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Sibling Gender Effects on Test Scores

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Abstract

This study examines the hypothesis that having an older sister causes one to perform relatively better at reading. For the analysis, a cross-subject analysis is conducted to examine a student's relative reading test score (reading test score minus math test score) based on older sibling gender. We found that a student's relative reading test score is larger when the student has an older sister than when he or she has an older brother. Further analyses show that although conversation frequency does not vary based on older sibling gender, siblings are more likely to talk about studying, career paths, or school life when an older sibling is a sister than when an older sibling is a brother.

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1. Introduction

In South Korea, girls have been, on average, better at reading and boys have been, on average, better at math. For example, the 2012 results from PISA showed that Korean girls had a reading score 23 points higher than that of Korean boys, and Korean boys had a math score 18 points higher than that of Korean girls (OECD, 2015). The 2003 results from PISA also showed that Korean girls performed better at reading than Korean boys by 21 points, and Korean boys performed better at math than Korean girls by 23 points (OECD, 2004).[2,3]

When girls are better at reading, and boy are better at math, one can say that, among siblings, sisters are better at reading and brothers are better at math, which translates into the idea that having a sister is akin to having a peer who is good at reading, while similarly, having a brother is like having a peer who is good at math. If peer effects exist between siblings, someone who has an older sister would thus be likely to be relatively better at reading, and someone who has an older brother would be likely to be relatively better at math (sibling gender effect).

This study examines the hypothesis that having an older sister causes one to perform relatively better at reading for the first time in literature. Although many studies have examined peer effects using peers at school (e.g., Sacerdote, 2001; Lavy, Silva, and Weinhardt, 2012; Hong and Lee, 2017), studies on sibling peer effect are relatively few. Hence, this study can be a valuable addition to peer effect literature, especially on sibling peer effect. Further, studies examining the family effect on child outcomes have mostly examined parental influence (e.g.,

[2] The standard deviation of each subject in PISA is 100 points; thus, 23 and 18 points are 0.23 and 0.18 standard deviations, respectively. The difference in reading score became 24 points in the 2018 PISA, but no significant difference was found in math test (OECD, 2019).

[3] Researchers have attempted to explain gender differences in math test scores. For example, Fryer and Levitt (2010) examined differences in investment in math by students and parental expectations, and Bharadwaj et al. (2016) examined parental background and investments, student ability, and classroom environment. Both studies, however, found that none of these factors explain the gap.

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Dahl and Lochner, 2012; Lundborg, Nilsson, and Rooth, 2014; Cho, 2017), but as children grow, they spend more time with siblings than with parents (Vandewater, Bickham, and Lee, 2006), which implies that investigating sibling effects as in this study is as important as analyzing parental effects.

The data are from Korean high school seniors and were obtained in 2004, when parents had no right to choose schools for their children, except for in small cities. When school choice is allowed, parents could send students with an older sister (brother) to schools that are more effective at teaching reading (math) than other subjects. Further, the sample is restricted to younger siblings in two-child families because the studies of sibling peer effects have focused on the effects of older siblings on younger siblings and families with more than two children are very few in Korean families.

Simply comparing test scores in a certain subject for students with different sibling gender compositions could give biased results, as parental interest in a child's education could depend on the gender composition of the siblings. For example, Becker and Tomes (1976) showed that parents want to invest more in the child with a higher marginal return to education, which implies that if boys have a higher marginal rate of return to education, girls with sisters will have more education or higher test scores than girls with brothers, and boys with sisters will have more education or higher test scores compared to boys with brothers. In other words, parental interest in each child's education or family-fixed effects has the potential to confound the sibling gender effects, i.e., the effect of having a sister on one's reading (or math) skill arising from peer effects that we attempt to estimate.

To circumvent this problem, we use the cross-subject analysis employed in Dee (2007), Clotfelter, Ladd, and Vigdor (2010), Lavy, Silva, and Weinhardt (2012), and Azam and Kingdon

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(2015). These studies analyzed data from students with test scores in multiple subjects for a certain year, and this feature of the data enabled them to control for student-fixed effects or family-fixed effects. For example, in order to estimate the effects of teacher credentials on student achievement, Clotfelter, Ladd, and Vigdor (2010) did not simply compare the test scores of students whose teachers had different credentials, as this could produce biased results since students may not be randomly assigned to teachers of different credentials. Instead, they removed each variable's student-specific means. For the dependent variable, they used a student's test score in a subject minus that student's average test score on all other tests, and for the teacher credential variable, the credential of a teacher in a subject minus the average credentials of teachers in other subjects was used. An advantage of this method, as Lavy, Silva, and Weinhardt (2012) stated, is that it provides an ability to control for a student's own unobservable ability as well as for unobserved family influences.

