Sibling Spillovers in Rural China: A Story of Sisters *

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September 8, 2022

Abstract

We study sibling spillover effects on the school performance of the elder sibling from the younger sibling using data on multi-children households in rural China. Using a cumulative measure of expected lawful years in school as an instrumental variable, we find a significant increase in school test scores for Chinese language of elder siblings for every year of schooling of the younger sibling. The strongest spillover effects occur when the younger sibling is a girl. Such increases in test scores come from a more intense academic atmosphere within a household when both children enroll in school and are not attributed to differential parental education investments or time inputs. Our findings suggest that policies promoting girls' education, pre-elementary school age education programs, and after school public resources can have multiplier effects through sibling spillovers.

JEL classification: E24, C68, J30.

Keywords: Human capital, peer effect, sibling spillover, rural China, sisters, girls, school enrollment, intra-household allocation, intra-household externality.

*We thank Shan Li, Zhiqiang Liu, Daniel Millimet, Juan Pedroza, Yang Song, and Xianfang Xiong for helpful comments on earlier drafts of this paper as well as participants at the 2020 CHLR International Symposium on Human Capital and Labor Markets, the 2020 SEA conference, and the 2019 APPAM meeting.

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1 Introduction

Investment in children's human capital has lifetime impacts. Childhood interventions can reduce inequalities and promote intergenerational mobility (e.g. Keane and Wolpin, 1997; Heckman, 2008; Black, Devereux, et al., 2011; Huggett, Ventura, and Yaron, 2011; Yang, 2021). Despite the importance of investing in children, most of our understanding of children's human capital production is limited to observations at the household level and from parental resource allocations to their children (e.g. Yang and Bansak, 2020; Del Boca, Flinn, and Wiswall, 2013; Ramey and Ramey, 2010; Guryan, Hurst, and Kearney, 2008; Blau and Currie, 2006; Blau, 1999). This paper extends the analysis to *within household* dynamics and investigates an externality between siblings on school performance in multi-children households in rural China.

We find that an elder child's school performance improves significantly when their younger sibling is in school. The increase in school performance does not rely on changes of family resources allocated to the elder sibling, but results from a positive externality from the younger sibling's studying to the elder sibling's academic achievements. We refer to this externality as a sibling spillover effect. This positive spillover effect differs across sibling gender-pairs, and is the strongest among children with a younger sister. To the best of our knowledge, we are the first to examine a spillover effect in school performance from the younger sibling to an elder sibling.

The biggest challenge in identifying the sibling spillover is to disentangle it from factors outside of the sibship (or common family factors) and to identify the direction of impact between siblings.[1] We use the variation in the younger sibling's schooling status (started school or not) and years of schooling to parse out the impact of spillover effects *from the younger sibling to the elder one.*[2] We exploit the arbitrary birth date cutoff imposed by

[1]As Black, Breining, Figlio, Guryan, Karbownik, Nielsen, Roth, and Simonsen (2017) review, siblings growing up in the same household are the ultimate peers, sharing the same parents, similar genetics and experiences.

[2]We use "years of schooling" and "years in school" interchangeably in this paper to mean the schooling progress of the younger siblings, who are all still in school during the survey time.

the Chinese Law of Compulsory Education as an exogenous variation in schooling status. The law stipulates that children must be at least 6 years old or above on August 31st to be admitted into elementary school in the new school year. This arbitrary day of birth cutoff generates exogenous variations in the younger sibling's eligibility of school enrollment, allowing us to attribute changes in the elder sibling's school performance to that of the enrollment of younger sibling.

We use data from the Rural Household Survey (RHS) of the Longitudinal Survey on Rural Urban Migration in China (RUMiC) to conduct our analysis. Having an in-school younger sibling leads to a 1.42 percentage point increase in Chinese scores for an elder sibling for each year the younger sibling is in school holding constant the grade of the elder sibling. Such an effect appears after controlling for differing gender ratios at the county-level, an approximation of the local son-preference culture[3], and for the annual education expenditures on the student. It is also robust to changes in the younger sibling's age range.

When further exploring the gender heterogeneity in sibling spillovers, we find that the second child being a girl creates a stronger effect on the spillover to the elder child's test scores. Having a younger sister in school leads to a 2.26 percentage point increase on the elder sibling's Chinese score for every year the younger sibling is in school. Meanwhile, when the younger child is a boy, the spillover effect is not statistically significant.

We conjecture that the positive spillover is a result of a positive at-home externality that occurs when both siblings are studying under the same roof. When the younger child begins school, the elder child may experience an increase in sibling studying time relative to sibling play time, a heightened household attention to school performance, or more frequent household discussions on school matters. Elder siblings more exposed to this heightened academic environment at home may see this emphasis on schoolwork translate to a better performance in school. Though difficult to directly measure, we consider siblings with more

[3]Male to female ratio at birth in China reaches the highest point in the first decade of 2000, and it remains high for many years. A major contribution to the imbalanced sex ratio is the son-preference culture (e.g. Jiang and Zhang, 2021; Chen and Zhang, 2019). The survey data we use were conducted in year 2008 and 2009 and cover younger siblings who were born around the peak of the imbalanced sex ratio.

time at home and a stronger home connection to experience a stronger spillover externality. We approximate the at-home time by investigating the different spillover effects among the elder children's home-school distance. The positive spillover effect diminishes for elder siblings attending a school that is further away from home compared to those who live closer. To further justify this potential mechanism of the positive spillover effects, we test for changes in parental resource allocation and parental presence when the younger sibling starts school. We find no evidence that the increase in the elder child's school performance is due to increased parental resource allocation or change in attention devoted to the older child.

