Additional Returns to Investing in Girls' Education: Impact on Younger Sibling Human Capital

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Abstract

A vast literature on the spillovers from girls' education focuses on the impact of maternal education on child outcomes. This paper is the first to investigate whether externalities from investing in girls' education may be realized earlier — before they have children of their own. In many developing countries, oldest sisters share significant child care responsibilities in the household and potentially play an important role in younger siblings' learning. I propose a model incorporating the effect of the oldest sister that predicts competing effects of increasing oldest sister's schooling on younger siblings' human capital. Using an identification strategy that exploits the gender segregation of schools in Pakistan, I estimate the impact of the oldest sister's schooling on the human capital acquisition of her younger brothers. I find that oldest sister's schooling has significant, beneficial impacts on younger brothers' schooling, enrollment, literacy and numeracy. An additional year of schooling for the oldest sister increases the younger brother's completed years of schooling by 0.42 years and his probability of being enrolled by 9.6 percent. It also increases the probability of a primary school-aged younger brother being literate and numerate by 7-19 percent. I discuss the implications of these results for policies targeting girls' education. These findings indicate that evaluations of such policies that consider only effects on the girls and their children but ignore potential impacts on younger siblings systematically underestimate the total benefits of these policies.

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1 Introduction

A vast literature establishes the beneficial impact of maternal schooling on a range of child outcomes: birth outcomes (Currie and Moretti, 2003), nutrition (Thomas et al., 1991), education (Haveman and Wolfe, 1995), and test scores (Rosenzweig and Wolpin, 1994). This paper investigates whether educating girls may yield significant externalities even before they have children of their own. I extend the literature on spillovers from educating girls in a new direction by investigating the externalities from girls' education on the human capital acquisition of younger siblings. This study uses data from rural Pakistan to identify spillover effects of the oldest sister's schooling on younger brothers' schooling, enrollment, literacy, and numeracy. I exploit the gender segregation of schools in Pakistan to generate quasi-experimental variation in oldest sister's schooling in order to identify causal impacts on younger brothers. While the impacts of oldest sister's schooling on both younger brothers and sisters are of theoretical interest, my preferred identification strategy only allows me to estimate causal impacts for younger brothers.

There are several reasons why the oldest sister's schooling could be important for younger siblings, especially in a developing country context. The oldest sister shares significant child care responsibilities in many developing countries (Levison and Moe, 1998; Ilahi, 2004; Edmonds, 2006). As someone who looks after and interacts with younger siblings extensively, the oldest sister has potential for significant influence on younger siblings' learning. In Pakistan, oldest sisters are also the most important source of help with studies for young children. Only one in five children get help with studies from a parent while over half report the family member helping them with studies on a regular basis is an older sister.

I propose a model that incorporates the effect of oldest sister's schooling on younger brother's human capital acquisition. I build on Becker's classic model of human capital by treating time spent with the oldest sister as a direct input into the younger brother's human capital production. This model yields competing effects of increasing oldest sister's schooling on younger brother human capital: a positive quality effect and a negative quantity effect. The positive quality effect captures the fact that increasing the oldest sister's schooling improves the quality of the time she spends with her younger brother. A key way in which oldest sister's schooling differs from parental schooling is that parental schooling is completed before children are born whereas oldest sister's schooling is likely to still be ongoing when the child is young. This creates a tradeoff for oldest sister's schooling which does not exist for parental schooling because increasing the schooling of the oldest sister requires allocating more time towards school work, and therefore leaves less time with the younger brother. I

term this negative spillover effect the quantity effect. Because increases in oldest sister's schooling are associated with a positive quality effect and a negative quantity effect, the net impact on younger brother human capital is theoretically ambiguous and therefore must be determined empirically.

Evaluating the impact of oldest sister's schooling on younger siblings is rife with selection issues because there are likely important differences in observed and unobserved characteristics across households which make different levels of investment in their daughter's schooling. This highlights the need for utilizing quasi-experimental variation in oldest sister's schooling in order to identify causal spillover effects on younger sibling human capital. My identification strategy relies on the gender segregation of schools in Pakistan. I use distance to closest girls' school, conditioning on distance to village center, and distance to closest boys' schools to create plausibly exogenous variation in the schooling of the oldest sister.[1] Increasing distance to girls' school significantly lowers the years of schooling acquired by girls as documented by Alderman et al. (2001) and Andrabi et al. (2008) in Pakistan, and Burde and Linden (2010) in Afghanistan. This distance penalty exists in my sample as well and arises because of safety and chastity concerns about girls outside the home. The fact that somebody needs to accompany the girl on her walk to and back from school creates a large burden on girls' schooling that does not exist for boys.

I provide several arguments for and tests of the validity of the instrument of distance to girls' school in this context. Since boys do not attend girls' schools, distance to girls' school can only affect boys indirectly through how it varies with other factors. First, I demonstrate that the usual concern with the use of distance to school instruments in the U.S. literature does not apply in the context of rural Pakistan. I show that most households in the data are agricultural households tied to their land, and have very restricted mobility and capacity to locate systematically with respect to schools. Second, I control for distance to village center to soak up any variation in distance to girls' schools driven by how centrally or remotely a household is located. Third, I control for distance to boys' schools the younger brothers will attend so that identification comes from comparing households equidistant from the village center and equidistant from the boys' school, and different only in their distance to girls' school. Fourth, I show that distance to boys' schools does not have any impact on oldest sister's schooling. Last, I implement a falsification test in which I analyze the impact of oldest

[1]Data contains GPS coordinates for all surveyed households and all schools in the village enabling me to calculate distances between each household and school. I use distance to closest government girls' school while controlling for distance to village center, distance to closest government boys' school, and distance to closest private school as an instrument for oldest sister's schooling.

sister's schooling on her older brothers' outcomes. The proposed model suggests spillover effects of oldest sister's schooling on her younger siblings due to her role and activities as an older sibling. Theoretically, the impact should only flow from older sister to younger siblings, and there should be no meaningful impact of oldest sister's schooling on her older brothers. I show that I do not find any statistically or economically significant impacts of oldest sister's schooling on older brothers' outcomes when I use this instrumental variables (IV) strategy. This evidence collectively provides strong justification for the validity of the conditional instrument of distance to girls' school in this context.

Using this IV, I find that the oldest sister's schooling has significant, beneficial impacts on younger brothers' human capital. In the context of my model, the quality effect of the oldest sister's increased schooling outweighs the quantity effect to produce a net positive impact. I find that an additional year of schooling completed by the oldest sister increases the younger brothers' years of schooling by 0.42 years and increases the probability of being enrolled in school by 9.6 percent. It also increases the probability of a primary school-aged younger brother being able to read, add, and count by 19, 12 and 7 percent, respectively. The impact on writing is positive but not statistically significant. Increasing oldest sister's schooling by one year increases her completed schooling by one-third of a standard deviation. Relative to the mean, an additional year increases oldest sister's schooling by 25 percent.

This is the first paper I am aware of to estimate the impact of oldest sister's schooling on any younger sibling outcome. Past studies on siblings have focused on the effects of the number and sex composition of siblings on education (Butcher and Case, 1994; Kaestner, 1997; Black et al., 2005). Shrestha (2011) highlights the potential for inter-sibling rivalry in education due to competition for resources by showing that an increase in male education decreases the education of female siblings in the household. This study is the first to conceptualize oldest sister's schooling as an input into younger siblings' learning, and therefore relates closely to the literature on impact of maternal schooling. I compare my results to the impacts of maternal schooling on children's schooling estimated in the literature and find them to be comparable in size.

I find evidence that suggests the spillover effects from oldest sister's schooling are larger in households with uneducated mothers. This is consistent with what is theoretically expected because oldest sister's education is a close substitute for mother's education in rural Pakistan. The schooling of the oldest sister may play a significant role in child learning if the oldest sister is relatively highly educated as compared with other child care providers, especially mothers. One might expect diminishing marginal returns to the education of

family members such that children gain substantially when the first family member acquires education but relatively less from increases in education in a family that is already well-educated. The treatment impacts I find relate closely to the low education of household members in the region. Seventy-five percent of mothers and 40 percent of fathers have no schooling. For many of these households, the oldest sister is therefore one of the first family members to acquire any schooling, and one would expect her schooling to generate large spillovers in the family.

This paper is organized as follows. Section 2 provides institutional background and motivation. I propose a model for how oldest sister's schooling might impact younger sibling human capital in section 3. Sections 4 and 5 describe the data and empirical strategy. Section 6 presents the main results while Section 7 discusses robustness checks. Section 8 discusses policy implications and concludes.

2 Institutional Background

Educational attainment in Pakistan is low and characterized by large gender gaps. Low perceived returns to and high cost of girls' schooling contribute to lower levels of girls' education. Female labor force participation rates are extremely low and post-marital residence virilocal i.e. girls move out of their parents' household and into their husband's household upon marriage[2]. Given that girls do not earn income through market work while sons provide support for parents in their old age, it is likely that it is efficient for parents to invest less in girls' schooling relative to boys' schooling (Strauss and Thomas, 1995).

Parents in Pakistan send their children to government schools or private schools. Enrollment in religious schools, madrassas, is a third option but this accounts for less than 1 percent of enrollment.[3] Government schools are free and gender segregated at all levels of instruction while private schools are relatively expensive, co-educational facilities that have opened up in large numbers starting in the mid-1990s.[4] Government schools still enroll over 70 percent of the children, and more than 75 percent of the girls in my sample of villages

[2]The female labor force participation rate for women 10 years and older was 20.66% in 2008-09 (Federal Bureau of Statistics, 2009)

[3]Contrary to popular press reports, Andrabi et al. (2006) document that madrassas account for about 1 percent of the enrollment share and there is no evidence of a significant increase in recent years.

[4]Ninety-four percent of the private schools in the sample villages are co-educational schools. The average annual fee charged by government schools was Rs. 10 in 2003 Pakistani rupees, approximately one-sixth of a USD according to the exchange rate at the time. The average annual fee charged by a private school was Rs. 870, or USD 14. The average household in the sample has expenditures per capita of approximately one USD a day. The rapid growth of the private school sector has been documented by Andrabi et al. (2008).

from rural Punjab. The main cost of schooling for girls who primarily attend government schools is therefore a distance cost.

An overwhelming majority of children walk to schools in these rural villages and the younger children are accompanied by a relative or friend as they walk to and back from school. In my data, ninety-four percent of children — boys and girls — younger than 10 years old have somebody walk them to school. The fraction of boys accompanied to school falls as boys grow older and are considered increasingly capable of taking care of themselves. The fraction of girls accompanied to school does not decline with girls' age leading to a statistically significant, 14 percentage point difference in the rates of accompaniment for girls and boys aged 13 and older.

This gender gap emerges because girls' mobility is restricted by safety concerns and these concerns intensify after girls reach the age of puberty. The need for households to ensure that somebody accompanies the girls to school is particularly burdensome as girls get older. Since there is a considerable drop-off in girls' enrollment after primary school, there are fewer options for girls to walk to school with other school-going girls who live in the neighborhood. Furthermore, the gender segregation of government schools means that less than 15% of girls are walked to school by a brother. The additional cost imposed by the need for somebody to accompany a girl to school creates a distance penalty that disproportionately impacts girls. Past studies have established distance to school as a strong determinant of girls' enrollment and schooling in this region — by Alderman et al. (2001) and Andrabi et al. (2008) in Pakistan and by Burde and Linden (2010) in Afghanistan. I will utilize this penalty imposed by distance to girls' school to generate plausibly exogenous variation in the oldest sister's schooling and use that to identify causal impacts on younger brothers.

Given the gender division in responsibilities, it is the older sister and not the older brother who takes care of younger siblings. Girls are responsible for housework including cooking, cleaning, taking care of younger siblings as well as farm and livestock-related chores while boys engage in market work and work on the farm. The typical 15-18 year old girl spends an average of 5.5 hours daily on housework compared to half an hour for similarly-aged boys.[5]

[5]These figures exclude time spent on farm-related chores from housework. When including time spent on these activities, girls spend an average of six hours and boys spend an average of 1.5 hours daily on housework. Boys are more likely to be engaged in paid work. The average 15-18 year old boy spends 2.5 hours a day on paid work compared with just 14 minutes for a girl of that age. While 83.1% of girls aged 15-18 report doing housework on a given day, only 18.5% of boys report doing so.

The oldest sister can affect younger sibling learning for a number of reasons. In Pakistan, older sisters are the most important source of help for children with their studies. Only one out of five children receiving help with studies from a family member get it from a parent. When parents are not the ones helping, the older sister is fulfilling that role 70% of the time. The older sister is twice as likely as an older brother to help out, and conditional on helping, she spends an average of 7 hours in a week helping a younger sibling with studies.

Since older sisters are also child care providers, the education of older sisters can potentially be an important input into younger siblings' learning. I analyze the relationship between the oldest sister's education and outcomes of younger brothers because the oldest sister bears the most responsibility of taking care of younger siblings. Edmonds (2006) highlights older girls' comparative advantage in home production, especially in caring for younger children, as an explanation for differences in hours worked across siblings. He shows that in Nepal, the oldest girl in a household with four children works 4.2 more hours per week than the second oldest girl.

Since oldest sisters spend significantly more time at home relative to oldest brothers, younger siblings also have greater potential interaction with the oldest sister in general even when the oldest sister is not actively looking after the younger sibling. As younger children spend the bulk of their time at home, this can be a channel through which older sisters can have non-trivial influence over younger siblings' learning.

3 Model

This section provides a theoretical model which predicts competing effects of an increase in the schooling of the oldest sister on younger sibling human capital. I start with the standard model of human capital investment (Becker, 1964) where parents determine investment allocations for each of their children by weighing the costs and benefits of the investment. Just as Becker modeled parents' time investment in children as an input into children's human capital production, I model time spent with the oldest sister as an input into the younger brother's human capital.[6] The rationale behind this extension is that oldest sisters have potential to meaningfully impact younger sibling learning for the reasons discussed above.

Having a more educated oldest sister increases the quality of the time younger brother spends with her. More educated oldest sisters are likely to use a greater number and variety

[6]I model the interaction between oldest sister and younger brother because that is what I empirically estimate. While there is nothing inherently different between younger brother and younger sister, I do not model the relationship between oldest sister and younger sister because I do not estimate that.

of words in their conversation with younger siblings. Studies from the child development literature find that younger siblings can benefit from the language skills of their older siblings, and that girls have more superior language skills than boys.[7] A more educated oldest sister could also be more likely to help younger siblings with studies and that help is likely to be of higher quality. I call this phenomenon whereby increased schooling for the oldest sister improves the quality of time spent with the younger brother the quality effect.

A key way in which oldest sister's schooling differs from parental schooling is that parental schooling is completed before children are born whereas oldest sister's schooling is likely to be ongoing when the child is young.[8] This creates a tradeoff for oldest sister's schooling which does not exist for parental schooling because increasing the schooling of the oldest sister requires allocating more time towards schooling, and hence potentially less time with the younger brother. The oldest sister's time spent in school, and traveling to and from school constitutes time that is not spent with the younger brother. This tradeoff is likely more acute when the younger brother is of pre-school age since he is not yet enrolled in school and spends most of his time at home. I denote this negative impact of increasing oldest sister's schooling on time spent with younger brother, and hence his human capital, the quantity effect.

3.1 Mechanics

I propose a model of human capital acquisition which incorporates the linkages described above. Consider the optimization problem for a household with parents and two children, an older girl and a younger boy. Parents maximize a separable utility function which is concave in period 1 consumption and the utility of their two children which is realized in period 2. In period 1, parents have access to wealth, W_p, and make the decisions of how much to consume, C, and how much of each of their children's time to allocate to schooling, y_i, where i equals s for the older sister and b for the younger brother. Children's time can either be

[7] Pine (1995) finds evidence that suggests younger siblings' vocabulary development increases as their older siblings' speech becomes more complex. Girls talk earlier, articulate more clearly, use longer sentences, and are more fluent (Maccoby, 1966) and the amount of language exposure is crucial for vocabulary growth in children (Huttenlocher et al., 1991). Highly educated mothers talk more, use more complex syntax and a more varied vocabulary when talking with their children, and their children have larger vocabularies (Brooks-Gunn and Markman, 2005; Hoff, 2003) It is thus plausible that younger siblings can benefit from language exposure from oldest sisters, especially if oldest sisters are highly educated relative to the mothers.

[8] While it is increasingly common for parents in developed countries to continue to acquire schooling after the birth of their children, this is very rare in Pakistan. Children drop out from school much earlier, many times even before the completion of primary school, and are therefore much less likely to return to school as adults.

allocated to schooling or household production at home or the family farm. Let y_i denote the share of child i's time allocated to schooling, and $x_i = 1 - y_i$ the share allocated to household production. With instruction time in the school day fixed, y_i can best be interpreted as years of schooling for child i.

