic Framework

Birth cohorts as units of analysis

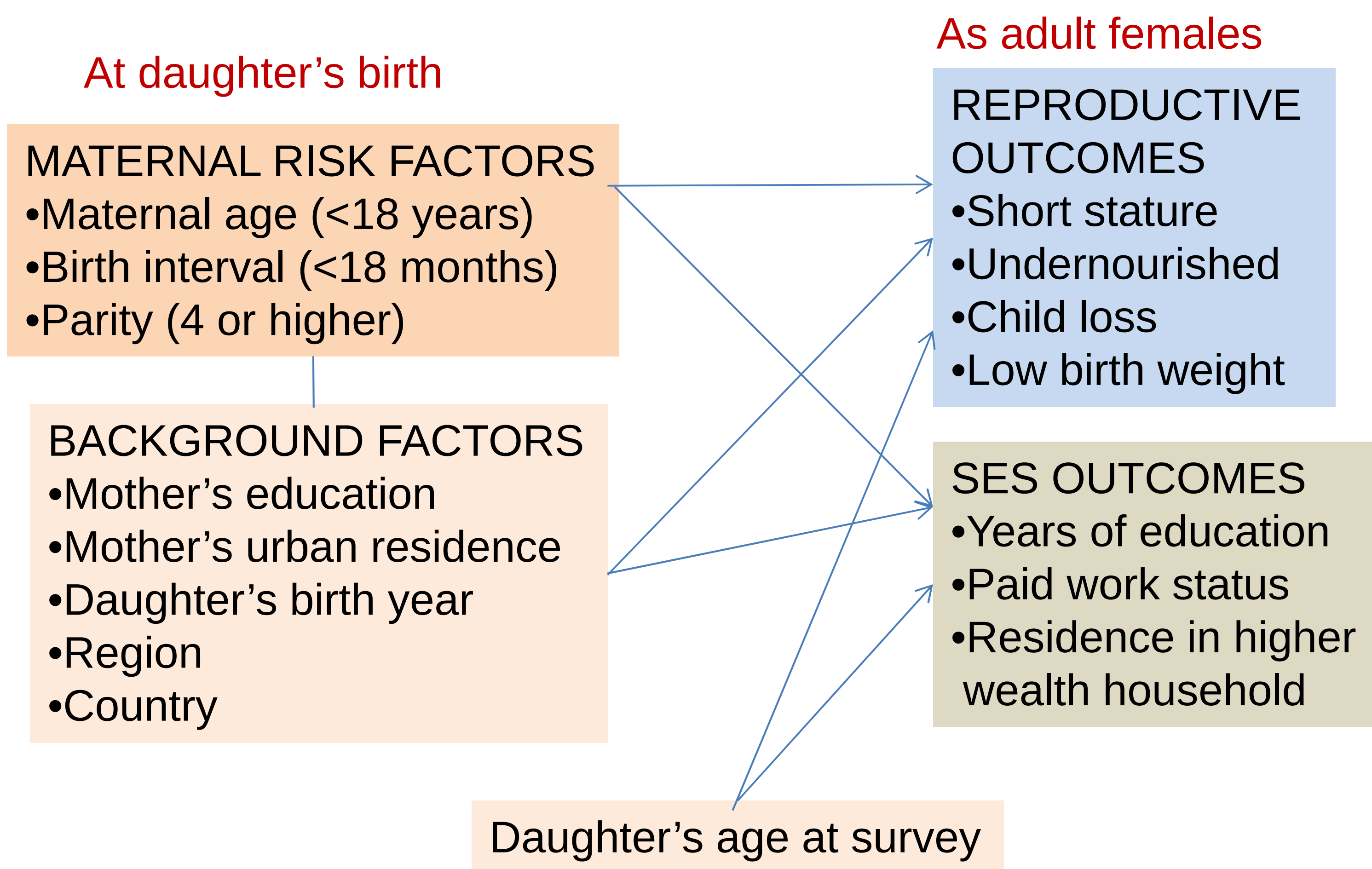


Figure 3. Observed and Predicted Cohort Proportions of Mothers Experiencing Child Loss before Age 5 by Type of Maternal Risk Factor Eliminated and Region