We use a student's relative reading test score—that is, the reading test score minus the math test score—from a college entrance exam administered in Korea as the dependent variable. Thus, the bias arising from parental interest in a child's education is removed. However, the estimate from the cross-subject analysis could still have bias when parents engage in subject-specific education correlated with older sibling gender. For example, families with a daughter as the first child might undertake reading-oriented education, regardless of the second child's gender. Such parental behavior could make a younger sibling with an older sister relatively better at reading. As mechanism checks, we examine whether parents exhibit such behaviors.

Our findings are as follows. A student's relative reading test score varies depending on the gender of his or her older sibling. Specifically, the score is 0.17 standard deviations higher when the student has an older sister than when he or she has an older brother. This result is

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equivalent to the finding that an older sister causally increases a younger sibling's reading test score by 0.081 standard deviations and causally decreases a younger sibling's math test score by 0.089 standard deviations. The mechanism analysis shows that although conversation frequency does not vary based on older sibling gender, the probability of siblings' talking about studying, career paths, or school life is higher by 10.8 percentage points when an older sibling is a sister than when an older sibling is a brother. In addition, parents do not engage in subject-specific education based on the older sibling's gender. Lastly, the finding of this study is relevant in the current COVID-era, during which many students do not go to school but stay at home. Siblings are likely to spend more time together, and the chances for their interactions are higher. Older siblings can play an important role in helping their younger siblings with in-home schooling, and parents may create home environments in which children can study together and observe each other.

The remainder of this paper is organized as follows: Section 2 describes the background of Korean school and family; Section 3 reviews related studies; Section 4 describes the data; Section 5 describes the empirical strategy employed in this study; Section 6 presents the estimation results; and Section 7 concludes the paper.

2. Background of Korean School and Family

2.1. Korean School System

Korean students go to primary school for grades 1–6, middle school for grades 7–9, and high school for grades 10–12. High schools consist of two types: college prep-schools and vocational schools. College-prep schools focus their instruction on reading, math, and English, which are considered the most important for college entrance. Among the three, students focus more on

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math because the subject is the most difficult. It covers more advanced concepts than high school math in other countries: there is even a word, supoja, which refers to students who have totally given up studying math, while no such words for reading and English are available.

College entrance exams are administered once a year on the second Thursday in November. High school seniors or high school graduates who intend to go to college take this test. As in other countries, girls have recently been more likely to go to college than boys, while competition for entering prestigious schools is very intense, with students spending a substantial amount of time at school and on tutoring and self-study.[4]

School choice is currently widely available, but in the early 2000s when the data of this study were obtained, it was restricted to students in small cities. Students in large cities, such as Seoul, the capital city, were assigned by lottery to one of their neighborhood schools. Once assigned to a school, students are assigned to a homeroom. This applies to high school students, too. Their homeroom assignment within a high school is based on students' overall performance, so that each homeroom has students of every ability level. In addition, students do not move from classroom to classroom for their classes but the subject teachers assigned to each homeroom visit the classroom and give lectures. The option to choose a teacher is unavailable to students.

2.2. Family Relationships and Cultural Aspects

Korean parents think that it is their responsibility to fully support their children, at least until their marriage. They tend to invest a substantial amount of resources, especially on their

[4] Lee (2007) reports that American students study more in college than in high school, whereas Korean students study more in high school. In addition, tutoring includes attending a private learning center called *hagwon* and one-to-one learning from privately employed tutors.

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children's education, to send them to selective colleges. This is applicable to both boys and girls, although people used to prefer having sons to having daughters and invested more in boys. However, the long-lasting son preference has recently vanished and parents now prefer having girls to boys.[5]

Korea has a lower fertility rate than other industrialised countries. It was 1.7 in 1985 but declined to 0.98 in 2018,[6] which means that many Korean parents have one child and families with three or more children are rare. This low rate has been partly caused by high education costs: School education is largely free until high school, but out-of-school education costs a large amount of money because most students attend several private tutoring programs. The data used in this study show that Korean parents spend about 18% of their monthly living expenses on tutoring children.[7]

3. Literature Review

Although no studies have examined sibling gender effects on academic abilities in certain subjects, i.e., the effect of having a sister on one's reading (or math) skill arising from sibling peer effects, a number of studies have examined the effects of sibling gender composition on overall educational attainment or years of schooling, which are considered to arise because sibling gender composition may change parental interest in a child's education. In addition, many studies have examined peer effects on various outcomes, including school outcomes.

Regarding the effects of sibling gender composition on overall educational attainment, in

5 See How South Korea Learned to Love Baby Girls (2017) for further information.
6 The fertility data can be downloaded at the following Statistics Korea website: http://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1B8000F&language=en
7 For education fever of Korean parents, see Education: The Other Arms Race (2013).

