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 the role that older sisters' education might play in the educational achievement of young children. In many developing countries, oldest sisters share significant child care responsibilities in the household and 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 effects of the oldest sister's schooling on the human capital of younger brothers. I find that oldest sister's schooling has significant, beneficial effects on younger brothers' schooling, enrollment, literacy and numeracy. An additional year of schooling for the oldest sister increases the younger brother's 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

There has been a remarkable increase in girls' education worldwide in recent years. The number of girls out of primary school has fallen from 61 million in 1999 to 35 million in 2009.[1] As older sisters, girls often play a significant role in raising young children. The role of older sisters may be particularly important in developing countries where they share considerable childcare responsibilities within the household (Levison and Moe, 1998; Ilahi, 2004; Edmonds, 2006). While there is a large literature on the impact of maternal education on a range of child outcomes, we know surprisingly little about the effect of older sister's education on child human capital development.[2]

The primary objective of this paper is to investigate the intra-household spillover effects from girls' education on the human capital acquisition of younger siblings. I estimate the effects of oldest sister's schooling on younger brothers' schooling, enrollment, literacy and numeracy using data from rural Pakistan. I exploit the gender segregation of schools in Pakistan that creates plausibly exogenous variation in oldest sister's schooling to identify causal effects of oldest sister's schooling 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 effects for younger brothers.

I propose a model that incorporates the effect of oldest sister's schooling by treating time spent with the oldest sister as an input into the younger brother's human capital. 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, 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.

[1] World Bank, World Development Report 2012

[2] See the studies on mother's education and birth outcomes (Currie and Moretti, 2003), nutrition (Thomas et al., 1991), education (Haveman and Wolfe, 1995), and test scores (Rosenzweig and Wolpin, 1994).

Evaluating the intra-household spillover effects from oldest sister's education is not straightfoward. There are likely important differences in observed and unobserved characteristics across households which educate their girls differently. The gender segregation of government schools in Pakistan provides a particularly good opportunity to evaluate the effects of oldest sister's education on younger brothers' human capital. I use distance to the closest government girls' school, conditional on distance to the closest government boys' school, distance to the closest private school, and distance to the village center, to create plausibly exogenous variation in the oldest sister's schooling. Distance to girls' school is associated with significant reductions in girls' schooling.[3] This distance penalty arises because of the safety and chastity concerns about girls going outside the home in this region.

I argue that in the case of rural Pakistan, a region where parents place low value on girls' schooling and households have limited mobility, the endogenous location of households with respect to girls' schools is unlikely conditional on covariates. Since boys do not attend girls' schools, distance to girls' school can only affect boys' educational achievement indirectly through how it varies with other factors. The inclusion of the other distance controls implies that identification comes from comparing households that are equidistant from the boys' schools and the village center but differ in their distance to the girls' school. I show that distance to boys' school does not have a significant effect on oldest sister's schooling which lends some credibility to the identifying assumption that distance to girls' school does not directly affect younger brothers' schooling.

I also provide evidence from a falsification test that suggests that distance to girls' school does not directly affect brothers' educational achievement. The theoretical model predicts spillover effects of oldest sister's schooling on younger brothers due to her role and activities as an *older* sibling. Based on these mechanisms, meaningful effects should only flow from the oldest sister to younger brothers and there should not be any sizable effects of the oldest sister's schooling on her older brothers. I show that when using the distance to girls' school instrument, I do not find any significant effects of oldest sister's schooling on older brothers' educational achievement which suggests that distance to girls' school is unlikely to directly affect younger brothers' educational achievement.

Using this conditional instrumental variables strategy, I find that the oldest sister's schooling has significant, beneficial effects on younger brothers' human capital. An additional year of schooling completed by the oldest sister increases the younger brothers' years of

[3]This is documented by Alderman et al. (2001) and Andrabi et al. (2008) in Pakistan, and Burde and Linden (2010) in Afghanistan.

schooling by 0.42 years or 14 percent, 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. While these net spillover effects are positive, I also provide suggestive evidence that increasing oldest sister's schooling is associated with both a positive quality effect and a negative quantity effect.

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 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 due to competition for resources by showing that an increase in male education decreases the education of female siblings in the household. My study differs from these previous analyses of sibling effects because it conceptualizes oldest sister's schooling as an input into younger siblings' human capital and provides the first credible estimates documenting this relationship.

The positive spillovers from oldest sister's schooling on child's educational achievement I find are the same order of magnitude of maternal education. The evidence in this paper suggests that the effects of oldest sister's schooling are larger among households with less educated mothers, in line with what one would expect theoretically. The treatment effects I find thus relate closely to the low education of household members in Pakistan. Seventy-five percent of mothers and 40 percent of fathers have no schooling. For many of these households, the oldest sister is 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 and high cost of girls' schooling contribute to low education for girls.[4] Children attend either government schools or private schools.[5] Government schools are free

[4]Investment in girls' schooling is relatively low because girls do not typically earn and move away after marriage while boys support their parents in old age (Strauss and Thomas, 1995).

[5]Contrary to popular press reports, Andrabi et al. (2006) show that religious schools, *madrassas*, account for one percent of the enrollment share and there is no evidence of a significant increase in recent years.

and gender segregated at all levels of instruction. Private schools are relatively expensive, co-educational facilities that have opened in large numbers starting in the mid-1990s.[6] Government schools enroll over 70 percent of the children, and more than 75 percent of the girls in my sample.

Most children walk to school in the rural villages of Pakistan. Ninety-four percent of the children, boys and girls, under the age of ten are accompanied by a relative or friend to school. The fraction of boys accompanied to school falls as they grow older and are considered increasingly capable of taking care of themselves. The fraction of girls accompanied to school, however, does not decline with age so that a statistically significant, 14 percentage point gender gap in the rates of accompaniment emerges for teenagers in my data.

This gender gap exists because social norms proscribe female mobility outside the house and there are safety concerns about girls that intensify after girls reach the age of puberty. Ensuring 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 in the neighborhood. The gender segregation of government schools and placement of boys' and girls' schools in different areas of the village means that less than 15% of girls are walked to school by a brother. The need for somebody to accompany a girl to school creates a distance penalty that disproportionately impacts girls. I 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 spillover effects on younger brothers.

There are several reasons why the oldest sister's schooling could be important for younger siblings, especially in a developing country context. Oldest sisters share considerable childcare responsibilities within the household and as one of the childcare providers, the education of the oldest sister has the potential to influence younger sibling learning.[7] I analyze the relationship between the oldest sister's schooling and younger sibling educational achievement because the oldest sister bears the most responsibility of looking after younger siblings.[8] In Pakistan, the oldest sister is also the most important source of help for children

[6]The average annual fee charged by government schools and private schools in 2003 was Rs. 10 (USD 0.166) and Rs. 870 (USD 14), respectively. The average household in my sample has expenditures per capita of about one USD a day. The growth of the private school sector is documented in Andrabi et al. (2008).

[7]There is a strong gender division of responsibilities with girls responsible for cooking, cleaning, and looking after younger siblings whereas boys work on the farm and in the labor market. The typical 15-18 year old girl spends 5.5 hours daily on housework compared to 0.5 hours by similarly-aged boys in my data.

[8]Edmonds (2006) shows that in Nepal, the oldest girl in a household with six or more children works 9.8 hours more than her next oldest resident sister. He explains this distribution of labor results as a function of the oldest girl's comparative advantage in home production and caring for younger children.

with studies. Only one out of five children who receive 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 and conditional on helping, she spends an average of 7 hours a week. Since oldest sisters spend most of their time at home, young children have immense potential for 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 an additional channel through which oldest sisters can influence younger siblings' learning.

3 Model

To incorporate oldest sister's schooling into the human capital production of younger brothers, I start with the standard human capital model (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.[9] The rationale behind this extension is that oldest sisters can potentially influence younger sibling learning for the reasons just discussed.

Time spent with a more educated oldest sister is likely higher quality time for several reasons. A more educated oldest sister might be more likely to help a child with studies, and any help given is likely to be of higher quality. Studies from the child development literature find that younger siblings can benefit from the language skills of their older siblings, and that children of more educated mothers have larger vocabularies.[10] It is thus plausible that younger brothers might benefit from language exposure from oldest sisters with more schooling. I term this overall phenomenon whereby increased schooling for the oldest sister improves the quality of time spent with the younger brother the quality effect.

Unlike parents' schooling, oldest sister's schooling is likely ongoing when the younger brother is a young child. Increasing the oldest sister's schooling requires enrollment in school and allocating more time towards school work which can potentially compete with time spent with the younger brother. This tradeoff is likely more acute when the younger brother is of

[9] I model the relationship between oldest sister and younger brother, and not that between the oldest sister and younger sister because I empirically estimate the former relationship only.

[10] Language exposure is crucial for vocabulary growth in children (Huttenlocher et al., 1991) and younger siblings' vocabulary increases as their older siblings' speech becomes more complex Pine (1995). 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).

pre-school age since he is not yet enrolled in school and spends most of his time at home. I denote this potential negative effect of increasing oldest sister's schooling on time spent with younger brother, and hence his human capital, the quantity effect.

3.1 Theoretical Predictions

Consider the optimization problem for a household with parents and two children, a girl who is the oldest sister and a boy who is the younger brother. Parents maximize a separable utility function which is concave in period 1 consumption and the utility of children, realized in period 2. In period 1, parents have access to wealth, W_p, and decide how much to consume, C, and how much of their children's time to allocate to schooling, y_i (i equals s for the oldest sister and b for the younger brother). Children's time can either be allocated to schooling, y_i, or household production at home or the family farm, $x_i = 1 - y_i$. 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 $H_s = f(y_s)$ and I assume that H_s is a positive but concave function of her years of schooling. The human capital production function of the younger brother is $H_b = g(y_b, x_s, H_s)$ so that the younger brother's human capital is a function of his years of schooling, the time the oldest sister spends at home, and the human capital of the oldest sister.[11] The oldest sister's time spent at home, x_s, is considered an input with the implicit assumption that time spent at home doing housework is also spent with the younger brother. This is reasonable because the oldest sister's responsibilities include looking after younger siblings, and even if she is working on other 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 complementarity between time spent with the oldest sister and brother's schooling, y_b. The oldest sister's human capital enters the production function directly because higher human capital raises the quality of the time that she spends with the younger brother.