Overall, this paper joins others in providing a new perspective on sibling spillovers. Frameworks providing insight on human capital production among siblings within a family typically take one of three approaches: they assess the quantity-quality trade-off needed with multiple children (e.g. Becker, 1960; Becker and Lewis, 1973; Becker and Tomes, 1976; Blake, 1981; Hanushek, 1992; Liang and Gibson, 2018), they allow for birth order effects (e.g. Black, Grönqvist, and Öckert, 2018; Breining, Doyle, Figlio, Karbownik, and Roth, 2020; Lin, Pantano, and Sun, 2020), and most recently, they look for possible sibling interactions (e.g. Joensen and Nielsen, 2018; Qureshi, 2018; Black et al., 2017; Breining, 2014; Yi, Heckman, Zhang, and Conti, 2015). To date, the literature on sibling spillovers has largely focused on high-income countries and the impact of older children on younger children. We contribute to the literature by studying the spillover effect of younger siblings on the school performance of elder siblings in low income communities[4].

In low income economies, educational resources are often scarce and gender inequality in educational resource allocation tends to be larger (e.g. Ozier, 2018; Attanasio, Baker-Henningham, Bernal, Meghir, Pineda, and Rubio-Codina, 2018; Alsan, 2017; Martinez, Naudeau, and Pereira, 2017). Only one paper we know of has looked at sibling spillovers in China and this was on the spillover effect from the older to the younger child (Biavaschi,

[4]The World Bank categorizes China as lower middle income in 2009. The rural China household's average income in 2010 was within the low-income country threshold.

Giulietti, and Zimmermann, 2015). The findings of our paper reveal a strong sibling spillover in school work, driven by sisters, consistent with the result from Jakiela, Ozier, Fernald, and Knauer (2020). However, they examine the impact from an older sibling to a younger one while we examine the impact of younger sibling on an elder child. Our results suggest that policies geared towards daughters and sisters in low income communities like rural China should produce large spillovers and increases in human capital development over time.

2 Data

We use data from the Rural Household Survey (RHS) to conduct our analysis. The RHS is one of three independent surveys housed under the Longitudinal Survey on Rural Urban Migration in China (RUMiC). The RHS consists of interviews of only rural non-migrant residents, compared to the other two that includes migrants and urban dwellers.[5] We choose the RHS data because it is the most comprehensive data covering a large population in rural China. The survey spans nine provinces: Anhui, Chongqing, Guangdong, Hebei, Henan, Hubei, Jiangsu, Sichuan, and Zhejiang.[6] More importantly, it provides valuable information on the test scores of children in school, which is a reliable measure of school performance of Chinese students.[7] The 2008 and 2009 waves of RHS in RUMiC are the only publicly available waves and we use them to identify geographic information, individual demographic characteristics, family relationships, parental education, parental income, and schooling information for all children under 16 in surveyed households. The 2009 wave surveys exam

[5]RUMiC is a collaboration project between the Australian National University, Beijing Normal University and the Institute for the Study of Labor (IZA). RUMiC consists of three independent surveys: the Urban Household Survey (UHS), the Rural Household Survey (RHS) and the Migrant Household Survey (MHS). Each of the three surveys include comprehensive information on household and personal characteristics, detailed health status, employment, income, training and education of adults and children, social networks, family and social relationships, life events, and mental health measures of the individuals.

[6]The data covers about 70 cities from these nine provinces. However, we cannot identify city names due to data's confidentiality.

[7]Although self-reported, test scores are likely accurate due to the fact that most Chinese schools give each student a booklet that has their scores recorded for each semester during the school year (Biavaschi et al., 2015; Chen, Huang, Rozelle, Shi, and Zhang, 2014).

scores in Chinese language and math for all in-school children.[8] The 2009 survey was conducted between March and June of that year (Dustmann, Fasani, Meng, and Minale, 2020); therefore we consider the 2009 surveyed test scores captures the school performance during the fall semester 2008.

Another reason that RUMiC suits our research goals is that it covers a relatively large number of multi-children households. Over a quarter (27 percent) of the children in the RHS of RUMiC live in two-children household, second to single-child families (69 percent), leaving only a small share of children in households with three or more children. We focus our analysis on two-children households and check for the robustness of our main estimates on three-children households.[9]

Our main sample used for the analysis in this paper includes 346 individuals (elder children) from two-children households where the younger sibling is between 3 and 9 in 2008. Table 1 provides summary statistics split by whether a younger child is in school or not. The top panel of Table 1 describes the average characteristics of the elder child, the subject of interest in our paper. The bottom panel presents the younger child's characteristics and each parent's wage and educational attainment. The key dependent variables for the study are the elder sibling's Chinese score and Math score. We standardize the test scores to percentage terms to remove differences in scaling across locations. Even so, test scores might differ by school grade, school or school district. The RUMiC dataset provides no geographic identification disaggregated below the city-level, so we do not observe school or school district information. Instead, we control for children's grade fixed effects, geographic location fixed effects, and family characteristics in all of our analysis to address this concern. The average scores for both Chinese and math are around 80 percent. The average scores

[8] The survey questions related to the test scores are: "What was his/her score of Chinese exam in the previous semester/the last semester before dropping out? "What was the full score of his/her Chinese exam in the previous semester/the last semester before dropping out?" "What was his/her score of Math exam in the previous semester/the last semester before dropping out?" "What was the full score of his/her Math exam in the previous semester/the last semester before dropping out?"

[9] Removing the households with more than two children also reduces the concern for the heterogeneity of family size to sibling peer effect (Chen, Chou, Wang, and Zhao, 2019). Our results remain when we relax the sample to include three-children households, accounting for 3 percent of all families in our sample.