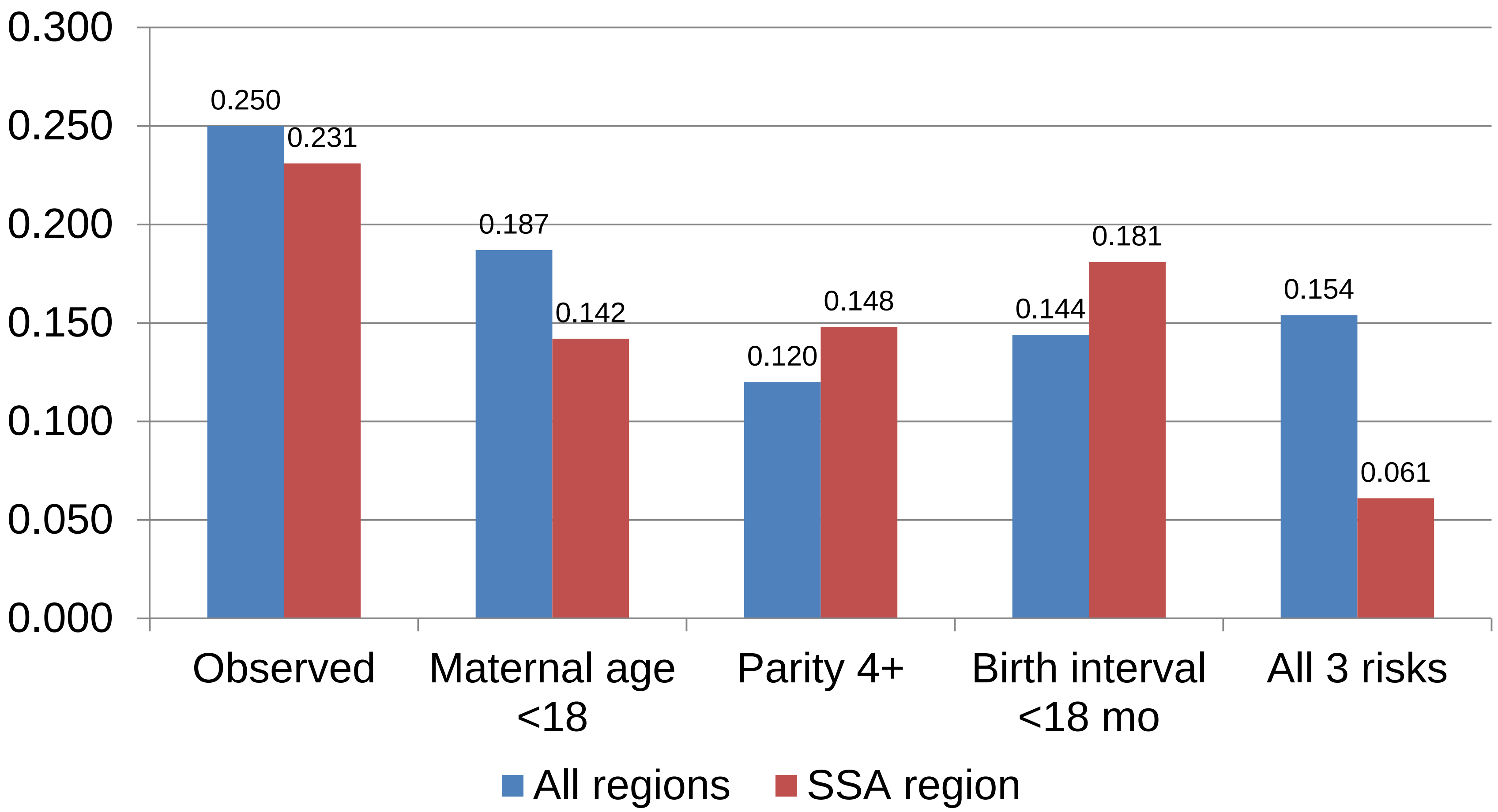


Figure 4. Observed and Predicted Cohort Average Years of Education for Adult Daughters by Type of Maternal Risk Factor Eliminated and Region