The productivity of time allocated to household production is allowed to vary by gender according to the parameters, p_s and p_b. I specify 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 are adults and 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 human capital, H_i, times the gender-specific

[11] These inputs exhibit positive and diminishing marginal returns in the production of human capital.

wage rate, r_i.[12] Parents derive utility from their children's period 2 utility according to altruism parameters, a_s and a_b, that are assumed to be ≤ 1.[13] Due to strong son preference, reliance on sons in old age, and virilocal marriages, it is likely that a_s is less than a_b.[14]

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.[15] Parents choose y_b^* 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 foregone household production and the distance cost of schooling.

The marginal benefit and marginal cost of oldest sister's schooling 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 of the quality effect which raises younger brother human capital. The costs of increasing oldest sister's schooling include foregone household production, the distance cost and the negative quantity effect since increasing oldest sister's schooling entails less time spent with the younger brother. Without knowledge of the relative magnitudes of the positive quality effect and the negative quantity effect, the net impact of oldest sister's schooling on younger brother human capital is theoretically ambiguous and needs to be determined empirically.

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 predicted quality effect overrides the quantity effect, and oldest sister's schooling has a net positive spillover on younger brother human capital. Even if

[12] The labor force participation rate for women 10 years and older was 20.66% in 2008-09 (Federal Bureau of Statistics, 2009). Since girls do not usually work, non-pecuniary returns to education including status, marriage market returns, and benefits for grandchildren etc. are more important for girls.

[13] Parents typically put less weight on children's utility as compared with their own.

[14] The missing girls phenomenon is one representation of strong son preference Sen (1992). It is customary for girls to move out of their parents' household and into their husband's household upon marriage.

[15] $U', V_{w_s}, V_{w_b}, f_{y_s}, g_{y_b}, g_{x_s}, g_{H_s}$ are 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 $g_{H_s H_s}$ assumed to be negative. 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 to get interior solutions for C, y_s, and y_b.

$a_s = 0$ and parents derive no utility from the sister's utility, it can still be optimal for them to invest in her schooling if it generates positive spillovers for the younger brother. If this net spillover is positive and parents ignore it in their schooling allocation decision, they will under-invest in the oldest sister's schooling.[16] In section 6, I show evidence that suggests parents might not be internalizing these spillovers. In case parents ignore these spillovers in allocating schooling, the younger brother will still be affected by the spillovers present in the human capital production function. I will therefore be able to empirically identify the spillover effects regardless of parents' behavior.

I calculate and discuss comparative static predictions in Appendix A.2.[17] Analyzing the effect of distance cost of girls' schooling, d_s, on younger brother's schooling is informative because that is the identifying source of variation I use to estimate the spillover effects of oldest sister's schooling. The model predicts that an increase in the distance to girl's school has three potential effects on younger brother's schooling: a positive substitution effect, a negative income effect and the spillover effect. The positive substitution effect arises from the fact that within a household, siblings compete for schooling investment from a common pool of resources. Parents might therefore respond to the higher distance to girls' school by reducing the oldest sister's schooling and substituting towards the relatively cheaper schooling of the younger brother.[18] If parents invest in the oldest sister's schooling despite the greater distance, the increased cost incurred squeezes household resources which can reduce the younger brother's schooling via an income effect. Since the distance cost of schooling is mainly the opportunity cost of the time it takes to walk to the girls' school, these effects are likely small. The third potential effect identifies how the distance-induced reduction in oldest sister's schooling reduces the spillover for the younger brother.

4 Data and Sample Characteristics

The data for the empirical analysis comes from the Learning and Educational Achievement in Punjab Schools (LEAPS), which is a longitudinal survey of 1800 households in Punjab

[16] The proof for this proposition is presented in Appendix A.1.

[17] Children's schooling is increasing in parental wealth. Increasing the relative altruism towards girls results in higher schooling for the oldest sister and lower schooling for the younger brother. Increasing the return to girls' human capital increases the sister's schooling while reducing the brother's schooling. Higher returns to boys' human capital increase the brother's schooling but have an ambiguous impact on the oldest sister's schooling since her schooling is also an input into the brother's human capital. Comparative statics with respect to $W_p, a_b, a_s, r_s, r_b, p_s, p_b, d_b$ and d_s are discussed in Appendix A.2.

[18] Shrestha (2011) found evidence of such inter-sibling rivalry in Nepal where increases in brothers' schooling reduced the schooling of their sisters.

province (home to 56% of the country's population). Data was collected for 112 rural villages in the three districts of Attock, Faisalabad, and Rahim Yar Khan from 2003-2006.[19] A random sample of households was selected from each village, and all the schools in these villages were surveyed.[20] The data contains household surveys, school surveys and geographical coordinates for all surveyed households and schools.

The typical village in the data has seven schools including two government boys' schools, 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. Age-specific enrollment rates plotted in Figure 1 reveal significant gender gaps. For children of primary school age (6-12 year olds), the average gender gap in enrollment rates is eight percentage points which widens to 14 percentage points 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 gender differences in completed schooling: 28.6% of the girls have zero years of schooling compared to 12.6% of boys. Many children, particularly girls, drop out after completing primary school.[21]

The analysis sample includes households with at least one girl and a younger boy. I restrict the sample to households where the oldest sister is between 8 and 30 years old in the first round. This upper bound on the oldest sister's age is important because oldest sister's schooling is observed only if she is still living with her parents. Since girls in rural Pakistan get married early and move out of the parents' household upon marriage, much older girls living with their parents are potentially selected. To avoid selection bias from marriage, I use the oldest sister among the siblings still living in the household in addition to imposing this age restriction. In 73% of the cases, the oldest sister I use is the oldest sister by birth rank. The results do not change if I limit to oldest sisters less than 20 years old. I show the robustness of results to these sample restrictions in Appendix B.

Descriptive statistics for the households used in the analysis are shown in Table 1.[22] The

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

[20]Villages were randomly selected from a list of villages with a private school and where the total number of schools did not exceed 20.

[21]Schooling is only observed for current members of the household so I show the distribution of schooling for 16-20 year olds to strike a balance between showing *completed* schooling and ensuring that I can observe girls' schooling before they marry and leave the household. Since schooling is completed for most girls but in progress for some boys, these figures represent lower bounds on the gap in completed schooling.

[22]The LEAPS contains four rounds but I exclude round 2 in my analyses because only an abridged version of the survey was administered due to funding issues. It was fielded in October-December of 2003, soon after the first round in February-April of 2003, unlike the other rounds which were all conducted in Spring. Literacy and numeracy questions were not asked. Some schooling information was collected but it is not possible to determine whether the first and second round interviews took place in the same academic year.

average household has eight members including five children, two parents and a grandparent. The average oldest sister is 16.2 years old, and the average younger brother is 10 years old. Parents, especially mothers, have low levels of education. Only a quarter of the mothers and 62% of the fathers have any schooling. The average years of schooling completed by mothers and fathers is 1.5 years and 4.4 years, respectively, while the typical oldest sister has completed four years of schooling. Ninety-four percent of the households own the house they live in and average expenditures per capita are about one USD a day.[23]

Literacy and numeracy are critical 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 the mother's response to the following questions asked for each child:[24]

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?

The progression of these skills by grade is shown in Figure 3. While these binary measures seem rudimentary, the learning of these children is poor and there is considerable variation in these measures. Less than half of the children in grade 3 (median age is 9 years) are able to read and only one in three are able to write. Andrabi et. al 2008 report for this sample that if a child were to leave school after grade 3, he/she would most likely be unable to write a simple sentence in Urdu (the vernacular of Pakistan). Only 65% of these children can subtract single-digit numbers, and only 19% can divide a three-digit number by a single-digit number.

Five-six year olds might be enrolled in kindergarten (*kacchi*) and will have started to learn how to count and add. The average child in grade 5, the last year of primary school, is 11.7 years old. Among 12-year old children, 92 percent can write, 97 percent can read, and almost all of them can add and count. Since these skills are universally acquired by the end of primary school, I examine effects of oldest sister's schooling on these outcomes for primary school-aged younger brothers only.[25] For the outcomes of schooling and enrollment,

[23]At the time of the survey, $1 was approximately 60 Pakistani rupees.

[24]One might worry that the mother's response to these questions may vary with the level of her schooling. I regressed the mother's response for child capability on mother's schooling and controls for the child's test score. Since the LEAPS contains test scores in English, Urdu (the vernacular of Pakistan), and Math for a subsample of children enrolled in certain grades in particular years, this allows me to control for the direct effect that mother's education has on her child's learning in Appendix Table C.1 to show that mothers with different schooling do not respond to the capability questions in significantly different ways.

[25]Of the households with an oldest sister of the right age with a younger brother, 94 percent have a younger

there is no theoretical reason to limit attention to these younger ages so I use a sample of 5-18 year old younger brothers. Indeed, schooling and enrollment are more elastic for boys after the completion of primary school. For boys of primary school-age, average enrollment rates are close to 90 percent but fall sharply after primary school indicating greater room for improvement and potential spillover effects from the oldest sister's schooling.

5 Empirical Strategy

The main empirical specification relates oldest sister's years of schooling to younger brother human capital. I also present alternative treatment specifications using an indicator for whether the oldest sister has any schooling, and an indicator for whether she has completed primary schooling. These are important margins because one in four oldest sisters has no schooling and 44.7% of oldest sisters have completed primary schooling. Roughly 40 percent of the oldest sisters in the data are currently enrolled in school. I account for this right-censoring of observed schooling by controlling for age of the oldest sister. Identification then comes from comparing oldest sisters who have more schooling, adjusting for their age and therefore the potential schooling they could have accumulated. In addition to estimating the net effects of oldest sister's schooling, I exploit variation in when the schooling was acquired based on oldest sister's age gap with the younger brother to try to identify the quality effect and quantity effect predicted by the model.