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theory, people with sisters may have either less education or more education than people with brothers. As described in Section 1, Becker and Tomes (1976) implied that having sisters increases one's educational attainment or test scores, because parents use more resources for children with higher returns to education, who are more likely to be sons. Another theory suggested by Behrman, Pollak, and Taubman (1982) posits that parents having an aversion to income inequality among their children would provide those children having lower returns to education, who are more likely to be daughters, with more education. In this case, having sisters may lower one's educational attainment or test scores. Empirical studies on this topic have shown mixed results. For example, Butcher and Case (1994) found that women with sisters receive less education than women with brothers but no sisters. Their study found no evidence that men who have sisters receive less education than men with brothers. Kaestner (1997) found that black adults who have sisters have a higher level of education attainment than those with no sisters. Finally, Hauser and Kuo (1998) and Amin (2009) found no sibling gender effects on educational attainment.

Regarding peer effects on school outcomes, previous studies primarily examined the effects of peers at school (e.g., Sacerdote, 2001; Lavy, Silva, and Weinhardt, 2012; Hong and Lee, 2017), and only a small number of studies have examined sibling peer effects on academic outcomes. One group of studies (e.g., Biavaschi, Giulietti, and Zimmermann, 2015; Nicoletti and Rabe, 2019) was concerned with the effect of older siblings' test scores on younger ones' (absolute) test scores, and the other group (e.g., Oettinger, 2000; Qureshi, 2018) examined the effect of older siblings' years of schooling on younger ones' years of schooling. Among them, Biavaschi, Giulietti, and Zimmermann (2015) and Nicoletti and Rabe (2019) found that an increase of one standard deviation in the test scores of older siblings increased the test scores of

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younger siblings by 0.4 and 0.11 standard deviations, respectively. Oettinger (2000) found that older siblings' high school graduation raised the probability of younger siblings' graduation by about 30%, and Qureshi (2018) found that a one-year increase in the oldest sister's schooling improved the younger brothers' schooling by 0.4 years.[8]

4. Data

The data used in this study are from the Korean Education & Employment Panel, which aims to analyze the educational and labor market experiences of youths in Korea.[9] In 2004, the first year of the study, 2,000 12th graders in 100 college preparatory high schools in 15 regions were surveyed.[10,11] Since 2004, the researchers have interviewed the students and their families annually. This study uses the data obtained in 2004. This year has been chosen for our analysis because, as described previously, school choice was available only in small cities, which implies the limited parental ability to choose schools, possibly based on the sibling gender.

The data include information regarding the students' scores on the college entrance exam. We use the standardized exam score for the analysis. The exam is graded by the government, and the test score used in this study is obtained through school administrators; thus, measurement error in test score is not a concern. The data also include information regarding the

8 Sibling peer effect studies of topics other than school outcomes include Goodman et al. (2015), Altonji, Cattan, and Ware (2017), Joensen and Nielsen (2018), Dahl, Rooth, and Stenberg (2020), Gurantz, Hurwitz, and Smith (2020), and Altmejd et al. (2020). They examined sibling effects on (same) college choice; smoking, drinking, and marijuana use of 15-to-19-years olds; high school students' choosing advanced math and science courses; high school major choice; Advanced Placement exam taking; and college enrollment. All studies examined the influence of older siblings on younger ones and found significant effects.

9 The data are publicly available at http://www.krivet.re.kr/eng/eu/eg/euCAADs.jsp.

10 At each school, four classes were randomly selected, and from each class, five students were randomly chosen, resulting in 20 students in total for each school. For any school that had fewer than four classes, all of the classes were chosen.

11 Korea consists of 16 regions: seven large cities and nine provinces. Among them, one province, Jeju, is not included in the survey. Figure A1 presents a map of Korea.

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students' gender, number of siblings, sibling sex and age, whether parents frequently read books for the students before entering school, how many novels, books of poetry or essays students read during high school, and the subject-specific out-of-school tutoring hours per week.[12] Regarding sibling interaction, information is provided on how often students converse with their siblings and the main topics of conversation. It is noteworthy that every question in the survey asked about students' experiences during high school, except for the question asking whether parents read books frequently before entering school.

Among the 2,000 students, 1,363 are from two-child families, of whom 595 are younger siblings.[13] Of these 595 younger siblings, about 80% or 472 were taken for the analysis. The decrease in sample size is due to the presence of students with unavailable test scores. There are two possible reasons for this: Some students did not take the college entrance exam, while others did not agree to provide their scores.[14] Table 1 presents the three groups of children: all 595 younger siblings in two-child families, the 472 of the analytical sample, and the 123 excluded from the analysis. One can see that the analytical sample is not different from the whole sample. For example, the proportion of children having an older sister is 44.8% and 46.0%, respectively, which implies that the analytical sample is representative of the whole sample. In addition, based on the *p*-value in column (4) of the table, most of the differences are insignificant between those included in the analysis and those who were not, but the interpretation of the result in this study should be restricted to those with college entrance exam scores or those who intend to go to college.