Table 1: Summary Statistics

	Younger Sibling Not in School		Younger Sibling in School		
	Obs. 200		Obs. 146		
Variable	Mean	SD	Mean	SD	Difference
Elder Sibling:					
Age	12.08	2.797	14.089	2.127	-2.009***
Female	0.655	0.477	0.719	0.451	-0.064
Birthweight	3263.75	423.342	3236.507	409.738	27.243
Chinese score	81.031	11.398	79.136	12.925	1.896
Math score	82.595	11.898	81.83	12.788	0.764
Distance to school (km)	4.711	8.177	8.979	34.139	-4.268*
Annual edu expenses (yuan)	1207.829	2416.499	2041.592	3520.124	-833.763**
Present Parents	0.505	0.501	0.589	0.494	-0.084
Younger Sibling and Parents:					
Younger sib's age	5.535	1.359	8.726	1.223	-3.191***
Younger sib is female	0.375	0.485	0.301	0.46	0.073
Younger sib' birthweight	3315.45	472.473	3310.685	476.21	4.765
Father's wage	1625.065	3446.031	1362.062	1968.416	263.003
Mother's wage	605.25	2212.866	343.274	586.929	261.976
Father Never Been to School	0.01	0.007	0.013	0.009	-0.003
Father Literacy Class	0.015	0.008	0	0	0.015
Father Elementary School	0.11	0.022	0.205	0.033	-0.095*
Father Junior Middle School	0.655	0.033	0.636	0.039	0.018
Father Senior Middle School	0.135	0.024	0.109	0.025	0.025
Father Specialized Secondary School	0.035	0.013	0.013	0.009	0.021
Father Polytechnic college	0.04	0.013	0.020	0.011	0.019
Father Undergraduate	0	0	0	0	0
Mother Never Been to School	0.015	0.008	0.027	0.013	-0.012
Mother Literacy Class	0.02	0.009	0.013	0.009	0.006
Mother Elementary School	0.195	0.028	0.315	0.038	-0.120**
Mother Junior Middle School	0.665	0.033	0.616	0.040	0.048
Mother Senior Middle School	0.075	0.018	0.027	0.013	0.047*
Mother Specialized Secondary School	0.015	0.008	0	0	0.015
Mother Polytechnic college	0.015	0.008	0	0	0.015
Mother Undergraduate	0	0	0	0	0

Notes: This table presents the summary statistics of the main variables that we used for analysis, separately by the schooling status of the younger siblings. Specifically, in the upper panel, we show the demographic characteristics, school characteristics, test scores, and parents' educational expense and worry of the elder sibling—the individuals of interest in our analysis. In the bottom panel, we show demographic information of the younger sibling, parent's wage and parents' educational attainments. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

are lower for elder siblings from families with a younger child in school but they are not statistically different. In our sample, families with both children in school are spending more money on educational expenditures, and are more likely to have the elder sibling in a school further away from home.

We find no statistical difference in mother's and father's wage income between families with a younger child in school and those with a younger child not enrolled in school. There is no gender or birth-weight differences among elder and younger siblings between the two groups. We also do not find statistical difference in the parental availability or parental time inputs for the elder child, measured as having parents present in the home. There is no significant difference in mother's and father's junior middle school completion rate — the most common educational attainment in our data — between the two groups. This suggests that the children and households with younger siblings are quite similar whether there is a young sibling in school or not.

3 Empirical strategy

We examine the impact of a younger sibling's schooling status on the educational outcomes of their older sibling, and refer to this as the sibship spillover effect. Ideally, we would like to regress the elder sibling's schooling performance on a variable capturing years of schooling for the younger sibling and control for a host of demographic and economic characteristics for both siblings, their parents and their location:

$$S_i^E = \alpha + \beta ActualYearsinSchool_i^Y + \Lambda X_i^E + \Gamma X_i^Y + \Pi X_i + \varepsilon_i \tag{1}$$

where E stands for the elder child, and Y stands for the younger child. Thus, S_i^E is the elder sibling's schooling performance, Chinese score or Math score, from household i. $ActualYearsinSchool_i^Y$ is a continuous variable capturing the years of schooling of the younger sibling. The corresponding coefficient, β, is our main coefficient of interest.

We include a number of controls for both siblings and household characteristics to absorb idiosyncratic variation. X_i^E is a vector of the elder sibling's characteristics, including the elder sibling's birth weight, gender, and grade fixed effects. X_i^Y is a vector of the younger sibling's characteristics, including birth weight, gender, and a linear trend of age. We also control for ethnicity and province fixed effects for the household, both parents' ages, wages, educational attainment, and educational expenses on the elder sibling in X_i.[10] We cluster all standard errors at the city level, the smallest locality level that we can identify.[11]

3.1 Identification

A main concern to the estimate, β, in Equation (1) is that the timing of the younger sibling's school enrollment and years of schooling may not be exogenous. For instance, parents may delay their younger child's schooling due to financial hardship and this may be correlated to the school performance of the elder child. Parents could also experiment on the timing of the younger child's school entrance based on their observation of the older child's performance and consider the age-school relationship in the enrollment decision. To account for such potential endogeneity on the spillover between the younger child's schooling and the older child's test scores, we take advantage of an arbitrary cutoff birth date for compulsory school entry age, stipulated by the Chinese Compulsory Education Law, and implement an instrumental variable indicating the younger child's cumulative lawful eligibility to be enrolled in school based on the policy.

