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Research Article

Learning and reproductive health: Do early cognitive skills contribute to better sexual and reproductive health outcomes among adolescents in Ethiopia?

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Abstract

BACKGROUND
Understanding the relationship between early learning and later fertility preferences and knowledge could yield important lessons for public policy in both the education and health sectors.

METHODS
With data from the Young Lives study in Ethiopia, we use linear regression models to evaluate how reading and numeracy skills during middle childhood (age 8) and early adolescence (age 12) affect sexual and reproductive health (SRH) knowledge and desired fertility during middle adolescence (age 15). Additionally, we analyze whether learning trajectories are associated with these outcomes, and we test gender differences for all analyses.

RESULTS
We find that better skills in numeracy are most consistently associated with higher SRH knowledge. Reading skills are most consistently associated with wanting fewer children and, to a lesser degree, wanting a first child at a later age. We also find that learning trajectories matter, particularly for better SRH knowledge and wanting fewer children.

CONCLUSION
These findings suggest that learning indicators, specifically literacy and numeracy, are possible antecedents on pathways between education and improved SRH outcomes.

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CONTRIBUTION
Overall, our study provides critical new evidence showing that children's early learning experiences may influence their fertility preferences and SRH knowledge during adolescence.

1. Introduction

Sexual and reproductive health (SRH), including the number and timing of children, is shaped by several factors, such as access to services, gender norms, fertility desires, SRH knowledge, and education. The role of education in influencing fertility outcomes has remained a subject of considerable interest in global development. However, much of the evidence on how education impacts fertility preferences and knowledge, which are pathways to fertility outcomes, focuses on educational attainment (Psaki et al. 2019). When studying sub-Saharan Africa (SSA), where the expansion of education has coincided with poor education quality and learning outcomes (Pritchett 2013) and where desired fertility is high compared to other regions (Bongaarts and Casterline 2013), it is important to move beyond educational attainment to understand the impact of learning on pathways that affect adolescents' fertility. From a policy perspective, distinguishing between different aspects of education, including learning, and how they are associated with pathways to critical health outcomes could inform evaluations of the full impact of investments in education.

Learning outcomes are typically measured through literacy or numeracy at a single point in time, but a growing literature has recognized that learning is not static (Bau, Das, and Chang 2021; Kaffenberger 2019). Early learning outcomes are linked to individuals' learning outcomes at later ages, demonstrating that "skills beget skills" (Cunha et al. 2006). Indeed, evidence using longitudinal data demonstrates that skills can change over time (Rolleston 2014) or be lost after school dropout and that learning loss may bear implications for fertility behavior (Soler-Hampejsek et al. 2018). Empirically, students' learning outcomes may remain unchanged or may improve or worsen as they progress to higher grades. We refer to this change in learning outcomes over time as a learning trajectory.

Both literacy and numeracy skills at a single point in time and learning trajectories may affect SRH knowledge and fertility preferences directly or through other educational pathways, such as school dropout and lower educational attainment for students with poor learning outcomes (Kaffenberger, Pritchett, and Viarengo 2021). Examining patterns of learning both in the cross section and over time may thus reveal important insights for how learning is associated with fertility-related outcomes.

Using longitudinal data from the Young Lives study (Duc et al. 2022; Sanchez et al. 2022) in Ethiopia – where evidence shows that learning levels are low and fertility is high (UNESCO 2024) – our study examines how reading and numeracy skills during middle childhood (age 8) and early adolescence (age 12) impact desired fertility and SRH knowledge during middle adolescence (age 15), by gender and age. Additionally, we analyze whether learning trajectories in reading and numeracy are associated with these outcomes. Our primary research questions are as follows:

1. Are earlier learning outcomes associated with the formation of fertility desires and SRH knowledge during middle adolescence?
2. Do children whose performance remains unchanged, or who experience improvement or deterioration in their learning outcomes, differ in reported fertility desires and SRH knowledge?
3. Are there gender differences in these relationships?

The rest of this paper is organized as follows: The next section details background and contextual evidence on key relationships of interest. We then estimate linear regression models to analyze whether numeracy and reading skills at ages 8 and 12 are associated with three standardized outcomes at age 15: ideal number of children, ideal age at first birth, and an SRH knowledge score. In addition, we estimate similar models for learning trajectories. We conclude with a discussion of our findings.

2. Background

2.1 Education, fertility desires, and SRH knowledge

Empirical evidence shows strongly significant associations and mixed causal evidence of the relationship between educational attainment and fertility preferences. Recent analyses of demographic and health survey (DHS) data from 34 SSA countries showed that an increase in the level of education was associated with a decrease in fertility desire among women and girls aged 15–49 at both the individual and community level (Kebede, Striessnig, and Goujon 2021).

However, a systematic review that analyzed the causal relationship between education and reproductive health outcomes, accounting for bias from reverse causality and unobserved variables, showed mixed evidence of a causal link between education and fertility preferences (Psaki et al. 2019). The authors of this review found that most studies based in SSA used quasi-experimental methods to examine such a link, and while some have found support for an inverse relationship with desired fertility among women

(Behrman 2015; Chicoine 2016; Grepin and Bharadwaj 2015; Keats 2018; Mocan and Cannonier 2012), others have found no relationship among both women (Argaw 2013) and men (Keats 2018; Mocan and Cannonier 2012). A study that used a randomized design and provided scholarships for free access to secondary school to both boys and girls in Ghana resulted in increased years of schooling and cognitive test scores but had no impact on desired fertility (Duflo, Dupas, and Kremer 2021). Speculatively, inconsistency in results may be driven by differences in methods, context, the age of children exposed to an intervention, and/or the types of interventions (e.g., primary vs. secondary school policies and incentives).

In Ethiopia, which is the focus of this paper, two studies that used DHS data to exploit variation in access to school through the implementation of universal primary education policies found that an additional year of schooling resulted in a reduction of 0.27 (Chicoine 2016) and 0.34 (Behrman 2015) in women's ideal number of children. Separately, a study that used variation in a policy that introduced mother tongue instruction and eliminated a national exam at the end of primary school in Ethiopia found no impact on the ideal number of children among women (Argaw 2013).

Previous studies also provide some support for causal links between education and different types of SRH knowledge. Similar to evidence for desired fertility, quasi-experimental studies in SSA have found a positive impact of educational attainment on women's knowledge about modern contraceptives, the fertile period, and HIV transmission in some contexts (Argaw 2013; Behrman 2015; Keats 2018). In Ethiopia, two studies showed that an increase in women's educational attainment resulted in improvements in knowledge of the fertile period (Argaw 2013), HIV transmission, and access to condoms (Behrman 2015). Critically, most of the evidence linking education with fertility desires and SRH knowledge focuses on educational attainment, not learning.

2.2 Learning, fertility desires, and SRH knowledge

A systematic review on causal evidence linking education and fertility found no studies that analyzed the relationship between learning and fertility (Psaki et al. 2019). However, the authors did find some evidence that showed improvements in academic skills because of increased educational attainment, suggesting that literacy and numeracy could plausibly lie on the pathway between education and health outcomes (Psaki et al. 2019). Yet such improvements in academic skills are not a guaranteed consequence of higher educational attainment, particularly in contexts like SSA, where increased school enrollment and attainment have not always led to improved learning outcomes (Pritchett 2013). This warrants the need to understand whether skills are an important mechanism through which education impacts fertility and the pathways associated with it, including fertility preferences and knowledge.

Although empirical evidence of such a link is limited, evidence from studies that examine learning and other outcomes shows promise. Using DHS data from 50 countries, Kaffenberger, Pritchett, and Viarengo (2021) created a literacy-adjusted measure of educational attainment and showed that it was associated with greater reductions in women's fertility compared to measures that used only educational attainment. Separately, work by Smith-Greenaway (2013) used DHS data from Nigeria to show that mothers' reading skills are strongly associated with child mortality among mothers who never attended secondary school. Another study examined the relationship between academic skills, including both literacy and numeracy, and HIV and HSV-2 incidence in Malawi and found no evidence of an association but reiterated the importance of building evidence on how academic skills affect reproductive health (Mensch et al. 2019). Evidence on other outcomes, including fertility desires and SRH knowledge, would strengthen the case for improving learning outcomes beyond their importance for educational and labor market outcomes.

The theoretical pathways that link learning with desired fertility and SRH knowledge are similar to those that link educational attainment with these outcomes. Better literacy and numeracy skills may impact SRH knowledge and fertility desires directly by changing or increasing access to sources of information (Mare and Maralani 2006) or by encouraging the process of thinking of future fertility goals in numerate terms. Other pathways may be more indirect. First, better learning outcomes may allow progression to higher grades, where students may be exposed to knowledge about SRH directly through comprehensive SRH education programs in school, if available (Behrman 2015). Second, literacy and numeracy skills may change or increase access to sources that can influence attitudes and preferences inside school through, for example, social and sexual networks (Mare and Maralani 2006) and outside school through channels such as mass media, digital media, and the health system (Reed, Briere, and Casterline 1999). Third, those with better skills may have a greater opportunity cost of higher desired fertility due to higher career aspirations and the ability to earn more income, leading to altered fertility preferences (Duflo, Dupas, and Kremer 2015; Jejeebhoy 1995; Lloyd and Mensch 1999). Fourth, a learning-driven increase in future income may allow access to better health services and general health-related information and an ability to communicate with health care providers more effectively. This could potentially reduce infant and child mortality and indirectly lower desired fertility due to increased expectations of child survival (LeVine et al. 2011; Schnell-Anzola, Rowe, and LeVine 2005; Shapiro and Tenikue 2017).