[12] For the tutoring hours, the students were asked to indicate how many hours of tutoring per week they received from September 2003 to February 2004.

[13] Only 106 and 101 students are second and third children from three-child families, respectively, and among them 77 and 73 students have test scores. Fourth or later children are a total of 52.

[14] The specific reason is not available to the public.

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For the mechanism analysis presented in subsection 6.3, when we examine whether parental behavior and sibling interaction differ based on the first child's (older sibling's) gender, we use the first child from two-child families in addition to the analytical sample. Using the first child is intended to complement the analysis of the analytical sample based on an assumption that parents behave similarly regardless of which child (the first or second) is a high school senior.

Lastly, as shown in Table 1, female students account for 37.7% of the analytical sample. The low proportion is driven by the small number of daughters as the second child in two-child families with a daughter as the first child. In fact, females account for 48.6% of the younger siblings in those families with a son as the first child, but 24.9% of the younger siblings in those families with a daughter as the first child. Son preference may play a role in this low proportion of girls. If parents with strong son preference have a daughter as a first child, they could have an abortion upon learning that a second child is also a daughter. In addition, they may have another child and become families with more than two children. Among the two hypotheses, the data support the latter. Having an abortion upon learning the second child's gender and becoming pregnant afterward is likely to increase the sibling age difference. However, the average age difference in the analytical sample is 2.8 years regardless of the older sibling's gender. For a robustness check against the sample selection, we include the second child from families with more than two children in the analysis, who would have been included in the analysis if no son preference had existed.

5. Empirical Strategy

Sibling peer effects on school outcomes can occur for two reasons: productivity spillover and

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role modeling. Older siblings may help younger siblings with homework or studying (productivity spillover), and younger siblings follow older siblings and imitate their behaviors (role modeling). Suppose a student's test score and her older sibling's test score are T and Ts. Then based on the findings of previous studies described in Section 3, we can say that $\partial T/\partial Ts > 0$, which implies that increased sibling test score increases one's test score. In addition to $\partial T/\partial Ts > 0$, when T is an increasing function of her effort level (e), i.e., $\partial T/\partial e > 0$, one can infer that e is an increasing function of Ts, i.e., $\partial e/\partial Ts > 0$ so that we have $\partial T/\partial Ts = \partial T/\partial e \times \partial e/\partial Ts > 0$. If e is not an increasing function of Ts, we cannot have $\partial T/\partial Ts > 0$. In other words, sibling peer effects occur when younger siblings' efforts are positively affected by older siblings' test scores.[15] Then, when $\partial e/\partial Ts > 0$, having an older sister leads to higher effort in reading but lower effort in math. Therefore, we can say that having an older sister increases reading scores but decreases math scores.

Consider the following equation for child i, the younger sibling from a two-child family.

$$R_i = \gamma_0 + \gamma_1 sister_i + \gamma_2 female_i + F_i + F_i^R + \upsilon_i \qquad (1)$$

where R is i's reading test score. The variable *sister* is a dummy variable, which is 1 if i has an older sister and 0 if i has an older brother. The variable *female* is a dummy variable indicating whether a student is female. Family-fixed effects consist of two parts: F reflects the parents' overall interest in the child's education, and F^R reflects reading-specific interest. υ is an error term. The parameter γ_1 measures the sibling gender effects on the reading test score. If the variable *sister* is correlated with family factors, estimating γ_1 by ordinary least squares (OLS) could provide a biased result. That is, the OLS estimate of γ_1 might include both sibling gender

[15] Although $\partial e/\partial Ts < 0$ is possible, positive sibling peer effects found in the previous studies imply that the negative value is not likely to be the majority.

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effects and parental effects on the reading test score.

When the math test score is the dependent variable in equation (2), OLS estimation will also produce biased results.

$$M_i = \delta_0 + \delta_1 sister_i + \delta_2 female_i + F_i + F_i^M + \tau_i \qquad (2)$$

where M is i's math test score, F^M is math-specific interest, and τ is an error term. To obtain a consistent estimate of sibling gender effects, it is necessary to remove any bias arising from the presence of family-fixed effects. To accomplish this, we employ a cross-subject analysis. Subtracting equation (2) from equation (1) gives

$$R_i - M_i = (\gamma_0 - \delta_0) + (\gamma_1 - \delta_1)\ sister_i + (\gamma_2 - \delta_2)\ female_i + (F_i^{\mathrm{R}} - F_i^{\mathrm{M}}) + (\upsilon_i - \tau_i)$$

$$or \quad T_i = \beta_0 + \beta_1 sister_i + \beta_2 female_i + (F_i^{\mathrm{R}} - F_i^{\mathrm{M}}) + \varepsilon_i \qquad (3)$$