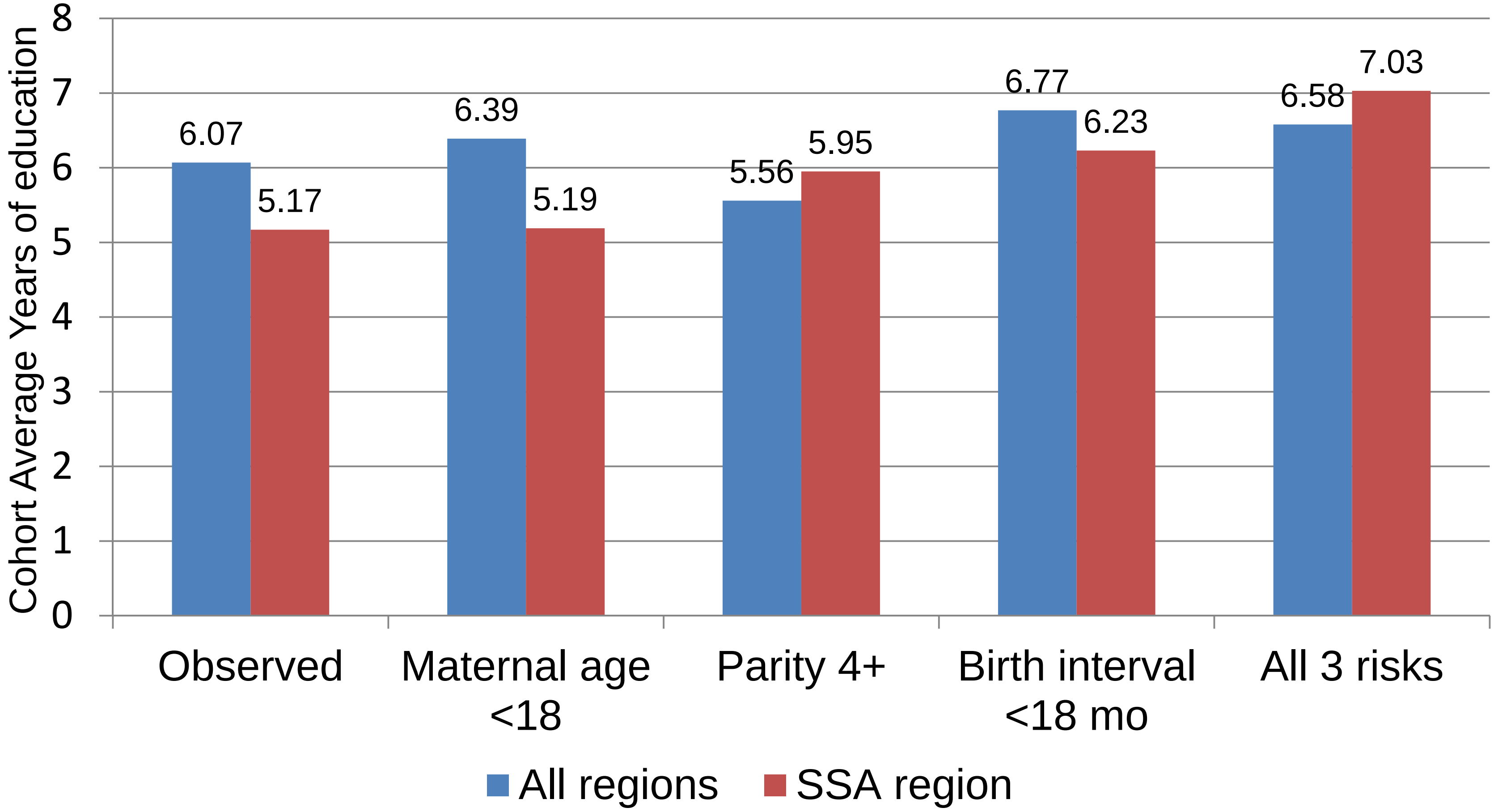


Table 1. Definitions of Cohort Measures of Reproductive and Socioeconomic Outcomes