2.3 Learning trajectories

A growing literature has emphasized the need to understand low learning levels in low- and middle-income countries (LMICs) by examining learning trajectories, though evidence remains largely descriptive. Learning trajectories track changes in learning over time to determine whether students' learning levels improve, deteriorate, or remain unchanged as they progress to higher grades. Existing empirical evidence mainly uses cross-sectional data to define learning trajectories, showing cohort-level changes in learning over different levels of education (Kaffenberger 2019). Such evidence has revealed that despite progression to higher grades, children's learning does not improve in some LMICs. However, a few studies have used longitudinal data to explore trends in test scores over time. A study using a unique longitudinal dataset from Pakistan, with age-appropriate tests designed and administered for three subjects over time, showed considerable learning gains as students progressed between grades 3 and 6 (Bau, Das, and Chang 2021). The authors also warned that despite this trend, learning can continue to vary, with improvement followed by "stagnation or reversals."

We know of three studies using Young Lives data that have examined learning trajectories in Ethiopia, Vietnam, Peru, and India. Evidence from these studies showed that initial achievement predicts later performance on cognitive tests and educational attainment and that gender gaps in learning widen over time, but only in some contexts (Rolleston 2014; Singh and Krutikova 2017). In addition, low performance in math at ages 8 and 12 was associated with school dropout at ages 12 and 15 for a combined sample of all four countries (Kaffenberger, Pritchett, and Viarengo 2021). This literature has thus far not examined the relationship between learning trajectories and fertility-related outcomes.

Theoretically, the pathways from learning to fertility preferences and SRH knowledge highlighted earlier may also apply to learning trajectories, but the direction of learning trajectories may determine the strength of these pathways. Learning trajectories thus provide an additional perspective on when it is important to acquire learning skills, whether catch-up in learning has the same impact as having better skills earlier in life, and the implications of losing skills in terms of their association with later SRH-related outcomes. For instance, children may consistently learn poorly because of weak early foundational skills, and this trajectory of continued poor learning might make them particularly vulnerable to early school dropout and lower educational attainment. The inability to recover from earlier learning deficits may thus result in lower opportunity costs for fertility and a preference to have children early or have more children as an alternative to schooling. Similarly, if students experience poor learning outcomes consistently or their learning outcomes worsen, their educational aspirations may be altered, impacting both their likelihood of school dropout (Zahra 2020) and their fertility aspirations. Lastly, learning trajectories may place learners in different social groups that influence SRH knowledge and fertility aspirations.

2.4 Notes on learning measures and actual fertility

We note that literacy and numeracy skills may affect later outcomes differently. Both literacy and numeracy are influenced by genetic, cognitive, and environmental factors. Cognitively, while certain functions, such as working memory, are important to the early development of both language and numeracy, some cognitive functions are uniquely engaged in the learning of specific skills (Litkowski et al. 2020). These and other differences, for example in the amount of subject-specific effort made at home or the quality of teaching in school, imply that while the development and trajectories of literacy and numeracy are correlated, such a correlation is not perfect. Although there are likely links between early literacy and numeracy and long-term learning outcomes within and across these skills (Purpura et al. 2011), and links with outcomes such as educational attainment, less clear are the reasons for differences in their influence on fertility preferences and SRH knowledge beyond their impact on educational pathways.

Finally, we note that while we focus on SRH knowledge and fertility desires in this study, the link between these pathways and fertility outcomes is complex. Evidence from a recent review suggests that fertility intentions are associated with women's actual number of children in some contexts but not others (Cleland, Machiyama, and Casterline 2020). A paper by Yeatman, Trinitapoli, and Garver (2020) examines another aspect of the relationship between fertility intentions and fertility outcomes: the timing of pregnancy. Based on data from Malawi, this study finds a predictive effect of fertility timing intentions on the timing of pregnancy and finds evidence of unintended pregnancies despite different fertility intentions. The authors state that "discordance between desires and behaviors reflects constraints to achieving one's fertility and the fluidity of desires, but not their irrelevance." Therefore we examine SRH knowledge and fertility desires with the expectation that they may or may not lead to impact on actual fertility outcomes.

2.5 Gender, adolescence, fertility preferences, and SRH knowledge

Much of the literature on fertility preferences and SRH knowledge has focused on women and older adolescents and has thus not captured how educational experiences during middle childhood and early adolescence shape fertility preferences and SRH knowledge during middle adolescence. This is important to examine because we know that fertility preferences change over time due to different circumstances, such as employment or relationship status (Sennott and Yeatman 2012), and are also influenced by the experience of childbearing, which can result in ex post facto rationalization of the reported ideal number of children. In contrast, little is known about what factors shape fertility desires before adolescents begin childbearing. To the extent that fertility preferences do not alter drastically from initial aspirations (Hayford 2009), understanding how these preferences are shaped by educational experiences may garner critical insights into fertility patterns among younger cohorts in high fertility contexts.

As another critical knowledge gap, gender differences in the formation of fertility preferences and SRH knowledge among adolescent boys and girls are poorly understood. Previous studies have shown that the relationship between fertility preferences and fertility is contingent on the preferences of both men and women, which can differ (Short and Kiros 2002), implying that early gender differences in fertility preferences could have a long-term impact on fertility choices.

Theoretically, gender norms may moderate the relationship between learning, fertility preferences, and SRH knowledge in several ways. First, girls, particularly in contexts with high gender inequality, may drop out of school earlier than boys (Psaki, McCarthy, and Mensch 2018). This may disrupt girls' ability to gain advanced literacy and numeracy skills, limit their exposure to school-based SRH education in higher grades, and affect their job opportunities and future income, which are pathways to fertility desires and SRH knowledge. Second, gender norms related to girls' and women's work could moderate the link between better skills and income if highly skilled girls and women are less likely to have access to jobs compared to similarly skilled boys and men. Third, gender norms around sexual activity (particularly before marriage) may influence adolescent boys' and girls' comfort with accessing SRH information and the information sources they feel they can access safely (Abajobir and Seme 2014), potentially affecting the accuracy of their SRH knowledge.

In this paper, we address multiple gaps in the literature, examining both age and gender to evaluate how reading and numeracy skills during middle childhood and early adolescence impact desired fertility and SRH knowledge during middle adolescence among Ethiopian children. Additionally, we analyze whether learning trajectories in reading and numeracy, measured through categories of improved, deteriorating, or unchanged performance, are associated with these outcomes.

2.6 Ethiopia study context

Ethiopia has the second-largest population in Africa, with more than 130 million people (UNFPA 2025) and more than 80 distinct ethnic groups and languages. Despite economic challenges that place it among low-income countries globally, Ethiopia has consistently prioritized investments in education since the early 1990s, with nearly a quarter of its budget dedicated to education (GPE 2020). These investments have resulted in impressive gains in primary school enrollment and gender parity at the primary level, but primary school completion and learning quality remain significant challenges.

Given that Ethiopian girls and women of reproductive age have an average of 4.5 children in their lifetime, based on existing fertility trends Ethiopia will have a population of more than 200 million by 2050 (UNFPA 2025). Educating a growing population of children will pose additional challenges for school enrollment, completion, and learning quality. However, policies that aim to improve educational outcomes may also affect future fertility preferences and, potentially, fertility outcomes.

Between 1993 and 1994, the Ethiopian government eliminated school fees for grades 1 through 10 (Joshi and Verspoor 2012), which resulted in an increase in school enrollment rates. In 2018, the primary school net enrollment rate stood at 95% (GPE 2020). More recent data on primary school completion show that in 2021, 65% of girls and 69% of boys completed primary school. Although fewer girls completed primary school relative to boys, there have been significant gains in gender parity in both enrollment and completion over the last two decades (GPE 2020). Data assessing trends in secondary school completion are less recent but show that in 2015, less than one-third of girls and boys enrolled in secondary school went on to complete it (29% of girls, 30% of boys) (UNESCO 2024).

Despite broader progress in enrollment and completion, learning outcomes in Ethiopia remain poor (Joshi and Verspoor 2012): 90.3% of Ethiopian children aged 10 are unable to read a short, age-appropriate text (Ethiopia Learning Poverty Brief 2019). The Ethiopian government recognized this learning crisis and in 2008, with a consortium of partners, implemented the General Education Quality Improvement Program (GEQIP). This policy led to some improvements in teacher training and learning (GPE 2020), but education quality and learning remain significant challenges today.

Based on evidence from existing literature, improvements in education outcomes like learning may have implications for future fertility trends, including antecedents such as fertility desires and SRH knowledge. While fertility and desired fertility in Ethiopia remain high, younger Ethiopians want fewer children compared to those who are older. According to the Ethiopia Demographic and Health Survey (EDHS) (CSA and ICF 2016), the total fertility rate (TFR) in Ethiopia is 4.6. Desired fertility closely matches the TFR, with men and women of reproductive age wanting an average of 4.6 and 4.5 children, respectively. However, boys and girls aged 15–19 report an ideal family size of 3.6, which is smaller than the ideal family size reported at older ages. Evidence from the full sample aged 15–49 also suggests that education is associated with fertility and fertility preferences: Ethiopian men and women with secondary education have lower actual and desired fertility than those with no education. Thus examining the link with learning as a different aspect of education may demonstrate learning-associated differences in fertility preferences.

Evidence on SRH knowledge among adolescents in Ethiopia is scarce in comparison to data on fertility desires. The EDHS (CSA and ICF 2016) indicates that knowledge of contraception is nearly universal among married men and women of reproductive age, but comparable measures for unmarried adolescent boys and girls are not available. Based on evidence from subregional studies, however, SRH knowledge in this group appears to be poor (Chuta, Birhanu, and Vinci 2021; Mezmur, Assefa, and Alemayehu al. 2021). In addition, few studies have examined gender differences in SRH knowledge in Ethiopia, but there is some evidence that girls have poorer SRH knowledge than boys (Abajobir and Seme 2014). This may partially be attributed to the lack of an integrated comprehensive sexuality education (CSE) program in Ethiopian schools (Le Mat et al. 2021). Although Ethiopia is a signatory to a 2013 regional ministerial commitment on CSE and SRH services for adolescents and youth in eastern and southern Africa, CSE programs are not part of the formal school curriculum. Instead, they are dependent on engagement and funding through civil society, making access to accurate, quality SRH knowledge uneven.