In equation (3), the dependent variable is the reading test score minus the math test score, which is called the relative reading test score, and ε is an error term. Although equations (1) and (2) contain overall parental interest in the child's education, which may cause bias in the estimated γ_1 or δ_1, equation (3) does not contain it. This means that such interest does not have any impact on the relative reading test scores, causing no bias in the estimated β_1, which measures the difference in the relative reading test scores between those who have an older sister and those who have an older brother. A positive value of β_1 implies that older sisters increase their younger siblings' relative reading test scores, which could occur either when older sisters increase their younger siblings' (raw) reading test scores or when they decrease their younger siblings' (raw) math test scores (sibling gender effects on academic abilities). It is noteworthy that because we use two subjects, using the relative reading test score is equivalent to using a test score in a subject minus the average test score on all other tests, as in the studies using the cross-subject analysis described in Section 1. In addition, because we assume that sibling gender has different

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effects on different subjects, unlike existing studies, we set the coefficient of interest to vary by subject.

Although estimating equation (3) does not cause bias due to overall interest, a bias source still remains. That is, when $F_i^R - F_i^M$ in equation (3), or the difference in subject-specific interest, is not equal to zero and is correlated with the *sister* variable, it is likely to cause bias in the estimate. For example, when families with a daughter as the first child undertake reading-oriented education for all children, such parental behavior could make students with an older sister relatively better at reading. We check whether the first child's gender causes such parental behavior in subsection 6.3.

Lastly, one may claim that equation (3) contains school-fixed effects correlated with the *sister* variable, causing bias in the estimated β_1. For example, students with an older sister may attend schools that are more effective at teaching reading than other subjects. Although in the early 2000s, including 2004 when the data of this study were obtained, parents—except for those in small cities—were not given the right to choose their children's schools, it is possible that parents had relocated their residence for school choice. To check this, we first examined whether parents had relocated for the second child in our analytical sample and found that such relocation was not common. That is, 10.1% of those with an older sister had relocated, and 12.5% of those with an older brother had moved. We also conducted a regression analysis and examined whether the older sibling's gender affected the likelihood of this type of moving but, as expected, found no significant effect.[16]

[16] The result is available upon request.

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6. Results

6.1. Is first child gender randomly determined?

Before showing the estimation results of equation (3), we check whether the older sibling's gender is randomly determined. To do so, we first test whether the proportion of children having an older sister, 46.0%, in Table 1 is equal to 48.3%, a proportion achieved when 107 boys are born per 100 girls (the ratio of 107 boys to 100 girls is considered to be in normal sex ratio at birth). The *p*-value is 0.32, and the hypothesis is not rejected,[17] which implies that sisters and brothers are well balanced. We also run a regression of first child gender on the parental characteristics, which includes parental education, age, and household income. As shown in Table 2, no coefficient is significant, and the *p*-value of the F-test is 0.35,[18] which implies that first child gender is not affected by parental characteristics and is determined randomly.

6.2. Sibling gender effects

Table 3 shows the estimation results of equation (3). Before showing the results, a prediction for the estimate is made based on the findings of previous studies. First, the studies described in Section 3 found a sibling peer effect size of 30–40% (Oettinger, 2000; Biavaschi, Giulietti, and Zimmermann, 2015; Qureshi, 2018), although Nicoletti and Rabe (2019) reported a smaller effect size of 11%. In addition, based on the 2003 PISA results for Korean students described in Section 1, older sisters have higher reading test scores than older brothers by 0.21 standard deviations and have lower math test scores by 0.23 standard deviations. Assuming that the effect

[17] Statistics Korea (2019) showed that the sex ratios of the first child born in 1983 and 1984 are within the normal range, which are 105.8 and 106.1, respectively (the students in the analytical sample of this study were in the 12th grade in 2004; hence, they were born in 1986, and their older siblings were likely to be born in 1983 or 1984).
[18] Although we include paternal and maternal age linearly in the regression equation, using dummy variables does not change the result.

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size found in previous studies is also valid in the situation of our study, we can predict that older sisters causally increases younger siblings' reading scores by 0.063 (= 0.21 × 30%) to 0.084 (= 0.21 × 40%) standard deviations and decreases younger siblings' math scores by 0.069 (= 0.23 × 30%) to 0.092 (= 0.23 × 40%) standard deviations. Therefore, the estimate in column (1) of Table 3 should be in the range of 0.132 (= 0.063 − (−0.069)) to 0.176 (= 0.084 − (−0.092)).