The oldest sister's human capital production function is $H_s = f(y_s)$. Time allocated towards schooling, y_s, is the only input into older sister's learning or human capital, H_s. The function $f(y_s)$ is assumed to be continuous and twice differentiable such that $f_{y_s} > 0$ and $f_{y_s y_s} < 0$ so that years of schooling exhibit positive but diminishing marginal returns in the production of human capital.

The human capital production function of the younger brother is $H_b = g(y_b, x_s, H_s)$ so that younger brother's human capital is a function of his own years of schooling, the time the oldest sister spends at home, and the human capital of the oldest sister. Each of the inputs individually have positive and diminishing marginal returns in the production of human capital so that $g_{y_b} > 0$, $g_{x_s} > 0$, $g_{H_s} > 0$, $g_{y_b y_b} < 0$, $g_{x_s x_s} < 0$, and $g_{H_s H_s} < 0$. I assume complementarities between the inputs with $g_{x_s y_b} > 0$, and $g_{x_s H_s} > 0$. The oldest sister's time spent at home, x_s, is treated as an input with the implicit assumption that the sister's time spent at home doing housework is also spent with the younger brother. This is reasonable because the older sister's responsibilities include caring for younger siblings, and even if the sister is engaged in other household chores, this time is still spent at home potentially interacting with the younger brother. Following Becker's treatment of parental time investment, I assume a complimentarity between time spent with older sister and brother's own schooling investment, y_b. The oldest sister's human capital also enters the production function directly because higher human capital increases the quality and productivity of the time that she spends with the younger brother.

The productivity of time allocated to household production, x_i, is allowed to vary by gender according to the parameters, p_s and p_b. I also model gender-specific cost of schooling with d_s and d_b, and interact these parameters with y_i so as to allow the total cost incurred to vary with years of schooling. Since government schools are free, the main cost of schooling captured by d_s and d_b is distance to girls' and boys' school. In period 2, the children who are now adults realize the returns to the human capital they accumulate in period 1. Each child's utility is a function of wealth, W_i, which equals his/her accumulated human capital, H_i, times the gender-specific wage rate, r_i.[9] Parents derive utility from their children's

[9]Since female labor force participation is low, market returns are not a significant component to the return to education for girls. Instead of labor market returns, parents might instead derive utility from the non-pecuniary returns to education including but not limited to gains in status, marriage market returns,

period 2 utility which translates into parents' utility according to gender-specific altruism parameters, a_s and a_b, that are typically assumed to be ≤ 1 because parents may put less weight on children's utility as compared with their own. Due to strong son preference, reliance on sons' in old age, and virilocal marriages that are customary in Pakistan, it is likely that a_s is less than a_b.[10]

The parents' objective function is to maximize the following utility $U(C) + a_s V(W_s) + a_b V(W_b)$ subject to the budget constraint $C + d_s y_s + d_b y_b = W_p + p_s(1 - y_s) + p_b(1 - y_b)$, and the technologies specified above.[11] Parents choose y_b^* so as to satisfy the following first-order condition:

$$a_b V_{w_b} r_b g_{y_b} = (p_b + d_b) U'(c) \qquad (1)$$

This yields the standard result that parents choose younger brother's schooling, y_b^*, so that the utility gain due to his increased wealth associated with a marginal increase in y_b equals the increase in the disutility associated with increased schooling costs. These costs include both the opportunity cost of foregone household production and the distance cost of schooling.

The marginal benefit and marginal cost of oldest sister's schooling will also include spillover effects on the younger brother. An increase in the oldest sister's schooling increases not only her wealth, but also the wealth of the younger brother because increasing the schooling and therefore human capital of the older sister increases the quality of the time spent with the younger brother which increases his human capital. The costs associated with increasing oldest sister's schooling include foregone consumption and a distance cost but also the negative quantity effect since increasing her schooling entails less time spent with the younger brother which reduces his human capital and wealth. An increase in oldest sister's schooling is therefore associated with two competing effects on younger brother's human capital acquisition, a positive quality effect and a negative quantity effect. Without knowledge of the relative magnitudes of these effects, the net impact of older sister's schooling is theoretically ambiguous and needs to be determined empirically.

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and benefits for grandchildren.

[10] There is very strong son preference in Pakistani society. Sen (1992) and others have documented the phenomenon of missing girls in many Asian countries, including Pakistan.

[11] $U', V_{w_s}, V_{w_b}, f_{y_s}, g_{y_b}, g_{x_s}, g_{H_s}$ are assumed to be positive, and $U'', V_{w_s w_s}, V_{w_b w_b}, f_{y_s y_s}, g_{y_b y_b}, g_{x_s x_s}$, and $g_{H_s H_s}$ are assumed to be negative. The parameters $W_p, a_s, a_b, r_s, r_b, p_s, p_b, d_s$, and d_b are exogenously determined. I assume the Inada conditions so that that we get interior solutions for consumption, C, oldest sister's years of schooling, y_s, and younger brother's years of schooling, y_b.

The first-order condition choosing y_s^* implies that:

$$a_s V_{w_s} r_s f_{y_s} + a_b V_{w_b} r_b [g_{H_s} f_{y_s} - g_{x_s}] = (p_s + d_s) U'(c) \qquad (2)$$

If $g_{H_s} f_{y_s} - g_{x_s} > 0$, the quality effect overrides the quantity effect, and oldest sister's schooling has a net positive spillover on younger brother human capital. This expression shows that even if $a_s = 0$ and parents derive no utility from the sister's utility, it can still be optimal for them to invest in her schooling when her schooling generates positive spillovers for the younger brother.

If the spillover from oldest sister's schooling is positive and parents ignore it in their schooling allocation decision, they will under-invest in the oldest sister's schooling.[12] I show evidence consistent with such investment in section 5. In the case where parents fail to internalize the spillover in their choice of schooling allocations, the younger sibling will still be impacted by the spillover because it is present in the human capital production function. I will thus still be able to empirically identify any spillover effects of older sister's education that exist regardless of the parent's behavioral response.[13]

In line with my empirical results, I assume that the net externality on younger brother human capital is positive for the purpose of calculating comparative statics. I discuss the comparative statics with respect to $W_p, a_b, a_s, r_s, r_b, p_s, p_b, d_b$ and d_s, and provide proofs in the theoretical appendices A2 and A3.[14] Here I discuss the comparative static of brothers schooling with respect to distance cost of girls schooling because that is the source of variation I use to identify the causal impact of oldest sisters schooling.

The model predicts that an increase in the distance cost of girl's schooling has three potential effects on younger brother's schooling: a positive substitution effect, a negative income effect and a negative spillover effect. The positive substitution effect arises from the fact that children compete for investment from a common pool of resources so parents will respond to the higher distance cost by reducing the sister's schooling and substituting towards the relatively cheaper brother's schooling. Shrestha found evidence consistent with this when documenting inter-sibling rivalry in Nepal where increases in boys schooling reduced

[12] This is proved formally in appendix A1.

[13] This is assuming that the quality effect and quantity effect do not exactly offset each other.

[14] Children's schooling is increasing in parental wealth. Increasing the relative altruism towards girls results in higher schooling for the sister and lower schooling for the brother. Higher market return to girls' human capital increases sister's schooling while reducing brother's schooling, whereas higher market return to boys' human capital increases the brother's schooling and has an ambiguous impact on sister's schooling since sister's schooling is also an input into brother's human capital.

the schooling of their sisters. If parents invest in the sister's schooling despite the higher cost, the increased cost incurred squeezes household resources which can reduce the brother's schooling via an income effect. Since the schooling distance cost is mainly a time cost, i.e. the opportunity cost of the time it takes the sister to walk to school, the income effect is likely to be modest. The third effect identifies how the distance-induced reductions in older sisters schooling reduce the positive spillovers for the younger brother. While the income effect has the same expected sign as the spillover effect, it is arguably modest, and the substitution effect has the opposite sign of the spillover effect which makes it harder to find evidence for positive externalities associated with the older sister's schooling.

4 Data and Sample Characteristics

This paper estimates the relationship between oldest sister's schooling and younger brother outcomes using data from rural Pakistan. I use the Learning and Educational Achievement in Punjab Schools (LEAPS) data, a longitudinal survey of 1800 households in the province of Punjab, home to 56% of the country's population. Data was collected for 112 villages in the three districts of Attock, Faisalabad, and Rahim Yar Khan from 2003-2006.[15] A random sample of households was selected from each village, and all the schools in these villages were surveyed.[16] The data contains household surveys, school surveys and detailed geographical coordinates for all surveyed households and all schools in the 112 villages sampled.

Table 1 shows the summary statistics on schools in these villages. The average village has seven schools with two government boys' schools, slightly less than two government girls' schools and three private schools. The average household is located 0.59 km from the closest government girls' school, and 0.61 km from the closest government boys' school.

Significant gender gaps in education are evident. Age-specific enrollment rates plotted in figure 1 show an 8 percentage point gender gap in enrollment for children of primary school-age (6-12 years old) which widens to a 14 percentage point gap for children 13-18 years old. Primary school in Pakistan comprises of grades 1-5, middle school grades 6-8 and high school grades 9 and 10. Figure 2 documents the gap in years of schooling completed: 28.6% of girls in these rural villages acquire no schooling compared to 12.6% of boys.[17]

[15] These districts represent an accepted stratification of Punjab province into North, Middle and South regions.

[16] A total of 112 rural villages were selected at random from a list of villages with an existing private school and where the total number of schools did not exceed 20.

[17] I show years of schooling completed for boys and girls aged 16-20 because the average 16 year old is old enough to have completed middle school if he/she were to stay enrolled in school till that age. Since

Descriptive statistics for the 1,215 households used in the analysis are included in table 2.[18] Since I analyze the impact of oldest sister's education on younger brothers, the sample of interest is households that have at least one daughter and a younger brother. The average household in this sample has eight members, of whom five are children, and the three adults are the two parents and a grandparent. The average oldest sister is 16.20 years old, and the average younger brother is 10.04 years old. Ninety-four percent of the households own the house they reside in. Average expenditures per capita were about one USD a day.[19]

Parents have very low educational attainment. Only a quarter of the mothers and 62% of the fathers have had any schooling. The average years of schooling completed is 1.47 years for mothers, and 4.36 years for fathers (5.25 years versus 6.86 years respectively when excluding those with no schooling). The average years of schooling completed by the oldest sister is 3.97 years and has a standard deviation of 3.22 years. While the typical oldest sister has acquired less than primary school education, she is still relatively highly educated compared to the average mother.

My basic specification relates oldest sister's years of schooling to younger brother outcomes. I also consider alternative specifications of the treatment using an indicator for whether the oldest sister has any schooling, and an indicator for whether she has completed primary schooling i.e. five years of schooling. One in four oldest sisters have no schooling and 44.7% of oldest sisters have completed primary schooling. Almost 40 percent of the oldest sisters are currently enrolled in school so the years of schooling observed is a right-censored variable for them. This right-censoring is not problematic because I control for age of the oldest sister in all my specifications. Identification involves comparing oldest sisters who have acquired more schooling adjusting for their age and therefore their capacity for how

schooling is completed for the overwhelming majority of girls in this age range while it is still in progress for some boys, these figures likely represent lower bounds on the gender gap in educational attainment. I chose 16-20 as the age range to show the distribution of years of schooling completed to strike a balance between being able to observe completed schooling and ensuring that I can still capture girls in the household before they move out upon marriage.

[18]While the LEAPS data consists of four rounds, I do not include the second round of data in the analyses. Due to funding issues, only an abridged version of the survey was administered in round 2 in October-December of 2003, just months after the first round in February-April of 2003, leading to data inconsistencies across rounds. Literacy and numeracy questions were not asked in round 2. While some schooling information was collected, its interpretation is problematic because the academic year for Pakistani schools starts in March/April and I can not determine if the first and second round interviews for a household took place in the same or different academic year. Children who were interviewed twice in the same academic year will have their grade completion appear artificially depressed relative to that of children who were interviewed in different academic years. Round 2 data also has seasonal differences because unlike all other round interviews which were conducted in the Spring, round 2 was administered in the Fall and/or Winter.

[19]The market exchange rate at the time of the survey was Pakistani rupees 60 to 1 USD.

much schooling they potentially could have accumulated by that time.

Some studies on the impact of maternal education employ fixed effects, such as Rosenzweig and Wolpin (1994) and Moore and Schmidt (2007), that identify the impact of mother's schooling or enrollment by analyzing mothers who go back to school between the births of two children. Although the LEAPS is a panel dataset, I do not use fixed effects. Using the variation in oldest sister's education over time would only identify an incremental, value added impact of the oldest sister continuing her education. The experiment associated with my research question compares the learning outcomes of a child who grows up in a household with an oldest sister who has low schooling, and a similar child in an otherwise comparable household in which the oldest sister had more years of schooling. Only 46 percent of the oldest sisters have time-varying years of schooling and would therefore contribute to the estimates in a fixed effects regression. For the specification where I define treatment as having an oldest sister with any schooling, a fixed effects approach would yield meaningless estimates because a switch in treatment status during the panel for the typical 16-year old oldest sister is extremely rare and likely to be measurement error.[20] This study does not use fixed effects because the results would not answer my research question, and would be identified from a severely limited, non-random sample of the data.

4.1 Outcomes of interest

I analyze the impact of oldest sister's schooling on years of schooling, enrollment status, literacy, and numeracy of younger brothers. Since most younger brothers are still enrolled in school, the schooling outcome is years of schooling that the brother has completed by that age rather than completed schooling.[21]

Literacy and numeracy are crucial basic skills that primary schools impart. These are also skills that might be more relevant in rural, agrarian societies where the return to higher education is likely limited. The literacy and numeracy measures are derived from answers to the following questions:

Can *name* read a postal letter or newspaper in any language?

Can *name* write a postal letter in any language?

Can *name* add or subtract?

Can *name* count?

[20]The indicator variable for whether the oldest sister has primary schooling is time-varying for only 30 percent of the oldest sisters.

[21]I control for the age of the younger brother in all specifications.

Figure 3 shows the gender gap in the mean reports for these outcomes for boys and girls aged 5-12 years. Three-quarters of the children can count and about 65 percent can add and subtract. Roughly 45 percent can read but only two in five can write. The progression of these skills by grade, shown in Figure 4, suggests that while these binary measures may seem rudimentary, the learning of children in this sample is quite poor and there is considerable variation in these measures. Less than half of the children in class 3 are able to read and only one in three are able to write. Andrabi et. al 2008 report that if a child were to leave school after class 3, he/she would most likely be unable to write a simple sentence in Urdu. Only 65 percent of the students in class 3 are able to subtract single-digit numbers, and only 19 percent are able to divide a three-digit number by a single-digit number.

In the vast majority of cases, the household member answering these questions about child capabilities is the mother. Since only a quarter of the mothers have any schooling, one may wonder whether uneducated mothers respond differently to questions about capabilities that they themselves may lack. If so, the reported literacy and numeracy responses may measure different things across children with mothers of different education. To test this, I studied the relationship between mother's education and her potentially subjective response for ability of child to read/write/add/count after controlling for child's test score. The LEAPS data contains test scores for a sub-sample of children who were enrolled in school in certain grades. I am unable to analyze the impact of oldest sister's schooling on younger brothers' test scores because these are available only for a select sample of children enrolled in school. This raises both sample selection concerns and yields samples that are too small to use with my instrument.

The problem with simply comparing capability reports by education of mother is that the mother's education has an independent impact on the child's capabilities. Differences in reported child abilities by mother's education do not necessarily mean that mothers are using different standards to define whether they think the child can read. More educated mothers might teach their children to read. Since test score is an objective — albeit noisy — measure of the accumulated learning of the child, it should include the learning impacts of the mother's education on the child. If I find that mother's education significantly predicts child's reported abilities even after controlling for test score, I would take this as evidence of the mothers' reports capturing different things for mothers of different education levels. I regressed each of the mother-reported capability measures on the most closely related test

score[22] and a measure of mother's education.[23] Appendix tables A1 and A2 show that there is no statistical or economically significant relationship between mother's education and reported capability of the child after controlling for child's test score. I conclude that mother-reported capability measures are reliable and appear not to capture significantly different concepts across mothers of varying education backgrounds.

4.2 Sample of Interest

The analysis sample includes households which have at least one daughter living in the household who also has a younger brother. I also restrict the sample to households where the oldest sister is between 8 and 30 years old in round 1. The upper bound on the oldest sister's age is important because girls get married early and move out of the parents' household upon marriage. Since I only know oldest sister's schooling if she is still living with her parents, the use of much older, single oldest sisters could create bias. To further avoid selection from marriage, I use the oldest sister among the siblings still living in the household. In 73% of the cases, the oldest sister I use is the oldest sister by birth rank. I discuss these sample restrictions and robustness checks I implement in more detail in the appendix.