Given these trends in education, fertility desires, and SRH knowledge, Ethiopia provides an interesting context for examining the association between learning and fertility-related outcomes. In a country with room to improve both educational attainment and learning, and where fertility remains high, future policies that impact education still have the potential to yield effects on non-educational outcomes, particularly for a cohort of adolescents whose fertility preferences may be different than those of adults.

3. Methods

3.1 Data

We use secondary data from the Young Lives study in Ethiopia. A longitudinal study, Young Lives has followed two cohorts of children since 2002 in Ethiopia, India, Peru, and Vietnam. Within each country, the baseline sample included 2,000 children between 6 and 18 months (the younger cohort) and 1,000 children ages 7 and 8 (the older cohort), randomly selected from 20 sentinel sites. The cohorts were interviewed in 2006, 2009, 2013, and 2016. In the follow-up rounds, on average, children were ages 5, 8, 12, and 15 in the younger cohort and ages 12, 15, 19, and 22 in the older cohort. Details on the Young Lives study are available elsewhere (Barnett et al. 2013).

The analytical sample for this study includes the younger cohort from Ethiopia, for whom relevant data are available at ages 5, 8, and 12, and data for at least one dependent variable are available at age 15. The analytical sample includes 1,772 respondents, representing 88.6% of the baseline younger cohort sample. We do not focus on the older cohort due to the absence of an early cognitive test prior to school enrollment, limited item numeracy tests at age 8, and higher attrition relative to the younger cohort.

3.2 Dependent variables

Our dependent variables, all reported at age 15, include: (1) ideal number of children, (2) ideal age for first child, and (3) SRH knowledge. Ideal number of children is measured as a continuous variable denoting the desired number of children, with 0 as a minimum and 10 as a maximum (indicating 10 or more children). Ideal age at first birth is a continuous variable indicating desired age (in years) at first birth. Respondents were first asked if they wanted to have children/another child one day; those who refused to answer this question (n = 5) were excluded from the analytical sample for both indicators. In addition, respondents who were undecided (n = 8) or did not want to answer (n = 2) were also excluded from the analytical sample for ideal number of children, and respondents who did not desire to have children (n = 24), were undecided (n = 25), refused to specify an age (n = 2), or reported an age below 10 or above 59 (n = 12) were excluded from the analytical sample for ideal age at first birth. SRH knowledge is a continuous variable operationalized through the sum of correct true/false responses to five statements: (1) “A woman/girl cannot get pregnant the first time she has sex”; (2) “If a girl washes herself after sex, she will not get pregnant”; (3) “Using a condom can prevent getting a disease through sex”; (4) “A person who looks very healthy cannot pass on a disease through sex”; (5) “A person can get HIV or AIDS by having sex.” Each statement was scored as 1 if the response was correct and as 0 if it was incorrect or the respondent did not know. Total scores range from 0 to 5.

3.3 Explanatory variables

Our main explanatory variables are reading and numeracy skills. Young Lives has administered a large number of tests that aim to track and measure cognitive skills across different domains, including language, reading, writing, and mathematics (Singh and Krutikova 2017). However, few tests are administered at multiple rounds. We considered both measure availability and sample size in choosing measures of cognitive skills at multiple ages, prior to the round in which outcome variables were measured.

We measure reading skills at age 8 and 12 from tests assessing whether the child could not read anything or could read letters, a word, a sentence, or multiple sentences (only at age 12). The reading test at age 8 was conducted in the language of instruction of the schools in the community. We assign a score from 0 to 3 indicating the child's best performance at age 8, with 0 meaning the child could not read anything and 3 signifying that the child could read a sentence. The reading test at age 12 was conducted in the child's mother tongue, Amharic, and English. We also assign a score from 0 to 3 indicating the child's performance at age 12, with 0 signifying that the child could not read anything in any language and 3 indicating that the child could read at least a sentence in one of the languages.

We measure numeracy skills at age 8 and 12 from comprehensive oral and paper-based math assessments with 28 or 29 questions, including calculations and word problems. The math tests were administered in the language in which the respondent was most comfortable. At each age, we score the tests with a range of 0 to 10 based on the highest number of correct answers, giving equal weight to each item. The highest number of correct answers was 28 (out of 29) at age 8 and 27 (out of 28) at age 12. Thus, at age 8, a child's math score = number of correct answers*10/28. At age 12, a child's math score = number of correct answers*10/27.

We also measure learning trajectories[4] by decomposing the performance at age 12 into the performance at age 8 plus the change between ages 8 and 12. In addition to measuring this change as a continuous variable, we also construct a three-category variable for each skill. For reading, the categories are defined as: (1) no change if the respondent had the same reading ability at both ages; (2) improved if the respondent had a higher reading ability at age 12 than at age 8; and (3) worsened if the respondent had a lower reading ability at age 12 than at age 8. For numeracy, the categories are defined relative to one standard deviation (1 SD) from the mean change: (1) no change if the difference between the respondent's scores at ages 8 and 12 is within ±1 SD of the mean change; (2) improved if the respondent's difference in scores is more than +1 SD from the mean change; and (3) worsened if the respondent's difference in scores is less than –1 SD from the mean change. We construct two similar numeracy change variables to assess the sensitivity of results to this measure, defining categories of change relative to 0.75 SD and 0.5 SD from the mean change instead of 1 SD.

[4] Some studies use cross-sectional data to define learning trajectories in terms of learning gains on the same subject test across successive grades at a country level (Kaffenberger 2019; Pritchett and Spivack 2021). Others define low learning using performance quartiles (Carter et al. 2020; Spaull and Kotze 2015) or use basic literacy or numeracy levels as a cut-off (Rolleston 2014). Recent work using longitudinal data from the Young Lives study analyzed learning trajectories using item response theory to generate comparable scores across subject-specific tests in four countries, including Ethiopia, and compared percentile-based performance across two successive rounds at a time (Singh and Krutikova 2017).

To explore whether preschool-age cognitive abilities explain associations between academic skills during school-age years and our outcomes, we use scores from a cognitive developmental assessment (CDA), conducted at age 5, that assessed children's quantitative ability. The CDA included 15 items. We construct a score with the range 0–10 based on the highest number of correct answers, giving equal weight to each item.

Other control variables include respondent's sex (1 if female, 0 if male), school enrollment status (1 if enrolled, 0 if not enrolled), highest grade attained, whether the mother completed primary school (1 if yes, 0 otherwise), number of siblings and half-siblings living in the same household, household wealth tertiles – derived from a wealth index constructed by Young Lives from three different indices: housing quality, access to services, and consumer durables (Briones 2017) – and urban vs. rural location (1 if urban, 0 if rural).

3.4 Analytical approach

To investigate whether reading and numeracy skills during childhood and early adolescence are associated with fertility desires and SRH knowledge at middle adolescence among the younger cohort, we estimate Equations (1) and (2) for each outcome:

$$Y_i^{15} = \beta_0 + \beta_1 R_i^{8,12} + \beta_2 N_i^{8,12} + \beta_3 C_i^5 + \beta_4 X_i^{8,12} + e_i \qquad (1)$$

$$Y_i^{15} = \gamma_0 + \gamma_1 R_i^8 + \gamma_2 (R_i^{12} - R_i^8) + \gamma_3 N_i^8 + \gamma_4 (N_i^{12} - N_i^8) + \gamma_5 C_i^5 + \gamma_6 X_i^{12} + u_i \qquad (2)$$

where *Y* is the outcome for child *i* measured at age 15, *R* represents reading skills at ages 8 or 12, *N* represents numeracy skills at ages 8 or 12, *C* represents cognitive development at age 5, *X* represents all other control variables at ages 8 or 12, and *e* is a random error.

We estimate Equations (1) and (2) using linear regression models, accounting for clustering at the sentinel area level. We estimate the regressions using standardized outcomes and standardized continuous skills variables that have a mean of 0 and a standard deviation of 1. We also estimate regression models separately for boys and girls to understand how reading and numeracy skills are related to SRH knowledge and fertility preferences for each gender. As a robustness check, we ran these models with cluster fixed effects, with clusters defined as sentinel sites, to control for variation between clusters. We conduct all statistical analysis in Stata 15.1.

4. Results

4.1 Descriptive results

Descriptively (see Table 1), adolescents want to begin childbearing in their late 20s, desire to have more than three children, and have some SRH knowledge. Specifically, adolescents aged 15 want an average of 3.6 children, want their first child at age 28.6 on average, and answer three out of five SRH knowledge questions correctly. On average, girls want to have their first child earlier than boys but want fewer children overall.

Math scores and reading ability generally improve between ages 8 and 12, but some children remain unable to read and gain numeracy. On average, children score 1.1 out of 3 on reading ability at age 8 and 2.3 out of 3 at age 12. Between ages 8 and 12, 58.6% of children improve their reading ability, while less than 1% experience a loss in reading ability. On average, children score 2.3 out of 10 on numeracy at age 8 and 3.4 out of 10 at age 12. Between ages 8 and 12, 16.4% of children improve their numeracy score by more than 1 SD above the mean change, while 16.0% experience a decline, scoring more than 1 SD *below* the mean change. On average, girls and boys have a similar performance in reading and numeracy at both ages.