Studies including Rosenzweig and Wolpin (1994) and Moore and Schmidt (2007) analyze the impact of maternal education using fixed effects, thereby studying children of 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 because using the variation in oldest sister's schooling over time would only identify an incremental, value-added impact of the oldest sister continuing her schooling.[26] Only 46 percent of the oldest sisters have time-varying years of schooling and would therefore contribute to estimates in a fixed effects regression.[27]

The model for spillover effects on younger brother human capital is given by:

$$Y_i = \beta_0 + \beta_1 \, Oldest \; Sister's \; Schooling_{\,i} + X_i \, \beta_2 + \epsilon_i \qquad (3)$$

brother in this age range.

[26] My study seeks to compare the learning of a child who grows up in a household with an oldest sister with low schooling, and a child in an otherwise comparable household with an oldest sister with more schooling.

[27] When treatment is defined as having an oldest sister with any schooling, a fixed effects approach would yield meaningless estimates because a switch in treatment status for a 16-year old girl is rare and likely measurement error. The indicator variable for the oldest sister having primary schooling is time-varying for only 30 percent of the oldest sisters.

where i indexes younger brothers, Y_i is the outcome of interest, $Oldest\ Sister's\ Schooling_i$ is either the oldest sister's years of schooling or an indicator variable based on it, and X_i represents a vector of demographic, family background, district, and child characteristics that influence outcomes. The vector ϵ_i represents unobserved determinants of the outcome and the coefficient β_1 represents the effect of oldest sister's schooling on younger brother educational achievement. OLS models of Equation 3 will yield consistent estimates of β_1 if $Cov(\epsilon_i, Oldest\ Sister's\ Schooling_i) = 0$, which is likely not satisfied because there are unobserved differences across households which educate their oldest daughters differently. It is plausible that households which educate their oldest daughters more value education highly and therefore invest more in the education of all children. Such unobserved differences would lead to OLS estimates of β_1 that are biased upwards.

My identification strategy exploits the gender segregation of government schools in Pakistan and uses distance to girls' school as an arguably exogenous source of variation in the oldest sister's schooling. The first stage-model takes the form:

$$Oldest\ Sister's\ Schooling_i = \alpha_0 + \alpha_1\ Distance\ to\ Girls'\ School_i + X_i\ \alpha_2 + \nu_i \qquad (4)$$

where $Distance\ to\ Girls'\ School_i$ is distance from the household to the closest government girls' school in kilometers, and ν_i represents unobserved determinants of oldest sister's schooling.[28] The coefficient β_1 identified in this IV model is consistent if the exclusion restriction is satisfied conditional on the covariates i.e. that $Cov(\epsilon_i, Distance\ to\ Girls'\ School_i |\ X_i) = 0$. The covariates in X_i include distance to the closest government boys' school, distance to the closest private school, distance to the village center, family size and composition, parents' education, wealth and asset measures, and district times year fixed effects.[29]

Since boys do not attend girls' schools, distance to girls' school can only affect younger brothers indirectly through how it varies with other factors. One possibility is that households that are distant from girls' schools might also be distant from boys' schools. This is not a potential threat to identification because X_i includes controls for distance to the schools that the younger brothers themselves would attend i.e. distance to the closest government

[28]The data contains GPS co-ordinates for all surveyed households and all schools in the sample villages which are used to create distance variables.

[29]The household controls include a quadratic in: age of oldest sister, age of younger brother, number of daughters, number of sons, and family size, as well as indicator variables for language spoken at home and month of interview. Parents' education controls include variables for whether the mother and father have any schooling, years of schooling completed, and indicators for whether these are missing. Asset and wealth controls include indicators for whether the family owns any land, owns the house they live in, 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), the type of water connection, and a quadratic in expenditure per capita.

boys' school and distance to the closest private school. One might worry that households located far from girls' schools may also be households that are remotely located in general. I follow the approach in Andrabi et al. (2010) in using an instrument of distance to school conditional on the distance to village center. The authors use the LEAPS to document that households are clustered around the village center with richer households located more centrally. Conditioning on the distance to village center then controls for the variation in distance to school that is correlated with access to earnings opportunities and other amenities. The identifying source of variation in this conditional IV strategy comes from comparing households that are equidistant to the closest boys' schools, equidistant from the village center, and share all the characteristics of the other controls while differing only in their distance to the closest girls' school.

A justifiable concern with using distance to school as an instrument in the U.S. is that household location is not random with respect to schooling options. Access to good quality schools is an important factor in an American family's decision of where to live. In the rural Punjabi villages studied here, the biggest determinant is land. These are highly agrarian villages where people reside on and make a living from land that has been passed down in their family for generations. Around 60% of the fathers work in agriculture, half of the families report owning land, and 94% own the house they live in.[30] Given this dependence on land, households have limited choice in where they locate. The main margin of mobility for these households is to have an adult male member migrate to the city.[31] This limited mobility means households have limited capacity to systematically locate their children closer to schools. They also place a lower value on education, particularly girls' education, making endogenous location of households based on distance to girls' schools even more unlikely.

A remaining potential threat to the identification strategy could be the selection into where the government decided to build schools. Most government boys' schools were built in the 1950s soon after Pakistan gained independence and most girls' schools were built in the 1980s.[32] Since girls' schools were often built decades after the boys' schools, they were built in different areas of the village which allows there to be sufficient variation in distance to girls' school after conditioning on distance to boys' school. Andrabi et al. (2010)

[30]The proportion working in agriculture is a lower bound because I assume those who report working in salaried occupations are not in agriculture. While I can not identify them, a sizable proportion of salaried people work in agriculture. It is a common arrangement for landlords to give tenants residence and the share-crop payment which leads to many families owning a house but not owning land.

[31]Even in these households, the children's location with respect to schools does not change since it is only the adult male member that migrates to the city who then sends back remittances (Mansuri, 2006).

[32]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. The placement of government schools on the periphery of villages allows there to be sufficient variation in distance to government schools after controlling for distance to village center. More importantly, it suggests that within-village location of government schools, unlike that of private schools which locate in the wealthier 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 population.[33]

Based on the theoretical predictions in section 3, an increase in distance to girls' school is associated with three effects on younger brother schooling: the spillover effect from distance-induced changes in oldest sister's schooling, an income effect and a substitution effect. The predicted income and substitution effects are likely to be negligible because the distance cost of girls' schooling is not an explicit cost but the opportunity cost of the time spent walking to the girls' school. Only 2% of girls walk to school with a parent while 37% walk with a friend.[34] The opportunity cost of time spent walking to school by the sister, and perhaps also by another household member, is low because it does not involve foregone adult earnings but might entail some foregone household production. Back-of-the-envelope calculations show that increasing distance to girls' school by one kilometer can reduce annual household production by 3% at most.[35] The expected sign of the income effect depends on how oldest sister's schooling changes in response to distance.[36] Regardless of the sign, this ambiguous income effect based on the opportunity cost of walking to school is arguably small.

[33]Government schools were to be built in villages with a population of at least 1000. Appendix Table C.2 shows the results which control for village size.

[34]Forty-three percent walk with a sister, 11% with a brother and 6% with another relative.

[35]This calculation assumes that it takes 30 minutes to walk this distance and that the sister and the accompanying household member account for two-thirds of total household production. I get this estimate after accounting for the number of school days in the year on which this commuting cost is incurred and assuming generously that all the time spent walking to school would have been spent in household production. For about 40% of the households where the oldest sister walks with a friend, the foregone household production would be half this amount. Furthermore, all empirical specifications include controls for expenditure and wealth so any effect on income will be muted.

[36]Using terminology from Angrist et al. (1996), the income effect for "always taker" households that invest in the oldest sister's schooling regardless of distance to girls' school is negative because an increase in distance raises the cost incurred. For complier households, an increase in distance reduces the oldest sister's schooling and therefore the cost incurred which is associated with a positive income effect. The expected income effect is zero for "never-taker" households that do not invest in oldest sister's schooling regardless of distance because they incur no investment cost.

The substitution effect from increasing distance to girls' school is unambiguously positive because the brother's schooling is now relatively cheaper. Since the predicted substitution effect has the opposite sign of the spillover effect, it biases against finding positive spillovers from oldest sister's schooling. As with the income effect though, the substitution effect is likely negligible because time spent walking to school has a low opportunity cost.

Conditional on instrument validity, the IV estimate captures the local average treatment effect (LATE) of oldest sister's schooling on younger brother human capital. Households that are induced into educating their oldest daughters more by the distance instrument are more likely to be relatively disadvantaged households with less educated parents. The spillovers from oldest sister's schooling may also differ by parental education. Since the oldest sister's role is similar to that of a mother, oldest sister's schooling likely has a larger impact in households with less educated mothers relative to households with more educated mothers. This leads us to expect the LATE estimates uncovered by the IV will be larger than the average treatment effects.

6 Results

I begin my analysis by documenting how distance to school affects the schooling and enrollment of boys and girls in these villages. Panel A of Table 2 shows that distance to boys' school does not significantly affect boys' schooling and enrollment once distance to village center is controlled for. Distance to girls' school, however, is associated with significant reductions in girls' schooling and probability of enrollment. While the strength of this relationship attenuates after controlling for distance to village center, distance to girls' school continues to exert meaningful influence. An increase in distance to girls' school of one kilometer is associated with a 3.8 percentage point reduction in the probability of a girl being enrolled in school.[37] While distance to school affects boys and girls differently, distance to village center influences both boys' and girls' schooling indicating that wealthier households which are more centrally located are more likely to educate their boys and girls.

As children get older, fewer boys are accompanied to school but girls still need to be walked to school. Since the gender difference in the need for somebody to walk girls and boys to school only arises for older children, one should similarly expect the gender difference in the penalty exerted by distance to school to be relevant for older children. Panel B of Table 2 shows the distance penalty on schooling and enrollment of boys and girls younger than 13

[37]Since distance to girls' school thus negatively affects girls' schooling and enrollment, it is not appropriate to use it as an instrument to analyze spillover effects on younger sisters' human capital.

years old, and those aged 13 and older separately. While there is no significant distance penalty for young or old boys, the penalty for girls is driven primarily by the older girls. The distance penalty on schooling for younger girls is small and not statistically distinguishable from zero but distance imposes a harsh, significant penalty on older girls.