For the literacy and numeracy outcomes, I analyze impact of oldest sister's education on younger brothers aged 5-12 years inclusive. Children aged 5-6 may be enrolled in kindergarten (kacchi class) and will have started to learn how to count and add. The average child in class 5 is 11.7 years old. By the time children are 12 years old, 92 percent can write, 97 percent can read, and almost all of them can add and count. Since these skills are largely acquired in the primary school years of 5-12, I examine impact of oldest sister's education in this age range.[24] For the outcomes of years of schooling and enrollment, there is no theoretical reason to limit attention to the younger ages, and I use a sample of 5-18 year old younger brothers. Indeed, schooling and enrollment are more elastic for children after the completion of primary schooling. For children of primary school-age, enrollment rates average above 80 percent and fall considerably for middle and high school grades indicating more room for improvement and potential impact of the oldest sister.

[22] I regressed reported reading and writing capabilities on both language test scores, and reported addition and counting capabilities on math test score.

[23] I used an indicator for any schooling as well as years of schooling of the mother. Additionally, I tried a specification where I interacted the mother's education with the child's test score to see if there is a gradient to the mother's report.

[24] Of the households with an oldest sister of the right age range, 94 percent have a younger brother in this age range.

5 Empirical Strategy

Evaluating the impact of oldest sister's schooling on younger siblings is rife with selection issues because the education of the oldest sister is not randomly assigned across households. There are likely important differences in observed and unobserved characteristics across households which educate their oldest daughters differently that could bias the results in unpredictable ways. If parents invest efficiently, they will concentrate human capital investments in particular children rather than equalize investments across their children. In this case, households that educate their oldest daughters more would have lower educational investments in their other children leading to downward biased results.[25] It is also possible that households which educate their oldest daughters more are the households which value education highly and are therefore likely to invest more in the education of all children, including their younger ones. Such unobserved differences would bias the results upward. OLS estimation of the relationship between oldest sister's years of schooling and younger sibling outcomes yields positive and statistically significant results suggesting that positive selection and an upward bias may be more of a concern.[26] These results are included in appendix table A3.

This highlights the need for an identification strategy that yields consistent results under the assumption of selection on unobservables. To overcome these challenges to identification, I exploit the gender segregation of government schools in Pakistan to create quasi-experimental variation in oldest sister's schooling. I instrument for oldest sister's years of schooling using distance to closest government girls' school and analyze impacts on younger brothers only. Since younger sisters also attend government girls' schools, distance to government girls' school is not a valid instrument for analyzing younger sister outcomes.[27]

The gender segregation of government schools is key for the identification strategy because it allows me to control for distance to all possible schools that the younger brothers themselves could attend. I control for distance to the closest government boys' school and

[25] In Becker and Tomes (1976), parents' investment decisions are driven by efficiency concerns and they will invest more in the human capital of the high endowment child and invest less in the low endowment child.

[26] Appendix table A3 contains OLS results which show that, after controlling for a rich set of characteristics, increased schooling for the oldest sister is significantly associated with improved learning outcomes and higher schooling for younger brothers.

[27] As I show later, distance imposes a strong penalty on girls' schooling so younger sisters' learning could be directly impacted by distance through its effect on their schooling. Additionally, distance could directly influence younger sister learning through affecting the number of absences or because time spent walking to a distant school is unproductive for learning. For this reason, this paper restricts attention to the impact of oldest sister's schooling on younger brother outcomes.

the closest private school in all specifications. Identification therefore comes from comparing households that are equidistant from the village center, equidistant to the closest boys' schools, share all the characteristics of the other controls, and differ only in their distance to closest government girls' school. The maintained identification assumption is that conditional on these controls, distance to closest government girls' school does not affect younger brothers' learning independently of changing oldest sister's education.

There are several reasons why the conditional instrument of distance to girls' school should not have a direct impact on younger brother learning in this context. Since boys do not attend girls' schools, distance to girls' school can only affect boys indirectly. I demonstrate that the usual selection concern with using distance to school instruments in the U.S. literature does not apply in the context of rural Pakistan. I also show results from a placebo test which provides strong justification for the validity of the distance instrument.

A justifiable concern with distance to school as an instrument in the U.S. literature is that household location is not random with respect to schooling options. Access to good quality schools is a very important factor in an American family's decision of where to live. In the rural Pakistani villages of this study, the biggest determinant is land. These villages are highly agrarian societies where people reside on and make a living from land that has been passed down in their family for generations. At least fifty-eight percent of fathers work in agriculture, half of the households report owning land, and 94% own the house they live in.[28] Given this dependence on agriculture and land, households have very little choice in where they locate. The main margin of mobility for these households is for an adult male member to migrate to the city. Even for the households where somebody migrates to an urban area, it is only the adult male members that migrate who then send back remittances to the wife and children (Mansuri, 2006). These households have very little capacity to systematically locate closer to schools even if they wished to do so. Restricted mobility aside, these households also place a much smaller value on girls' education as compared with U.S. households making endogenous selection of household location based on girls' schools even more unlikely.

I follow the approach in Andrabi et al. (2010) in using an instrument of distance to school conditional on the distance to village center. They use conditional distance to private

[28]This is likely a lower bound because I treat those who report working in salaried occupations as not working in agriculture. While many in salaried occupations will hold non-farm jobs, a sizable proportion whom I can not identify will include skilled, salaried people who operate farm equipment such as harvesters, threshers, tube wells, and tractors, for example. It is a common arrangement for landlords to give tenants a residence in addition to the share-crop payment. This leads to many tenant families owning a house but not owning any farmland of their own.

school as an instrument for private school attendance to determine its impact on learning. Households located far from girls' schools may also be households that are remotely located in general. Controlling for the distance to village center soaks up the variation in distance to school that is correlated with access to earnings opportunities and other amenities. Andrabi et al. (2010) document that government schools were built on common land which is typically located on the periphery of the village because it was cheaper. Households are clustered around the village center with richer households located more centrally. The placement of government schools on the periphery of villages by the government allows there to be sufficient variation in distance to government schools after controlling for distance to center. More importantly, it indicates that within-village location of government schools, unlike that of private schools which locate in the center, is likely not driven by demand considerations. Alderman et al. (1997) find that village-level characteristics such as mean income and indicators of political influence do not explain local availability of a government school in Pakistan. According to government documents, village size is the stated determinant for building government schools across villages, and I show that my results are robust to controlling for village size.[29]

While the theoretical framework in section 3 models important spillover effects from oldest sister's education on her younger siblings, it does not allow for any effect to flow from younger to older siblings. The mechanisms behind the impact of oldest sister's education on her younger brothers are inextricably tied to the role of the oldest sister as an *older* sibling. The oldest sister's education matters because she provides child care, she helps the younger siblings with their studies, and she is a role model to them. Therefore, the model predicts that oldest sister's education should have no meaningful impact on her older brothers.[30] This suggests a falsification test for the proposed identification strategy. If the IV strategy yields significant, sizable impacts of oldest sister's schooling on her older brothers' learning, this finding would be inconsistent with the theoretical model and therefore suggestive of selection bias confounding the estimation strategy. Table 3 shows that using the IV strategy, oldest sister's schooling does not have a statistically or economically significant impact on any of the older brother outcomes.[31]

[29]Government schools were to be built in villages with a population of at least 1000 in their catchment area. Appendix table A4 shows the results which control for village size.

[30]While there may be some spillovers for an older sibling from interacting with more educated younger siblings, I expect such an effect to be drastically smaller than the impact of an oldest sister on younger sibling for the reasons listed above. I also expect this pure interaction effect on older brothers to be negligible because there is very limited interaction between older brothers (who work outside the home) and their younger sisters compared to older sisters' interaction with younger brothers whom they look after.

[31]Far from finding a positive impact, I can actually never reject the one-tailed hypothesis that these

Next I establish that distance to girls' school is a strong instrument. Table 4 shows the distance penalty for girls and boys.[32] While the distance penalty attenuates after adding the control for distance to village center, distance to girls' school continues to have a statistically and economically significant impact on girls' schooling. Distance to school has a much smaller impact on boys' schooling and adding the control for distance to center causes the distance to school coefficient to lose statistical significance in two of the three specifications. Distance to the village center, however, is a significant negative determinant of boys' schooling as it is of girls' schooling. Both boys' and girls' schooling is negatively impacted by distance to center which indicates that wealthier households which are located more centrally are more likely to educate their children. The stronger impact of distance to school for girls relative to boys reflects the fact that girls' mobility outside the house is restricted by safety and chastity concerns, and imposes an additional cost on the schooling of girls.

As described earlier, almost all children walk to school in these rural villages and young children must be accompanied by someone to and from school. As children get older, the need for somebody to accompany boys falls but girls still need to be walked to school by someone. Since the gender difference in the need for somebody to accompany girls and boys to school only arises for older children, one should expect that the gender difference in the distance penalty should also arise only for older children. Table 5 shows the distance penalty for schooling and enrollment of boys and girls younger than 13 years old, and aged 13 and older separately. While there is no statistically distinguishable distance penalty for schooling or enrollment of young or old boys, the distance penalty for girls is driven primarily by the older, teenage girls. The distance penalty for schooling for girls younger than 13 years old is very small and not statistically distinguishable from zero but distance to girls' school is a strong determinant of schooling for girls 13 years and older.

Conditional on instrument validity, the IV estimate captures the local average treatment effect (LATE) of oldest sister's schooling on younger brother learning. Households which are induced into sending their oldest daughters to school longer by the distance instrument are more likely to be relatively disadvantaged households with less educated parents. The returns to oldest sister's schooling for younger siblings may also differ by parental education. Since the oldest sister's role is most similar to that of a mother, the oldest sister's education likely has a larger impact in households with uneducated mothers relative to households with educated mothers. These reasons lead us to expect the LATE estimates

estimates are non-positive.

[32]This is the distance penalty that exists even after controlling for household characteristics, parents' education, wealth and asset controls and distance times year fixed effects.

uncovered by the IV strategy to be larger than average treatment effects.

6 Results

Table 6a shows the IV results for impact of oldest sister's years of schooling on younger brother literacy, numeracy, schooling and enrollment. As described earlier, for the outcomes of literacy and numeracy capabilities, the regressions use a sample of 5-12 year old, primary school-aged younger brothers, whereas for enrollment and schooling the sample includes 5-18 year old younger brothers. This specification controls for distance to closest government boys' school, distance to the closest private school, distance to village center, a rich set of household characteristics, parents' education, wealth and asset controls and district times year fixed effects.[33] The F statistic values on the excluded variable of distance to government girls' school in the first stage regressions show that distance to government girls' school is a strong instrument. Holding all these other controls fixed, an increase in distance to closest government girls' school of 1 km is associated with the oldest sister completing 0.40 fewer years of schooling. The IV results show statistically significant, positive impacts of oldest sister's schooling on younger brother's reading, adding and counting capabilities, years of schooling, and enrollment status. The point estimate for impact on ability to write is positive but lacks statistical significance.

An increase in the oldest sister's schooling of one year increases younger brothers' schooling by 0.42 years, and his probability of being enrolled by 7.5 percentage points. It makes the younger brother 7.7 percentage points more likely to be able to read, and 7.6 percentage points and 5.5 percentage points more likely to be able to add and count, respectively. Increasing oldest sister's schooling by one year increases her schooling by a third of a standard deviation. Relative to the mean, an additional year increases oldest sister's schooling by 25 percent. Compared to the mean of these dependent variables for younger

[33]The household controls include a quadratic in: age of oldest sister, age of younger sibling, number of daughters, number of sons, and total family size, as well as a dummy for language spoken at home, and dummies for month of interview. Since age gap between oldest sister and younger sibling is a linear combination of oldest sister's age and age of the younger sibling, the inclusion of these two variables non-parametrically controls for the age gap as well. Parents' education controls include a set of indicators for whether the mother and father have any education, variables including their years of schooling completed and indicators for whether any of these are missing. As is the case with most developing country data, the survey does not contain information on income since it is so hard to measure. Instead I try to capture wealth and resources by controlling for whether the family owns any land, indicator for the type of house they live in (permanent i.e. made of kiln bricks, temporary i.e. made of mud bricks, or semi-permanent i.e. made of kiln and mud bricks), indicator for the type of water connection the house has, and a quadratic in food expenditure per capita.

brothers, the effect sizes represent a 14 percent and 9.6 percent increase in younger brothers' schooling and enrollment probability, and a 19, 12 and 7 percent increase in reading, adding and counting capabilities, respectively.

Tables 6b and 6c show the IV results for younger brothers using the indicator for whether the oldest sister has any schooling, and indicator for whether she has completed primary schooling, respectively. Here too I find important beneficial impacts of oldest sister's education on younger brothers. The spillover benefits from having an oldest sister with any schooling and an oldest sister with at least primary schooling are not statistically distinguishable from each other although it appears that having a primary-educated older sister tends to generate somewhat larger returns. As in the basic specification, the impacts on all outcomes except for writing are significant and positive. It is not clear whether this indicates that oldest sister's schooling does not have an impact on younger brother's writing or whether it is too small to detect precisely.

It is important to note that distance to closest boys' school does not matter for oldest sister's schooling in any of the first stages of the IV regressions. The coefficients are neither statistically nor economically significant in any of the 18 specifications shown in tables 6a-6c. If households that really valued both girls' and boys' schooling located significantly closer to schools, one would expect to see that picked up as a meaningful correlation between oldest sister's schooling and distance to boys' school. This suggests that households that are located closer to schools do not appear to place a differential value on education than those further away, further support for the identification strategy used.

6.1 Heterogeneity

Next I explore heterogeneity in the treatment effects, and show evidence that suggests that the marginal effects uncovered by the distance instrument are larger than the average treatment effects. I study differences in the distance penalty imposed, and heterogeneity in the impact of oldest sister's schooling by level of maternal education. Mother's education is an important factor to consider when investigating heterogeneity in impact of oldest sister's education. Given the negligible labor force participation for mothers in this region, increased market work and earnings are not important channels through which maternal education impacts her children.[34] The primary mechanism for impact of maternal education on children is through her role as the primary child care provider, and the time she spends with

[34]Only 10.5% of mothers report spending any time on paid work in a given day. Ninety-six percent of fathers report work as their primary occupation compared with only 11.5% of mothers. This figure drops to 7.15% if I exclude work in agriculture or herding that is potentially performed on the family farm.

her children. Given that I modeled younger siblings' time spent with the oldest sister as the main channel through which oldest sister's education impacts younger siblings, oldest sister's education is likely a close substitute for mother's education.

I use a binary indicator to capture maternal education: the mother is uneducated if she has zero years of schooling and is considered educated if she has any non-zero schooling. When a mother is educated under this definition, the father is almost certainly educated as well. Only 30 of the 1200 households in my sample have an educated mother but uneducated father, so having an educated mother essentially means both parents are educated.[35] Table 7a shows how the distance penalty for oldest sister's schooling differs across households with uneducated and educated mothers. The instrument has a stronger impact on oldest sister's education in households with uneducated mothers as compared with households with educated mothers.[36] While small sample size for educated mother households contributes to the lack of statistical significance by inflating standard errors, the first stage coefficient estimates for the educated mother sample are 35-60% smaller than the coefficients for households with uneducated mothers. To interpret these differences in the first stage, recall that both parents are educated when the mother is educated in this sample. One would expect households where both parents are educated to place high value on education of their children. While counterfactual outcomes are unobserved, it makes sense intuitively that households with both parents educated will typically educate the oldest sisters highly regardless of distance to girls' school. In households with both parents educated, 95 percent of the oldest sisters have some schooling and 63 percent have completed primary schooling. Analogous figures for households with uneducated mothers are 69 percent and 39 percent, respectively. It is thus plausible that households with both parents educated are more likely to be always takers and hence are relatively less responsive to the instrument.[37]

Table 7a shows that IV estimates will be disproportionately based on households with uneducated mothers because these households comply more strongly with the instrument as compared to households with educated mothers. Next, I explore how treatment effects vary with mother's education. While the preferred identification strategy is to use IV estimation, it is unfortunately infeasible for the set of households with educated mothers. The

[35]Since very few households have an educated mother but uneducated father, I do not consider them in the subgroup analysis.

[36]While the first stage coefficients are not statistically significantly larger for uneducated mother households relative to educated mother households, the estimates are considerably different and the trend is consistent across all outcomes.

[37]Using the language from Angrist et al. (1996), in this context, always takers refers to households which get treated i.e. educate the oldest sister, regardless of the value of the instrument of distance to girls' school.

instrument is very weak for this group, with the F statistic on the excluded variable in the first stage approximately equal to one across all outcomes. Table 7b then uses OLS to estimate treatment effects for oldest sister's schooling separately for households with uneducated mothers and households with educated mothers. While the treatment impacts are statistically significantly different for adding and counting ability only, the impacts for all outcomes are considerably larger in households with uneducated mothers as compared to households with educated mothers. The impacts for reading, writing, schooling and enrollment are 75%, 18%, 45%, and 100% larger in uneducated mother households relative to educated mother households. Significant impacts for adding and counting ability only exist in households with uneducated mothers, and they disappear in households where the mother has any schooling.