In addition (see Table A-1), more than three-quarters of children are enrolled in school at age 8, a figure that increases to 95% at age 12; around 15% have mothers who completed primary school; and around two-thirds reside in rural areas. At age 12, 93.4% of boys are enrolled in school, compared to 96.7% of girls. Overall, grade attainment is low among 12-year-olds, with 3.5 grades completed on average and a small difference between boys (3.4) and girls (3.6).

Table 1: Summary statistics for dependent variables and key explanatory variables

	(1) Full sample	(2) Boys	(3) Girls	(4) Diff. p-value
Dependent variables at age 15				
Ideal number of children, mean (SD)	3.6 (1.6)	3.7 (1.7)	3.5 (1.5)	0.002
Sample	1,760	936	824	
Ideal age for first child, mean (SD)	28.6 (4.3)	29.7 (4.4)	27.4 (3.9)	0.000
Sample	1,708	913	795	
SRH knowledge score (0–5), mean (SD)	3.1 (1.3)	3.1 (1.3)	3.0 (1.3)	0.081
Sample	1,513	802	711	
Key explanatory variables at ages 8 and 12				
Reading scores (0–3), mean (SD)				
At age 8	1.1 (1.3)	1.1 (1.3)	1.1 (1.3)	0.177
At age 12	2.3 (1.1)	2.3 (1.1)	2.3 (1.1)	0.340
Scores 0 at both age 8 and 12, %	12.2	12.6	11.7	0.544
Change in reading score ages 8–12, mean (SD)	1.2 (1.2)	1.2 (1.2)	1.2 (1.2)	0.570
Change in reading score ages 8–12, %				
No change	40.6	39.7	41.7	0.678
Improved	58.6	59.4	57.6	
Worsened	0.8	0.8	0.7	
Numeracy scores (0–10), mean (SD)				
At age 8	2.3 (1.9)	2.3 (1.9)	2.2 (1.9)	0.370
At age 12	3.4 (2.4)	3.4 (2.4)	3.4 (2.5)	0.745
Scores 0 at both age 8 and 12, %	3.4	3.1	3.9	0.371
Change in numeracy score ages 8–12, mean (SD)	1.1 (1.8)	1.1 (1.8)	1.2 (1.8)	0.601
Change in numeracy score ages 8–12, %				
Within ±1 SD of mean change	67.6	69.0	66.0	0.408
Above +1 SD of mean change	16.4	15.6	17.2	
Below –1 SD of mean change	16.0	15.4	16.7	
Sample	1,772	942	830	

Notes: P-values in column 4 are from comparing boys and girls using two-sided t-tests with equal variances for continuous variables and Pearson χ^2 tests for categorical variables.

4.2 Analytical models

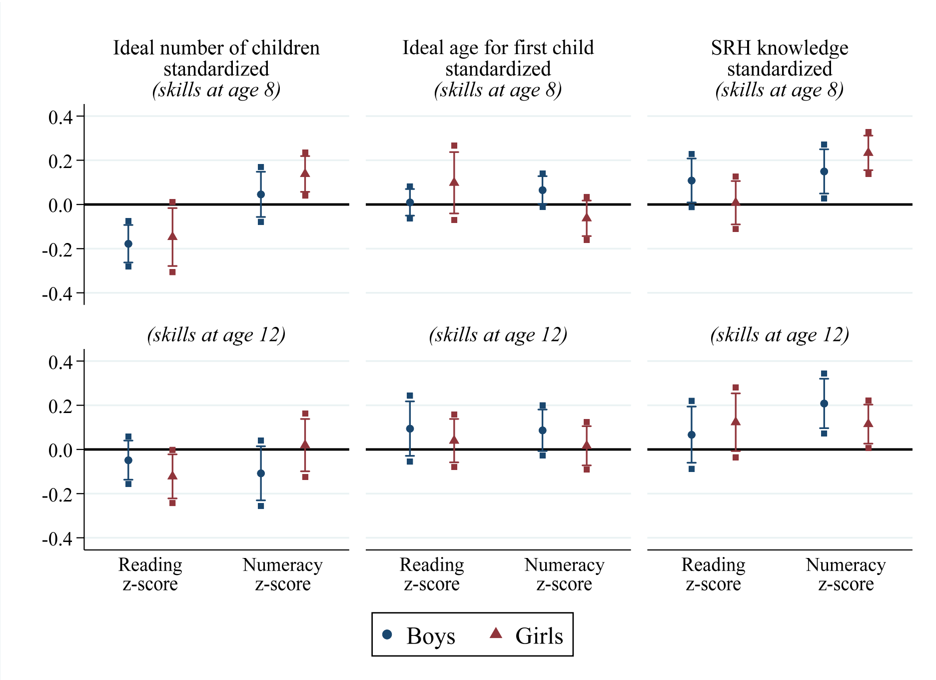
A 1 SD increase in reading scores at age 8 is associated with a 0.16 SD decrease in ideal number of children (or wanting 0.26 fewer children) at age 15 (see Table 2). Effect sizes are smaller for reading at age 12, but the direction of the effect is the same. The coefficient for numeracy is positive at age 8 and negative at age 12. In terms of learning trajectories for reading, when we decompose the reading score at age 12 into the score at age 8 and the change in scores across ages, scoring 1 SD above the mean at age 8 is associated with a 0.32 SD decrease in the ideal number of children at age 15, while improving reading ability between ages 8 and 12 is associated with a 0.28 SD decrease in the ideal number of children at age 15. For numeracy learning trajectories, effect sizes are positive but close to zero. In terms of other covariates (see full results in Table A-2), girls want fewer children than boys, children from wealthier households want fewer children than those from poorer households, and those with more siblings want more children. Higher grade attainment is also associated with wanting more children. None of the effects for reading, math, and related learning trajectories substantively differ between boys and girls (see Figure 1 and Figure 2).

Table 2: Results from linear regressions for standardized ideal number of children measured at age 15

	(1) Skills at age 8 Coef. (95% CI)	(2) Skills at age 12 Coef. (95% CI)	(3) Trajectory ages 8–12 Coef. (95% CI)	(4) Trajectory ages 8–12 Coef. (95% CI)
Reading				
Standardized score at age 8	–0.160 (–0.274, –0.046)		–0.295 (–0.441, -0.149)	–0.316 (–0.440, –0.192)
Standardized score at age 12		–0.091 (–0.196, 0.014)		
Change in score ages 8–12				
Standardized change			–0.099 (–0.219, 0.021)	
No change (ref.)				
Improved				–0.283 (–0.473, –0.093)
Worsened				–0.044 (–0.853, 0.765)
Numeracy				
Standardized score at age 8	0.084 (–0.018, 0.185)		0.046 (–0.071, 0.164)	0.034 (–0.071, 0.139)
Standardized score at age 12		–0.038 (–0.169, 0.093)		
Change in score ages 8–12				
Standardized change			–0.003 (–0.093, 0.087)	
Within ±1 SD of mean (ref.)				
Above +1 SD of mean				0.041 (–0.119, 0.200)
Below –1 SD of mean				0.065 (–0.113, 0.243)
Sample	1,760	1,760	1,760	1,760
F-stat	9.73	16.29	13.28	12.09
R-squared	0.148	0.158	0.172	0.178

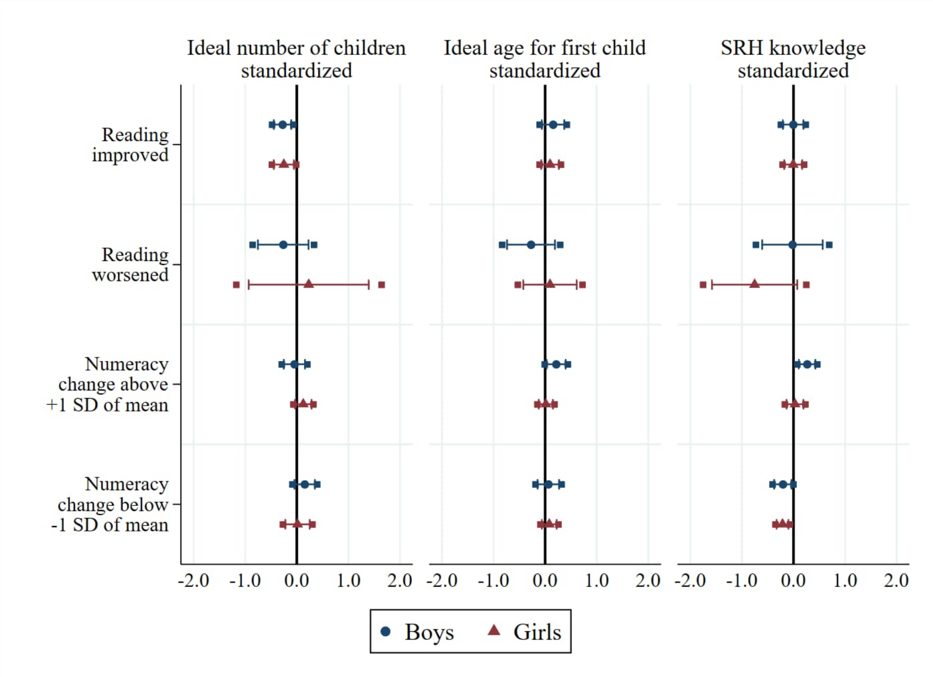
Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. All regressions included controls for gender, cognitive development score measured at age 5, and the following covariates measured at age 8 (model 1) or age 12 (models 2–4): enrolled in school, highest grade attained, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence.