The estimate is 0.170, which implies that an older sister increases a younger sibling's relative reading test score by 0.170 standard deviations. When an increase of an older sibling's test score by one standard deviation increases a younger sibling's test score by 38.7%, or 0.387 standard deviations, an older sister increases a younger sibling's reading test score by 0.081 (= 0.21 × 38.7%) standard deviations and decreases his or her math test score by 0.089 (= 0.23 × 38.7%) standard deviations. One can see that the sum of two numbers, 0.081 and 0.089, or 0.081 − (−0.089), is 0.170, which is the estimate.[19]

Table 3 also shows the estimation results of equations (1) and (2). The coefficient for *sister* is 0.237 for reading and 0.067 for math. Considering that, as described previously, older sisters are likely to increase younger siblings' reading scores by 0.063 to 0.084 standard deviations and are likely to decrease younger siblings' math scores by 0.069 to 0.092 standard deviations, these estimates are likely biased. Moreover, although the coefficient for *sister* is likely to be smaller than the coefficient for *female*, the former is larger than the latter (0.206). Lastly, it is noteworthy that the difference between 0.237 and 0.067 (0.170) is equal to the estimate in column (1), because we have $\beta_1 = \gamma_1 - \delta_1$ in equation (3). In addition, unlike equations (1) and (2), estimating equation (3) does not provide any information on the effect of the older

[19] We also estimated the effect controlling for various school variables, but found that the result did not change (Table A1).

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sibling's gender on each of the subject test scores, but the estimated β_1 is not subject to bias arising from F_i, family-fixed effects, because F_i is removed in equation (3).

6.3. Mechanism for the effect

In this subsection, following Lavy and Schlosser (2011) and Bifulco, Fletcher, and Ross (2011), we examine the mechanism for the effect found in column (1) of Table 3 (i.e., increased reading test scores and decreased math test scores due to the existence of an older sister). The mechanisms are intermediate outcomes, so a significant effect of the treatment variable on intermediate outcomes is a necessary condition for the outcomes to have operated as a mechanism through which treatment impacts the final outcome of interest. The mechanisms could be parental behavior and sibling interaction. Parents in families with a girl as the first child might undertake reading-oriented education for all children, and, as described in the Empirical Strategy section, interaction with an older sister could lead to relatively higher effort in reading.

In Table 4, we first compare the means of several variables based on the older sibling' gender. The variables include whether parents read books to the surveyed children often before the children entered school and whether the students read six or more novels or books of poetry or essays during high school.[20] Parents who read books to children rather than playing with math toys or posing math problems are likely to be more interested in reading-oriented education, and the children of such parents are likely to read novels, poetry, or essays frequently. However, as the table shows, parents' behaviors do not vary based on first child gender. We also examine whether children converse with their sibling frequently[21] and whether the main topic of such

[20] The number six was chosen because this number approximately evenly splits students.
[21] The question includes a five-point Likert scale, and those who chose four or five are considered to converse frequently.

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conversation is studying, career paths, or school life.[22] Having a frequent conversation with sibling does not differ based on the gender of older sibling, but individuals with an older sister are more likely to talk about studying, career paths, or school life (p-value = 0.11).

Table 5 shows the regression results. Panel A of the table is restricted to the first children in two-child families, and panel B, the analytical sample of this study. As expected from the results in Table 4, no parental behaviors differ by first child gender (older sibling gender). For example, in column (1), when the dependent variable is whether parents read books to the surveyed children frequently before they entered school, the estimates are 0.053 and −0.034, and they are all insignificant. Regarding sibling interaction in columns (4) and (5), although conversation frequency does not vary based on older sibling gender, siblings are more likely to talk about studying, career paths, or school life when the first child is a girl (panel A) and an older sibling is a sister (panel B). Comparing the effects found in column (5), the effect is smaller in panel A (7.1 percentage points) than in panel B (10.8 percentage points), possibly because high school seniors do not talk about such topics with younger siblings, but rather with older siblings. The results in Tables 4 and 5 imply that the findings in column (1) of Table 3 were driven by interaction with an older sibling, not by parental behaviors.

When do sibling peer effects occur most frequently? As stated in the Empirical Strategy section, the following two conditions are necessary for the effects: sibling interaction and study effort. Comparing high school and middle school years,[23] the degree of sibling interaction is not likely to differ because the data used in this study show that 60.5% of 12th graders responded that

[22] They were provided nine choices of possible topics, including study and career paths as well as school life, and they were asked to choose one. We calculated the proportion of students who chose either of the two choices.
[23] Although elementary school children are likely to spend significant time with their siblings, they are less likely to spend much time on studying.

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they had frequent conversations with their siblings, while the analysis of 9th graders' data[24] shows that 64.1% responded in this manner. Considering that students spend more time on studying during high school than in middle school, sibling peer effects are more likely to occur during high school.

6.4. Does sample selection cause any bias?

In Section 4, we stated that the low proportion of female students in the sample was likely caused by parental decisions to become families with more than two children (sample selection). Before examining whether the sample selection causes any bias, we first examine whether having a girl as the first child affects the total number of children. Panel A of Table 6 shows that having a girl as the first child decreases the probability of having only child by 8.2 percentage points, and increases the probability of having more than two children by 26.0 percentage points. This implies that the first child's gender affects the total number of children in a family.