3.1.1 China's compulsory education and education in rural China

China passed its Compulsory Education Law in 1986 with the aim to establish universal education for all school-aged children. The universal education mandates nine years of

[10]We impute zeroes for missing wages of parents and include an indicator for a missing wage in our regressions.

[11]Note that a city is the largest administrative division under a province and it covers both rural and urban areas.

schooling spanning from elementary school to junior high school.[12] Depriving school-aged children from enrollment by parents is considered a crime. Across China, schools have September 1st as the official first day of a school year. The implementation of the Compulsory Education Law requires that children who have their sixth birthday before August 31st must enroll in an elementary school on September 1st of the same year. Children who reach six years old after August 31st must wait until the following school year for enrollment.

Importantly, the birth date of August 31st becomes an arbitrary cutoff for schooling among six-year-olds. Having a birth date before or after August 31st creates an exogenous variation in school start dates. Fang, Eggleston, Rizzo, Rozelle, and Zeckhauser (2012) document that there were variations in the enforcement of the school starting cutoff date in the early implementation of the Law. However, Zhang and Xie (2018) find that the actual birth date eligible for school entry is now largely in compliance with the August 31st cutoff. Meanwhile, Huang, Zhang, and Zhao (2020) show evidence of birth planning around the school entry date in certain areas. In Figure 1, however, we find that there is no evidence of birth planning around August 31st in our sample. Along these lines, it is also reasonable to assume that the exact birth date of one child is not correlated with the school performance of another child.

It is worth noting that for our data period, before enrolling in elementary school, children in rural China primarily stay within the household with the care and education provided by parents or grandparents rather than through nursery school, kindergarten (also known as "pre-school" in the US context) (Luo, Lyu, Rozelle, and Wang, 2020; Johnstone, Yang, Xue, and Rozelle, 2021; Sylvia, Warrinnier, Luo, Yue, Attanasio, Medina, and Rozelle, 2021).

[12]The elementary school enrolls students from age six (grade one) and ends at age twelve (grade six), with a curriculum focusing on Chinese, math and physical education. Urban elementary schools also include music, drawing, science, and morality and ethics. Some advanced urban schools introduce English courses. Junior high schools cover a more comprehensive curriculum, including Chinese, Mathematics, English, Biology, Politics, Geography, History, Physical Education as the main subjects that students have to take mid-term and final exams in each semester. Although we do not have test scores for subjects other than Chinese and math for the junior high students, one could argue that Chinese and math are two of the most important subjects in the sense of how much weight is given to these tests, even in the senior high school exams and college entrance exams.

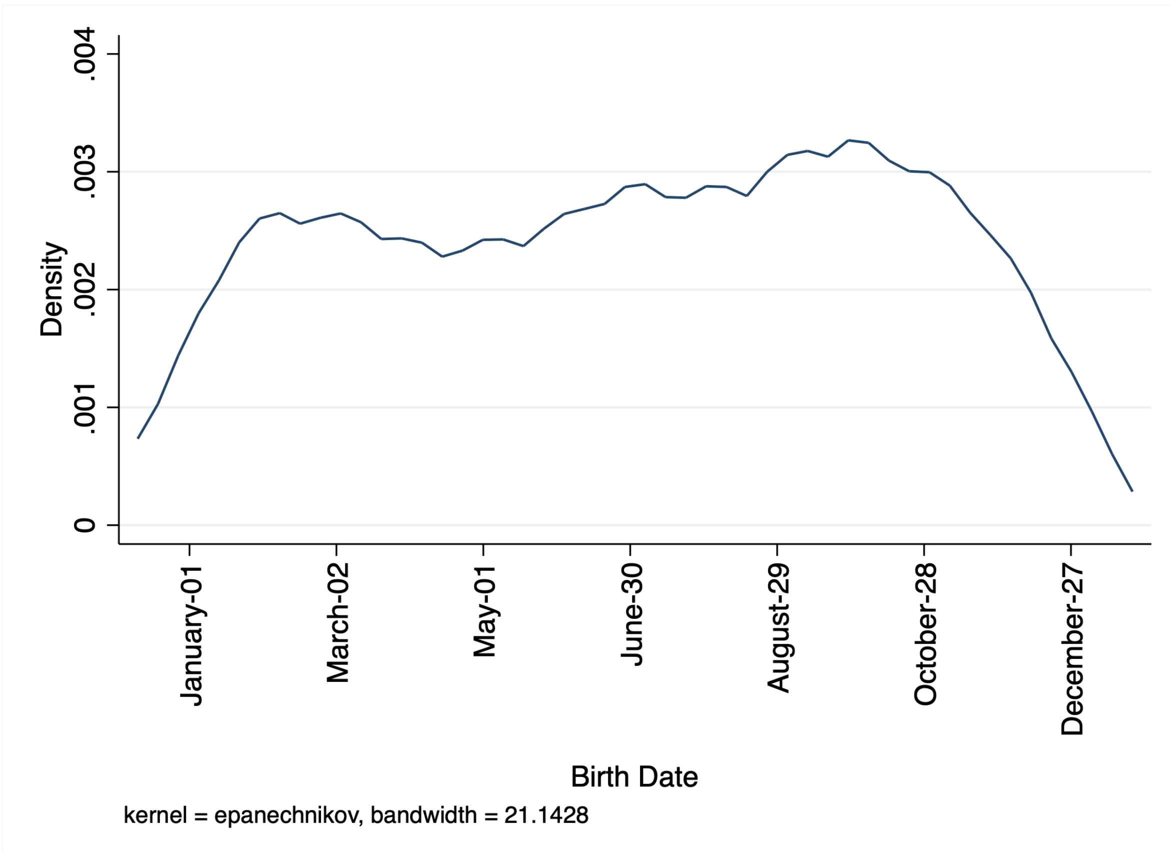

Figure 1: Density of Children's Birth Date

Notes: This figure plots the kernel density of birth dates (month and date) of all younger children in our sample. The purpose of this figure is to show there are no breaks in the density around August and September.