Figure 1: Results by gender for reading and numeracy z-scores from linear regressions for fertility preferences and SRH knowledge measured at age 15



Notes: Figure 1 shows coefficients, along with 95% and 90% confidence intervals, for reading and numeracy z-scores from regressions for outcomes standardized to have a mean of 0 and an SD of 1. Regressions were estimated separately for boys and girls, with robust standard errors clustered at the sentinel site level. All regressions included controls for cognitive development score measured at age 5 and the following covariates measured at age 8 (for models with skills at age 8) or at age 12 (for models with skills at age 12): enrolled in school, highest grade attained, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence.

Figure 2: Results by gender for reading and numeracy learning trajectories from linear regressions for fertility preferences and SRH knowledge measured at age 15



Notes: Figure 2 shows coefficients, along with 95% and 90% confidence intervals, for reading and numeracy learning trajectories between ages 8 and 12, controlling for performance at age 8, from regressions for outcomes standardized to have a mean of 0 and an SD of 1. Reference categories are no change for reading and change within 1 SD of mean change for numeracy. Regressions were estimated separately for boys and girls, with robust standard errors clustered at the sentinel site level. All regressions included controls for cognitive development score measured at age 5 and the following covariates measured at age 12: enrolled in school, highest grade attained, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence.

Children with higher reading and numeracy scores want to have their first child at later ages, but the effect sizes are small or close to zero (see Table 3). Specifically, a 1 SD increase in reading scores at age 8, and in both reading and math scores at age 12, is associated with a 0.05–0.07 SD (0.24–0.30 year) increase in desired age for a first child reported at age 15. Effect sizes are larger when examining learning trajectories: A 1 SD increase in reading scores at age 8 is associated with a 0.13 SD increase in ideal age at first birth reported at age 15, while improving reading ability between ages 8 and 12 is associated with a 0.12 SD increase. Improvements in numeracy between ages 8 and 12 above 1 SD from the mean change are associated with a 0.12 SD increase in ideal age at first birth. In terms of other covariates (see full results in Table A-3), girls want to have their first child at younger ages than boys, higher grade attainment at age 12 is associated with a younger desired age for a first child, and a higher cognitive score at age 5 is associated with an older desired age for a first child. Similar to results for number of children, the effects of learning on the ideal age for a first child do not differ between boys and girls (see Figure 1 and Figure 2).

Table 3: Results from linear regressions for standardized ideal age for first child measured at age 15

	(1) Skills at age 8 Coef. (95% CI)	(2) Skills at age 12 Coef. (95% CI)	(3) Trajectory ages 8–12 Coef. (95% CI)	(4) Trajectory ages 8–12 Coef. (95% CI)
Reading				
Standardized score at age 8	0.055 (–0.037, 0.147)		0.146 (–0.030, 0.322)	0.131 (–0.011, 0.272)
Standardized score at age 12		0.069 (–0.051, 0.189)		
Change in score ages 8–12				
Standardized change			0.078 (-0.054, 0.210)	
No change (ref.)				
Improved				0.120 (–0.090, 0.330)
Worsened				–0.133 (–0.593, 0.328)
Numeracy				
Standardized score at age 8	0.002 (–0.052, 0.056)		0.033 (–0.051, 0.117)	0.023 (–0.057, 0.104)
Standardized score at age 12		0.059 (–0.012, 0.130)		
Change in score ages 8–12				
Standardized change			0.029 (–0.017, 0.075)	
Within ±1 SD of mean (ref.)				
Above +1 SD of mean				0.123 (–0.011, 0.258)
Below –1 SD of mean				0.060 (–0.117, 0.238)
Sample	1,708	1,708	1,708	1,708
F-stat	8.92	11.40	10.63	10.53
R-squared	0.088	0.104	0.106	0.106

Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. All regressions included controls for gender, cognitive development score measured at age 5, and the following covariates measured at age 8 (model 1) or age 12 (models 2–4): enrolled in school, highest grade attained, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence.

In contrast to fertility desires, higher scores in numeracy at earlier ages are consistently associated with better SRH knowledge at age 15 (see Table 4). At age 8, a 1 SD increase in numeracy scores is associated with a 0.19 SD increase in SRH scores. At age 12, a 1 SD increase in numeracy scores is associated with a 0.16 SD increase in SRH scores. In terms of learning trajectories, in the model with standardized continuous change (model 3 in Table 4), reading and numeracy at age 8 and improvements in both skills between ages 8 and 12 are associated with higher SRH knowledge at age 15. For categorical change in learning trajectories for numeracy, a 1 SD increase in numeracy scores at age 8 is associated with a 0.21 SD increase in SRH knowledge, while, relative to those whose change is within 1 SD of the mean, an improvement above 1 SD from the mean change is associated with a 0.14 SD increase in SRH knowledge. For other covariates, girls have poorer SRH knowledge than boys (see Table A-4). However, results do not substantively differ by gender (see Figure 1 and Figure 2).

Table 4: Results from linear regressions for standardized sexual and reproductive health knowledge measured at age 15

	(1) Skills at age 8 Coef. (95% CI)	(2) Skills at age 12 Coef. (95% CI)	(3) Trajectory ages 8–12 Coef. (95% CI)	(4) Trajectory ages 8–12 Coef. (95% CI)
Reading				
Standardized score at age 8	0.059 (–0.027, 0.146)		0.139 (–0.022, 0.301)	0.032 (–0.075, 0.138)
Standardized score at age 12		0.099 (–0.021, 0.220)		
Change in score ages 8–12				
Standardized change			0.120 (–0.009, 0.250)	
No change (ref.)				
Improved				0.012 (–0.172, 0.197)
Worsened				–0.274 (–0.730, 0.181)
Numeracy				
Standardized score at age 8	0.189 (0.111, 0.268)		0.204 (0.099, 0.310)	0.211 (0.110, 0.312)
Standardized score at age 12		0.155 (0.052, 0.257)		
Change in score ages 8–12				
Standardized change			0.073 (0.011, 0.136)	
Within ±1 SD of mean (ref.)				
Above +1 SD from mean				0.137 (–0.017, 0.290)
Below –1 SD from mean				–0.198 (–0.331, –0.065)
Sample	1,513	1,513	1,513	1,513
F-stat	15.49	9.27	11.82	13.79
R-squared	0.044	0.055	0.062	0.057

Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. All regressions included controls for gender, cognitive development score measured at age 5, and the following covariates measured at age 8 (model 1) or age 12 (models 2–4): enrolled in school, highest grade attained, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence.

For models with cluster fixed effects (see Tables A-5 to A-7), results differ from the main models in terms of magnitude and statistical significance of point estimates, but the broader story of the relationship between learning and fertility intentions and SRH knowledge remains the same.

Finally, results from models using numeracy change categories defined relative to 0.75 SD and 0.5 SD from the mean change (see Tables A-8 to A-10) are in line with results in our main models that use a definition of change relative to 1 SD from the mean change.

5. Discussion and conclusion

Education has long been identified as an influence on the timing and number of children, with multiple different pathways hypothesized. Our study provides critical evidence showing that learning is predictive of at least two important antecedents to SRH outcomes. Using longitudinal data spanning middle childhood and early and middle adolescence, we find that skills in numeracy are most consistently associated with better SRH knowledge. That is, children with better numeracy skills at ages 8 and 12 have higher SRH knowledge scores at age 15. Associations with fertility preferences are mixed but in the expected direction; in particular, children with better reading skills want fewer children and want to have children at later ages. Effect sizes are larger for ideal number of children and within the range (a reduction of 0.26 to 0.5 children) of previous studies that have examined the impact of educational attainment on desired fertility in Ethiopia (Behrman 2015; Chicoine 2016). Although we can only speculate why we observe differences in the association of learning with these two outcomes, one explanation may be that as a precondition, learning is more closely linked than fertility preferences to acquiring information on SRH from written sources.

These findings echo studies that demonstrate a link between educational attainment and SRH knowledge and fertility preferences (Psaki et al. 2019) but suggest that learning as an aspect of education, which is perhaps poorly captured by educational attainment alone, is important to consider. From a policy perspective, this underscores that simply getting children into school is not enough to reap the full benefits of education's impact on SRH. In addition, these findings emphasize that early skills in literacy and numeracy matter for fertility-related preferences and SRH knowledge during adolescence, emphasizing the potential significance of timing in interventions for children who are not learning. Lastly, to the extent that fertility preferences do not drastically deviate from initial aspirations (Hayford 2009) and that better SRH knowledge is a pathway to realizing fertility goals, higher proficiency in reading and numeracy may impact realized fertility over the life course. This potential dual long-term benefit of early learning-focused interventions thus carries policy implications across both education and health sectors.

Evidence on learning trajectories demonstrates that learning is not static and that improvement and deterioration in reading and numeracy skills over time matter for SRH knowledge and fertility preferences. This highlights not only the need to identify and improve learning outcomes through early targeted interventions for children but also that not doing so could have implications beyond educational outcomes. Programs to improve early learning outcomes in SSA generally target wider access to early childhood education, on-time primary school enrollment, high-quality teacher training and instructional materials, and parental engagement (Gove et al. 2017). In Ethiopia, the government is committed to early childhood education and has included multiple pre-primary education objectives in the current Ethiopian Education Sector Development Plan 2020/21 – 2024/25. School-based reforms under the GEQIP, which began in 2008, are another example of such an effort, though its impact on learning outcomes is yet to be assessed (Hoddinott et al. 2019). If evaluated rigorously, such interventions, together with qualitative data, could provide much-needed evidence on the causal mechanisms that link improvements in learning and fertility-related outcomes.

We found no gender differences in the association between learning and fertility preferences or SRH knowledge but did observe gender differences in overall average fertility preferences. This does not rule out the presence of gender differences in pathways that link learning with SRH knowledge and fertility preferences, but we may be unable to capture such differences here for two reasons. First, pathways such as income and sexual activity are difficult to observe given that the population in our sample is too young to work and that a vast majority are not sexually active. Second, we do not observe substantive gender differences in learning or other educational outcomes in this sample, but such differences might be found in settings or among subpopulations with higher gender inequality in education.