To check whether there is any bias arising from the sample selection, we add the second children from families with more than two children in the analysis: 84 children, 73 of whom are girls. In panel B of Table 6, the coefficient for *sister* is 0.164, which is not that different from the estimate in Table 3. This result implies that the low proportion of girls in the sample does not result in any bias.

[24] The data are a part of the Korean Education & Employment Panel, which includes information on 2,000 9th graders. The data are also publicly available at http://www.krivet.re.kr/eng/eu/eg/euCAADs.jsp

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6.5. Heterogeneous effects

To examine whether sibling gender effect found in Table 3 differs based on the second child's gender, we include the interaction between *sister* and *female* in equation (3). When, say, sibling peer effects are stronger for girls, the coefficient for the interaction term is likely to be positively significant. However, as Table 7 shows, the coefficient is −0.021 and is not significant, which implies that the effect does not differ based on second child gender.

7. Discussion and conclusion

Previous studies of sibling peer effects on test scores found that when older sibling's test scores increase, younger siblings' test scores increase, and that the effect size is 30–40%. Based on the results of previous studies, this study hypothesized for the first time in literature that having an older sister (brother) increases one's reading (math) score because sisters (brother) are likely to have higher reading (math) scores. Simply comparing the test scores in a certain subject for students with different sibling gender compositions could give biased results; thus, we use a student's relative reading test score as the dependent variable. We find that a student's relative reading test score is higher by 0.17 standard deviations if he or she has an older sister than if he or she has an older brother. This finding, according to subection 6.2, indicates that sibling peer effects on test scores are approximately 40% (38.7%). Because literature on sibling peer effects on test scores (e.g., Biavaschi, Giulietti, and Zimmermann, 2015; Nicoletti and Rabe, 2019) is scarce, this finding contributes to the literature by providing evidence of sibling peer effects on test scores.

The interaction between siblings, if any, could be initiated by an older sibling, a younger sibling, or both. For example, younger siblings may ask their older siblings study-related

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questions. It is also possible that older siblings may check first whether their younger ones have any problems with their studying or homework. In addition, the interaction can be initiated or encouraged by parents or even teachers if they attend the same school. For example, parents may have siblings share a room at home so that they have many chances to talk with and see (observe) each other. Either scenario appears to be plausible. Testing each of these hypotheses is beyond the scope of this study, and future studies may examine the sources of interactions between siblings.

The examination of the topic of this study requires students' test scores, their sibling's information—including gender and birth order—, and parental interest in children's education. There are numerous data sources for the first two factors—test scores and sibling information—but few provide information on parental interest in education, especially subject-specific interest, which implies that the analysis of the topic is limited in the majority of datasets containing student and family information, and the finding of this study could be a valuable addition to the literature.

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https://doi.org/10.1162/edfp_a_00352

References

Altmejd, Adam et al. 2020. O brother, where start thou? Sibling spillovers on college and major choice in four countries. CEP Discussion Paper No. 1691.

Altonji, Joseph G., Sarah Cattan, and Iain Ware. 2017. Identifying sibling influence on teenage substance Use. *Journal of Human Resources*, 52(1): 1-47.

Amin, Vikesh. 2009. Sibling sex composition and educational outcomes: A review of theory and evidence for the UK. *Labour*, 23(1): 67-96.

Azam, Mehtabul, and Geeta G. Kingdon. 2015. Assessing teacher quality in India. *Journal of Development Economics*, 117(6): 74-83.

Becker, Gary, and Nigel Tomes. 1976. Child endowments and the quantity and quality of children. *Journal of Political Economy*, 84(4): S143-S162.

Behrman, Jere R., Robert A. Pollak, and Paul Taubman. 1982. Parental preferences and provision for progeny. *Journal of Political Economy*, 90(1): 52-73.

Bharadwaj, Prashant, Giacomo De Giorgi, David Hansen, and Christopher A. Neilson. 2016. The gender gap in mathematics: Evidence from Chile. *Economic Development and Cultural Change*, 65(1): 141-166.

Biavaschi, Costanza, Corrado Giulietti, and Klaus F. Zimmermann. 2015. Sibling influence on the human capital of the left-behind. *Journal of Human Capital*, 9(4): 403-438.

Bifulco, Robert, Jason M. Fletcher, and Stephen L. Ross. 2011. The effect of classmate characteristics on post-secondary outcomes: Evidence from the Add Health. *American Economic Journal: Economic Policy,* 3(1): 25-53.

Butcher, Kristin F., and Anne Case. 1994. The effect of sibling sex composition on women's education and earnings. *Quarterly Journal of Economics*, 109(3): 531-563.

Education Finance and Policy Just Accepted MS.
https://doi.org/10.1162/edfp_a_00352

Cho, Hyunkuk. 2017. The effects of fathers' working hours on youth behavior: Evidence from a change in the standard workweek. *Korean Economic Review*, 33(2): 295-324.