For the rest of this paper, we use the term *pre-school* to refer to the age period before children reach their age limit for elementary school, rather than referring to institutions like kindergarten or nursery school.

3.1.2 Instrumental variable analysis

Incorporating the arbitrary birth-date cutoff, we employ a two-stage estimation procedure using the arbitrary birth-date cutoff to define an instrumental variable for the younger child's lawful years of schooling. Specifically, we construct a continuous variable, which equals to zero for any younger sibling who was ineligible to go to school in 2008 (born after August 31st, 2002). For any younger siblings who were born before August 31st, 2002, the lawful years of schooling equals to an integer, (*2008 - birth year - 6*) if birth date is before August 31, and (*2008 - birth year - 7*) if birth date is after August 31. For example, the lawful years of schooling is 1 for a child who was born in August 1, 2001 and the lawful years of schooling is 2 for a child who was born in September 1, 1999. The endogenous variable is the actual years of schooling of the younger sibling.

Our first-stage estimation is specified as:

$$ActualYearsinSchool_i^Y = \alpha + \theta LawfulYears_i^Y + \Lambda X_i^E + \Gamma X_i^Y + \Pi X_i + \varepsilon_i \tag{2}$$

where $ActualYearsinSchool_i^Y$ is a continuous variable for the younger sibling's actual years of schooling, reported in the survey data. $ActualYearsinSchool_i^Y = 0$ for the younger children who have not yet in school (i.e., pre-school children). The parameter θ provides the propensity of a child to have the lawful years of schooling. We would expect θ to be positive and close to one.

Our primary parameter of interest then will be β^{IV} from the second stage regression:

$$S_i^E = \alpha + \beta^{IV} ActualY\widehat{earsin}School_i^Y + \Lambda X_i^E + \Gamma X_i^Y + \Pi X_i + \varepsilon_i \tag{3}$$

This gives the impact of an additional year of the younger sibling's schooling on the older sibling's test scores. It will be positive if there is a sibling spillover effect.

4 Results

In this section, we present our main results, the effects of sibship spillover and the heterogeneity across sibling gender composition. We further explore a potential mechanism associated with the spillover.

4.1 Sibship spillover

We estimate the impact of younger sibling's in-school status on the elder sibling's schooling performance, measured by Chinese and math test scores. We present the results in Table 2. The top panel of Table 2 reports the IV estimation results and the bottom panel presents the OLS estimates for comparison purposes. The odd-numbered columns have the standardized Chinese test score as the outcome variable and the even-numbered columns have the standardized math test score as the outcome variable. We control for the elder sibling's grade fixed effects (capturing both the elder sibling's age and academic standing), both sibling's birth weight (a commonly used proxy for health), family characteristics including ethnicity and province fixed effects, both parent's age, income, and educational attainment in all columns. It is likely that the age distribution of older siblings with a younger child in school may differ from those with younger child not in school. The grade level fixed effects address this concern. Our instrument is strong, with a Kleibergen-Paap rk Wald F-statistic of over 140 for our baseline model. We present our first-stage estimates in Table A.2.

While the estimates in columns (1) and (2) of Table 2 are positive, they do not provide statistically significant evidence that having the younger sibling enrolled in school improves the elder child's test scores. However, when we add controls in Columns (3) and (4) we find a sibling spillover effect. Specifically, we find that a younger sibling's additional years in school

Table 2: Sibling Spillover Effects

	(1) Chinese	(2) Math	(3) Chinese	(4) Math
Younger Sib's Actual Years in School	0.499	0.107	1.420**	1.115
	(0.717)	(0.703)	(0.663)	(0.710)
Elder Sib is Female			2.483*	1.001
			(1.283)	(1.288)
Younger Sib is Female			2.721**	1.943
			(1.228)	(1.286)
County Children Female Ratio			-7.587	7.075
			(18.75)	(18.26)
ln(Edu Expense)			0.118	0.149
			(0.504)	(0.553)
First Stage F-Stats	144.66	144.66	91.29	91.29
Observations	346	346	289	289
OLS Estimates:				
Younger Sib's Actual Years in School	-0.598	0.436	-0.0689	0.663
	(0.826)	(0.699)	(0.656)	(0.612)

Notes: This table presents the IV and OLS estimates of the main analysis. The regression sample only includes households with the younger sibling aged 3-9. The upper panel shows the IV estimates of three different specifications. The lower panel shows the corresponding OLS estimates. Each column is a separate regression. The dependent variable in odd-numbered columns is Chinese test score and the dependent variable in even-numbered columns is Math test score. The test scores are standardized to 100-point scale. The key variable of interest is the continuous variable of younger sibling's actual years of schooling. Columns (1) and (2) are the results of the baseline model, including both sibling's birth weight, younger sibling's age, elder sibling's school grade fixed effects, both parent's age, income, and education, the household's ethnicity, province fixed effects. Columns (3) and (4) are adding both sibling's gender, county level children girl ratio, and the log annual educational expense on the elder sibling. All standard errors are clustered at city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

boost the Chinese test score of the elder child by 1.42 percentage points for every additional year of schooling. In these specifications, we add both sibling's gender and a county-level girl ratio to capture potential gender-specific educational resource allocation based on a son-preference culture rooted in rural China.[13] We approximate son preference by exploring the shares of girls in each county. The county-level girl ratio is calculated by using the total number of girls under the age of 18 divided by the total number of children under the age of 18. We further control for the log of annual educational expenses spent on the elder sibling to capture the possibility for parents to switch the allocation of resource dedicated to the elder sibling when the younger one begins school. This is our preferred specification.