Our study has some limitations. First, while our explanatory and outcome variables are causally ordered, limiting concerns for reverse causality, these data cannot account for unobserved characteristics that may affect both learning and fertility preferences. Our results should therefore be interpreted as associations that provide stronger evidence than cross-sectional data but not causal evidence. Second, the Young Lives study sample for Ethiopia is skewed toward communities that are wealthier than the national average, limiting the representativeness of our results. Third, part of the math assessments and the assessment for SRH knowledge were intended to be self-administered. Although interviewers could intervene if respondents were not able to read, it is likely that these assessments were biased toward students with better reading and comprehension ability. In addition, the sample size for SRH knowledge is smaller relative to the other outcomes.

Overall, our findings provide empirical evidence for two ways learning may impact future fertility: via SRH knowledge and via fertility preferences. For future research, it is important to examine learning as an antecedent to fertility relative to other factors, such as access to services or social norms, and to understand how learning interacts with other pathways, such as employment aspirations, to impact fertility. In recognition of this, estimating the full impact of learning on fertility would require a thorough examination of additional mediating pathways (Zahra, Haberland, and Psaki 2022).

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Appendix

Table A-1: Summary statistics for other control variables

	(1) Full sample	(2) Boys	(3) Girls	(4) Diff. p-value
Girl (vs. boy), %	46.8			
Cognitive score (0–10) at age 5, mean (SD)	5.9 (2.1)	5.9 (2.2)	5.9 (2.1)	0.761
Enrolled in school at age 8, %	77.3	76.0	78.8	0.162
Enrolled in school at age 12, %	95.0	93.4	96.7	0.001
Highest grade completed at age 8, mean (SD)	0.7 (0.8)	0.6 (0.7)	0.7 (0.8)	0.121
Highest grade completed at age 12, mean (SD)	3.5 (1.8)	3.4 (1.8)	3.6 (1.7)	0.030
Mother completed primary at age 8, %	14.7	15.5	13.9	0.330
Mother completed primary at age 12, %	15.5	16.5	14.5	0.247
Coresident siblings at age 8, mean (SD)	3.3 (2.2)	3.3 (2.1)	3.3 (2.2)	0.793
Coresident siblings at age 12, mean (SD)	3.7 (2.2)	3.7 (2.2)	3.7 (2.3)	0.989
Household wealth at age 8, %				
Poorest tercile	33.6	33.7	33.5	0.689
Middle tercile	33.4	32.6	34.3	
Wealthiest tercile	33.0	33.8	32.2	
Household wealth at age 12, %				
Poorest tercile	34.3	34.5	34.0	0.430
Middle tercile	33.1	31.8	34.6	
Wealthiest tercile	32.6	33.7	31.4	
Urban (vs. rural) residence at age 8, %	35.1	34.5	35.8	0.573
Urban (vs. rural) residence at age 12, %	36.5	36.1	37.0	0.696
Sample	1,772	942	830	

Notes: P-values in column 4 are from comparing boys and girls using two-sided t-tests with equal variances for continuous variables, two-sided tests of proportions for binary variables, and Pearson χ^2 tests for categorical variables.

Table A-2: Full results from linear regressions for standardized ideal number of children measured at age 15

	(1) Skills at age 8 Coef. (95% CI)	(2) Skills at age 12 Coef. (95% CI)	(3) Trajectory ages 8–12 Coef. (95% CI)	(4) Trajectory ages 8–12 Coef. (95% CI)
Reading z-score at age 8	–0.160 (–0.274, –0.046)		–0.295 (–0.441, –0.149)	–0.316 (–0.440, –0.192)
Reading z-score at age 12		–0.091 (–0.196, 0.014)		
Change reading score ages 8–12				
Standardized change			–0.099 (–0.219, 0.021)	
No change (ref.)				
Improved				–0.283 (–0.473, –0.093)
Worsened				–0.044 (–0.853, 0.765)
Numeracy z-score at age 8	0.084 (–0.018, 0.185)		0.046 (–0.071, 0.164)	0.034 (–0.071, 0.139)
Numeracy z-score at age 12		–0.038 (–0.169, 0.093)		
Change numeracy score ages 8–12				
Standardized change			–0.003 (–0.093, 0.087)	
Within ±1 SD of mean (ref.)				
Above +1 SD from mean				0.041 (–0.119, 0.200)
Below –1 SD from mean				0.065 (–0.113, 0.243)
Girl (vs. boy)	–0.142 (–0.232, –0.052)	–0.153 (–0.238, –0.068)	–0.142 (–0.227, –0.057)	–0.147 (–0.228, –0.066)
Cognitive z-score at age 5	0.013 (–0.064, 0.091)	0.000 (–0.072, 0.072)	0.003 (–0.072, 0.078)	0.006 (–0.071, 0.082)
Enrolled in school	0.013 (–0.272, 0.298)	–0.318 (–0.834, 0.199)	–0.356 (–0.846, 0.134)	–0.331 (–0.853, 0.191)
Grade attainment	0.107 (–0.026, 0.240)	0.112 (0.024, 0.201)	0.139 (0.046, 0.232)	0.145 (0.048, 0.243)
Mother completed primary	–0.108 (–0.317, 0.101)	–0.110 (–0.332, 0.111)	–0.106 (–0.320, 0.107)	–0.106 (–0.314, 0.103)
Coresident siblings	0.081 (0.055, 0.106)	0.094 (0.065, 0.123)	0.089 (0.062, 0.117)	0.087 (0.061, 0.114)
Household wealth (ref: poorest)				
middle	–0.301 (–0.552, –0.050)	–0.258 (–0.483, –0.032)	–0.257 (–0.477, –0.036)	–0.254 (–0.469, –0.038)
wealthiest	–0.368 (–0.622, –0.113)	–0.267 (–0.513, –0.021)	–0.261 (–0.502, –0.019)	–0.264 (–0.497, –0.032)
Urban residence (vs. rural)	–0.180 (–0.600, 0.239)	–0.276 (–0.697, 0.146)	–0.200 (–0.602, 0.203)	–0.195 (–0.590, 0.199)
Constant	0.020 (–0.385, 0.425)	–0.078 (–0.675, 0.519)	–0.154 (–0.733, 0.424)	–0.044 (–0.687, 0.600)
Sample	1,760	1,760	1,760	1,760
F-stat	9.73	16.29	13.28	12.09
R-squared	0.1481	0.1577	0.1715	0.1784

Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. Enrolled in school, grade attainment, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence are measured at age 8 in model 1 and at age 12 in models 2–4.

Table A-3: Full results from linear regressions for standardized ideal age for first child measured at age 15

	(1) Skills at age 8 Coef. (95% CI)	(2) Skills at age 12 Coef. (95% CI)	(3) Trajectory ages 8–12 Coef. (95% CI)	(4) Trajectory ages 8–12 Coef. (95% CI)
Reading z-score at age 8	0.055 (–0.037, 0.147)		0.146 (–0.030, 0.322)	0.131 (–0.011, 0.272)
Reading z-score at age 12		0.069 (–0.051, 0.189)		
Change reading score ages 8–12				
Standardized change			0.078 (–0.054, 0.210)	
No change (ref.)				
Improved				0.120 (–0.090, 0.330)
Worsened				–0.133 (–0.593, 0.328)
Numeracy z-score at age 8	0.002 (–0.052, 0.056)		0.033 (–0.051, 0.117)	0.023 (–0.057, 0.104)
Numeracy z-score at age 12		0.059 (–0.012, 0.130)		
Change numeracy score ages 8–12				
Standardized change			0.029 (–0.017, 0.075)	
Within ±1 SD of mean (ref.)				
Above +1 SD from mean				0.123 (–0.011, 0.258)
Below –1 SD from mean				0.060 (–0.117, 0.238)
Girl (vs. boy)	–0.524 (–0.658, –0.390)	–0.517 (–0.650, –0.384)	–0.520 (–0.653, –0.386)	–0.524 (–0.659, –0.390)
Cognitive z-score at age 5	0.062 (0.022, 0.102)	0.063 (0.026, 0.101)	0.061 (0.024, 0.098)	0.058 (0.021, 0.095)
Enrolled in school	–0.073 (–0.289, 0.143)	0.145 (–0.105, 0.395)	0.160 (–0.078, 0.399)	0.187 (–0.046, 0.420)
Grade attainment	–0.106 (–0.226, 0.015)	–0.111 (–0.200, –0.023)	–0.123 (–0.218, –0.028)	–0.112 (–0.206, –0.019)
Mother completed primary	0.145 (–0.013, 0.303)	0.117 (–0.046, 0.281)	0.111 (–0.051, 0.273)	0.119 (–0.044, 0.281)
Coresident siblings	–0.008 (–0.029, 0.012)	–0.017 (–0.041, 0.007)	–0.016 (–0.039, 0.008)	–0.015 (–0.040, 0.010)
Household wealth (ref. poorest)				
middle	0.025 (–0.173, 0.224)	0.077 (–0.118, 0.273)	0.077 (–0.117, 0.270)	0.076 (–0.120, 0.272)
wealthiest	–0.058 (–0.286, 0.171)	–0.043 (–0.226, 0.141)	–0.048 (–0.232, 0.136)	–0.053 (–0.241, 0.136)
Urban residence (vs. rural)	0.074 (–0.292, 0.440)	0.149 (–0.180, 0.479)	0.118 (–0.222, 0.458)	0.124 (–0.216, 0.463)
Constant	0.361 (0.111, 0.612)	0.474 (–0.058, 1.005)	0.511 (–0.032, 1.054)	0.348 (–0.113, 0.810)
Sample	1,708	1,708	1,708	1,708
F-stat	8.92	11.40	10.63	10.53
R-squared	0.0882	0.1043	0.1062	0.1058

Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. Enrolled in school, grade attainment, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence are measured at age 8 in model 1 and at age 12 in models 2–4.