Cohort-level Measure	Definition
Reproductive Outcome	
Proportion of children who died before age 5	Proportion of births to women in cohort reported to have died before age 5
Proportion of children reported to have died at any time	Proportion of births to women in cohort reported to have died at any age
Proportion of mothers who report ever losing a child	Proportion of mothers in cohort who report ever any child loss
Proportion of mothers who report ever losing a child by age 5	Proportion of mothers in cohort who report any child loss by age 5
Proportion of children reported born small	Proportion of recent births reported by mothers to be born very small or small
Proportion of females ever having a small baby	Proportion of mothers reporting a recent birth to be born very small or small
Proportion of adult daughters with BMI < 18.5	Proportion of female respondents in linked birth cohort with body mass index of 18.5 or less
Proportion of adult daughters with height < 145 cm	Proportion of female respondents in linked birth cohort with height under 145 cms
Socioeconomic Outcome	
Proportion of adult daughters with paid work	Proportion of female respondents in linked birth cohort who are currently working and being paid in cash or kind
Adult daughter's average years of education	Average years of education of female respondents in linked birth cohort
Adult daughter's household wealth	Proportion of adult daughters residing in households falling into the two highest wealth quintiles
Maternal Risk Factors	
Maternal age<18 at daughter's birth	Proportion of mothers under age 18 at time of daughters' birth
Daughter born parity 4 or higher	Proportion of daughters born at parity four or higher
Daughter born within 18 months of preceding birth	Proportion of daughters born within 18 months of preceding birth
Covariates	
Maternal education	Proportion of daughters born to mothers with any schooling
Maternal residence in urban area	Proportion of daughters born to mothers living in urban areas at time survey
Birth year of daughter's cohort	Year of birth for daughter
Age of daughters at outcome survey round	Average age of daughter at time of reproductive/socioeconomic outcome
Age of daughters at covariate survey round	Average age of daughter time when covariates measured (round when mother is survey respondent)

Table 2. Means, Standard Deviations and Minimum/Maximum Values of Cohort Prportions on Reproductive Health and Socioeconomic Outcomes by Region

Cohort measure	All regions (n=2542)				SSA (n=1386)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Proportion of children who died before age 5	0.079	0.046	0.000	0.300	0.100	0.047	0.000	0.300
Proportion of mothers who report ever losing a child by age 5	0.125	0.093	0.000	0.597	0.166	0.103	0.000	0.597
Proportion of children reported born small	0.142	0.073	0.000	0.439	0.128	0.068	0.021	0.403
Proportion of females ever having a small baby	0.147	0.064	0.000	0.376	0.151	0.065	0.006	0.318
Proportion of adult daughters with BMI < 18.5	0.113	0.092	0.000	0.571	0.121	0.069	0.000	0.472
Proportion of adult daughters with height < 145 cm	0.042	0.054	0.000	0.464	0.022	0.023	0.000	0.212
Proportion of adult daughters with paid work	0.330	0.174	0.006	0.839	0.388	0.160	0.067	0.839
Adult daughter's average years of education	6.881	2.557	0.712	12.263	5.253	2.246	0.712	9.813
Adult daughter's household wealth								
Maternal age<18 at daughter's birth	0.097	0.044	0.000	0.256	0.108	0.039	0.000	0.235
Daughter born parity 4 or higher	0.425	0.076	0.064	0.619	0.454	0.054	0.271	0.584
Daughter born within 18 months of preceding birth	0.156	0.064	0.018	0.431	0.125	0.042	0.018	0.293
Maternal education	0.555	0.263	0.065	1.000	0.465	0.242	0.065	0.983
Maternal residence in urban area	0.349	0.165	0.074	0.849	0.278	0.107	0.086	0.679
Birth year of daughter's cohort	1983.7	5.4	1971.0	1996.0	1984.0	5.3	1971.0	1995.0
Age of daughters at outcome survey round	21.76	4.66	16.00	39.00	21.85	4.77	16.00	38.00
Age of daughters at covariate survey round	9.18	3.88	0.00	14.00	9.04	3.93	0.00	14.00
Proportion of cohorts in region								
Central, South and Southeast Asia (438)	0.172							
Latin America and Caribbean (487)	0.191							
North Africa/West Asia/Eastern Europe (235)	0.092							
Sub-Saharan Africa (1386)	0.544							

Table 3.1 Results of Generalized Linear Model Estimation of Cohort Proportions for Reproductive and Socioeconomic Outcomes in 50 Developing Countries Regressed on Maternal Risk Factors, Maternal Attributes and Region