This heterogeneity analysis indicates that the LATE estimated by the instrument is capturing marginal returns for complier households that are larger than the return for non-complying households. Households which comply the most strongly with the instrument are households with uneducated mothers for whom the returns to oldest sister's schooling are considerably higher.[38] This is in line with what one would expect theoretically if oldest sister's education is a close substitute for mother's education in rural Pakistan.

6.2 Testing the Model

Having identified the impact of oldest sister's schooling on younger brother learning, I now turn to further tests of the theoretical model I outlined: 1) analyzing the competing positive and negative effects of sister's schooling on younger sibling outcomes, 2) mechanisms through which oldest sister's schooling raises younger brother learning, and 3) whether parents internalize the externality from sister's schooling in their investment decisions.

While the net estimated impact of oldest sister's schooling is positive, I present some evidence that suggests that both a quality and a quantity effect of older sister's schooling exist. Theoretically, the negative quantity effect arises from the fact that increasing oldest

[38] I also divided the households into three categories of i) neither parent educated, ii) father educated but mother uneducated and ii) both father and mother educated. A parent is considered educated if he/she has any schooling. I find that the largest treatment effects are for households with neither parent educated and mother uneducated. There is a slight attenuation of treatment effects for households with father educated but mother uneducated relative to the category of households where neither parent is educated. Treatment effects attenuate sharply when comparing the impacts for households with father educated and mother uneducated to impacts from households with both parents educated indicating that oldest sister's education is particularly important when the mother is uneducated. The strongest compliers with the instrument are households with educated fathers and uneducated mothers suggesting that IV captures a LATE that is disproportionately comprised of households with educated fathers but uneducated mothers for whom treatment impacts are quite large.

sister's schooling requires her to be enrolled in school longer which may compete with time spent with the younger brother at home. A direct test of this is not possible since there is no time use data that allows us to identify who children spend their time with. Instead, I analyze whether the impact of oldest sister's schooling varies with whether it was acquired before the younger brother was enrolled in school or after. If the younger brother is of pre-school age and not yet enrolled in school, the sister's time spent at school is time that could have been spent with the younger brother at home but is not. If the younger brother is enrolled in school, increases in oldest sister's schooling do not reduce the time spent with the younger brother because he is not at home while she is in school. Thus the negative quantity effect would theoretically only exist for oldest sister's schooling acquired when the younger brother is of pre-school age while the positive quality effect should be associated with schooling acquired prior to the younger brother's enrollment as well as after. Therefore, one would expect the net impact of sister's schooling acquired before the younger brother is enrolled to be smaller and less positive than the impact of schooling acquired afterwards. In line with this, Table 8 shows that the impact of schooling that was acquired prior to the younger brother's enrollment - while still positive - is consistently and considerably smaller than the impact of schooling acquired after the brother's enrollment. [39] These coefficients are statistically significantly smaller for four (five) of the six outcomes considered at the 5% (10%) significance level which is a pattern of evidence that is consistent with a negative quantity effect.[40]

In order to further shed light on the channels through which oldest sister's schooling impacts younger brothers' learning, I analyze which family member (if any) helps the child with studies at home. Table 9 presents the coefficients from IV regressions of an indicator for whether the oldest sister helps the younger child on the oldest sister's schooling. More educated oldest sisters are significantly more likely to help their younger brothers with their studies. An increase in the oldest sister's schooling of one year increases the probability that

[39]The results presented are instrumental variable estimates where the two endogenous pre-enrollment and post-enrollment years of schooling variables are instrumented for using the distance to the closest girls' school instrument as well as the interaction of distance with age gap. OLS results also demonstrate the similar pattern with significantly smaller coefficients for the pre-enrollment schooling compared with those for post-enrollment schooling.

[40]It is possible that different treatment effects for schooling acquired before and after the younger brother's enrollment are due to heterogeneity of impacts by age of the younger brother. Cunha and Heckman (2007), for instance, report that earlier, pre-school investments in the sensitive periods of the life cycle of the child are more effective than later investments. The pattern of results in table 8 therefore is not conflated by heterogeneous treatment effects rather the pattern exists despite these heterogeneous effects by age. The pattern of smaller effects for pre-enrollment schooling for all outcomes even though these are likely to have different sensitive periods further indicates that it is likely capturing the quanity-quality tradeoff.

she helps her younger brother with studies by 4.8 percentage points.

Finally I test whether there is any evidence that parents internalize the positive externality from the oldest sister's schooling in their choice of schooling allocations. If parents effectively internalized the spillover from oldest sister's schooling, one would expect to observe higher levels of oldest sister's schooling when the value of the spillover from her schooling is greater. Table 10 tests this by comparing the schooling of oldest sisters who have a younger brother to those who do not have a younger brother. I also study the relationship between oldest sister's schooling and the total number of younger brothers she has. When the oldest sister has at least one or more younger brothers who can benefit from the externality, her schooling is more valuable and we should therefore see greater levels of schooling if parents actually internalize the spillover in their decisions. I do not find any evidence for a meaningful relationship between oldest sister's schooling and the value of the spillover using these two formulations of its value. Given these results, parents do not appear to be internalizing the spillovers from oldest sister's schooling. This is not unexpected given the very low levels of education of these parents in rural, agrarian villages of Pakistan, and the fact that this is the first study to posit and find evidence for such a spillover. This has important policy implications because failure to internalize the spillover will lead to inefficiently low levels of girls' education from a social standpoint, and there is a role for government intervention to remedy this through gender-targeted education policies.

6.3 How important are these spillovers?

In order to put the older sister spillover effects into context, I compare the estimates to the impact of mother's education as found in past studies, and also calculate impact of mother's education in my data. Using OLS, I found the impact of an additional year of schooling for the oldest sister on younger brothers' schooling to be 0.15 years. In the literature, the median impact of an additional year of schooling for the mother on her children's schooling is 0.23 years.[41] The impact of an additional year of schooling for the oldest sister in my preferred IV specification is 0.42 additional years of schooling for younger brothers. This is at the higher end of the range of impacts of mother's education (0.02-0.65 years) reported by Behrman (1997), although these estimates are not directly comparable.[42]

To make a comparison in the same population, I estimate the effect of parents' educa-

[41] Behrman (1997)

[42] The impact estimates summarized by Behrman (1997) include results from OLS and IV specifications in many countries for children of different age ranges, and different instruments move people on different margins for whom treatment impacts may be very different.

tion on younger brothers' learning and schooling in the LEAPS data. I use the same sample and control specifications I used in the analysis for the impact of oldest sister's education except that I do not control for oldest sister's education because that would amount to conditioning on an outcome. I find significant positive effects for both father's and mother's education as measured by the indicator for any schooling as well as years of schooling completed in table 11. Since very few mothers have any schooling, one may expect that the more meaningful impact of mother's education would be on the extensive margin. Having a mother with any education is associated with 0.42 more years of schooling for younger brothers while the similar impact of oldest sister is 0.66 additional years of schooling.[43] These estimates for impact of mother's schooling and the impact of oldest sister's schooling are not directly comparable for a number of reasons. First, I lack an instrumental variable for parental education although a comparison of the OLS results also points to impacts for oldest sister's schooling that are sizable in comparison to impacts of mother's schooling. Second, I try to keep the specifications and controls similar when analyzing impact of parents' education and oldest sister's education but this means that the specifications are over-controlled for finding the effect of parents' education. Since the specification analyzing the impact of mother's schooling controls for the father's schooling as well as household wealth and assets, it is controlling for important mechanisms through which mother's schooling impacts her children via assortative mating. Given these caveats, I conclude that the evidence suggests the impact of the oldest sister's schooling is meaningful even compared to the impact of maternal schooling.

There are several reasons why I find such important spillover impacts of oldest sister's education. The frequency and type of interaction of children with siblings who are their closest peers and are similar to them in age might mean a sibling's education is a critical input into the learning of children. The oldest sister is also the most important source of help with studies for young children in Pakistan. Oldest sister's education has the potential to have a particularly large impact in this setting because parents, and especially mothers, are very poorly educated. I found evidence that suggests the impact of oldest sister's schooling is larger in households with uneducated mothers. In 75% of these households, the mother is uneducated and in 35% of the households, both parents are uneducated. Since the oldest sister is one of the first household members to get any education in a sizable fraction of these households, one would expect her schooling to generate large spillovers within her family.

[43]This estimate for older sister impact is the OLS estimate from Appendix table A3. Since the marginal effects uncovered by IV are larger than OLS, and I lack an instrumental variable for mother's schooling, I compare OLS estimates for both the mother's and sister's treatment effects.

7 Robustness Checks

Two of the three treatment specifications presented involve binary formulations of oldest sister's education: an indicator for oldest sister having any schooling, and an indicator for whether the oldest sister has completed primary schooling. The presence of any measurement error in these binary formulations of treatment would cause the IV estimates to be upward biased. I explore this possibility in this section, and show that the prevalence of measurement error in the binary treatment variables is quite low. I present estimates that explicitly incorporate the presence of non-classical measurement error, and show that although these estimates are relatively attenuated, they remain considerably large. Accounting for the upper bounds on measurement error yields effect sizes that are still at least 85% of the original IV estimates presented.

Let D^* denote the true treatment variable, D the observed treatment variable, and U any measurement error that captures the difference between D and D^*. Any measurement error in binary variables is mean-reverting by construction with $\sigma_{D^*,U} < 0$ (Aigner, 1973) which creates upward bias in IV estimates (Black et al., 2000). Any measurement error in the indicator for any schooling and the indicator for at least primary schooling completed by the oldest sister will cause the IV estimates to be biased upwards.

Frazis and Loewenstein (2003) (F&L hereafter) propose a technique to compute lower bounds of IV estimates for binary explanatory variables under relatively weak assumptions. I implement their method to provide lower bounds for the impact estimates from the binary treatment specifications which incorporate upper bounds on the prevalence of measurement error. With binary explanatory variables, the presence of measurement error is more naturally thought of in terms of probabilities of false negatives and false positives. Defining the error probabilities of false positives and false negatives as $\alpha_0 = Pr(D = 1|D^* = 0) = Pr(U = 1|D^* = 0)$ and $\alpha_1 = Pr(D = 0|D^* = 1) = Pr(U = -1|D^* = 1)$, F&L and Bound et al. (2001) have shown that the IV estimate relates to the true treatment effect, β,as follows: $\beta_{IV} = \frac{\beta}{(1-\alpha_0-\alpha_1)}$. F&L show that we can estimate lower bounds of the true treatment effect by finding upper bounds on α_0 and α_1 under assumptions and a procedure that I describe in detail in appendix C. Table 12 shows the estimates of α_0 and α_1, the 95 percent confidence intervals for each, as well as the implied adjustment factors which need to be multiplied to the IV estimates to get the lower bounds on the true treatment impacts. The upper bounds of α_0 and α_1 from their 95% confidence intervals for the indicator whether the oldest sister has any education are 11.6 percent and 3.1 percent, respectively.[44] This shows that the

[44]For the indicator of whether the oldest sister has primary schooling, the upper bounds of α_0 and α_1

prevalence of measurement error is quite low. The relative magnitudes of these bounds are intuitively plausible, as it seems less likely that parents would forget or neglect to report their oldest daughter acquiring any education rather than for parents to incorrectly report their daughter did receive an education when she did not. The adjustment factors using the upper bound from the 95 percent confidence intervals for α_0 and α_1 yield lower bounds of the treatment effects which are still sizable. The lower bounds of effects for the indicator that oldest sister has any schooling are at least 85% of the original IV estimates, and those for the indicator that the oldest sister has completed primary schooling are at least 89% of the original IV results reported in section 6.

In order to better avoid any selection due to marriage of the oldest sister, I also check the robustness of my results to limiting the sample to oldest sisters less than 19 years old. Since girls move out of the household upon marriage, I worry about selection of which older sisters I observe still living with their parents, and are therefore in my sample. I avoid most of this potential endogeneity bias from marriage by using oldest sister among the siblings living in the household instead of the oldest according to birth rank. I also restrict the sample to analyze impact of oldest sister according to birth rank only. The impact estimates are robust to both checks and I find similarly sized, significant positive impacts on younger brother outcomes. A fuller discussion is presented in appendix B.

8 Conclusion

This is the first study to conceptualize oldest sister's schooling as an input into younger sibling human capital. I propose a theoretical model that predicts competing effects of increasing oldest sister's schooling on younger brother human capital: a positive quality effect and a negative quantity effect. I find that oldest sister's schooling has significant positive impacts on younger brothers' schooling, enrollment, literacy and numeracy, indicating that the positive quality effect outweighs the negative quantity effect. While the net externality from oldest sister's schooling is positive, I also show evidence that is consistent with the existence of a negative quantity effect.

I find evidence that suggests parents do not effectively internalize this positive externality of oldest sister's schooling in their decisions about schooling investment allocations. Since this leads to inefficiently low levels of girls' education from a social standpoint, there is a role for government intervention to remedy this through gender-targeted education policies. My findings also have important implications for the evaluation of policies targeting girls'

from their 95% confidence intervals are 8.2 percent and 1.6 percent, respectively.

education including gender-targeted conditional cash transfer programs such as the Female Secondary School Stipend Program in place in Pakistan. Evaluations and cost-benefit analyses of such programs that consider only effects on the girls and their children but ignore potential impacts on younger siblings will systematically underestimate their total benefits. This study identifies spillovers from girls' education that accrue contemporaneously to the current generation as opposed to benefits from maternal education which are realized by the future generation. Finally, by highlighting the role that oldest sister's education plays in fostering the learning of younger siblings, the study makes an important contribution to our understanding of human capital production.

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A Model Appendix

A.1 Proof of proposition stated in Section 3

Proposition. *Let parents' investment in older sisters schooling be y_s^{**} when net externality of the older sisters schooling on younger brother is positive, and parents take this externality into account when making the schooling decision. Let y_s^{***} denote parents investment in older sisters schooling if they fail to internalize the spillover effect on younger brother. It can be shown that parents will under-invest in the older sisters schooling if they fail to internalize the net positive externality i.e. y_s^{***} is lower than y_s^{**}.*

Consider the case where the net externality of the older sisters schooling on younger brother human capital is positive so that $g_{H_s} f_{y_s} - g_{x_s} > 0$ i.e. the positive quality effect of increasing older sisters schooling outweighs the associated negative quantity effect.

Suppose parents are unaware of the spillover effects of older sisters schooling on younger brother, and hence do not internalize the spillover benefit and cost associated with sisters schooling in deciding about schooling investments. Such parents would consider the younger brothers human capital production function to simply be a function of his own years of schooling with $H_b = g(y_b)$. Such parents will choose y_s^{***} so as to satisfy the following first-order condition where they only consider the private benefits and costs of the older sisters schooling and ignore the spillover on the brother:

$$a_s V_{w_s} r_s f_{y_s} = (p_s + d_s) U'(c) \qquad (4)$$

Consider the case where parents internalize the externality of the older sisters schooling on younger brother human capital. They will choose y_s^{**} so as to equate the complete marginal benefits of older sisters schooling with the complete marginal cost as indicated by the following condition.

$$a_s V_{w_s} r_s f_{y_s} + a_b V_{w_b} r_b [g_{H_s} f_{y_s} - g_{x_s}] = (p_s + d_s) U'(c) \qquad (5)$$

Compared to (4), this equation has an additional positive term on the left-hand side because parents are aware that the positive externality from older sisters schooling increases their utility by increasing the younger brothers human capital and wealth. In order to equalize the marginal utility from investment in sisters schooling with its marginal cost, parents will increase the investment in older sisters schooling. This has the effect of decreasing the first term on the left-hand side in equation (5) since $f_{y_s y_s}$ is negative, and hence equalizes the left-hand side with the right-hand side. The equilibrium investment in older sisters schooling in this case, y_s^{**}, is therefore higher than y_s^{***}, the investment that occurred in equilibrium when parents did not internalize the spillovers on younger brother learning.

A.2 Derivation of comparative static with respect to distance to girls school

In a model without any spillovers, an increase in the cost of girls schooling has an ambiguous effect on brothers schooling because it includes a positive substitution effect (brothers and sisters are competing for schooling investment from a common pool of resources so decreasing sisters schooling frees up resources for the brother), and a negative income effect (if the sister is getting schooling and incurring the cost, the higher cost squeezes household resources thereby leaving less for the brother). Since schools only charge nominal fees, we expect the income effect of this cost which is a distance burden to be small so that the substitution effect is expected to dominate in the model without spillovers. Without spillovers, brother and sister schooling are hence likely to be in direct competition with each other so that an increase in girls schooling cost may help increase brothers schooling. Shrestha found evidence for such inter-sibling rivalry in Nepal where increases in boys schooling reduced the schooling of female siblings.