While only significant in column (3), the IV estimate shows that the school enrollment of the second child has a statistically strong, and economically meaningful positive effect on the elder child's Chinese performance, but less so on the Math performance. This compares to the null effects estimated in the OLS regressions and suggests a downward bias to the OLS results. This downward bias could occur if parents chose to delay schooling of the younger child to focus on schooling of the elder child. In this case, the first-child preference would be negatively correlated with having the second child in school and positively correlated with the older child's test score. Meanwhile, the estimated impact of the control variables are similar in both economic and statistical significance in the OLS regressions compared to the IV regression model and the estimates are presented in Table A.1.

4.2 Robustness of results

To minimize the concern that our IV estimates might be driven by those with birth dates further away from the cutoff date, we further narrow the age window of the younger siblings to check for the robustness of our results and present further-restricted sample results from

[13] A substantial literature documents the son-preference culture in Asian communities and its impact on resource allocation to children of opposite genders (e.g. Blau, Kahn, Brummund, Cook, and Larson-Koester, 2020; Kaul, 2018; Hong Chew, Yi, Zhang, and Zhong, 2017; Das Gupta, Zhenghua, Bohua, Zhenming, Chung, and Hwa-Ok, 2003). During the time of our survey data were collected, son-preference still prevailed, shown by the peak of the imbalanced sex ratio in China.

our preferred specification in Table 2.

Table 3: Robustness: Sibling Spillover Effects

	(1) Chinese 4-9	(2) Math 4-9	(3) Chinese 4-8	(4) Math 4-8	(5) Chinese 5-9	(6) Math 5-9	(7) Chinese 5-8	(8) Math 5-8
Younger's Actual Years in School	1.470**	1.072	4.675***	2.465	1.241*	1.011	4.930***	0.110
	(0.606)	(0.656)	(1.759)	(1.557)	(0.699)	(0.769)	(1.869)	(1.790)
Elder Sib is Female	2.729*	0.542	3.023	0.963	2.838*	1.233	3.884*	2.094
	(1.520)	(1.401)	(1.930)	(1.609)	(1.536)	(1.572)	(2.234)	(1.832)
Younger Sib is Female	4.177***	3.509**	3.891***	3.827**	3.225**	2.370	2.989	2.826*
	(1.375)	(1.473)	(1.416)	(1.616)	(1.562)	(1.677)	(1.880)	(1.598)
County Children Female Ratio	-16.97	-11.34	-20.18	-32.13*	-20.80	-15.85	-31.11	-64.10**
	(19.51)	(18.11)	(18.74)	(18.21)	(21.54)	(22.84)	(22.97)	(26.36)
ln(Edu Expense)	0.326	0.644	0.277	0.735	0.299	0.582	0.0770	0.877
	(0.487)	(0.530)	(0.443)	(0.497)	(0.596)	(0.623)	(0.608)	(0.634)
Observations	241	241	196	196	196	196	151	151

Notes: This table presents the IV estimates from running the same specification in columns (3) and (4) in Table 2 on sub-samples with different age ranges of the younger siblings. Columns (1) and (2) show estimates from the sample with younger sibling's age ranging 4-9. Columns (3) and (4) show estimates from the sample with younger sibling's age ranging 4-8. Columns (5) and (6) are estimates from the sample with younger sibling's age ranging 5-9. Columns (7) and (8) are estimates from the sample with younger sibling's age ranging 5-8. All standard errors are clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Columns (1) and (2) restrict the younger siblings to those aged between 4 and 9 years old in 2008; Columns (3) and (4) restrict the the younger sibling's ages to be within 4 and 8 in year 2008; Columns (5) and (6) restrict the younger sibling's age to fall between 5 and 9 years old in year 2008, and Columns (7) and (8) limit the age to be between 5 and 8 in year 2008. As the age band shrinks, the number of observations falls noticeably. Notwithstanding this limitation, we find that the younger sibling's schooling status has a robust positive effect on the elder sibling's Chinese score in all estimations regardless of sample restrictions. The estimates on Math test scores are also positive but not statistically significant at conventional levels. Compared to Table 2, we gain significance for most of the estimates of Chinese test scores with this conservative specification. By the narrowest window of age 5-8, the impact of an additional year of schooling is estimated to be as large as 4.93 percentage points.

4.3 Story of sisters

In our dataset, we find that female students have relatively higher mean and lower standard deviations in both their Chinese and math scores (see the lower panel in Table 4). This confirms what has been found in the literature in that girls consistently outperform boys in school (e.g. Duckworth and Seligman, 2006; Goldin, Katz, and Kuziemko, 2006; Buchmann, DiPrete, and McDaniel, 2008; DiPrete and Jennings, 2012; Lundberg, 2017; Jiang, 2020). Compared to boys, girls begin school more prepared, spend more hours on homework, and have fewer disruptive behaviors (e.g. DiPrete and Jennings, 2012; Becker, Hubbard, and Murphy, 2010; Goldin et al., 2006). To examine whether gender differences in learning also affect sibling spillover effects, we tested and allowed for differential effects by gender of the younger sibling. We find that the sibling spillover is driven by girls.

We present these heterogeneity results of the spillover effects by gender of the younger sibling in the top panels in Table 4. We find striking positive spillover effects for which the younger sibling is a girl in columns (1) for Chinese test scores. Having a younger sister in school leads to a 2.26 percentage point increase in the elder sibling's Chinese score for each additional year of schooling of the younger sibling. The results presented in columns (3) and (4), where the younger brothers are attending schools, show null effects on the elder sibling's Chinese and Math performance.