	All regions							
Covariate	Proportion of children died before age 5	Proportion of mothers who report ever losing a child before age 5	Proportion of births reported born small	Proportion of mothers reporting ever having a small baby	Proportion of adult daughters with BMI < 18.5	Proportion of adult daughters with height < 145cm	Proportion of adult daughters currently with paid work	Average years of education for adult daughters
Maternal education	-0.698***	-0.819***	-0.578***	-0.546***	-0.822**	0.549	0.242	7.426***
	(0.249)	(0.301)	(0.191)	(0.197)	(0.347)	(0.604)	(0.384)	(0.677)
Maternal age<18	2.022***	3.215***	-1.416**	2.110**	2.303*	2.108	-4.315***	-2.194
	(0.707)	(0.792)	(0.642)	(0.919)	(1.239)	(1.280)	(1.216)	(2.596)
Born in parity>=4	0.938*	1.212**	0.928**	1.959***	0.145	0.188	-0.983	1.585
	(0.486)	(0.538)	(0.458)	(0.554)	(0.883)	(1.685)	(0.985)	(1.777)
Birth Interval<18m	0.697	1.365	1.026*	2.055***	0.646	0.411	1.014	-3.630
	(0.714)	(0.836)	(0.583)	(0.650)	(1.291)	(2.032)	(1.358)	(2.649)
Maternal residence in urban area	-0.037	-0.053	0.316	0.322	-0.091	-2.290	0.322	-0.337
	(0.330)	(0.401)	(0.302)	(0.334)	(0.556)	(1.459)	(0.524)	(1.174)
Birth year of the cohort	-0.026***	-0.023***	0.001	0.001	0.013	-0.041*	0.010	0.044*
	(0.005)	(0.006)	(0.006)	(0.006)	(0.010)	(0.024)	(0.025)	(0.026)
Age of cohort at outcome survey	-0.021***	0.055***	-0.119***	0.029***	-0.059***	-0.054***	0.113***	0.085***
	(0.005)	(0.007)	(0.006)	(0.007)	(0.011)	(0.017)	(0.015)	(0.026)
Region (Latin America and Caribbean=Ref)								
North Africa/West Asia/Europe	-0.377**	-0.499**	-0.429**	-0.265*	-0.969*	-2.192***	-1.986***	1.070*
	(0.175)	(0.193)	(0.168)	(0.139)	(0.541)	(0.379)	(0.167)	(0.565)
Central Asia/South & Southeast Asia	0.258	0.086	-0.149	-0.053	1.313***	-0.029	-0.412**	-0.214
	(0.175)	(0.183)	(0.141)	(0.143)	(0.431)	(0.841)	(0.170)	(0.469)
Sub-Saharan Africa	0.552***	0.625***	-0.325**	-0.078	0.543	-1.701**	0.368**	-1.459***
	(0.179)	(0.195)	(0.137)	(0.129)	(0.385)	(0.658)	(0.170)	(0.443)
Constant	48.833***	41.731***	-1.728	-5.720	-26.502	80.174	-23.587	-86.436
	(10.043)	(11.821)	(12.351)	(11.988)	(20.441)	(48.203)	(50.696)	(51.859)
Cohort observations	2,542	2,542	1,052	1,052	1,985	1,985	1,054	2546

Regression coefficients shown with standard errors in parentheses

*p<0.10 **p<0.05 ***p<0.001

Table 3.2 Results of Generalized Linear Model Estimation of Cohort Proportions for Reproductive and Socioeconomic Outcomes in 27 Sub-Saharan African Countries Regressed on Maternal Risk Factors and Attributes

Covariate	Proportion of children died before age 5	Proportion of mothers who report ever losing a child before age 5	Proportion of births reported born small	Proportion of mothers reporting ever having a small baby	Proportion of adult daughters with BMI < 18.5	Proportion of adult daughters with height < 145cm	Proportion of adult daughters currently with paid work	Average years of education for adult daughters
Maternal education	-0.480	-0.517	-0.548**	-0.497**	-0.859**	0.955	0.287	7.401***
	(0.292)	(0.348)	(0.258)	(0.219)	(0.379)	(0.669)	(0.541)	(0.767)
Maternal age<18	2.760***	3.842***	-0.297	3.445**	0.581	-1.752	-4.475	-0.167
	(0.787)	(1.089)	(0.952)	(1.439)	(2.109)	(2.405)	(3.061)	(4.286)
Born in parity>=4	1.233**	1.904***	0.699	2.653***	0.813	0.138	-1.740	-2.184
	(0.512)	(0.681)	(0.499)	(0.612)	(0.834)	(0.989)	(2.003)	(1.731)
Birth Interval<18m	1.509	2.202*	0.849	1.937**	1.570	4.569	2.225	-7.436*
	(0.914)	(1.100)	(0.841)	(0.726)	(1.796)	(3.261)	(1.481)	(4.010)
Maternal residence in urban area	0.393	0.483	0.013	0.030	-0.127	-0.894	0.654	-2.109
	(0.285)	(0.402)	(0.373)	(0.403)	(0.628)	(1.051)	(0.627)	(1.295)
Birth year of the cohort	-0.027***	-0.023***	0.001	0.006	0.008	0.009	0.000	-0.026
	(0.006)	(0.007)	(0.007)	(0.008)	(0.010)	(0.017)	(0.035)	(0.020)
Age of cohort at outcome survey	-0.017**	0.068***	-0.118***	0.043***	-0.054***	-0.052***	0.097***	-0.009
	(0.007)	(0.008)	(0.006)	(0.006)	(0.013)	(0.019)	(0.021)	(0.019)
Constant	51.763***	41.544***	-1.517	-15.344	-17.291	-20.999	-2.314	55.083
	(11.408)	(14.039)	(14.831)	(15.414)	(20.079)	(33.527)	(70.431)	-40.041
Cohort observations	1,386	607	607	1,153	1,153	484	484	1386