In a model with spillovers, an increase in the cost of girls schooling has three effects: the positive substitution effect, the negative income effect as well as a negative spillover effect (assuming the net externality of sister schooling is positive). This last new term captures the fact that distance-induced reductions in older sisters schooling lead to a reduction in the net positive spillover for the younger brother. Although the overall sign of the comparative static is ambiguous, relative to the model without spillovers, an increase in the cost of girls schooling in a world with positive spillovers is associated with a more negative impact on brothers schooling.

I derive the comparative static of brother and sister schooling with respect to distance cost of girls schooling two ways: in a model with spillover and a model without any spillover. In a model without any spillovers, the SOCs are as follows:

MB of y_b with respect to y_b:

$a_b V''(W_b) r_b^2 g_{y_b}^2 + a_b V'(W_b) r_b g_{y_b y_b}$. Let this equal Y.

MB of y_s with respect to y_s:

$a_s V''(W_s) r_s^2 f_{y_s}^2 + a_s V'(W_s) r_s f_{y_s y_s}$. Let this equal Z.

$\frac{\partial y_s}{\partial d_s} = YU' - y_s(p_s + d_s)YU'' + (p_b + d_b)^2 U'U''$ which is negative. Increase in the distance cost of girls school decreases sisters schooling because sisters schooling is more costly. Also, for a sister who is getting some schooling (non-corner solution for y_s), there is a negative income effect from incurring the distance cost. $\frac{\partial y_b}{\partial d_s} = -(p_b + d_b)(p_s + d_s)U'U'' - y_s(p_b + d_b)ZU''$, where the first term is positive and the second is negative. The first term is a positive substitution effect while the second term is a negative income effect which exists if there is a non-corner solution for sister schooling. Since the distance cost of schooling is just a time cost and schools only charge nominal fees, I expect the income effect of this distance cost to be small so that the substitution effect is expected to dominate.

In a model with spillovers, the SOCs are as follows:

MB of y_b with respect to y_b:

$a_b V''(W_b) r_b^2 g_{y_b}^2 + a_b V'(W_b) r_b g_{y_b y_b}$ Let this equal A.

MB of y_b with respect to y_s:

$a_b V''(W_b) r_b^2 g_{y_b} g_{y_s} + a_b V'(W_b) r_b g_{y_b y_s}$. Let this equal B.

MB of y_s with respect to y_s:

$a_sV''(W_s)r_s^2f_{y_s}^2 + a_sV'(W_s)r_sf_{y_sy_s} + a_bV''(W_b)r_bg_{y_s}^2 + a_bV'(W_b)r_bg_{y_sy_s}$. Let this equal C. Notice that C = Z + K where K $= a_bV''(W_b)r_bg_{y_s}^2 + a_bV'(W_b)r_bg_{y_sy_s}$.

I assume the first- and second-order conditions described in section 2, that the net externality of sisters schooling on younger brother human capital is positive with diminishing returns ($g_{y_s} > 0$ and $g_{y_sy_s} < 0$). These assumptions yield that $g_{y_sy_s} = g_{H_s}f_{y_sy_s} + g_{H_sH_s}f_{y_s} - g_{H_sx_s}f_{y_s} + g_{x_sx_s} - g_{x_sH_s}f_{y_s}$ which is negative because $g_{H_s} > 0, f_{y_s} > 0, f_{y_sy_s} < 0, g_{H_sH_s} < 0, g_{x_sx_s} < 0$ due to the assumption of positive and diminishing marginal returns of the inputs, and $g_{H_sx_s} > 0$ due to the assumed complimentarity between sister's human capital and time spent with brother. I assume that the term B i.e. the differential of the MB of y_b with respect to y_s is negligible but also separately describe the results that would hold if there was a strong complimentarity between y_b and y_s such that $B > 0$.

$\frac{\partial y_s}{\partial d_s} = AU' + y_s(p_b+d_b)BU'' - y_s(p_s+d_s)AU' + (p_b+d_b)^2U'U$" which is negative as in the model without spillovers.[45]. $\frac{\partial y_b}{\partial d_s} = -(p_b+d_b)(p_s+d_s)U'U'' - y_s(p_b+d_b)ZU'' - y_s(p_b+d_b)KU'' + [y_s(p_s+d_s)U'' - U']B$ which is ambiguous as in the model without spillovers. Notice that while the positive substitution effect is the same in both models, even if we assume B=0, the model with spillovers picks up an additional negative term due to the spillover. [46] Now, an increase in the distance cost of girl's schooling has three effects: the positive substitution effect, the negative income effect as well as a negative spillover effect.

A.3 Derivation of comparative statics with respect to parental wealth, parental altruism, returns to schooling and productivity in household production

I calculate comparative statics with respect to the exogenous parameters $W_p, a_b, a_s, r_s, r_b, p_s$, and p_b which yield the following propositions:

1. $\frac{\partial y_b}{\partial W_p} > 0$ and $\frac{\partial y_s}{\partial W_p} > 0$: Wealthier parents invest more in children's schooling
2. $\frac{\partial y_s}{\partial r_s} > 0$ and $\frac{\partial y_b}{\partial r_s} < 0$: Parents substitute away from brother's schooling and towards sister's schooling when market returns to sister's human capital increase
3. $\frac{\partial y_b}{\partial r_b} \lessgtr 0$ and $\frac{\partial y_s}{\partial r_b} \lessgtr 0$: The impact on brother and sister schooling is ambiguous when market returns to brother's human capital increase.
4. $\frac{\partial y_b}{\partial a_s} < 0$ and $\frac{\partial y_s}{\partial a_s} > 0$: Parents substitute away from investing in brother's schooling towards investing more in the sister's schooling when they care more about the sister's utility.
5. $\frac{\partial y_b}{\partial a_b} \lessgtr 0$ and $\frac{\partial y_s}{\partial a_b} \lessgtr 0$: The impact on parents' investment in brother and sister schooling is ambiguous when parents' altruism toward brother increases.
6. $\frac{\partial y_b}{\partial p_b} \lessgtr 0$ and $\frac{\partial y_s}{\partial p_b} \lessgtr 0$: Parents invest more in sister's schooling when brother's productivity in household production is higher, ceteris paribus. The impact of investment in brother's own schooling is ambiguous when brother's productivity in household production increases.

[45] This expression is negative if B is negligible or if $B > 0$.

[46] If $B > 0$, then the expression is even more negative because there is a strong complimentarity between sister and brother schooling such that there is pressure for brother schooling to fall in response to the distance-induced decrease in sister schooling.

Proof

1. $\frac{\partial y_b}{\partial W_p} = C(p_b + d_b)U'' - B(p_s + d_s)U''$ and $\frac{\partial y_s}{\partial W_p} = A(p_s + d_s)U'' - B(p_b + d_b)U''$. Both expressions are positive given the assumptions outlined above.

2. $\frac{\partial y_s}{\partial r_s} = -Aa_sV'(W_s)f_{y_s} - (p_b + d_b)^2 a_s V'(W_s)f_{y_s}U''$ which is positive. Since parents respond to higher market return to sister human capital by investing more in the sister, this leaves less resources for the brother, and puts downward pressure on brother's schooling. The first term in $\frac{\partial y_b}{\partial r_s} = (p_b + d_b)(p_s + d_s)(a_sV'(W_s)f_{y_s})U'' + Ba_sV'(W_s)f_{y_s}$ is negative if B is negligible. This highlights the usual competition effect between sister and brother schooling since they both draw from the same pool of household resources, an increase in one usually entails a reduction in the other. The expression also highlights a special case in which y_b may increase in response to an increase in r_s. If $B > 0$, the marginal benefit from y_s is increasing y_b, and if this is sufficiently large to overcome the negative competition effect, it may be optimal for the parents to increase y_b as well since the investment of each unit y_b is now more productive with higher y_s.

3. Let F$=-a_bV'(W_b)g_{y_b}$ and G$=-a_bV'(W_b)g_{y_s}$, then $\frac{\partial y_b}{\partial r_b} = CF + (p_s + d_s)^2 FU'' - (p_s + d_s)(p_b + d_b)GU'' - BG$. The impact of an increase in return to younger brother human capital is ambiguous without further assumptions because both y_b and y_s can be increased to increase younger brother human capital. If I impose that y_b is more effective at creating younger brother human capital than y_s so that $g_{y_b} > g_{y_s}$, as seems plausible, then we get the prediction that brother schooling increases in response to an increase in market return to brother human capital. $\frac{\partial y_s}{\partial r_b} = -BF + AG - p_b(1 + d_b)p_s(1 + d_s)FU'' + p_b(1 + d_b)^2 GU''$ remains ambiguous because the resulting increase in brother schooling crowds out sister schooling but sister schooling is also productive in increasing brother human capital, the return to which has gone up.

4. Let O$=-V'(W_s)r_sf_{y_s}$, then $\frac{\partial y_s}{\partial a_s} = (p_b + d_b)^2 OU'' + AO$ and $\frac{\partial y_b}{\partial a_s} = -(p_b + d_b)(p_s + d_s)OU'' - BO$. Parents increase sister's schooling when altruism towards sister is higher. This crowds out investment in schooling for brothers and leads to a reduction in y_b. If $B > 0$, the strong complimentarity between y_b and y_s means that there is a positive pressure on y_b because the increased y_s means y_b is more productive.

5. Let M$=-V'(W_b)r_bg_{y_b}$ and N$=-V'(W_b)r_bg_{y_b}$, then $\frac{\partial y_b}{\partial a_b} = CM - (p_s + d_s)^2 MU'' - (p_b + d_b)(p_s + d_s)NU'' - BN$ and $\frac{\partial y_s}{\partial a_b} = AN - (p_b + d_b)(p_s + d_s)MU'' + (p_b + d_b)^2 NU'' - BM$ The impact of an increase in altruism toward younger brother is ambiguous because both y_b and y_s can be increased to increase younger brother human capital. If I impose that y_b is more effective at creating younger brother human capital than y_s, then we get the prediction that brother schooling increases if parents' altruism towards brother increases. The impact on sister schooling remains ambiguous because the increased brother schooling crowds out sister schooling but sister schooling is also productive in creating brother human capital.

6: $\frac{\partial y_s}{\partial p_s} = AU' - (1-y_s)(p_b+d_b)BU'' + (1-y_s)(p_s+d_s)AU'' + (p_b+d_b)^2U'U''$ and $\frac{\partial y_b}{\partial p_s} = -BU' + (1-y_s)(p_b+d_b)CU'' - (1-y_s)(p_s+d_s)BU'' - (p_b+d_b)(p_s+d_s)U'U''$ Higher household productivity for the sister has an ambiguous effect on her own schooling because there is a a negative substitution effect (because the sister is now more productive in the household) and a positive income effect (from her enhanced household productivity which increases income). Increasing the household productivity of the sister increases brother's schooling because for the brother the substitution effect and income effect both are positive. The relationship is analogous for an increase in brother's household productivity with $\frac{\partial y_b}{\partial p_b} \lessgtr 0$ and $\frac{\partial y_s}{\partial p_b} > 0$.

B Data Appendix

Construction of Sample of Interest

The identification of oldest sisters and younger siblings is complicated by the survey format and timing. Age reports contain significant amounts of measurement error in developing countries. For this reason, I choose to identify older and younger pairs of siblings based on complete fertility histories that were asked of mothers. As part of the fertility histories, mothers were asked to rank the birth order of all their children ever born. I use this history to determine who is the older and the younger individual in all sibling pairs. Since the fertility histories were only administered in round 3, any children who were not living in the household in round 3 do not get tagged as either the oldest sister or her younger sibling. I describe the procedure by which I determined the relationships for such individuals in detail later in this section.

Instead of limiting my focus to the absolute oldest sister (in terms of birth order), I look at the oldest sister among the sisters still living in the household. In 73 percent of the households I use in my analyses, the oldest sister in the household is in fact the oldest daughter that was ever born to that household. The reason for defining oldest as oldest living in the household is two-fold. I have education information only for individuals who have lived in the household at some point during the panel. If the oldest sister in a household moved out of the household before data collection, I know of her existence from the fertility history but I lack information about her education. Secondly, it is not very interesting to ask about the impact of an oldest sister with whom the younger sibling would have spent very few years interacting since she moved out of the household a long time ago.

Age of oldest sister

The effective sample of interest includes 1211 households in which I have identified the oldest sister and at least one sibling younger than her aged 5-12 years old inclusive. I limit the sample to households in which the oldest sister is between 8 and 30 years old in round 1. Only 1 percent of the sisters have age greater than 30 in round 1, so dropping these observations is reasonable trimming of extreme outliers. On the lower bound of age, I drop sisters who

are too young to have acquired any schooling.

Recall that the sample includes oldest sisters who are the oldest among the sisters still living in the household. In case the absolute oldest sister never lived in the household during the data collection period, I substitute with the oldest of the sisters that does appear in the data. Although the substitution with oldest of the sisters living in the household makes the sample selection less problematic, the sample still conditions on the sister not having moved out of the household before the panel starts. Girls in Pakistan move out of their parents household to live with their husbands family at the time of marriage. Marriage accounts for 99 percent of the girls moves out of the household observed in my data. Since the length of a girls stay in her household is dictated by her marital status, my sample based on older sisters who are still living in the house may be a non-random sample. If education improves the probability of getting married, the better quality, more educated oldest sisters are already married off by the time data collection starts, and dropped from my analysis because I do not know their education. In this case, my sample of oldest sisters is adversely selected, has lower education than the population and the positive estimates I obtain from my sample are likely lower bounds of the true treatment effect for the population.[47] I also conduct a robustness check by limiting to oldest sisters who are aged less than 20 years old in section 8.

The complete fertility histories which I use to determine birth order of siblings were administered in round 3 of the panel, and they also list the identifier, name, gender, age, whether the child still lives in the household, and reason for the child not living in the household. If the oldest sister no longer lives in the household in round 3, the survey data does not report her member ID the within-household identification number in the fertility history section. For this reason, some of the oldest sisters do not get flagged as such even though they may appear somewhere else in the panel data because they were living in the household in a different round. If I were to rely only on matching of member ID in round 3, I only identify oldest sisters in 1060 of the 1646 households that report having at least one daughter born to them. Next I describe the procedure I use to identify the remaining oldest sisters.

There are two types of oldest sisters with missing ID in the fertility history section: i) some of these have lived in the household recently enough to have been captured in the panel data in at least one round, and ii) other oldest sisters have moved out of the household such that they are never captured in the data. For i), I am interested in identifying these girls as the oldest sister because I have valid education information for them since they appear in the panel at some point. I matched these girls' reported names in the fertility histories to the female names listed in the household roster in all rounds. Since there are no uniform rules for the transliteration of Urdu names into English (the data is in English), I had to match these names manually on the basis of the phonetics. Using this procedure, I was able

[47] One could also imagine higher education competing with marriage for girls if, as in urban Pakistan, most girls discontinue their schooling and take on household and family responsibilities after they get married. Education and the incidence of marriage could have a negative relationship. Given that the median age of marriage is 20 while the average schooling for the 20-year olds is 5 years (achieved at roughly 13/14 years of age), it does not seem that marriage should compete with schooling for these rural girls in this way.

to identify another 129 oldest sisters.

In case ii), the oldest sister has left the household for a sufficiently long time so that she never appears as living in the household during the duration of a four-year panel. For these households, I flag the next oldest daughter who does appear in the data at some point as the oldest sister. By thus flagging later-born daughters who are the oldest among the children still in the household, I identify the oldest sister in an additional 374 households. Finally, not all households have valid fertility histories filled out. 1727 of 1807 households have a valid fertility history section filled out. For these households, I determine who is older and younger in sibling pairs based on the reported age of children of the household head. At the end of all these steps, I am able to flag 1630 households with the oldest sister. Out of the 1727 households that had valid fertility histories, 5 percent never had a daughter born to them. Having identified 1630 households with an oldest sister means I have captured 90 percent of my sample households. While the 10 percent of households I lose in my sample is bigger than the 5 percent we expect not to have any daughters born to them, this is very reasonable attrition considering that attrition can be caused due to several reasons including not having a daughter ever born to you, not having any daughters survive or having daughters that have moved out of the household before the panel starts. On the other side, I also use the birth order from the fertility history to identify younger siblings. For 193 younger siblings who had moved out of the house in round 3 but did appear in the data at some point, I match them by name so they can be flagged as younger and used in the analyses.