I present results from OLS regressions of younger brother learning and schooling outcomes first. Table 3 shows that an additional year of schooling for the oldest sister is associated with an increase of 0.15 years of schooling for the younger brother.[38] This table shows positive and statistically significant associations between oldest sister's schooling and all six outcomes for younger brothers conditional on the controls for family size and composition, parents' education, wealth and asset measures, and district times year fixed effects.

The results using the preferred IV strategy are presented in Table 4. The first stage estimates show that conditional on the full set of controls, a one kilometer increase in distance to girls' school is associated with a reduction in oldest sister's schooling of about 0.4 years. Distance to girls' school is a strong instrument with the F-statistic on distance to girls' school exceeding 20 in all of the outcome specifications. Distance to boys' school does not affect oldest sister's schooling: the coefficients are neither statistically nor economically significant in any of the first stage regressions. If households that really valued both boys' and girls' schooling were located closer to schools, one would expect to see that picked up as a meaningful correlation between distance to boys' school and oldest sister's schooling. The lack of a significant relationship between distance to boys' school and oldest sister's schooling lends further credibility to the identification assumption that distance to girls' school does not directly affect younger brothers' educational achievement conditional on covariates.

Table 4 shows statistically significant, positive effects of oldest sister's schooling on younger brother learning and schooling outcomes. 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 and 5.5 percentage points more likely to be able to add and count, respectively. The point estimate for the effect of oldest sister's schooling on ability to write is positive but lacks statistical significance. Compared to the means of these outcomes, 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.

[38]Since the typical younger brother is still enrolled in school and I control for the age of the younger brother in all empirical specifications, the schooling outcome should be interpreted as years of schooling that the brother has completed by that age rather than completed schooling.

Table 5 shows results for alternative measures of oldest sister's schooling including an indicator for whether the oldest sister has any schooling, and an indicator for whether she has completed primary schooling, respectively. These coefficients echo the positive results found in Table 4 with significant, positive effects for all outcomes, except for writing. It is not clear whether this indicates that oldest sister's schooling does not have an impact on younger brother's writing or whether the effect is too small to detect precisely. 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 larger returns.

The IV estimates presented identify causal spillover effects from oldest sister's schooling under the assumption that conditional on the controls, distance to girls' school does not affect younger brother learning independently of how it changes oldest sister's schooling. While this is an inherently untestable assumption, I implement an indirect placebo test using outcomes for older brothers. The mechanisms underlying the predicted effects of oldest sister's schooling on younger brother human capital 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, is a tutor and a role model to the younger siblings. Based on these mechanisms, there should be no sizable impact of the oldest sister's schooling on her older brothers' educational achievement.[39] This prediction suggests a falsification test that can be used to test empirical strategies analyzing the effects of oldest sister's schooling. If the empirical strategy used yields significant and sizable effects of oldest sister's schooling on her older brother's learning, this finding would be inconsistent with the theoretical model and therefore suggestive of selection bias confounding the estimation. Table 6 uses OLS to estimate the relationship between oldest sister's schooling and older brother human capital and finds positive, statistically significant associations for all six outcomes. These sizable point estimates demonstrate that the OLS estimates of oldest sister's schooling on younger brother outcomes are likely biased. Table 7 shows the results from applying the same falsification test to the IV strategy. The IV results show that oldest sister's schooling does not have a statistically or economically significant effect on any of the older brother educational outcomes which boosts confidence in the research design.[40]

[39]While there may be some spillovers for an older brother from interacting with a more educated younger sister, I expect such an effect to be much smaller than the impact of the oldest sister on her younger brothers. Any such interaction spillover on older brothers will also likely be small because older brothers who work and spend most of their time outside the home have limited interaction with their younger sisters.

[40]Far from finding a positive impact, I can actually never reject the one-tailed hypothesis that these estimates are non-positive.

6.1 Why are IV Effects Larger than OLS?

While the IV effects of oldest sister's schooling on younger brother human capital in Table 4 are not statistically significantly different from the OLS effects presented in Table 3, they are considerably larger for all of the outcomes considered.[41] This pattern of results runs counter to the expectation that - conditional on the validity of the instrument - the unbiased IV estimates should be smaller than the OLS estimates which are upwards-biased due to positive selection into treatment. This finding of IV effects exceeding OLS despite the expectation that OLS results are upwards biased is common in the returns to schooling literature (Card 2001) and the literature on impact of parental education (for example, Currie and Moretti 2003 and Carneiro, Meghir and Parey forthcoming).

Measurement error in the measure of oldest sister's years of schooling can potentially explain why the IV estimates exceed the OLS estimates. One might expect considerable measurement error in the schooling measure in developing countries, particularly when the parents responding to the household survey have such low levels of schooling themselves. Most general forms of measurement error in the oldest sister's schooling measure would bias the OLS results downward but yield consistent estimates using IV.

The fact that oldest sister's years of schooling is a proxy for her education is a more general measurement issue that would also contribute to OLS effects being attenuated relative to IV effects. Imagine two oldest sisters who have completed four years of schooling each but one of the sisters had high attendance during those years while the other sister barely went to school. This noise in the proxy measure of years of schooling attenuates the OLS estimates but the IV estimates would be larger due to improved signal-noise ratio because proximity to school improves attendance and therefore the education received.

Next I study differences in the distance penalty, and heterogeneity in the spillover effects of oldest sister's schooling by level of maternal education. Mother's education is an important factor to consider when investigating heterogeneity in effects of oldest sister's education because oldest sister's education is likely a close substitute for mother's education. Given the low labor force participation for mothers in this sample, increased market work and earnings are likely not important channels through which maternal education affects children.[42] The primary mechanisms for the impact of maternal education on children are the mother's role as the primary childcare provider, and the time she spends with her children.

[41] Hausman test results indicate that the IV and OLS estimates are significantly different in only one of the six outcome specifications.

[42] Only 10.5% of mothers report spending any time on paid work in a given day.

Given that oldest sisters also look after younger siblings and that I modeled time spent with the oldest sister as an input into the younger brother's human capital, oldest sister's education is a particularly close substitute for mother's education in this context.

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 schooling. When a mother is educated under this definition, the father is almost certainly educated as well.[43] Table 8 shows that the distance instrument has a stronger impact on oldest sister's schooling in households with uneducated mothers as compared with households with educated mothers.[44] While small sample size of households with educated mothers contributes to the lack of statistical significance, the first stage coefficient estimates for this sample are 35-60% smaller than the coefficients for households with uneducated mothers. Recall that both parents are educated when the mother is educated in this sample, and 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 plausible that households with both parents educated are more likely to be "always takers" and hence are relatively less responsive to the instrument.

Table 8 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 show that effects of oldest sister's schooling vary considerably 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 because the instrument is very weak.[45] Table 9 therefore reports OLS estimates of the effects of oldest sister's schooling separately for households with uneducated mothers and households with educated mothers. While these spillover effects are statistically significantly different for adding and counting ability only, the effects for all outcomes are considerably larger in households with uneducated mothers as compared to households

[43]Only 30 of the 1200 households in my sample have an educated mother but uneducated father. Since the number is so small, I do not consider them in the subgroup analysis.

[44]While the first stage coefficients are not statistically significantly larger for households with uneducated mothers relative to those with educated mothers, all six estimates are consistently and considerably larger.

[45]The F-statistic on distance to girls' school is about one in all specifications.

with educated mothers. The effects for reading, writing, schooling and enrollment are 75%, 18%, 45%, and 100% larger in households with uneducated mothers relative to households with educated mothers. Significant impacts for adding and counting ability only exist in households with uneducated mothers, and they are close to zero in households where the mother is educated.[46]

This heterogeneity indicates that the LATE estimated by the IV is capturing returns for complier households that are larger than those for non-complying households. That the households which comply more strongly with the instrument are households with uneducated mothers for whom the returns to oldest sister's schooling are larger illustrates why IV effects are larger than OLS effects. This pattern of results is also in line with what one would expect theoretically if oldest sister's education is a close substitute for mother's education.

6.2 How important are these spillovers?

To put these spillover effects into context, I compare the results to estimates of the effect of mother's education. While I find that an additional year of schooling for the oldest sister increases younger brother schooling by 0.4 years, Behrman's review of the literature finds the median impact of mother's schooling on children's schooling to be 0.23 years (the range is from 0.02 to 0.65 years).[47] I regress the younger brother's schooling on mother's schooling in my sample and get a coefficient of 0.097. Table 10 shows estimates of spillovers from oldest sister's schooling and mother's schooling from several specifications. While this exercise only yields ballpark estimates, it suggests that the effects of oldest sister's schooling are important even relative to the effect of mother's schooling.[48]

There are several reasons why I find such important spillover effects of oldest sister's schooling. 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 so the treatment considered - the effect of one additional year of schooling - represents a substantial increase in schooling which can be expected to generate meaningful spillovers. The frequency and type of interaction of children with siblings who are their closest peers and 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

[46]IV estimation for households with uneducated mothers in Appendix Table C.5 yields effects of oldest sister's schooling that are slightly larger but qualitatively similar to those found for the full sample. This suggests the IV strategy identifies effects for compliers households that typically have uneducated mothers.

[47]Behrman (1997)

[48]The estimates for mother's schooling are associations that allow one to roughly compare the estimate sizes and are not intended as credible impact estimates.

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, have low levels of education, and spillovers appear to be considerably 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 the family.

6.3 Testing the Model

Having identified the net effects of oldest sister's schooling on younger brother learning, I now turn to further tests of the theoretical model: 1) testing for the predicted positive quality and negative quantity effects of oldest sister's schooling, 2) mechanisms through which oldest sister's schooling raises younger brother learning, and 3) whether parents internalize the spillover from oldest sister's schooling in their investment decisions.