Our findings in Table 4 contribute to the sibling gender literature by showing that having a younger sister in school provides a strong and positive impact on the elder sibling's school performance, compared to having a younger brother being in school.

4.4 Home connections and potential mechanisms

As we find a strong positive impact from the second child's enrollment status on the older child's school performance, we hypothesize that this improvement is due to a positive at-home externality from both siblings studying together. When the younger child is enrolled in school, the older child would likely be exposed to a more intense academic atmosphere

Table 4: Heterogeneity of spillover by siblings gender pairs

	Younger Sib is Female		Younger Sib is Male	
	(1)	(2)	(3)	(4)
	Chinese	Math	Chinese	Math
Younger Sib's Actual Years in School	2.256**	0.853	1.251	1.017
	(1.014)	(1.134)	(0.802)	(0.945)
County Children Female Ratio	23.42	-10.03	-30.92	13.11
	(24.46)	(24.25)	(25.54)	(22.15)
ln(Edu Expense)	0.594	0.800	0.171	0.135
	(0.712)	(0.874)	(0.617)	(0.686)
Observations	103	103	186	186

Test Score Statistics	*Chinese*		*Math*	
	Mean	S.D.	Mean	S.D.
Younger Sister's Score:	82.48889	9.931634	85.66102	10.46056
Younger Brother's Score:	81.39323	13.65065	83.03486	11.77295
Elder Sister's Score:	80.77442	12.25048	82.73597	12.00601
Elder Brother's Score:	79.06667	11.68808	81.27675	12.81397

Notes: This table presents the IV estimates from running the same specification in columns (3) and (4) in Table 2 on subsamples with different genders of the younger siblings. Columns (1)-(2) are subsamples with the younger sibling being female and columns (3)-(4) are subsamples with the younger sibling being male. All standard errors are clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The lower panel shows summary statistics of test scores by 4 groups of children, which indicate that females in general have relatively higher mean and lower standard deviations in both test scores.

at home. This could be reflected as an increase in studying time among siblings at home, a heightened household attention to school performance, or to more frequent household discussions of school matters. Waldfogel and Washbrook (2011) demonstrate that home learning environment, along with parenting style, are the most important factors explaining children's learning gaps. Alexander, Entwisle, and Olson (2007) and Downey, Von Hippel, and Broh (2004) show that home academic environment differs by family socioeconomic level and that students' achievement gap widens across income class during summer months when they spend extended time at home.

Conditional on the variables provided by our data, we infer such mechanisms through the variations on the elder sibling's home-school distance. A shorter home-school distance may also suggest a tighter social connection between a child and family members and an increased amount of time studying together at home. Following our hypothesis, we test whether children who spend more time at home and have stronger social connections at home are more likely to be positively influenced by the intense home academic atmosphere when the younger sibling begins school. This would be evident by observing a large sibling spillover when the older child's school is closer to home.

To illustrate this mechanism, we add an indicator of whether the elder sibling's home-school distance is above the median and an interaction between the indicator and the younger sibling's actual years in school to our main specification. The results are shown in columns (1)-(2) in Table 5.

Table 5: Sibling spillover by elder child's home-school distance

	(1) Chinese	(2) Math
Younger's Actual Years in School	3.951**	2.831
	(1.702)	(1.835)
Younger's Actual Years in School*Elder Sib in School > Median Distance	-3.080*	-2.076
	(1.814)	(1.870)
Elder Sib in School > Median Distance	2.107	1.983
	(1.936)	(2.436)
Observations	289	289
School-home Distance Statistics	*Younger Sib is Female*	*Younger Sib is Male*
School-home Distance (km):	8.576	5.416
	(3.406)	(0.630)
	Ho: diff = 0	***t-stat: -1.197***

Notes: This table illustrates the potential mechanism of the sibling spillover effects by exploring the distance to school of the elder sibling. The dependent variable is either Chinese test score or Math test score, in 100-point scale. The key independent variable in columns (1) and (2) is an interaction tern of the indicator of the younger sibling's actual years of schooling and the indicator of the elder sibling's school distance is above the sample median.

The results in Table 5 provide some support our hypotheses. In column (1), we see that the impact of the years of schooling goes down dramatically for Chinese test score if the elder sibling attends a school that is farther from home. They experience a 3.1 percentage points reduction in the positive sibling's spillover in Chinese scores for every year of schooling of their younger sibling, relative to their counterparts who attend schools closer to home. Due to the small sample, we cannot further break the analysis down to sibling gender pairs. Instead we provide the average school-to-home distance by gender of the younger sibling and show that there is no statistically significant difference. In other words, the school-to-home distance for the older sibling is not a function of the gender of the younger sibling. This provides further confirmation that the sibling spillover effect is driven by the younger sisters impact on the elder sibling in the home and the intensity of the spillover depends on the school-home distance of the elder sibling.

Lastly, we address potential concerns that alternative channels such as a direct adjustment of educational resources or attention from parents to the elder child when the younger child starts school might explain the increase in performance, rather than the at-home externality we show above. It is well documented that a significant portion of human capital development is attributed to parental attention and monetary investment on children (e.g. Guryan et al., 2008; Blau and Currie, 2006; Yum, 2016; Del Boca et al., 2013; Yang and Bansak, 2020). To rule out changes in resources dedicated to the older child, we conduct additional tests in Table A.3 and do *not* find significant changes in education expenditure and the status of parents present in household to the elder child when the younger child begins school. Thus, we infer that the improvement in elder sibling's performance when the younger sibling starts school is not derived from changes in parental education spending or parental concerns or attention.