Selection of oldest sister

This study estimates the impact of the oldest sister's education on younger sibling learning and education where the oldest sister is defined as the oldest of the sisters living in the household during the panel. The main reason for using the oldest sister living in the household is to mitigate selection concerns arising from girls' moving away after marriage. One may expect that the role model effects of the education of the absolute oldest sister may be more important than that of the oldest among the sisters living in the household. A higher age gap between the absolute oldest sister and the younger sibling may mean the oldest sister had a greater role in taking care of the younger sibling. On the other hand, it may imply less interaction overall than a younger sibling may have with another older sister who is closer to him/her in age, particularly because the absolute oldest sister gets married earlier. For these reasons, the impact of the absolute oldest sister may diverge from that of the oldest sister as defined in the paper so far i.e. the oldest of the sisters living in the household. In 73 percent of the cases, the oldest of the sisters living in the household is also the absolute oldest sister. Here I present results after limiting the sample to just the absolute oldest sisters as a robustness check.

Table A5 shows the IV results for the absolute oldest sister's years of completed schooling. The treatment effects are about the same for adding and counting, bigger for writing and schooling, and smaller for reading and enrollment than those found in the IV specification in table 6a. The coefficients for read, add, count, schooling and enrollment are statistically sig-

nificant as before. It seems that there is no systematic variation across the two specifications so it is hard to discern whether the greater role model effects of the absolute oldest sister and any effects from the increased care-taking role she takes on for her younger siblings outweigh the effect of decreased interaction with younger siblings. It is important to also realize that limiting attention to the absolute oldest sisters entails a necessarily selected sample because I know the absolute oldest sister's education only if she is still living in the household and not married.

The next robustness check deals with selection due to marriage. All girls move out of their parents' household and into the husband's family after marriage. I only observe education of the oldest sister if she is still living in the household and is therefore still single. If education improves a girl's marriage prospects, my treatment impacts may be estimated from an adversely selected sample. If education competes with a girl's transition into marriage (which is unlikely given the low educational attainment of girls), the impact may be estimated from a positively selected sample. Defining the oldest sister as the oldest sister among the sisters residing in the household helps mitigate the selection to some extent because we can substitute for the oldest sisters that got married really early. As an additional check, I restrict the sample to oldest sisters less than 20 years old. Only 15.6 percent of the oldest daughters aged 15-19 years old were married in my sample. Table A6 shows the results from the sample of oldest sisters aged 19 and under. I find that there is no qualitative difference in the estimates after restricting the sample. The impact estimates for reading, writing, and adding are smaller while the estimates for counting, schooling and enrollment are bigger than those found using the more general sample.

C Measurement Error Appendix

Estimating lower bounds of the treatment effect with binary mismeasured explanatory variables

F&L describe a procedure that allows us to estimate lower bounds of the true treatment effect β by finding upper bounds on α_0 and α_1 under the following assumptions: i) these probabilities are assumed to be independent of X and ϵ, and ii) $Cov(D, D^*) > 0$ (if this is not the case, measurement error is so severe that $(1 - D)$ is a better measure of $D*$ than D is). Then independence of X and the measurement error process yields that

$$\begin{aligned} Pr(D = 1|X) &= (1 - \alpha_1)Pr(D^* = 1|X) + \alpha_0(1 - Pr(D^* = 1|X) \\ &= \alpha_0 + (1 - \alpha_0 - \alpha_1)Pr(D^* = 1|X) \end{aligned}$$

This equation implies that $\alpha_0 \leq Pr(D = 1|X) \leq 1 - \alpha_1$ for all X. F&L propose that one can obtain the tightest possible bound for $\alpha_0(\alpha 1)$ by estimating $E(T|X \in S)$ over the subset of sample S having the lowest (highest) expected value of T. In order to get the lowest (highest) expected value of T, they propose estimating $Pr(D = 1|X)$ by regressing D on X and the instrument Z, and then calculating $E(T|X)$ over the observations with percentile

rank of $Pr(D = 1|X)$ less (more) than q. The optimal choice of q is left as an open question for future research but the authors use q = 5 themselves. Since $\alpha_0 \leq Pr(D = 1|X) \leq 1 - \alpha_1$ for all X, an incorrect functional form only affects the tightness of the bounds, not their validity.

Figure 1

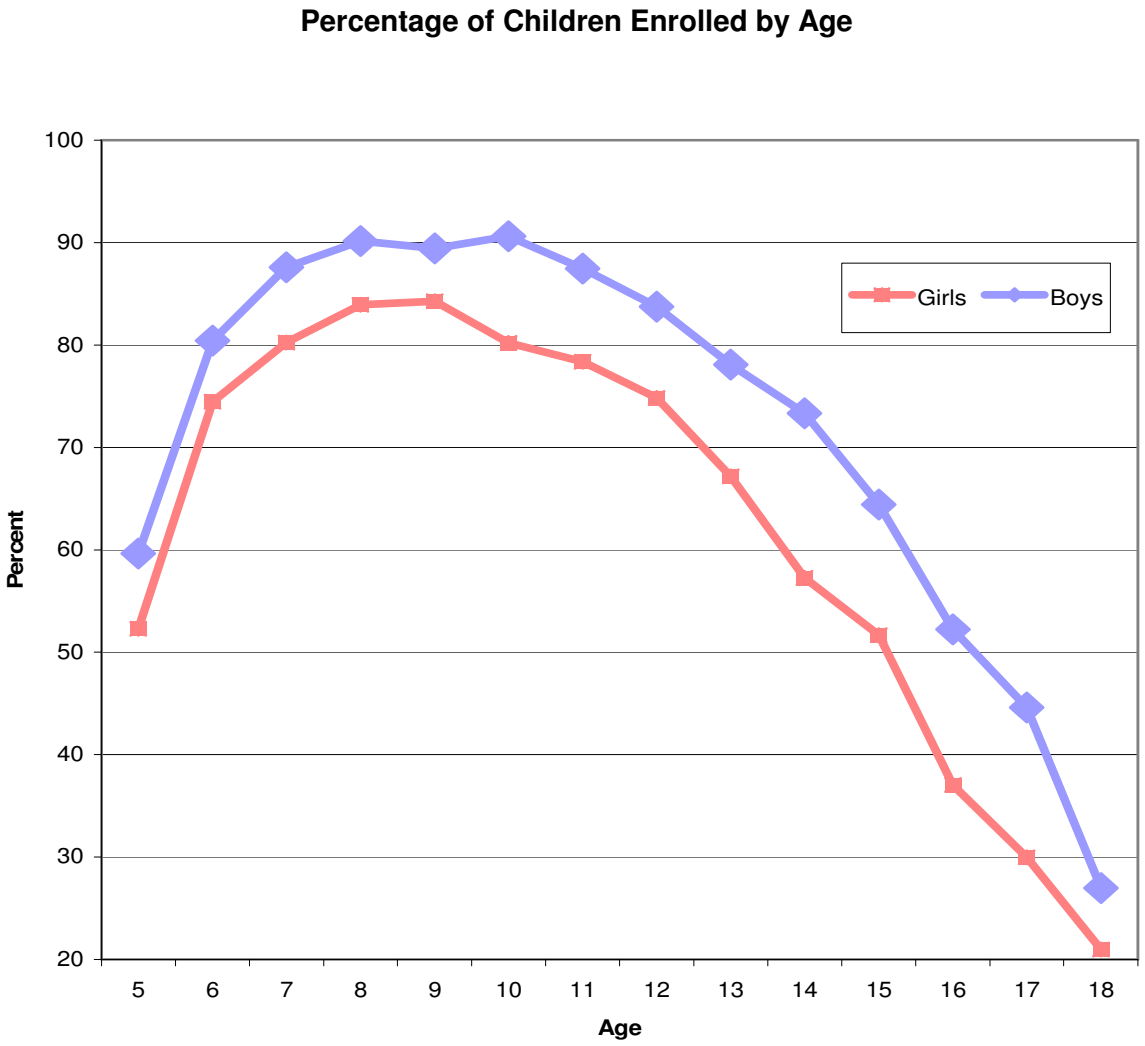
Percentage of Children Enrolled by Age
100
90
80
70
60
50
40
30
20
Percent
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Age
Girls
Boys