The predicted negative quantity effect arises from the fact that increasing oldest sister's schooling requires her to be enrolled in school longer which may compete with time spent with the younger brother at home. While a direct test of this is not possible since there is no time use data identifying who children spend their time with, I analyze whether the impact of oldest sister's schooling varies with whether it was acquired before the younger brother was enrolled in school. If the younger brother is not yet enrolled in school, the sister's time spent at school is time that could potentially have been spent with the younger brother at home. Oldest sister's time at school therefore competes with time spent with the pre-school aged younger brother. If the younger brother is enrolled in school, however, increases in oldest sister's schooling do not reduce time spent with the younger brother since he is not at home during the school day either. This yields a clear prediction that the negative quantity effect should only affect oldest sister's schooling that is 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. Based on this reasoning, one would expect the net impact of oldest sister's schooling acquired before the younger brother's enrollment (call this pre-enrollment schooling) to be smaller and less positive than the impact of schooling acquired afterwards (call this post-enrollment schooling). In line with this, Table 11 shows that the impact of pre-enrollment schooling - while still positive - is consistently and considerably smaller than the impact of post-enrollment schooling.[49]

[49]The results presented are IV estimates where the endogenous variables of pre-enrollment schooling and

These coefficients are statistically significantly smaller for four (five) of the six outcomes considered at the 5% (10%) significance level which is consistent with the presence of a statistically distinguishable negative quantity effect.[50]

Increases in oldest sister's schooling can raise the likelihood that the oldest sister helps younger siblings with their studies and improve the quality of the help given. While quality of help is unobserved, Table 12 shows that oldest sister's schooling has a significant impact on the extensive margin of the sister helping. An increase in the oldest sister's schooling of one year increases the probability that she helps her younger brother with studies by 4.8 percentage points.

Whether parents internalize the spillovers from the oldest sister's schooling in their schooling allocation decisions has important implications for whether current investments are socially optimal. I conduct a test for this based on the assumption that parents value positive spillovers on their boys' learning and have greater incentive to invest in the oldest sister's schooling when the value of the spillover from her schooling is higher. I compare the schooling of oldest sisters who have a younger brother (who could benefit from her schooling) to oldest sisters who do not have one. I also relate oldest sister's schooling to the number of younger brothers she has who can potentially benefit from her since this can be thought of as another measure of the potential value of the spillover. I analyze the relationship between oldest sister's schooling and number of younger brothers after controlling for the number of brothers, number of younger sisters and number of older sisters the oldest sister has, a quadratic term in her age, birth order fixed effects, a quadratic term in total family size, and the set of usual controls including parents' education, wealth and asset controls, and district times year fixed effects.[51] The same controls are used in the specification relating the oldest sister's schooling to an indicator for having a younger brother. It is important to control for the total number of brothers and these other household characteristics as they might be associated with differing resources and distribution of household activities within the

post-enrollment schooling are instrumented for using distance to girls' school and the interaction of distance with age gap. OLS estimates also yield a similar pattern of results.

[50]While it is possible that different treatment effects for pre-enrollment and post-enrollment schooling are related to differential impacts by age of the younger brother, the pattern of results found is likely not conflated by such heterogeneity. Cunha and Heckman (2007) report that earlier, pre-school investments in the sensitive periods of the development life cycle of the child are more effective than later investments. The pattern of results in Table 11, however, demonstrates *smaller* effects for the earlier, pre-school years, and therefore exists despite any such heterogeneity. 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 quantity-quality tradeoff instead of heterogeneity of effects by age.

[51]The oldest sister is the oldest among the sisters living in the household at the time of data collection but she might have sisters older than her who do not live in the same household.

household. Table 13 finds no evidence for a meaningful relationship between oldest sister's years of schooling and these two measures of the potential spillover value. While this is not conclusive evidence, it is consistent with parents appearing not to internalize the spillovers from oldest sister's schooling. The failure of parents to internalize these positive spillovers would lead to inefficiently low levels of girls' education from a societal standpoint.

7 Robustness Checks

Table 5 presented results using binary formulations of oldest sister's schooling: an indicator for oldest sister having any schooling, and an indicator for the oldest sister having 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 are close to the original IV estimates. 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 having completed primary schooling 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 that 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, β_{IV}, 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 14 shows the results from this procedure including estimates of α_0 and α_1, and the implied adjustment factors which need to be multiplied to the IV estimates to get

the lower bounds of the true treatment impacts. For the indicator of oldest sister having any schooling, the upper bounds of α_0 and α_1 from their 95% confidence intervals are 11.6 percent and 3.1 percent, respectively.[52] This shows that the prevalence of measurement error is quite low. The relative magnitudes of these bounds are intuitively plausible too as it seems less likely that parents would forget or neglect to report their oldest daughter acquiring any schooling than for parents to incorrectly report their daughter did receive an education when she did not. The adjustment factors using these upper bound estimates 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 estimates.

8 Conclusion

This is the first study to conceptualize oldest sister's schooling as an input into younger sibling human capital and empirically estimate the spillover effects of oldest sister's schooling on younger brother learning. I find evidence for significant positive effects on younger brothers' schooling, enrollment, literacy and numeracy in rural Pakistan. Future research should consider an expanded role of family members other than parents in affecting a child's development. In particular, studies can explore the potential role of older brothers in influencing younger sibling learning.[53]

The finding of significant spillovers has important implications for the evaluation of policies targeting girls' education including gender-targeted conditional cash transfer programs such as the Female Secondary School Stipend Program in Pakistan. Evaluations and cost-benefit analyses of such programs that consider only effects on the girls and their children but ignore potential effects 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.

[52]For the indicator of whether the oldest sister has primary schooling, the upper bounds of α_0 and α_1 from their 95% confidence intervals are 8.2 percent and 1.6 percent, respectively.

[53]While the gender segregation of schools in Pakistan also allows for an identification strategy linking oldest brother's schooling to younger sisters' human capital, distance to boys' school is not an effective instrument because it does not significantly affect boys' schooling conditional on the controls included.

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Table 1: Summary Statistics of Households in Analysis Sample, 2003-2006

	Mean	**Std Dev**	**N**
Household size	7.85	2.63	1,211
Number of children (0 to 18 years old)	5.09	1.92	1,211
Number of boys (0 to 18 years old)	2.39	1.36	1,211
Number of girls (0 to 18 years old)	2.62	1.42	1,211
Mother has any schooling	0.24	0.43	1,202
Father has any schooling	0.62	0.49	1,087
Mother's years of schooling	1.46	2.77	1,202
Father's years of schooling	4.40	4.17	1,087
Own any land	0.48	0.46	1,210
Own house living in	0.94	0.21	1,210
Reside in brick house	0.51	0.37	1,210
Reside in mud brick house	0.11	0.24	1,210
Reside in semi-permanent house	0.38	0.34	1,210
Water source is a hand pump	0.24	0.27	1,211
Water source is tap water	0.14	0.21	1,211
Water source is a motor pump	0.19	0.27	1,211
Water source is external like pond, stream etc.	0.10	0.22	1,211
Expenditure per capita (Rs./month)	1,852.46	3,852.01	1,210
District: Attock	0.34	0.47	1,211
District: Faisalabad	0.39	0.49	1,211
District: Rahim Yar Khan	0.28	0.45	1,211

Note: The universe is households with an oldest sister aged $8-30$ in round 1 with non-missing education, and 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 2: Distance Penalty on Schooling and Enrollment for Boys and Girls

	Boys				Girls			
	Years of Schooling		Enrollment		Years of Schooling		Enrollment	
Panel A: Results for all children								
Distance to closest boys/girls school (km)	-0.164*	-0.074	-0.019	-0.008	-0.187***	-0.115**	-0.057***	-0.038***
	(0.091)	(0.098)	(0.012)	(0.012)	(0.050)	(0.054)	(0.012)	(0.014)
Distance to center		-0.188***		-0.021**		-0.256***		-0.038***
		(0.057)		(0.010)		(0.063)		(0.013)
Number of observations	7,292	7,292	7,287	7,287	7,869	7,869	7,806	7,806
R^2	0.545	0.547	0.234	0.235	0.431	0.433	0.309	0.311
Panel B: Results separately by age								
	Age < 13	Age ≥ 13	Age < 13	Age ≥ 13	Age < 13	Age ≥ 13	Age < 13	Age ≥ 13
Distance to closest boys/girls school (km)	-0.079	-0.136	-0.015	-0.002	-0.058	-0.239***	-0.036**	-0.045***
	(0.051)	(0.161)	(0.013)	(0.020)	(0.045)	(0.078)	(0.018)	(0.017)
Distance to center	-0.114**	-0.263**	-0.027**	-0.003	-0.131***	-0.420***	-0.031*	-0.046***
	(0.045)	(0.102)	(0.012)	(0.016)	(0.042)	(0.104)	(0.017)	(0.016)
Number of observations	4,299	2,993	4,329	2,958	4,329	3,540	4,370	3,436
R^2	0.543	0.218	0.128	0.235	0.513	0.303	0.202	0.290

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses are clustered at household level.
This table shows how distance to school affects years of schooling and enrollment of girls and boys aged 5-18 years old. The top panel shows how an increase in distance to the closest girls/boys school by an additional kilometer affects the years of schooling and probability of enrollment of girls/boys, with and without controlling for the distance from the household to the village center. The bottom panel shows the distance penalty from increasing distance to the closest girls/boys school separately for girls and boys aged younger than 13, and aged 13 years and older. The regressions in panel B all control for distance to the village center as well as household characteristics, parents' education, wealth controls and district times year fixed effects.

Table 3: OLS Estimates of the Effects of Oldest Sister's Schooling on Younger Brother Human Capital

	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)
Mean of outcome	0.410	0.325	0.642	0.780	2.942	0.781
Observations	3,553	3,542	3,523	3,561	5,333	5,349
R^2	0.387	0.364	0.395	0.313	0.607	0.224

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses.
The dependent variables read, write, add, and count are indicator variables for whether the younger brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the child is currently enrolled. All regressions control for household characteristics, parents' education, wealth and asset controls, and district times year fixed effects.

Table 4: IV Estimates of the Effects of Oldest Sister's Years of Schooling on Younger Brother Human Capital

	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
IV Result						
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)
Mean of outcome	0.408	0.323	0.642	0.779	2.935	0.780
First Stage						
Distance to 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)
Distance to 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)
F-statistic on distance to girls' school	22.373	23.912	23.136	21.902	29.052	30.030
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.
The dependent variables read, write, add, and count are indicator variables for whether the younger brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the child is currently enrolled. The instrument is distance to the closest government girls' school. All IV regressions control for distance to the closest government boys' school, distance to the closest private school, distance to the village center, household characteristics, parents' education, wealth and asset controls, and district times year fixed effects.