5 Conclusion

We find that having a younger sibling enrolled in school will significantly increase the elder sibling's test scores in Chinese. We refer to this result as the positive sibling spillover effect from the younger sibling to the elder. The main driver of the positive spillover comes from the younger sibling being a female. This set of findings contributes to the literature of gender inequality in education and adds empirical evidence to the positive externalities of women's educational improvement. As more than 130 million girls are estimated to be out of school, there are clear gender inequalities in education worldwide (UNESCO, 2016). Studies have shown that better educated girls contribute more to economic development and increase mobility across generations (Evans and Yuan, 2019; Kwauk and Braga, 2017;

World Bank, 2017). Our finding implies that investing in girls has an additional impact on their siblings. Thanks to these spillovers, policies that promote young women's education may have important effects on other children as well, suggesting a potential multiplier effect of a policy.

The potential mechanism of this spillover effect is that the more the in-school siblings interact with each other at home, the better the elder sibling performs. When the older child is away, the beneficial impact of having a younger sister at home diminishes. This mechanism also suggests that it could be beneficial to increase the time period in which spillovers occur by offering pre-school children earlier education programs. In this case, siblings would be in school together longer. This could be done by introducing pre-K programs such as Head Start in the US. In such programs, children younger than the compulsory enrollment birth date would have access to school readiness programs at an younger age. Sibling spillover effects could be larger if additional after school public services were made freely available, such as library access. They could enhance at-home academic culture and further facilitate sibling spillovers. These offerings could be targeted at low income families to reduce future income inequality.

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Appendix A Additional Tables and Figures

We present the OLS estimates of the impact of the younger sibling's enrollment status on test scores of the older child in Table A.1. When the younger sibling enters school, there is no statistically significant effect in any of the OLS regressions at the standard levels. Interestingly, compared to the IV regressions in Table 2, all other variables are similar in scale and level of significance.

Table A.1: Sibship spillover - OLS

	(1) Chinese	(2) Math	(3) Chinese	(4) Math
Younger Sib's Actual Years in School	-0.598	0.436	-0.0689	0.663
	(0.814)	(0.709)	(0.656)	(0.612)
Elder Sib is Female			2.654*	1.037
			(1.381)	(1.403)
Younger Sib is Female			2.686**	1.975
			(1.306)	(1.375)
County Children Female Ratio			-10.30	6.619
			(21.01)	(19.84)
ln(Edu Expense)			0.219	0.193
			(0.550)	(0.606)
Observations	346	346	289	289

Notes: This table presents the OLS estimates of the main regression. Each column is a separate regression. The dependent variable is either Chinese test score or Math test score, in 100-point scale. The key variable of interest is a dummy variable of younger sibling enrolled in school. Column (1) and (2) are the results of the baseline model, including both sibling's birth weight and age, both parent's age, income, and education, the household's ethnicity, province fixed effects. Column (3) and (4) are adding both sibling's gender, county level children girl ratio, and the yearly log educational expense on the elder sibling. All standard errors are clustered at city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We show the first stage results in Table A.2, using the August 31st birth date cutoff through the compulsory education. The coefficients on the instrumental variable are all negative and significant, as expected. Children who are ineligible for school are far less likely to be enrolled in school. These results are robust across various samples at the 1 percent level of significance.

In Table A.3, we run the preferred specification of our main IV regression with the annual educational expense and an indicator of either parent presents in the household as

Table A.2: First Stage: Propensity of the Younger Sibling to have the Lawful Years of Schooling

	(1)	(2)	(3)	(4)
Younger Sib's Lawful Years in School	0.614***	0.614***	0.625***	0.625***
	(0.051)	(0.051)	(0.066)	(0.066)
K-P rk Wald F-Statistic	144.66	144.66	91.29	91.29
Observations	346	346	289	289

Notes: This table presents the first stage of the IV estimation and the Kleibergen-Paap rk Wald F-statistics, corresponding to our main table, Table 2. The dependent variable is the actual years of the younger sibling enrolled in school.

the dependent variable to address concerns that parents are adjusting their resources to the elder child when the younger child enters school. Though we control for the annual education expenditure in our main regressions, columns (1) and (2) provide additional evidence showing that educational expenditure on the elder sibling is not a function of when the second child begins school. We use an additional variable, an indicator of whether either parents present in the household, to measure the possible variation in parent's attention. Columns (3) and (4) show that having a second child in school does not impact parental presence, a suggestive measure of parents adjusting their care.

Table A.3: Educational Expense and Parental Attention to the Elder when the Younger Starts School

	(1)	(2)	(3)	(4)
	2009	2008&2009	2009	2008&2009
	Edu Expense	Edu Expense	Present Parents	Present Parents
Younger Sib's Actual Years in School	0.196	-0.0624	0.0315	-0.0103
	(0.298)	(0.0869)	(0.0949)	(0.0228)
Observations	289	648	289	648

Notes: This table shows estimates from regressions with dependent variable as parents' educational expenditure on the elder child or whether either parent presents in household. All regressions include the same set of independent variables in columns (3) or (4) in Table 2. In columns (1) and (2), we examine what happens to total education expense on the elder child when the second child enters school. In columns (3) and (4), we use self-reported either parent present in household as an indicator for parental attention to the child. The odd-numbered columns include the 2009 sample, same as the one in our main regressions, and the even-numbered columns include both 2008 and 2009 waves, to show robust results. Again, we only have test scores for one year (2009) but have most of other variables for both years.