Regression coefficients shown with standard errors in parentheses
*p<0.10 **p<0.05 ***p<0.001

Table 4. Observed Cohort Proportions and Simulated Proportions with Maternal Risk Factor Eliminated: All Regions and Sub-Saharan Africa Only

Outcome	Expected proportion with elimination of risk factors	All regions		SSA	
		Mean	SD	Mean	SD
Proportion of children who died before age 5	Observed	0.084	0.037	0.109	0.032
	Maternal age<18	0.084	0.037	0.074	0.016
	Born in parity>=4	0.062	0.023	0.075	0.031
	Birth Interval<18m	0.064	0.032	0.090	0.024
	All three risk factors	0.075	0.034	0.040	0.008
Proportion of mothers who report ever losing a child before age 5	Observed	0.187	0.133	0.231	0.136
	Maternal age<18	0.187	0.133	0.142	0.074
	Born in parity>=4	0.120	0.070	0.148	0.123
	Birth Interval<18m	0.144	0.126	0.181	0.110
	All three risk factors	0.154	0.116	0.061	0.041
Proportion of children reported born small	Observed	0.116	0.084	0.117	0.077
	Maternal age<18	0.116	0.084	0.121	0.078
	Born in parity>=4	0.133	0.090	0.092	0.059
	Birth Interval<18m	0.087	0.061	0.107	0.072
	All three risk factors	0.100	0.076	0.086	0.055
Proportion of mothers reporting ever having a small baby	Observed	0.156	0.056	0.152	0.052
	Maternal age<18	0.156	0.056	0.095	0.027
	Born in parity>=4	0.118	0.032	0.070	0.044
	Birth Interval<18m	0.094	0.056	0.119	0.038
	All three risk factors	0.110	0.034	0.030	0.010
Proportion of adult daughters with BMI < 18.5	Observed	0.103	0.070	0.103	0.040
	Maternal age<18	0.103	0.070	0.096	0.039
	Born in parity>=4	0.076	0.053	0.078	0.027
	Birth Interval<18m	0.099	0.068	0.085	0.035
	All three risk factors	0.094	0.066	0.059	0.023
Proportion of adult daughters with height < 145cm	Observed	0.052	0.051	0.018	0.010
	Maternal age<18	0.052	0.051	0.022	0.011
	Born in parity>=4	0.038	0.033	0.017	0.009
	Birth Interval<18m	0.049	0.049	0.010	0.006
	All three risk factors	0.048	0.047	0.011	0.006
Proportion of adult daughters with paid work	Observed	0.335	0.163	0.384	0.146
	Maternal age<18	0.335	0.163	0.380	0.144
	Born in parity>=4	0.413	0.189	0.341	0.149
	Birth Interval<18m	0.330	0.163	0.356	0.139
	All three risk factors	0.316	0.158	0.310	0.138
Adult daughter's average years of education	Observed	6.072	2.244	5.168	1.852
	Maternal age<18	6.394	2.168	5.193	1.849
	Born in parity>=4	5.558	2.247	5.949	1.871
	Birth Interval<18m	6.773	2.343	6.225	1.794
	All three risk factors	6.579	2.303	7.031	1.789

Elimination of maternal risk factors individually and then collectively