Table 5: IV Estimates of the Effects of Oldest Sister Having Any Schooling and Oldest Sister Having Primary Schooling on Younger Brother Human Capital

	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Panel A: Effect of oldest sister having any schooling						
IV Result						
Oldest sister has any schooling	0.463*	0.282	0.434**	0.326*	3.125***	0.465**
	(0.238)	(0.203)	(0.203)	(0.193)	(0.899)	(0.182)
Mean of outcome	0.408	0.323	0.642	0.779	2.935	0.780
First Stage						
Distance to 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)
Distance to 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)
F-statistic on distance to girls' school	28.837	32.036	32.376	30.803	38.069	42.120
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
Panel B: Effect of oldest sister having primary schooling						
IV Result						
Oldest sister has primary schooling	0.508**	0.250	0.500**	0.384**	2.799***	0.563***
	(0.220)	(0.196)	(0.213)	(0.195)	(0.920)	(0.200)
Mean of outcome	0.408	0.323	0.642	0.779	2.935	0.78
First Stage						
Distance to 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)
Distance to 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)
F-statistic on distance to girls' school	20.160	21.344	20.612	19.714	23.814	24.305
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.
The dependent variables read, write, add, and count are indicator variables for whether the younger brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the child is currently enrolled. The instrument is distance to the closest government girls' school. All IV regressions control for distance to the closest government boys' school, distance to the closest private school, distance to the village center, household characteristics, parents' education, wealth and asset controls, and district times year fixed effects.

Table 6: OLS Estimates of the Effects of Oldest Sister's Schooling on Older Brother Human Capital: Falsification Test

	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Oldest sister's years of schooling	0.028***	0.026***	0.012***	0.009***	0.168***	0.021***
	(0.006)	(0.007)	(0.003)	(0.003)	(0.039)	(0.008)
Mean of outcome	0.789	0.751	0.949	0.965	5.786	0.633
Number of observations	1,565	1,562	1,566	1,566	1,907	988
R^2	0.181	0.195	0.080	0.063	0.348	0.350

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses.
The dependent variables read, write, add, and count are indicator variables for whether the older brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the child is currently enrolled. All regressions control for household characteristics, parents' education, wealth/asset controls, and district times year fixed effects.

Table 7: IV Estimates of the Effects of Oldest Sister's Schooling on Older Brother Human Capital: Falsification Test

	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
IV Result						
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)
Mean of outcome	0.787	0.748	0.947	0.965	5.745	0.624
First Stage						
Distance to 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 on distance to girls' school	8.123	8.066	8.821	8.821	9.734	12.110
Observations	1,501	1,498	1,502	1,502	1,819	945
R^2	0.141	0.123	0.002	0.004	0.365	0.252

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses.
The dependent variables read, write, add, and count are indicator variables for whether the older brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the older brother is currently enrolled. The instrument is distance to the closest government girls' school. All IV regressions control for distance to the closest government boys' school, distance to the closest private school, distance to the village center, household characteristics, parents' education, wealth/asset controls, and district times year fixed effects.

Table 8: Heterogeneity in First Stage Impact of Distance on Oldest Sister's Schooling by Maternal Education

	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Panel A: Households with uneducated mothers						
First Stage						
Distance to girls' school	-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 on distance to girls' school	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
Panel B: Households with educated mothers						
First Stage						
Distance to girls' school	-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 on distance to girls' school	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.
Panel A shows the first stage IV results for the sample of households with uneducated mothers or mothers with no schooling, while panel B shows the first stage IV results for the sample of households with educated mothers, i.e. mothers who have any schooling. The dependent variables read, write, add, and count are indicator variables for whether the younger brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the child is currently enrolled. The instrument used is distance to the closest government girls' school measured in kilometers. All IV regressions control for distance to the closest government boys' school, distance to the closest private school, distance to the village center, household characteristics, parents' education, wealth and asset controls, and district times year fixed effects.

Table 9: OLS Estimates Showing the Heterogeneity in Spillovers from Oldest Sister's Schooling by Maternal Education

	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Panel A: Households with uneducated mothers						
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 outcome	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
R^2	0.357	0.339	0.392	0.314	0.566	0.211
Panel B: Households with educated mothers						
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 outcome	0.478	0.391	0.708	0.835	3.324	0.894
Observations	630	629	627	630	888	890
R^2	0.505	0.479	0.480	0.352	0.766	0.202

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses.
Panel A shows the OLS estimates for the effects of oldest sister's years of schooling on younger brother human capital for the sample of households with uneducated mothers or mothers with no schooling. Panel B shows the OLS estimates for the effects of oldest sister's schooling on younger brother human capital for the sample of households with educated mothers, i.e. mothers who have any schooling. The dependent variables read, write, add, and count are indicator variables for whether the younger brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the child is currently enrolled. All regressions control for household characteristics, parents' education, wealth and asset controls, and district times year fixed effects.

Table 10: Spillover Effects from Mother's Schooling and Oldest Sister's Schooling on Younger Brothers

	Younger brother's years of schooling			
	OLS regression coefficients		**IV regression coefficients**	
	(1)	**(2)**	**(3)**	**(4)**
Panel A				
Mother's years of schooling	0.053***	0.097***		
	(0.015)	(0.015)		
Observations	5,100	5,100		
R^2	0.582	0.565		
Panel B				
Oldest Sister's years of schooling	0.147***	0.162***	0.420***	0.398***
	(0.014)	(0.013)	(0.125)	(0.089)
Observations	5100	5100	5100	5100
R^2	0.609	0.602	0.547	0.548

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses.
Panel A contains results from regressions that relate mother's years of schooling and younger brother's years of schooling while Panel B contains results from regressions that relate oldest sister's years of schooling to younger brother's years of schooling. Specification 1 controls for household characteristics, parents' education, wealth and asset controls, and district times year fixed effects. Since this set of controls contains variables like father's schooling, and wealth and asset variables that are potential channels through which mother's schooling might impact the outcome, specification 2 uses a narrower set of controls by dropping the variables of father's schooling, and the set of wealth and asset controls. The IV regression in specification 3 uses distance to the closest government girls' school as the instrument for oldest sister's schooling, and controls for distance to the closest government boys' school, distance to the closest private school, distance to the village center, household characteristics, parents' education, wealth and asset controls, and district times year fixed effects. Specification 4 has the controls in specification 3 excluding father's schooling, and the set of wealth and asset controls.

Table 11: IV Estimates of the Positive Quality and Negative Quantity Effects of Oldest Sister's Schooling

	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Pre-enrollment years of schooling	0.035**	0.010	0.028*	0.008	0.194***	0.038***
	(0.017)	(0.016)	(0.015)	(0.017)	(0.060)	(0.014)
Post-enrollment years of schooling	0.123**	0.107**	0.087*	0.128***	0.670***	0.096***
	(0.050)	(0.048)	(0.045)	(0.049)	(0.097)	(0.022)
Distance to closest boys school	0.002				0.003	0.003
	(0.006)				(0.006)	(0.006)
Mean of outcome	0.410	0.325	0.645	0.781	2.937	0.780
P-value for one-sided inequality test	0.054	0.034	0.113	0.013	0.000	0.008
Observations	3,427	3,419	3,402	3,437	5,136	5,148
R^2	0.376	0.353	0.385	0.254	0.591	0.181

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses.
This table separates the effects of oldest sister's schooling into the effects of pre-enrollment years of schooling, i.e. oldest sister's schooling that was acquired before the younger brother enrolled in school, and the effects of post-enrollment years of schooling that is schooling acquired after the younger brother was enrolled. The instruments used for pre-enrollment and post-enrollment schooling are distance to the closest government girls' school, and distance interacted with age gap between the oldest sister and the younger brother. The dependent variables read, write, add, and count are indicator variables for whether the younger brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the child is currently enrolled. All IV regressions control for a quadratic in the oldest sister's age, a quadratic in the younger brother's age, distance to the closest government boys' school, distance to the closest private school, distance to the village center, household characteristics, parents' education, wealth and asset controls, and district times year fixed effects. P-values shown are for one-sided tests of the null hypothesis that the coefficient estimates of the effects of pre-enrollment schooling are greater than or equal to the coefficient estimates of the effects of post-enrollment schooling.

Table 12: IV Effects of the Oldest Sister's Schooling on the Extensive Margin of Helping a Younger Brother with Studies

	Oldest sister helps		
Oldest sister's years of schooling	0.048**		
	(0.020)		
Oldest sister has any schooling		0.301**	
		(0.135)	
Oldest sister has primary schooling			0.361**
			(0.148)
Mean of outcome	0.113	0.113	0.113
Observations	5,100	5,100	5,100
R^2	0.173	0.089	0.117

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses.
The dependent variable is an indicator variable for whether the oldest sister helps the younger brother with his studies. The instrument is distance to the closest government girls' school. All IV regressions control for distance to the closest government boys' school, distance to the closest private school, distance to the village center, household characteristics, parents' education, wealth and asset controls, and district times year fixed effects.