Table A-4: Full results from linear regressions for standardized sexual and reproductive health knowledge measured at age 15

	(1) Skills at age 8 Coef. (95% CI)	(2) Skills at age 12 Coef. (95% CI)	(3) Trajectory ages 8–12 Coef. (95% CI)	(4) Trajectory ages 8–12 Coef. (95% CI)
Reading z-score at age 8	0.059 (–0.027, 0.146)		0.139 (–0.022, 0.301)	0.032 (–0.075, 0.138)
Reading z-score at age 12		0.099 (–0.021, 0.220)		
Change reading score ages 8–12				
Standardized change			0.120 (–0.009, 0.250)	
No change (ref.)				
Improved				0.012 (–0.172, 0.197)
Worsened				–0.274 (–0.730, 0.181)
Numeracy z-score at age 8	0.189 (0.111, 0.268)		0.204 (0.099, 0.310)	0.211 (0.110, 0.312)
Numeracy z-score at age 12		0.155 (0.052, 0.257)		
Change numeracy score ages 8–12				
Standardized change			0.073 (0.011, 0.136)	
Within ±1 SD of mean (ref.)				
Above +1 SD from mean				0.137 (–0.017, 0.290)
Below –1 SD from mean				–0.198 (–0.331, –0.065)
Girl (vs. boy)	–0.088 (–0.180, 0.004)	–0.109 (–0.199, –0.018)	–0.100 (–0.192, –0.007)	–0.097 (–0.189, –0.006)
Cognitive z-score at age 5	0.014 (–0.042, 0.069)	0.014 (–0.046, 0.074)	0.003 (–0.058, 0.064)	0.003 (–0.058, 0.065)
Enrolled in school	0.025 (–0.117, 0.167)	0.158 (–0.146, 0.463)	0.183 (–0.134, 0.500)	0.230 (–0.065, 0.525)
Grade attainment	0.002 (–0.116, 0.119)	0.031 (–0.019, 0.081)	0.005 (–0.048, 0.058)	0.023 (–0.028, 0.073)
Mother completed primary	–0.098 (–0.307, 0.111)	–0.085 (–0.299, 0.129)	–0.113 (–0.324, 0.098)	–0.108 (–0.316, 0.100)
Coresident siblings	0.008 (–0.016, 0.031)	0.011 (–0.012, 0.034)	0.011 (–0.011, 0.033)	0.011 (–0.012, 0.034)
Household wealth (ref. poorest)				
middle	0.027 (–0.142, 0.197)	0.057 (–0.107, 0.221)	0.058 (–0.102, 0.218)	0.072 (–0.091, 0.235)
wealthiest	–0.093 (–0.287, 0.102)	–0.029 (–0.263, 0.205)	–0.057 (–0.285, 0.172)	–0.046 (–0.284, 0.191)
Urban residence (vs. rural)	–0.075 (–0.249, 0.100)	–0.037 (–0.252, 0.179)	–0.082 (–0.300, 0.136)	–0.081 (–0.310, 0.147)
Constant	0.034 (–0.187, 0.256)	–0.286 (–0.685, 0.114)	–0.191 (–0.584, 0.203)	–0.291 (–0.654, 0.071)
Sample	1,513	1,513	1,513	1,513
F-stat	15.49	9.27	11.82	13.79
R-squared	0.0437	0.0546	0.0617	0.0574

Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. Enrolled in school, grade attainment, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence are measured at age 8 in model 1 and at age 12 in models 2–4.

Table A-5: Full results from linear regressions with cluster fixed effects for standardized ideal number of children measured at age 15

	(1) Skills at age 8 Coef. (95% CI)	(2) Skills at age 12 Coef. (95% CI)	(3) Trajectory ages 8–12 Coef. (95% CI)	(4) Trajectory ages 8–12 Coef. (95% CI)
Reading z-score at age 8	–0.084 (–0.142, –0.026)		–0.144 (–0.229, –0.058)	–0.154 (–0.231, –0.077)
Reading z-score at age 12		–0.039 (–0.107, 0.030)		
Change reading score ages 8–12				
Standardized change			–0.051 (–0.128, –0.027)	
No change (ref.)				
Improved				–0.149 (–0.286, –0.012)
Worsened				0.083 (–0.735, 0.900)
Numeracy z-score at age 8	–0.008 (–0.066, 0.049)		0.011 (–0.072, 0.095)	–0.001 (–0.075, 0.073)
Numeracy z-score at age 12		0.012 (–0.077, 0.101)		
Change numeracy score ages 8–12				
Standardized change			0.033 (–0.031, 0.097)	
Within ±1 SD of mean (ref.)				
Above +1 SD from mean				0.108 (–0.015, 0.230)
Below –1 SD from mean				0.027 (–0.118, 0.173)
Girl (vs. boy)	–0.156 (–0.246, –0.067)	–0.146 (–0.234, –0.059)	–0.144 (–0.231, –0.056)	–0.146 (–0.232, –0.061)
Cognitive z-score at age 5	0.017 (–0.026, 0.061)	0.014 (–0.025, 0.054)	0.016 (–0.026, 0.058)	0.017 (–0.025, 0.060)
Enrolled in school	–0.009 (–0.124, 0.105)	–0.343 (–0.722, 0.036)	–0.366 (–0.736, 0.003)	–0.339 (–0.737, 0.058)
Grade attainment	0.029 (–0.016, 0.074)	0.006 (–0.032, 0.043)	0.029 (–0.008, 0.066)	0.036 (–0.002, 0.074)
Mother completed primary	–0.038 (–0.178, 0.102)	–0.061 (–0.211, 0.088)	–0.053 (–0.190, 0.084)	–0.045 (–0.178, 0.088)
Coresident siblings	0.043 (0.020, 0.065)	0.041 (0.017, 0.065)	0.040 (0.016, 0.064)	0.039 (0.015, 0.064)
Household wealth (ref. poorest)				
middle	–0.085 (–0.187, 0.017)	–0.049 (–0.109, 0.010)	–0.053 (–0.115, 0.008)	–0.052 (–0.112, 0.008)
wealthiest	–0.068 (–0.175, 0.038)	0.004 (–0.113, 0.120)	0.010 (–0.104, 0.123)	0.006 (–0.110, 0.122)
Urban residence (vs. rural)	–0.055 (–0.287, 0.177)	–0.117 (–0.342, 0.108)	–0.085 (–0.300, 0.131)	–0.075 (–0.295, 0.145)
Constant	–0.005 (–0.138, 0.128)	0.290 (–0.095, 0.675)	0.218 (–0.155, 0.592)	0.234 (–0.188, 0.656)
Sample	1,760	1,760	1,760	1,760
F-stat	4.33	4.12	5.14	5.63
R-squared overall	0.1255	0.1168	0.1333	0.1405

Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. Enrolled in school, grade attainment, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence are measured at age 8 in model 1 and at age 12 in models 2–4.

Table A-6: Full results from linear regressions with cluster fixed effects for standardized ideal age for first child measured at age 15

	(1) Skills at age 8 Coef. (95% CI)	(2) Skills at age 12 Coef. (95% CI)	(3) Trajectory ages 8–12 Coef. (95% CI)	(4) Trajectory ages 8–12 Coef. (95% CI)
Reading z-score at age 8	0.019 (–0.037, 0.075)		0.078 (–0.042, 0.198)	0.053 (–0.054, 0.160)
Reading z-score at age 12		0.052 (–0.030, 0.135)		
Change reading score ages 8–12				
Standardized change			0.062 (–0.030, 0.154)	
No change (ref.)				
Improved				0.070 (–0.111, 0.251)
Worsened				–0.168 (–0.603, 0.266)
Numeracy z-score at age 8	0.023 (–0.033, 0.079)		0.012 (–0.061, 0.084)	0.009 (–0.061, 0.080)
Numeracy z-score at age 12		–0.003 (–0.066, 0.061)		
Change numeracy score ages 8–12				
Standardized change			–0.011 (–0.062, 0.039)	
Within ±1 SD of mean (ref.)				
Above +1 SD from mean				0.085 (–0.060, 0.229)
Below –1 SD from mean				0.126 (–0.051, 0.304)
Girl (vs. boy)	–0.536 (–0.672, –0.401)	–0.542 (–0.675, –0.409)	–0.541 (–0.673, –0.409)	–0.544 (–0.676, –0.412)
Cognitive z-score at age 5	0.054 (0.011, 0.096)	0.055 (0.014, 0.097)	0.054 (0.013, 0.095)	0.052 (0.010, 0.094)
Enrolled in school	0.052 (–0.080, 0.185)	0.049 (–0.119, 0.217)	0.056 (–0.111, 0.222)	0.088 (–0.072, 0.247)
Grade attainment	–0.003 (–0.077, 0.071)	–0.001 (–0.051, 0.049)	–0.008 (–0.061, 0.044)	–0.001 (–0.053, 0.051)
Mother completed primary	0.065 (–0.055, 0.185)	0.047 (–0.068, 0.162)	0.042 (–0.076, 0.159)	0.051 (–0.064, 0.166)
Coresident siblings	0.007 (–0.012, 0.025)	0.001 (–0.019, 0.021)	0.001 (–0.019, 0.021)	0.001 (–0.020, 0.022)
Household wealth (ref. poorest)				
middle	0.035 (–0.079, 0.150)	0.107 (–0.005, 0.219)	0.108 (–0.004, 0.220)	0.109 (0.000, 0.219)
wealthiest	–0.022 (–0.215, 0.171)	–0.027 (–0.212, 0.157)	–0.030 (–0.214, 0.154)	–0.032 (–0.217, 0.154)
Urban residence (vs. rural)	–0.098 (–0.380, 0.184)	0.155 (–0.149, 0.459)	0.144 (–0.165, 0.454)	0.148 (–0.162, 0.458)
Constant	0.209 (0.013, 0.406)	0.117 (–0.216, 0.451)	0.140 (–0.199, 0.480)	0.008 (–0.323, 0.339)
Sample	1,708	1,708	1,708	1,708
F-stat	21.53	21.27	25.20	30.67
R-squared overall	0.0703	0.0802	0.0814	0.0824

Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. Enrolled in school, grade attainment, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence are measured at age 8 in model 1 and at age 12 in models 2–4.