Figure 2

Distribution of Years of Schooling for Boys and Girls aged 16-20 years old

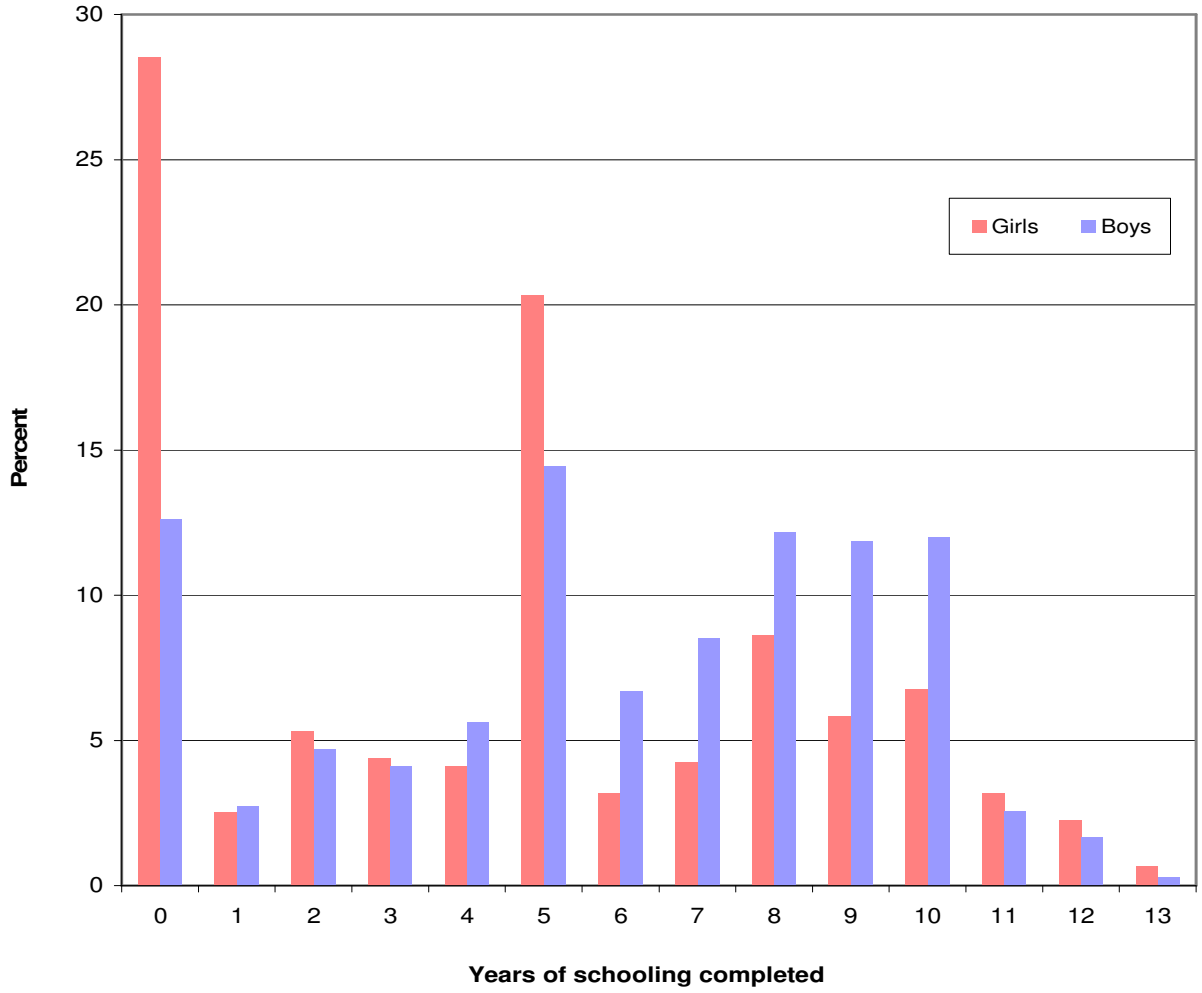

Figure 3

Literacy and Numeracy Capabilities of Younger Siblings aged 5-12 years old

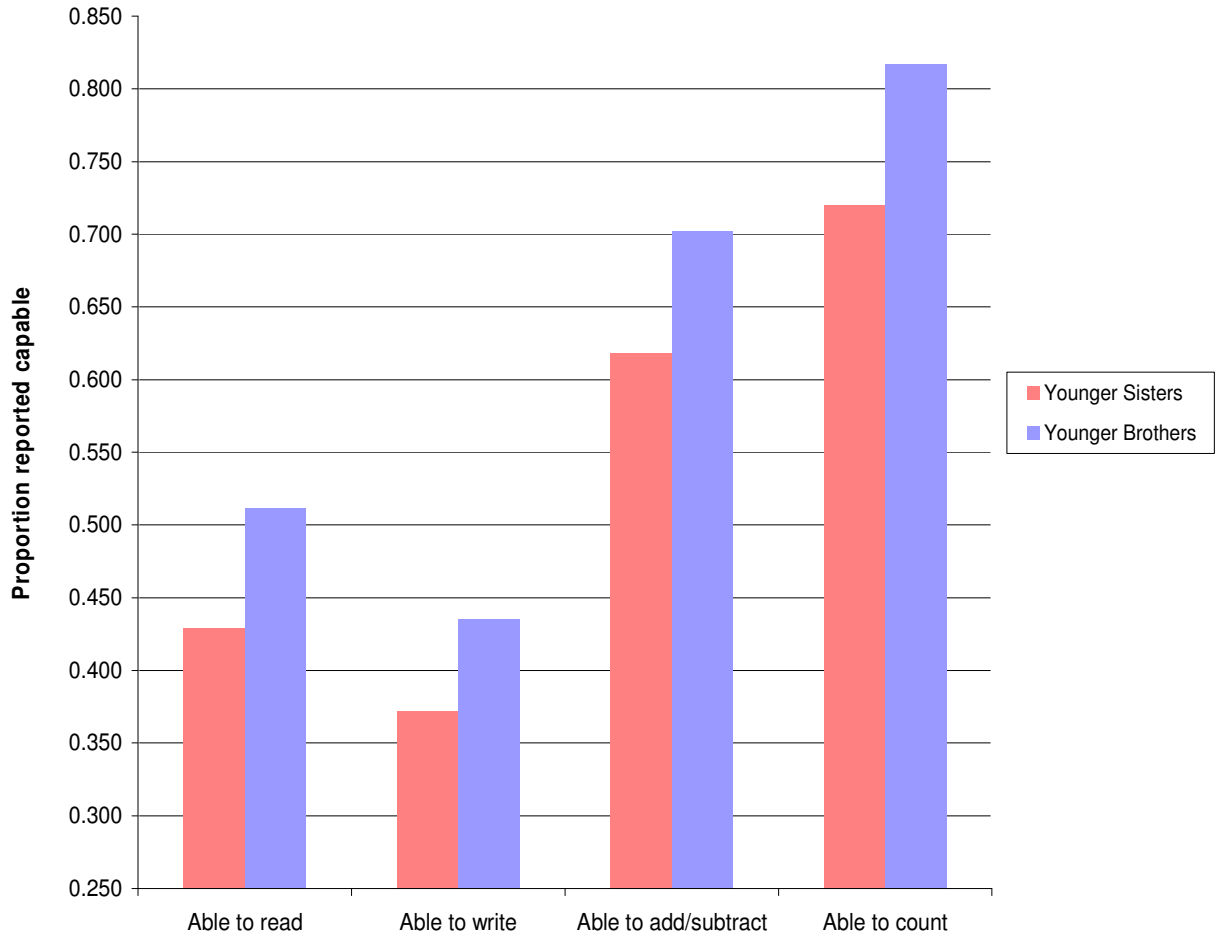

Figure 4

Distribution of Reported Literacy and Numeracy Capabilities by Class

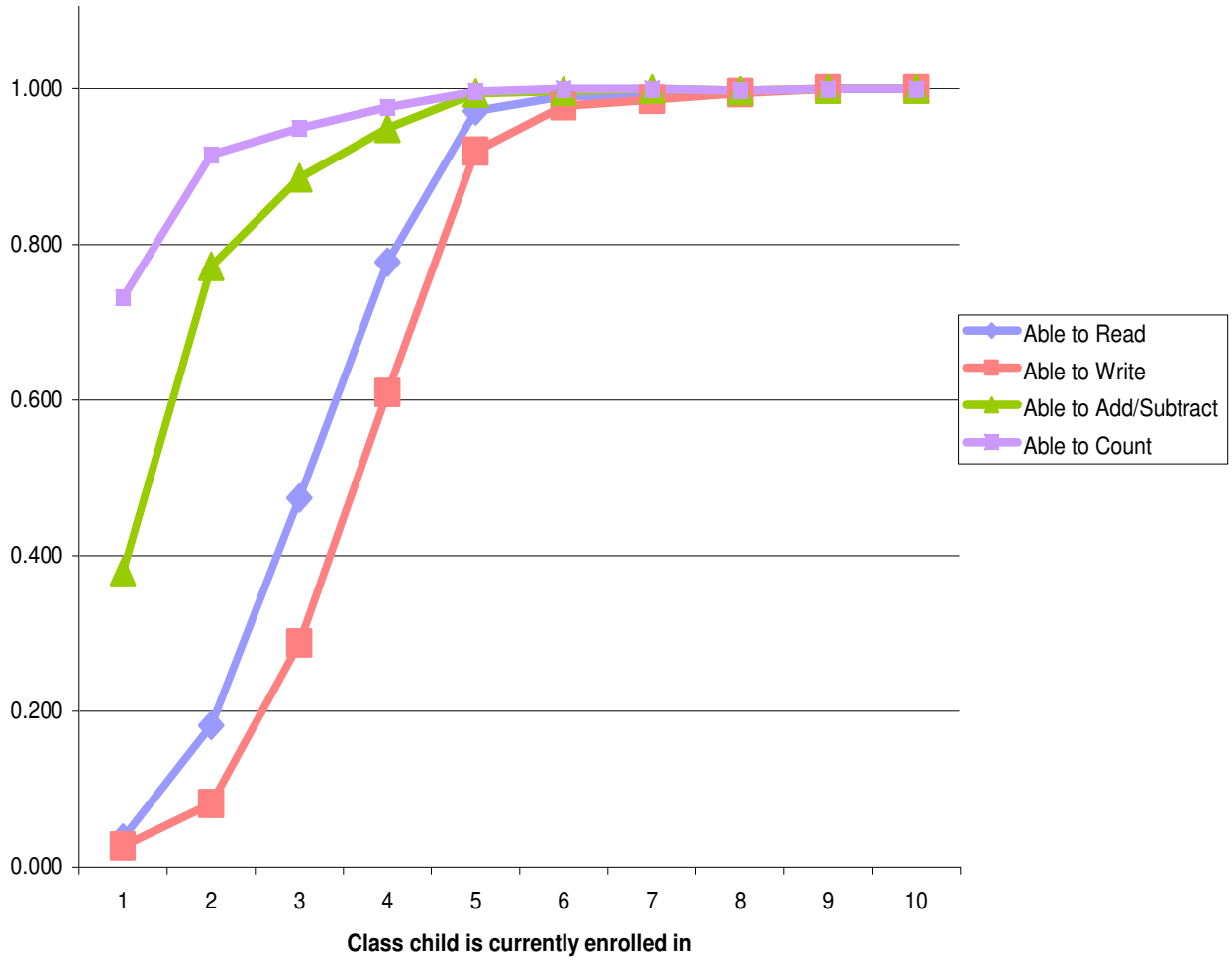

Table 1: Summary Statistics on School Characteristics

A. Household-level characteristics	**Mean**	**Std Dev**	**Min**	**Max**	**N**
Distance to closest government girls' school	0.598	0.676	0	5.917	1,178
Distance to closest government boys' school	0.607	0.635	0	5.573	1,190
Distance to closest private school	0.573	0.711	0	5.644	1,190
Distance to village center	0.625	1.004	0	14.228	1,210
B. Village-level characteristics					
Number of government girls' schools in village	1.786	1.166	0	6	112
Number of government boys' schools in village	2.089	1.504	1	8	112
Number of private schools in village	3.134	2.338	0	13	112

Panel A provides summary statistics on household-level variables. Distance to closest government girls' school is missing for 12 more households than distance to closest government boys' school is missing for. This is due to the two villages that do not have a government girls' school. Panel B provides summary statistics for the 112 villages in the dataset.

Table 2: Summary Statistics of Households

	Mean	Std Dev	N
Household size	7.854	2.634	1,211
Number of children 0 to 18 yrs old	5.095	1.921	1,211
Number of boys 0 to 18 yrs old	2.394	1.364	1,211
Number of girls 0 to 18 yrs old	2.620	1.422	1,211
Indicator mother is educated	0.237	0.425	1,202
Indicator father is educated	0.616	0.486	1,087
Indicator oldest sister is educated	0.731	0.431	1,211
Mother's education (years)	1.457	2.768	1,202
Father's education (years)	4.404	4.169	1,087
Oldest sister's education (years)	3.97	3.221	1,211
Own any land	0.478	0.460	1,210
Own house living in	0.937	0.212	1,210
Reside in kiln brick house	0.508	0.375	1,210
Reside in mud brick house	0.108	0.236	1,210
Reside in kiln and brick house	0.384	0.336	1,210
Water source is a hand pump	0.241	0.270	1,211
Water source is tap water	0.141	0.208	1,211
Water source is a motor pump	0.191	0.268	1,211
Water source is external like pond, stream etc.	0.100	0.222	1,211
Expenditure per capita (Rs/month)	1,852.459	3,852.013	1,210
Age of oldest sister	16.206	4.163	1,211
Age of younger brother	10.042	4.123	1,211
District: Attock	0.336	0.473	1,211
District: Faisalabad	0.386	0.487	1,211
District: RYK	0.277	0.448	1,211

The universe is households with an oldest sister aged 8-30 in round 1 who has at least one younger sibling aged 5-12 years old inclusive. At the time of the survey, 1 USD = 60 Pakistani rupees, on average.

Table 3: Falsification test: Effects of Oldest Sister's Education on Older Brother Outcomes

	Read	Write	Add	Count	Schooling	Enrollment
Oldest sister's years of schooling	-0.005	-0.024	-0.033	-0.020	0.163	-0.087
	(0.062)	(0.070)	(0.037)	(0.030)	(0.324)	(0.074)
First stage results						
Distance to closest girls' school	-0.339***	-0.337***	-0.356***	-0.356***	-0.333***	-0.389***
	(0.119)	(0.119)	(0.120)	(0.120)	(0.107)	(0.112)
F statistic	8.123	8.066	8.821	8.821	9.734	12.110
Number of observations	1,501	1,498	1,502	1,502	1,819	945
Indicator oldest sister education >=5 yrs	-0.038	-0.179	-0.209	-0.134	-0.264	-1.260
	(0.350)	(0.372)	(0.218)	(0.174)	(2.113)	(1.280)
First stage results						
Distance to closest girls' school	-0.055***	-0.056***	-0.056***	-0.056***	-0.057***	-0.031
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.023)
F statistic	7.618	7.728	7.784	7.840	8.237	1.716
Number of observations	1,501	1,498	1,502	1,502	1,819	945
Mean of dependent variable	0.787	0.748	0.947	0.965	5.745	0.624

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

This table investigates the impact of oldest sister's schooling on the learning outcomes of older brothers. Since the theoretical model predicts spillover effects of oldest sister's schooling on younger sibling human capital due to the role of the oldest sister as an older sibling, theoretically, we do not expect there to be a significant relationship between oldest sister's schooling and older brother outcomes. This table shows that the instrumental variable identification strategy passes this falsification test because we do not find any meaningful, sizable relationship between oldest sister's schooling and older brother outcomes. The dependent variables read, write, add, count are indicator variables for whether younger siblings are reported as capable of reading writing, add/subtracting or counting. The dependent variable schooling refers to years of completed schooling as an outcome and enrollment is an indicator for whether the child is currently enrolled. The IV regression results reported are from the fullest control specification which controls for household variables, parents' education, wealth controls, distance to center, distance to closest government boys' school as well as district times year fixed effects.

Table 4: Distance Penalty for Girls' and Boys' Schooling

Distance penalty for girls						
	Years of schooling		Indicator any education		Indicator education >= 5 years	
Distance to closest girls' school (km)	-0.187***	-0.115**	-0.046***	-0.023*	-0.034***	-0.027***
	(0.050)	(0.054)	(0.011)	(0.012)	(0.007)	(0.009)
Distance to center		-0.256***		-0.052***		-0.013
		(0.063)		(0.012)		(0.008)
Number of observations	7,869	7,869	7,869	7,869	7,869	7,869
R^2	0.431	0.433	0.312	0.316	0.347	0.347
Distance penalty for boys						
	Years of schooling		Indicator any education		Indicator education >= 5 years	
Distance to closest boys' school (km)	-0.164*	-0.074	-0.045***	-0.035***	-0.015	-0.015
	(0.091)	(0.098)	(0.012)	(0.012)	(0.012)	(0.012)
Distance to center		-0.188***		-0.020**		-0.016**
		(0.057)		(0.009)		(0.008)
Number of observations	7,292	7,292	7,292	7,292	7,292	7,292
R^2	0.545	0.547	0.314	0.315	0.414	0.414

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses are clustered at household level.
This table shows the distance penalty for schooling for girls and boys aged 5-18 years old. The distance penalty shows how an increase in distance to the closest girls/boys' school by an additional km affects the schooling of girls/boys, with and without controlling for the distance from the household to the village center. The regression results reported also control for household variables, parents' education, wealth controls as well as district*year effects.

Table 5: Distance Penalty for Girls' and Boys' Schooling by Age

	Distance penalty for girls			
	Years of schooling		Indicator for enrollment	
	Age < 13	**Age>=13**	**Age<13**	**Age>=13**
Distance to closest girls' school (km)	-0.058	-0.239***	-0.036**	-0.045***
	(0.045)	(0.078)	(0.018)	(0.017)
Distance to center	-0.131***	-0.420***	-0.031*	-0.046***
	(0.042)	(0.104)	(0.017)	(0.016)
Number of observations	4,329	3,540	4,370	3,436
R^2	0.513	0.303	0.202	0.290
	Distance penalty for boys			
	Years of schooling		Indicator for enrollment	
	Age < 13	**Age>=13**	**Age<13**	**Age>=13**
Distance to closest boys' school (km)	-0.079	-0.136	-0.015	-0.002
	(0.051)	(0.161)	(0.013)	(0.020)
Distance to center	-0.114**	-0.263**	-0.027**	-0.003
	(0.045)	(0.102)	(0.012)	(0.016)
Number of observations	4,299	2,993	4,329	2,958
R^2	0.543	0.218	0.128	0.235

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses are clustered at household level.
This table shows how the distance penalty for education and enrollment varies by age. The distance penalty shows how an increase in distance to the closest girls/boys' school by an additional km affects the schooling and enrollment of girls/boys respectively, while controlling for the distance from the household to village center. The results are shown for boys/girls younger than 13 and aged 13 and older separately. The regression results reported also control for household variables, parents' education, wealth controls as well as district*year effects.

Table 6a: Effects of Oldest Sister's Schooling on Younger Brother Learning and Schooling

	Read	Write	Add	Count	Schooling	Enrollment
Second stage IV results						
Oldest sister's years of schooling	0.077**	0.039	0.076**	0.055*	0.420***	0.075***
	(0.034)	(0.030)	(0.032)	(0.032)	(0.125)	(0.028)
First stage results						
Distance to closest girls' school	-0.391***	-0.406***	-0.400***	-0.386***	-0.398***	-0.405***
	(0.083)	(0.083)	(0.083)	(0.083)	(0.074)	(0.074)
F statistic	22.373	23.912	23.136	21.902	29.052	30.030
Distance to closest boys' school	0.002	0.003	0.003	0.002	-0.003	-0.003
	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)
Mean of dependent variable	0.408	0.323	0.642	0.779	2.935	0.780
Number of observations	3,413	3,405	3,386	3,422	5,100	5,115
R^2	0.337	0.353	0.331	0.270	0.547	0.162

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.
This table shows results for spillover effects of oldest sister's years of schooling on younger brother outcomes. The dependent variables read, write, add, count are indicator variables for whether younger siblings are reported as capable of reading writing, add/subtracting or counting. The dependent variable schooling refers to years of completed schooling as an outcome and enrollment is an indicator for whether the child is currently enrolled. The IV regression results reported are from the fullest control specification which controls for household variables, parents' education, wealth controls, distance to center, distance to closest government boys' school as well as district times year fixed effects.

Table 6b: Oldest Sister's Schooling and Younger Brother Outcomes: Indicator for Any Schooling

	Read	Write	Add	Count	Schooling	Enrollment
Second stage IV results						
Indicator oldest sister has any	0.463*	0.282	0.434**	0.326*	3.125***	0.465**
Education	(0.238)	(0.203)	(0.203)	(0.193)	(0.899)	(0.182)
First stage results						
Distance to closest girls' school	-0.061***	-0.065***	-0.066***	-0.064***	-0.059***	-0.064***
	(0.011)	(0.012)	(0.012)	(0.012)	(0.010)	(0.010)
F statistic	28.837	32.036	32.376	30.803	38.069	42.120
Distance to closest boys' school	-0.001	-0.001	0.000	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Mean of dependent variable	0.408	0.323	0.642	0.779	2.935	0.780
Number of observations	3,413	3,405	3,386	3,422	5,100	5,115
R^2	0.318	0.327	0.338	0.274	0.507	0.182

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.
This table shows results for spillover effects of oldest sister's schooling on younger brother outcomes where oldest sister's schooling is measured as an indicator variable for whether the oldest sister has completed primary schooling. The dependent variables read, write, add, count are indicator variables for whether younger siblings are reported as capable of reading writing, add/subtracting or counting. The dependent variable schooling refers to years of completed schooling as an outcome and enrollment is an indicator for whether the child is currently enrolled. The IV regression results reported are from the fullest control specification which controls for household variables, parents' education, wealth controls, distance to center, distance to closest government boys' school as well as district times year fixed effects.

Table 6c: Oldest Sister's Schooling and Younger Brother Outcomes: Indicator for Primary Schooling

	Read	Write	Add	Count	Schooling	Enrollment
Second stage IV results						
Indicator oldest sister education	0.508**	0.250	0.500**	0.384**	2.799***	0.563***
>= 5 yrs	(0.220)	(0.196)	(0.213)	(0.195)	(0.920)	(0.200)
First stage results						
Distance to closest girls' school	-0.060***	-0.062***	-0.061***	-0.060***	-0.056***	-0.056***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.011)	(0.011)
F statistic	20.160	21.344	20.612	19.714	23.814	24.305
Distance to closest boys' school	0.001	0.001	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Mean of dependent variable	0.408	0.323	0.642	0.779	2.935	0.78
Number of observations	3,413	3,405	3,386	3,422	5,100	5,115
R^2	0.316	0.340	0.316	0.256	0.515	0.131

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

This table shows results for spillover effects of oldest sister's schooling on younger brother outcomes where oldest sister's schooling is measured as an indicator variable for whether the oldest sister has any schooling. The dependent variables read, write, add, count are indicator variables for whether younger siblings are reported as capable of reading writing, add/subtracting or counting. The dependent variable schooling refers to years of completed schooling as an outcome and enrollment is an indicator for whether the child is currently enrolled. The IV regression results reported are from the fullest control specification which controls for household variables, parents' education, wealth controls, distance to center, distance to closest government boys' school as well as district times year fixed effects.

Table 7a: Heterogeneity in First Stage impact of Instrument by Maternal Education

	Mother uneducated					
	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Oldest sister's years of schooling						
First stage results						
Distance to closest girls school (km)	-0.416***	-0.437***	-0.426***	-0.419***	-0.396***	-0.453***
	(0.092)	(0.093)	(0.093)	(0.093)	(0.079)	(0.082)
F statistic	20.250	22.278	20.976	20.430	25.000	30.140
Observations	2,570	2,564	2,547	2,578	3,574	3,897
	Mother educated					
	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Oldest sister's years of schooling						
First stage results						
Distance to closest girls school (km)	-0.270	-0.265	-0.247	-0.270	-0.122	-0.181
	(0.268)	(0.268)	(0.268)	(0.268)	(0.236)	(0.230)
F statistic	1.020	0.980	0.846	1.020	0.270	0.624
Observations	630	629	627	630	888	890

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses are clustered at household level.

This table shows the heterogeneity in the first stage impact of the instrument of distance to closest girls school on oldest sister's years of schooling by maternal education. I show the first stage results for the instrument separately for the subsample of households with uneducated mothers, and the subsample of households with educated mothers. The coefficient on distance to closest girls school indicates how an increase in distance to closest girls school of 1 km impacts oldest sister's years of schooling completed. The top panel shows that the instrument has a strong, highly statistically significant impact on oldest sister's schooling in households where the mother is uneducated, and that the distance penalty is considerably attenuated and lacks statistical significance for households with educated mothers. The first stage results are shown for each of the 6 outcomes considered and are from regressions using the fullest specifications which control for household variables, father's education, wealth controls as well as district*year fixed effects.

Table 7b: Heterogeneity in Treatment Impact by Maternal Education: OLS estimates

Mother Uneducated						
	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Oldest sister's years of schooling	0.027***	0.020***	0.023***	0.017***	0.161***	0.022***
	(0.004)	(0.004)	(0.003)	(0.003)	(0.016)	(0.003)
Mean of dependent variable	0.385	0.303	0.621	0.763	2.836	0.752
Observations	2,570	2,564	2,547	2,578	3,886	3,897
Mother Educated						
	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Oldest sister's years of schooling	0.016**	0.017**	0.003	0.003	0.112***	0.011**
	(0.007)	(0.008)	(0.006)	(0.006)	(0.032)	(0.005)
Mean of dependent variable	0.478	0.391	0.708	0.835	3.324	0.894
Observations	630	629	627	630	888	890

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses are clustered at household level.
This table shows the OLS results for treatment impact of oldest sister's schooling estimated separately for households with uneducated mothers and households with educated mothers. The term "educated" refers to an indicator for whether the mother has had any formal schooling. The results show that oldest sister's schooling has larger treatment impacts on younger brother learning and education in households where the mother is uneducated relative to households where the mother has some education. The regression results use the fullest specification which controls for household variables, wealth controls as well as district*year fixed effects.