Table 13: Do Parents Internalize Spillovers? OLS Estimates Relating Oldest Sister's Schooling and Potential Spillover Value

	Oldest sister's years of schooling	**Oldest sister's years of schooling**
	(1)	**(2)**
Has a younger brother	0.065	
	(0.308)	
Number of younger brothers		0.031
		(0.169)
Mean of outcome	4.101	4.101
Observations	3,206	3,206
R^2	0.331	0.331

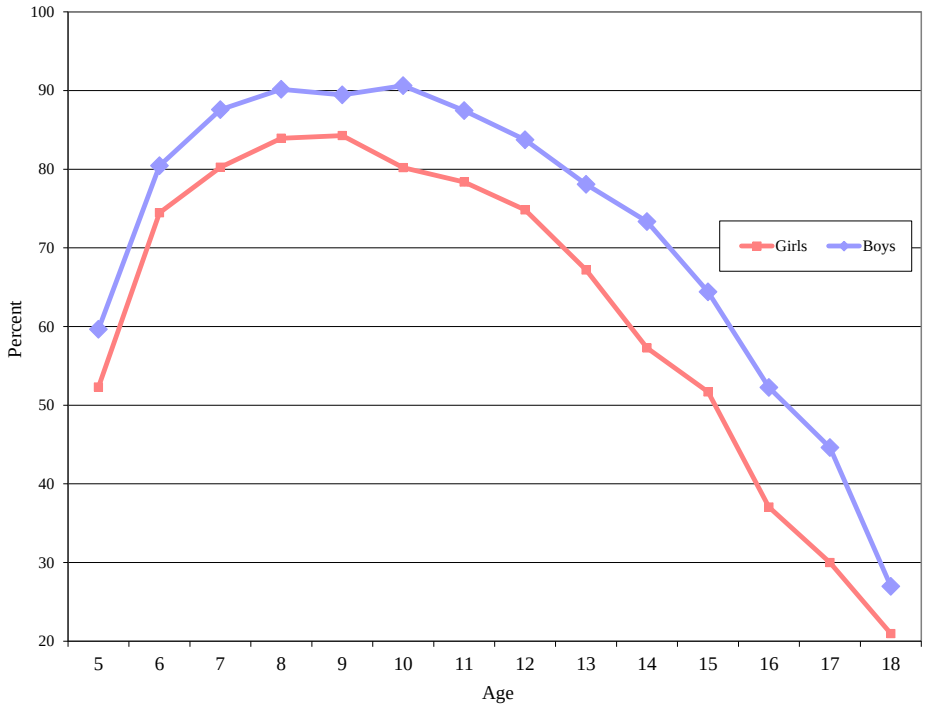
Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses.
The OLS regression in specification 1 relates oldest sister's years of schooling to whether she has a younger brother, and the OLS regression in specification 2 relates oldest sister's years of schooling to the number of her younger brothers. Both regressions control for total number of brothers, number of younger sisters, number of older sisters, a quadratic in the age of the oldest sister, a quadratic in total family size, dummies for the birth order of the oldest sister as well as the household characteristics, parents' education, wealth and asset controls and district times year fixed effects.

Table 14: Estimates of Measurement Error and Bounds for the Spillover Effects of Oldest Sister's Schooling

Panel A: Bounding the effects of oldest sister having any schooling						
Measurement error parameters		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-a_0-a_1)		0.902			0.853[a]	
	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Effects of oldest sister having any schooling						
IV estimate, b	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, b*(1-α_0-α_1)	0.418	0.254	0.391	0.294	2.819	0.419
Adjusted IV estimate, b*(1-α_0-α_1)[a]	0.395	0.241	0.370	0.278	2.666	0.397
Panel B: Bounding the effects of oldest sister having primary schooling						
Measurement error parameters		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-α_0-α_1)		0.933			0.894[a]	
	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
Effects of oldest sister having primary schooling						
IV estimate, b	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, b*(1-α_0-α_1)	0.474	0.233	0.467	0.358	2.612	0.525
Adjusted IV estimate, b*(1-α_0-α_1)[a]	0.454	0.223	0.447	0.343	2.501	0.503

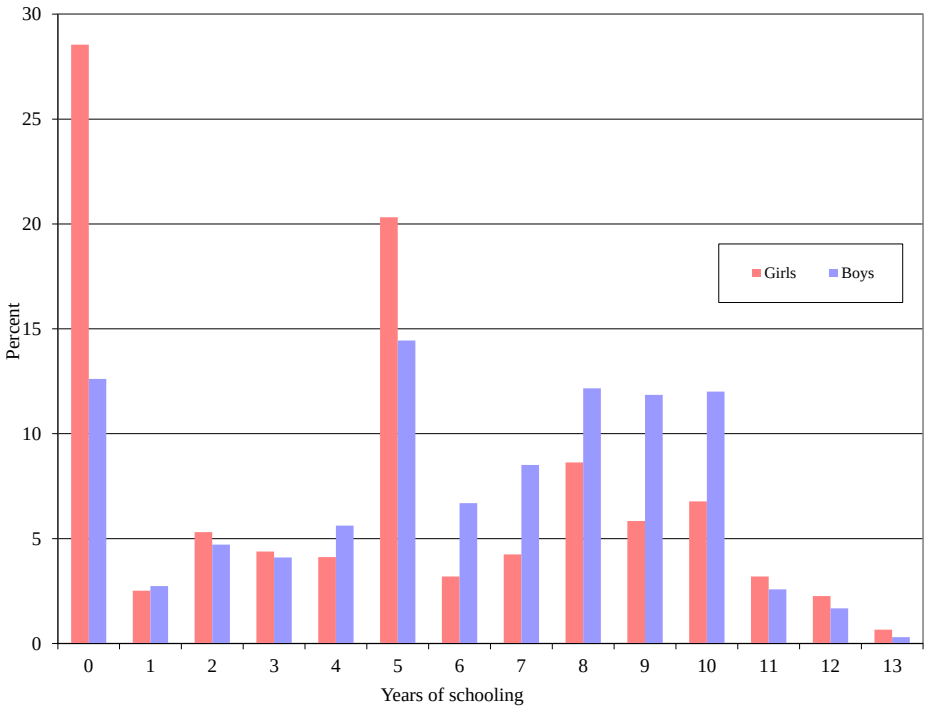
Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses.
[a] Lower bound for adjustment factor using the upper bounds of α_0 and α_1 estimates from the 95% confidence intervals. α_0 is the probability that the indicator for treatment status equals zero but the reported treatment 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 estimates for the effects of oldest sister having any schooling and oldest sister having primary schooling on younger brother human capital. Ninety-five percent confidence intervals on measurement error prevalence in these two measures of treatment are shown. The lower bounds on IV estimates that incorporate upper bounds of measurement error prevalence from these 95% confidence intervals are also shown.

Figure 1: Enrollment-age profiles for Boys and Girls in rural Punjab



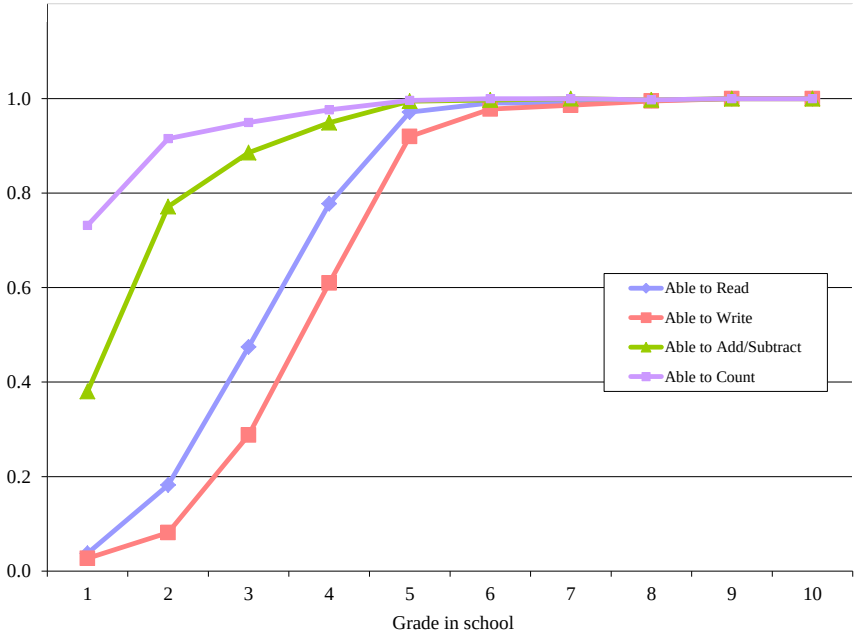
Note: The figure shows the percent of boys and girls in the LEAPS sample that are currently enrolled in school by age.

Figure 2: Distribution of Years of Schooling completed by Boys and Girls aged 16-20 years old



Note: Bar graph shows the percent of boys and girls aged 16-20 years old in the LEAPS sample reporting having completed different years of schooling. Completing five years of schooling corresponds with the completion of primary school, eight years with completion of middle school, and ten years with completion of high school in Pakistan.

Figure 3: Distribution of Literacy and Numeracy Capabilities by Grade



Note: The figure shows the fraction of children that are reported as capable of reading, writing, adding, and counting by grade that the child is currently enrolled in. The sample includes children who are currently enrolled in grades 1-10 in school.

A Model Appendix

A.1 Spillover and Investment in Oldest Sister's Schooling

Proposition. *Let parents' investment in oldest sister's schooling be y_s^{**} when net externality of the oldest sister's 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 oldest sister's schooling if they fail to internalize the spillover effect on younger brother. It can be shown that parents will under-invest in the oldest sister's 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 oldest sister's 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 oldest sister's schooling outweighs the associated negative quantity effect. Suppose parents are unaware of the spillover effects of oldest sister's schooling on younger brother, and do not internalize the spillover associated with sister's schooling in deciding about schooling investments. Such parents would choose y_s^{***} to satisfy the following first-order condition where they only consider the private benefits and costs of the oldest sister's schooling:

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

When parents internalize the spillover of the oldest sister's schooling on younger brother human capital, they will choose y_s^{**} 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 spillover from oldest sister's schooling increases their utility by increasing the younger brother's human capital and wealth. In order to equalize the marginal utility from investment in sister's schooling with its marginal cost, parents will increase the investment in oldest sister's 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 oldest sister's schooling in this case, y_s^{**}, is therefore higher than y_s^{***}.

A.2 Comparative static predictions

Comparative static with respect to distance to girl's school

Comparative statics of schooling with respect to distance cost of girl's schooling are derived with and without spillovers. 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. An increase in the distance cost of girl's school decreases sister's schooling and for the non-corner solution for y_s, there is also a negative income effect. $\frac{\partial y_b}{\partial d_s} = -(p_b + d_b)(p_s + d_s)U'U'' - y_s(p_b + d_b)ZU''$, 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.

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 $y_s = a_s V''(W_s) r_s^2 f_{y_s}^2 + a_s V'(W_s) r_s f_{y_s y_s} + a_b V''(W_b) r_b g_{y_s}^2 + a_b V'(W_b) r_b g_{y_s y_s}$.
Let this equal C. Notice that C = Z + K where K $= a_b V''(W_b) r_b g_{y_s}^2 + a_b V'(W_b) r_b g_{y_s y_s}$.