Table A-7: Full results from linear regressions with cluster fixed effects for standardized sexual and reproductive health knowledge measured at age 15

	(1) Skills at age 8 Coef. (95% CI)	(2) Skills at age 12 Coef. (95% CI)	(3) Trajectory ages 8–12 Coef. (95% CI)	(4) Trajectory ages 8–12 Coef. (95% CI)
Reading z-score at age 8	0.045 (–0.063, 0.153)		0.118 (–0.048, 0.284)	0.045 (–0.065, 0.156)
Reading z-score at age 12		0.073 (–0.043, 0.189)		
Change reading score ages 8–12				
Standardized change			0.092 (–0.035, 0.219)	
No change (ref.)				
Improved				0.034 (–0.152, 0.220)
Worsened				–0.213 (–0.660, 0.234)
Numeracy z-score at age 8	0.176 (0.071, 0.282)		0.195 (0.071, 0.318)	0.197 (0.077, 0.317)
Numeracy z-score at age 12		0.161 (0.055, 0.267)		
Change numeracy score ages 8–12				
Standardized change			0.082 (0.024, 0.140)	
Within ±1 SD of mean (ref.)				
Above +1 SD from mean				0.162 (0.010, 0.315)
Below –1 SD from mean				–0.174 (–0.332, –0.015)
Girl (vs. boy)	–0.079 (–0.173, 0.016)	–0.095 (–0.184, –0.006)	–0.089 (–0.180, 0.001)	–0.087 (–0.178, 0.004)
Cognitive z-score at age 5	0.023 (–0.034, 0.081)	0.015 (–0.040, 0.071)	0.011 (–0.046, 0.067)	0.010 (–0.046, 0.067)
Enrolled in school	–0.050 (–0.194, 0.093)	0.281 (–0.045, 0.607)	0.313 (–0.025, 0.651)	0.349 (0.006, 0.691)
Grade attainment	–0.014 (–0.142, 0.114)	0.015 (–0.040, 0.069)	–0.013 (–0.078, 0.051)	0.000 (–0.058, 0.057)
Mother completed primary	–0.098 (–0.267, 0.072)	–0.079 (–0.253, 0.096)	–0.098 (–0.272, 0.076)	–0.089 (–0.262, 0.084)
Coresident siblings	0.002 (–0.027, 0.031)	0.003 (–0.024, 0.030)	0.003 (–0.023, 0.029)	0.003 (–0.023, 0.030)
Household wealth (ref. poorest)				
middle	0.017 (–0.199, 0.234)	0.067 (–0.056, 0.191)	0.071 (–0.055, 0.197)	0.085 (–0.043, 0.213)
wealthiest	–0.056 (–0.290, 0.177)	–0.030 (–0.224, 0.165)	–0.041 (–0.239, 0.157)	–0.027 (–0.228, 0.175)
Urban residence (vs. rural)	0.271 (–0.210, 0.753)	0.254 (–0.092, 0.601)	0.221 (–0.149, 0.591)	0.225 (–0.145, 0.595)
Constant	–0.026 (–0.334, 0.282)	–0.443 (–0.837, –0.049)	–0.358 (–0.759, 0.043)	–0.461 (–0.890, –0.032)
Sample	1,513	1,513	1,513	1,513
F-stat	5.59	9.34	10.91	20.54
R-squared overall	0.0270	0.0410	0.0458	0.0419

Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. Enrolled in school, grade attainment, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence are measured at age 8 in model 1 and at age 12 in models 2–4.

Table A-8: Key results from linear regressions for standardized ideal number of children measured at age 15

	(1) Numeracy change relative to 1 SD from mean change Coef. (95% CI)	(2) Numeracy change relative to 0.75 SD from mean change Coef. (95% CI)	(3) Numeracy change relative to 0.5 SD from mean change Coef. (95% CI)
Reading			
Standardized score at age 8	–0.316	–0.316	–0.308
	(–0.440, –0.192)	(–0.438, –0.193)	(–0.428, –0.188)
Change in score ages 8–12			
No change (ref.)			
Improved	–0.283	–0.279	–0.261
	(–0.473, –0.093)	(–0.459, –0.099)	(–0.439, –0.084)
Worsened	–0.044	–0.032	–0.036
	(–0.853, 0.765)	(–0.838, 0.774)	(–0.843, 0.771)
Numeracy			
Standardized score at age 8	0.034	0.035	0.027
	(–0.071, 0.139)	(–0.070, 0.139)	(–0.081, 0.134)
Change in score ages 8–12			
Within ±(1; 0.75; 0.5) SD of mean (ref.)			
Above +(1; 0.75; 0.5) SD from mean	0.041	0.055	0.038
	(–0.119, 0.200)	(–0.097, 0.206)	(–0.102, 0.178)
Below –(1; 0.75; 0.5) SD from mean	0.065	0.068	0.098
	(–0.113, 0.243)	(–0.053, 0.188)	(0.013, 0.183)
Sample	1,760	1,760	1,760
F-stat	12.09	11.01	12.07
R-squared	0.1784	0.1787	0.1792

Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. All regressions included controls for gender, cognitive development score measured at age 5, and the following covariates measured at age 12: enrolled in school, highest grade attained, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence.

Table A-9: Key results from linear regressions for standardized ideal age for first child measured at age 15

	(1) Numeracy change relative to 1 SD from mean change Coef. (95% CI)	(2) Numeracy change relative to 0.75 SD from mean change Coef. (95% CI)	(3) Numeracy change relative to 0.5 SD from mean change Coef. (95% CI)
Reading			
Standardized score at age 8	0.131	0.119	0.115
	(–0.011, 0.272)	(–0.017, 0.255)	(–0.012, 0.242)
Change in score ages 8–12			
No change (ref.)			
Improved	0.120	0.105	0.100
	(–0.090, 0.330)	(–0.100, 0.310)	(–0.096, 0.297)
Worsened	–0.133	–0.100	–0.100
	(–0.593, 0.328)	(–0.552, 0.353)	(–0.551, 0.351)
Numeracy			
Standardized score at age 8	0.023	0.032	0.037
	(–0.057, 0.104)	(–0.045, 0.109)	(–0.039, 0.113)
Change in score ages 8–12			
Within ±(1; 0.75; 0.5) SD of mean (ref.)			
Above +(1; 0.75; 0.5) SD from mean	0.123	0.081	0.115
	(–0.011, 0.258)	(–0.027, 0.189)	(–0.005, 0.235)
Below –(1; 0.75; 0.5) SD from mean	0.060	–0.011	–0.001
	(–0.117, 0.238)	(–0.094, 0.071)	(–0.098, 0.095)
Sample	1,708	1,708	1,708
F-stat	10.53	11.36	29.92
R-squared	0.1058	0.1047	0.1061

Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. All regressions included controls for gender, cognitive development score measured at age 5, and the following covariates measured at age 12: enrolled in school, highest grade attained, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence.

Table A-10: Key results from linear regressions for standardized sexual and reproductive health knowledge measured at age 15

	(1) Numeracy change relative to 1 SD from mean change Coef. (95% CI)	(2) Numeracy change relative to 0.75 SD from mean change Coef. (95% CI)	(3) Numeracy change relative to 0.5 SD from mean change Coef. (95% CI)
Reading			
Standardized score at age 8	0.032 (–0.075, 0.138)	0.037 (–0.065, 0.138)	0.038 (–0.067, 0.142)
Change in score ages 8–12			
No change (ref.)			
Improved	0.012 (–0.172, 0.197)	0.014 (–0.161, 0.189)	0.018 (–0.159, 0.194)
Worsened	–0.274 (–0.730, 0.181)	–0.307 (–0.737, 0.124)	–0.316 (–0.743, 0.111)
Numeracy			
Standardized score at age 8	0.211 (0.110, 0.312)	0.203 (0.103, 0.302)	0.202 (0.096, 0.307)
Change in score ages 8–12			
Within ±(1; 0.75; 0.5) SD of mean (ref.)			
Above +(1; 0.75; 0.5) SD from mean	0.137 (–0.017, 0.290)	0.147 (0.043, 0.250)	0.137 (0.011, 0.262)
Below –(1; 0.75; 0.5) SD from mean	–0.198 (–0.331, –0.065)	–0.112 (–0.255, 0.030)	–0.095 (–0.256, 0.066)
Sample	1,513	1,513	1,513
F-stat	13.79	30.68	15.07
R-squared	0.0574	0.0566	0.0573

Notes: CI = confidence interval. Regressions were estimated with robust standard errors clustered at the sentinel site level. All regressions included controls for gender, cognitive development score measured at age 5, and the following covariates measured at age 12: enrolled in school, highest grade attained, mother completed primary school, number of coresident siblings, household wealth, and urban vs. rural residence.