Table 8: Evidence for Positive Quality and Negative Quantity Effect of Oldest Sister's Schooling

	Read	Write	Add	Count	Schooling	Enrollment
Oldest sister's schooling acquired pre-enrollment	0.013***	0.008***	0.008***	0.006**	0.070***	0.011***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.011)	(0.003)
Oldest sister's schooling acquired post-enrollment	0.035***	0.027***	0.023***	0.015***	0.179***	0.021***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.017)	(0.004)
Observations	3,553	3,542	3,523	3,561	5,333	5,349
P-value of coefficient difference	0.000	0.000	0.002	0.042	0.000	0.020
Mean of dependent variable	0.410	0.325	0.642	0.780	2.942	0.781

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses are clustered at household level.

This table shows the treatment impact of oldest sister's years of schooling separately by whether it was acquired before the younger brother enrolled in school or after he enrolled. The dependent variables read, write, add, count are indicator variables for whether younger siblings are reported as capable of reading writing, add/subtracting or counting. The dependent variable schooling refers to years of completed schooling as an outcome and enrollment is an indicator for whether the child is currently enrolled. All regression specifications control for a quadratic function of oldest sister's age, a quadratic function of the age gap between oldest sister and younger brother, household variables, parents' education, wealth controls, distance to center, distance to closest government boys' school as well as district*year fixed effects.

Table 9: Effects of Oldest sister's Education on Extensive Margin of Helping with Studies

	Indicator that oldest sister helps with studies		
Oldest sister's years of schooling	0.048**		
	(0.020)		
Indicator oldest sister has any schooling		0.301**	
		(0.135)	
Indicator oldest sister has primary schooling			0.361**
			(0.148)
Observations	5,100	5,100	5,100

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

This table presents the IV results for the impact of oldest sister's education on the likelihood that a younger brother receives help from her with studies. The dependent variable is an indicator variable for whether the oldest sister helps the child with his studies. The regression controls for household variables, parents' education, wealth controls, distance to closest boys' school, distance to closest private school, distance to village center as well as district times year fixed effects.

Table 10: Oldest Sister's Education and Value of Spillover

	Years of schooling	Years of schooling
	(1)	(2)
Indicator has a younger brother	-0.030	
	(0.190)	0.037
Number of younger brothers		(0.109)
Mean of dependent variable	4.115	4.115
Observations	2,357	2,357

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses are clustered at household level.
This table tests whether parents internalize the spillover from the oldest sister's education on younger sibling learning. The spillover from oldest sister's education is more valuable if she has a younger brother, and its value is increasing in the number of younger brothers. The first column shows that parents do not invest significantly highly in oldest sisters that have a younger brother relative to those that do not have a younger brother. The second column shows that oldest sister's education is not significantly increasing in the number of younger brothers she has. The regression includes controls for family size, number of younger brothers, number of younger sisters, number of older brothers and older sisters. The results use the fullest specification which controls for household variables, wealth controls as well as district*year fixed effects.

Table 11: Mother's and Father's Education and Younger Brother Outcomes: OLS results

	Indicator variables for any education of mother and father					
	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Indicator mother has any education	0.072***	0.069***	0.073***	0.053***	0.423***	0.071***
	(0.021)	(0.022)	(0.019)	(0.017)	(0.091)	(0.017)
Indicator father has any education	0.074***	0.054***	0.037*	0.060***	0.563***	0.106***
	(0.021)	(0.019)	(0.019)	(0.017)	(0.099)	(0.019)
Number of observations	3,553	3,542	3,523	3,561	5,333	5,349
Mean of dependent variable	0.410	0.325	0.642	0.780	2.942	0.781
	Years of schooling of mother and father					
	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Mother's years of schooling	0.012***	0.011***	0.011***	0.007**	0.053***	0.008***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.015)	(0.003)
Father's years of schooling	0.010***	0.010***	0.008***	0.010***	0.082***	0.015***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.011)	(0.002)
Number of observations	3,553	3,542	3,523	3,561	5,333	5,349
	Mean	**Std Dev**	**N**			
Indicator mother is educated	0.237	0.425	1,202			
Indicator father is educated	0.616	0.486	1,087			
Mother's education (years)	1.457	2.768	1,202			
Father's education (years)	4.404	4.169	1,087			

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses are clustered at household level.

This table shows the effect of mother's and father's education on learning and education outcomes for the sample of younger brothers used to analyze the impact of oldest sister's education. The sample thus consists of boys aged 5-12 for literacy and numeracy outcomes, and aged 5-18 for schooling and enrollment. The dependent variables of read, write, add and count refer to indicators for whether the boy can read, write, add/subtract or count. The dependent variable of schooling is years of completed schooling and enrollment is an indicator for current enrollment status. The regression results use the fullest specification which controls for household variables, wealth controls as well as district*year fixed effects.

Table 12: Estimates and Bounds for Treatment Impacts and Measurement Error Parameters

Indicator oldest sister has completed any schooling						
	α_0	α_1			α_0 95% CI	α_1 95% CI
Upper bound estimates	0.082	0.016			[0, .116]	[0, 0.031]
Adjustment factor $(1-\alpha_0-\alpha_1)$	0.902				0.853[a]	
	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
IV estimate, β	0.463*	0.282	0.434**	0.326*	3.125***	0.465**
	(0.238)	(0.203)	(0.203)	(0.193)	(0.899)	(0.182)
Adjusted IV estimate, $\beta*(1-\alpha_0-\alpha_1)$	0.418	0.254	0.391	0.294	2.819	0.419
Adjusted IV estimate, $\beta*(1-\alpha_0-\alpha_1)$[a]	0.395	0.241	0.370	0.278	2.666	0.397
Indicator oldest sister has completed at least primary schooling						
	α_0	α_1			α_0 95% CI	α_1 95% CI
Upper bound estimates	0.008	0.059			[0, 0.019]	[0, .088]
Adjustment factor $(1-\alpha_0-\alpha_1)$	0.933				0.894[a]	
	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
IV estimate, β	0.508**	0.250	0.500**	0.384**	2.799***	0.563***
	(0.220)	(0.196)	(0.213)	(0.195)	(0.920)	(0.200)
Adjusted IV estimate, $\beta*(1-\alpha_0-\alpha_1)$	0.474	0.233	0.467	0.358	2.612	0.525
Adjusted IV estimate, $\beta*(1-\alpha_0-\alpha_1)$[a]	0.454	0.223	0.447	0.343	2.501	0.503

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses are clustered at household level.

[a] Lower bound for adjustment factor using the upper bounds of α_0 and α_1 estimates from the 95% confidence intervals α_0 is the probability that the indicator for treatment status equals zero but the reported treatment status equals 1, and α_1 is the probability that the indicator for treatment status equals one but the reported treatment status equals 0.

This table shows the original IV treatment estimates for oldest sister having any education and oldest sister having at least primray schooling, the upper bounds on the prevalence of measurement error in these two binary treatment variables, as well as the lower bounds on the IV treatment effects after incorporating the upper bounds on the measurement error. I also show the 95% confidence interval for the estimated measurement error probabilities, and calculate the lower bounds of the IV treatment effects using the upper bound from the 95% confidence interval of the estimated measurement error prevalence.

Appendix Table A1: Mother's Education (Any Schooling) and Child Literacy and Numeracy Reports

	Read	Read	Read	Read	Write	Write	Write	Write
Indicator mother educated	0.004	0.006	0.011	0.012	0.004	0.006	0.011	0.011
	(0.016)	(0.016)	(0.016)	(0.016)	(0.020)	(0.020)	(0.019)	(0.020)
English test score	0.074***	0.078***			0.100***	0.105***		
	(0.007)	(0.008)			(0.009)	(0.011)		
Urdu test score			0.077***	0.080***			0.118***	0.120***
			(0.007)	(0.008)			(0.009)	(0.010)
Interaction English test score		-0.017				-0.015		
		(0.016)				(0.021)		
Interaction Urdu test score				-0.012				-0.007
				(0.016)				(0.020)
Number of observations	2,360	2,360	2,360	2,360	2,341	2,341	2,341	2,341

	Count	Count	Add	Add
Indicator mother educated	0.001	0.001	0.001	0.000
	(0.005)	(0.005)	(0.008)	(0.008)
Math test score	0.013***	0.011***	0.021***	0.019***
	(0.002)	(0.003)	(0.004)	(0.004)
Interaction Math test score		0.006		0.008
		(0.006)		(0.009)
Number of observations	2,369	2,369	2,348	2,348

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.
This table explores whether there are any systematic differences in literacy and numeracy capability reporting across uneducated and educated mothers. The concern is that mother's education may play a role in how she reports her child's ability to read/write/add/count, holding fixed the child's true capabilities. I regress the indicators for reading, writing, counting and adding on an indicator for mother's education to see if they are significantly correlated after controlling for child test scores. The idea is that test scores are an objective measure of the child's accumulated learning and if mother's education significantly predicts child's reported abilities even after controlling for test scores, educated mothers answer the child ability question significantly differently than uneducated mothers do. When considering mother report of child reading and writing abilities, I control for English and Urdu (Pakistani vernacular) test scores separately while for adding and counting abilities, I control for Math test score. I interact the indicator for mother's education with test score to see if there is a gradient to mother's report of child ability.

Appendix Table A2: Mother's Education (Years of Schooling) and Child Literacy and Numeracy Reports

	Read	Read	Read	Read	Write	Write	Write	Write
Mother's schooling (years)	0.002	0.003	0.004	0.004*	0.001	0.001	0.003	0.003
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
English test score	0.073***	0.077***			0.100***	0.098***		
	(0.007)	(0.008)			(0.009)	(0.010)		
Urdu test score			0.076***	0.081***			0.118***	0.117***
			(0.007)	(0.008)			(0.009)	(0.010)
Interaction English test score		-0.003				0.001		
		(0.003)				(0.003)		
Interaction Urdu test score				-0.003				0.001
				(0.003)				(0.003)
Number of observations	2,360	2,360	2,360	2,360	2,341	2,341	2,341	2,341

	Count	Count	Add	Add
Mother's schooling (years)	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Math test score	0.013***	0.013***	0.021***	0.022***
	(0.002)	(0.003)	(0.004)	(0.004)
Interaction Math test score		-0.001		-0.001
		(0.001)		(0.001)
Number of observations	2,369	2,369	2,348	2,348

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.
This table explores whether there are any systematic differences in literacy and numeracy capability reporting across mothers with different years of schooling. The concern is that mother's education may play a role in how she reports her child's ability to read/write/add/count, holding fixed the child's true capabilities. I regress the indicators for reading, writing, counting and adding on an indicator for mother's education to see if they are significantly correlated after controlling for child test scores. The idea is that test scores are an objective measure of the child's accumulated learning and if mother's education significantly predicts child's reported abilities even after controlling for test scores, educated mothers answer the child ability question significantly differently than uneducated mothers do. When considering mother report of child reading and writing abilities, I control for English and Urdu (Pakistani vernacular) test scores separately while for adding and counting abilities, I control for Math test score. I interact the indicator for mother's education with test score to see if there is a gradient to mother's report of child ability.

Appendix Table A3: Oldest sister's Schooling and Younger Brother Outcomes: OLS Results

	Read	Write	Add	Count	Schooling	Enrollment
Oldest sister's years of schooling	0.027***	0.019***	0.018***	0.013***	0.151***	0.019***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.014)	(0.002)
Indicator oldest sister has any schooling	0.106***	0.057***	0.085***	0.064***	0.664***	0.126***
	(0.023)	(0.022)	(0.022)	(0.021)	(0.098)	(0.020)
Indicator oldest sister has primary schooling	0.132***	0.085***	0.097***	0.072***	0.359***	0.077***
	(0.019)	(0.018)	(0.018)	(0.017)	(0.058)	(0.014)
Mean of dependent variable	0.410	0.325	0.642	0.780	2.942	0.781
Number of observations	3,553	3,542	3,523	3,561	5,333	5,349

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

The dependent variables read, write, add, count are indicator variables for whether younger siblings are reported as capable of reading writing, add/subtracting or counting. The dependent variable schooling refers to years of completed schooling as an outcome and enrollment is an indicator for whether the child is currently enrolled. The OLS regression results reported are from the fullest control specification which controls for household variables, parents' education, wealth controls, as well as district times year fixed effects.

Appendix Table A4: Effects of Oldest Sister's Schooling with controls for Determinants of School Provision

	Read	Write	Add	Count	Schooling	Enrollment
Oldest sister's years of schooling	0.077**	0.037	0.077**	0.054*	0.399***	0.074***
	(0.035)	(0.030)	(0.033)	(0.032)	(0.125)	(0.028)
First stage results						
Distance to closest girls school	-0.384***	-0.400***	-0.393***	-0.381***	-0.394***	-0.399***
	(0.083)	(0.083)	(0.083)	(0.083)	(0.074)	(0.074)
F statistic	21.530	23.136	22.278	21.252	28.409	29.268
Observations	3,368	3,360	3,341	3,377	5,034	5,048

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

This table presents the IV results from a specification that additionally controls for village size. Government documents stated village size as the determinant for building and providing government schools across villages. The analysis in this table shows that the results for oldest sister spillovers using the distance to government girls' school instrument are robust to controlling for village size which is a supply-side factor which drove government school location. The dependent variables read, write, add, count are indicator variables for whether younger siblings are reported as capable of reading writing, add/subtracting or counting. The dependent variable schooling refers to years of completed schooling as an outcome and enrollment is an indicator for whether the child is currently enrolled. The rest of the controls are the same as the ones from the basic specification which controls for household variables, parents' education, wealth controls, distance to closest boys' school, distance to closest private school, distance to village center as well as district times year fixed effects.

Appendix Table A5: Effects of Absolute Oldest Sister's Schooling on Younger Brother Outcomes

	Read	Write	Add	Count	Schooling	Enrollment
Second stage IV results						
Oldest sister's years of schooling	0.065**	0.054	0.072**	0.053*	0.468***	0.063**
	(0.029)	(0.033)	(0.029)	(0.029)	(0.136)	(0.030)
First stage results						
Distance to closest girls' school	-0.528***	-0.496***	-0.523***	-0.508***	-0.432***	-0.440***
	(0.100)	(0.100)	(0.101)	(0.100)	(0.089)	(0.089)
F statistic	27.563	24.602	27.040	25.705	23.523	24.305
Number of observations	2,685	2,677	2,667	2,691	3,835	3,845
R^2	0.386	0.358	0.361	0.286	0.581	0.184

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.
This analysis limits the sample to the absolute oldest sisters i.e. the first born daughter of the household unlike the rest of the analysis where I defined oldest sister as the oldest out of those still living in household during some point in the panel. The dependent variables read, write, add, count are indicator variables for whether younger siblings are reported as capable of reading writing, add/subtracting or counting. The dependent variable schooling refers to years of completed schooling as an outcome and enrollment is an indicator for whether the child is currently enrolled. The IV regression results reported are from the fullest control specification which controls for household variables, parents' education, wealth controls, distance to center, distance to closest government boys' school as well as district times year fixed effects.

Appendix Table A6: Oldest Sister Spillovers for Oldest Sisters aged less than 20

	Read	Write	Add	Count	Schooling	Enrollment
Second stage IV results						
Oldest sister's years of schooling	0.060*	0.031	0.070**	0.079**	0.432***	0.083***
	(0.033)	(0.031)	(0.034)	(0.033)	(0.130)	(0.030)
First stage results						
Distance to closest girls' school	-0.413***	-0.428***	-0.417***	-0.412***	-0.406***	-0.404***
	(0.087)	(0.087)	(0.087)	(0.087)	(0.082)	(0.082)
F statistic	22.658	24.305	23.040	22.563	24.503	24.404
Number of observations	2,841	2,834	2,819	2,848	3,753	3,765
R^2	0.378	0.364	0.366	0.259	0.560	0.159

Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.
This table presents the IV results for the impact of oldest sister's education on younger brother learning and schooling using a sample of oldest sisters under the age of 20 only. The sample limitation should minimize the potential endogeneity from the oldest sister's marriage after which girls leave their parents household and would not be present in the sample. The results are very similar to those obtained in the full sample in table 6a. The regression controls for household variables, parents' education, wealth controls, distance to closest boys' school, distance to closest private school, distance to village center as well as district times year fixed effects.