Assuming that the net spillover of oldest sister's schooling is positive, $g_{y_s y_s} = g_{H_s} f_{y_s y_s} + g_{H_s H_s} f_{y_s} - g_{H_s x_s} f_{y_s} + g_{x_s x_s} - g_{x_s H_s} f_{y_s}$ which is negative because $g_{H_s} > 0, f_{y_s} > 0, f_{y_s y_s} < 0, g_{H_s H_s} < 0, g_{x_s x_s} < 0$ due to the assumption of positive and diminishing marginal returns of the inputs, and $g_{H_s x_s} > 0$ due to the assumed complementarity 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.

$\frac{\partial y_s}{\partial d_s} = AU' + y_s(p_b + d_b)BU'' - y_s(p_s + d_s)AU' + (p_b + d_b)^2 U'U$" which is negative as in the model without spillovers.[A.1] $\frac{\partial y_b}{\partial d_s} = -(p_b + d_b)(p_s + d_s)U'U'' - y_s(p_b + d_b)ZU'' - y_s(p_b + d_b)KU'' + [y_s(p_s + d_s)U'' - U']B$ which is ambiguous as in the model without spillovers. While the positive substitution effect exists in both models, even if we assume B=0, the model with spillovers picks up an additional negative term due to the spillover.[A.2]

In a model without any spillovers, an increase in the distance cost of girl's schooling has an ambiguous effect on brother's schooling. There is a positive substitution effect (brothers' schooling is now relatively cheaper), and a negative income effect (if parents still invest in girls' schooling and incur the higher cost, this cost squeezes household resources). Since schools only charge nominal fees, the income effect of this cost which is a time cost is likely small. The substitution effect is expected to dominate the income effect so that increases in the distance cost of girls' schooling should increase brother's schooling.

In a model with spillovers, 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 (assuming the net externality of sister schooling is positive). This last new term captures the fact that distance-induced reductions in oldest sister's 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 distance cost of girl's schooling in a world with positive spillovers is associated with a more negative impact on brother's schooling.

[A.1] This expression is negative if B is negligible or if $B > 0$.

[A.2] If $B > 0$, then the expression is even more negative because there is a strong complementarity 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.

Comparative statics with respect to $W_p, a_b, a_s, r_s, r_b, p_s,$ and p_b

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. $\frac{\partial y_b}{\partial r_b} \lesseqgtr 0$ and $\frac{\partial y_s}{\partial r_b} \lesseqgtr 0$: 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. $\frac{\partial y_b}{\partial a_b} \lesseqgtr 0$ and $\frac{\partial y_s}{\partial a_b} \lesseqgtr 0$: The impact on parents' investment in brother and sister schooling is ambiguous when parents' altruism toward brother increases.
6. $\frac{\partial y_b}{\partial p_b} \lesseqgtr 0$ and $\frac{\partial y_s}{\partial p_b} \lesseqgtr 0$: 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.

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. $\frac{\partial y_s}{\partial r_s} = -Aa_sV'(W_s)f_{y_s} - (p_b + d_b)^2a_sV'(W_s)f_{y_s}U''$ which is positive. Since parents invest more in the sister's human capital, this leaves less resources for the 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 competition between sister's and brother's schooling since they both draw from the same pool of resources. 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 competition effect, parents might increase y_b since the investment of each unit y_b is 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 $\frac{\partial y_b}{\partial r_b} = CF + (p_s + d_s)^2FU'' - (p_s + d_s)(p_b + d_b)GU'' - BG$. The impact of an increase in return to younger brother's human capital is ambiguous because y_b and y_s increase younger brother human capital. Imposing that y_b is more effective at creating younger brother human capital than y_s, $g_{y_b} > g_{y_s}$, brother's schooling rises. $\frac{\partial y_s}{\partial r_b} = -BF + AG - p_b(1 + d_b)p_s(1 + d_s)FU'' + p_b(1 + d_b)^2GU''$ remains ambiguous because the increase in brother's schooling crowds out sister's schooling but the latter is also productive in increasing brother's human capital.

4. Let O=$-V'(W_s)r_sf_{y_s}$, then $\frac{\partial y_s}{\partial a_s} = (p_b + d_b)^2OU'' + AO$ 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 her is higher. This crowds out brother's schooling. If $B > 0$, the strong complementarity between y_b and y_s means there is a positive pressure on y_b since increased y_s means y_b is more productive.

5. Let M=$-V'(W_b)r_b g_{y_b}$ and N=$-V'(W_b)r_b g_{y_b}$, 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 brother is ambiguous because y_b and y_s can both increase brother's human capital. Imposing $g_{y_b} > g_{y_s}$, brother's schooling increases. The impact on sister schooling remains ambiguous because increased brother's schooling crowds out her schooling but her schooling is productive in creating brother human capital.

6: $\frac{\partial y_s}{\partial p_s} = AU' - (1 - y_s)(p_b + d_b)BU'' + (1 - y_s)(p_s + d_s)AU'' + (p_b + d_b)^2 U'U''$ 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 schooling because there is a a negative substitution effect and a positive income effect. It increases brother's schooling because the substitution and income effects are both positive. The relationship is analogous for an increase in brother's household productivity with $\frac{\partial y_b}{\partial p_b} \lesseqgtr 0$ 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. Since age reports contain significant measurement error, I identify older and younger siblings based on complete fertility histories in which mothers ranked the birth order of all their children ever born. 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 used in my analyses, the oldest sister in the household is the oldest daughter that was ever born to that household. 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 don't observe her schooling. [B.1]

Age of oldest sister

The sample of interest includes 1160 households in which I have identified the oldest sister and at least one sibling younger aged 5-18 years old. 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 1while the lower bound of age drops 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 appears in the data. Although the substitution with oldest of the sisters living in the household makes the sample

[B.1] It is also not as interesting to explore the impact of an oldest sister with whom the younger sibling spent few years interacting since she moved out of the household a long time ago.

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 husband's 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 girl's stay in her household is dictated by her marital status, my sample based on oldest 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.[B.2] 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 matched these names manually on the basis of the phonetics. Using this procedure, I was able 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

[B.2] 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.

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 oldest 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 C.3 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 4. The coefficients for read, add, count, schooling and enrollment are statistically significant 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 C.4 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.

Table C.1: Mother's years of schooling and reported child literacy and numeracy

	Read	**Read**	**Read**	**Read**	**Write**	**Write**	**Write**	**Write**
Panel A: Mother's report for reading and writing								
Mother's years of schooling	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)
Mother's years of schooling X English test score		-0.003				0.001		
		(0.003)				(0.003)		
Mother's years of schooling X Urdu test score				-0.003				0.001
				(0.003)				(0.003)
Observations	2,360	2,360	2,360	2,360	2,341	2,341	2,341	2,341

	Count	**Count**	**Add**	**Add**
Panel B: Mother's report for adding and counting				
Mother's years of schooling	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)
Mother's years of schooling X Math test score		-0.001		-0.001
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 relates the reading/writing/adding and counting capability reports provided for each child by their mother with the mother's years of schooling and child test score in English/Urdu/Math. Some regression specifications additionally control for an interaction term between the mother's years of schooling and child's test score.

Table C.2: Robustness of IV Estimates of the Effects of Oldest Sister's Years of Schooling to Controlling for Village Size

	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
IV Result						
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						
Distance to 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 on distance to girls' school	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
R^2	0.336	0.354	0.328	0.271	0.560	0.162

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses.
The dependent variables read, write, add, and count are indicator variables for whether the younger brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the child is currently enrolled. The instrument is distance to the closest government girls' school. All IV regressions control for population of the village, distance to the closest government boys' school, distance to the closest private school, distance to the village center, household characteristics, parents' education, wealth and asset controls, and district times year fixed effects.

Table C.3: IV Estimates of the Effects of Absolute Oldest Sister's Schooling on Younger Brother Human Capital

	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
IV Result						
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						
Distance to 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 on distance to girls' school	27.563	24.602	27.040	25.705	23.523	24.305
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 only the absolute oldest sisters i.e. the first-born daughters. The rest of the analyses defined oldest sister as the oldest out of the girls still living in the household during the panel data collection. The dependent variables read, write, add, and count are indicator variables for whether the younger brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the child is currently enrolled. The instrument is distance to the closest government girls' school. All IV regressions control for distance to the closest government boys' school, distance to the closest private school, distance to the village center, household characteristics, parents' education, wealth and asset controls, and district times year fixed effects.

Table C.4: IV Estimates of the Effects of Oldest Sister's Schooling for Oldest Sisters aged less than 20 years old

	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
IV Result						
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						
Distance to 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 on distance to girls' school	22.658	24.305	23.040	22.563	24.503	24.404
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 analysis limits the sample of oldest sisters to those under the age of 20 years old. The dependent variables read, write, add, and count are indicator variables for whether the younger brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the child is currently enrolled. The instrument is distance to the closest government girls' school. All IV regressions control for distance to the closest government boys' school, distance to the closest private school, distance to the village center, household characteristics, parents' education, wealth and asset controls, and district times year fixed effects.

Table C.5: IV Estimates of the Effects Of Oldest Sister's Schooling in Households with Uneducated Mothers

	Read	**Write**	**Add**	**Count**	**Schooling**	**Enrollment**
IV Result						
Oldest sister's years of schooling	0.077**	0.015	0.084**	0.064**	0.417***	0.088***
	(0.035)	(0.030)	(0.034)	(0.031)	(0.141)	(0.028)
Mean of outcome	0.385	0.303	0.621	0.763	2.836	0.752
First Stage						
Distance to girls' school	-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 on distance to girls' school	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

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
This table shows the IV estimates of the effects of oldest sister's years of schooling on younger brother human capital for the sample of households with uneducated mothers only. The dependent variables read, write, add, and count are indicator variables for whether the younger brother is reported as being capable of reading, writing, adding/subtracting, and counting, respectively. The dependent variable schooling is years of schooling completed and enrollment is an indicator for whether the child is currently enrolled. The instrument is distance to the closest government girls' school. All IV regressions control for distance to the closest government boys' school, distance to the closest private school, distance to the village center, household characteristics, parents' education, wealth and asset controls, and district times year fixed effects.