Clotfelter, Charles T., Helen F. Ladd, and Jacob L. Vigdor. 2010. Teacher credentials and student achievement in high school: A cross-subject analysis with student fixed effects. *Journal of Human Resources*, 45(3): 655-681.

Dahl, Gordon B., and Lance Lochner. 2012. The impact of family income on child achievement: Evidence from the earned income tax credit. *American Economic Review*, 102(5): 1927-1956.

Dahl, Gordon B., Dan-Olof Rooth, and Anders Stenberg. 2020. Family spillovers in field of study. NBER Working Paper No. 27618.

Dee, Thomas S. 2007. Teachers and the gender gaps in student achievement. *Journal of Human Resources*, 42(3): 528-554.

Education: The Other Arms Race. 2013. The Economist. Retrieved from https://www.economist.com/news/special-report/21588204-south-koreas-education-fever-needs-cooling-other-arms-race

Fryer Jr, Roland G., and Steven D. Levitt. 2010. An empirical analysis of the gender gap in mathematics. *American Economic Journal: Applied Economics*, 2(2): 210-40.

Goodman, Joshua, Michael Hurwitz, Jonathan Smith, and Julia Fox. 2015. The relationship between siblings' college choices: Evidence from one million SAT-taking families. *Economics of Education Review*, 48(5), 75-85.

Gurantz, Oded, Michael Hurwitz, and Jonathan Smith. 2020. Sibling effects on high school exam taking and performance. *Journal of Economic Behavior & Organization*, 178(10): 534-549.

Education Finance and Policy Just Accepted MS.
https://doi.org/10.1162/edfp_a_00352

Hauser, Robert M., and Hsiang-Hui D. Kuo. 1998. Does the gender composition of sibships affect women's educational attainment?. *Journal of Human Resources*, 33(3): 644-657.

Hong, Sok Chul, and Jungmin Lee. 2017. Who is sitting next to you? Peer effects inside the classroom. *Quantitative Economics*, 8(1): 239-275.

How South Korea Learned to Love Baby Girls. 2017. *The Economist*. Retrieved from https://www.economist.com/international/2017/01/19/how-south-korea-learned-to-love-baby-girls

Joensen, Schrøter J., and Helena S. Nielsen. 2018. Spillovers in education choice. *Journal of Public Economics*, 157(1): 158-183.

Kaestner, Robert. 1997. Are brothers really better? Sibling sex composition and educational achievement revisited. *Journal of Human Resources*, 32(2): 250-284.

Lavy, Victor, and Analia Schlosser. 2011. Mechanisms and impacts of gender peer effects at school. *American Economic Journal: Applied Economics*, 3(2): 1-33.

Lavy, Victor, Olmo Silva, and Felix Weinhardt. 2012. The good, the bad, and the average: Evidence on ability peer effects in schools. *Journal of Labor Economics*, 30(2): 367-414.

Lee, Sanghoon. 2007. The timing of signaling: To study in high school or in college?. *International Economic Review*, 48(3): 785-807.

Lundborg, Petter, Anton Nilsson, and Dan-Olof Rooth. 2014. Parental education and offspring outcomes: Evidence from the Swedish compulsory school reform. *American Economic Journal: Applied Economics*, 6(1): 253-278.

Nicoletti, Cheti, and Birgitta Rabe. 2019. Sibling spillover effects in school achievement. *Journal of Applied Econometrics*, 34(4): 482-501.

Education Finance and Policy Just Accepted MS.
https://doi.org/10.1162/edfp_a_00352

OECD. 2004. *Learning for Tomorrow's World–First results from PISA 2003*. PISA, OECD Publishing, Paris.

OECD. 2015. *The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence*. PISA, OECD Publishing, Paris.

OECD. 2019. *PISA 2018 Results (Volume II): Where All Students Can Succeed*. PISA, OECD Publishing, Paris.

Oettinger, Gerald S. 2000. Sibling similarity in high school graduation outcomes: Causal interdependency or unobserved heterogeneity?. *Southern Economic Journal*, 66(3): 631-648.

Qureshi, Javaeria A. 2018. Additional returns to investing in girls' education: Impact on younger sibling human capital. *The Economic Journal*, 128(616): 3285-3319.

Sacerdote, Bruce. 2001. Peer effects with random assignment: Results for Dartmouth roommates. *Quarterly Journal of Economics*, 116(2): 681-704.

Statistics Korea. 2019. 2018 Birth statistics. Downloadable at http://kostat.go.kr/portal/korea/kor_nw/1/1/index.board?bmode=read&aSeq=377055 (written in Korean)

Vandewater, Elizabeth A., David S. Bickham, and June H. Lee. 2006. Time well spent? Relating television use to children's free-time activities. *Pediatrics*, 117(2): e181-e191.

Education Finance and Policy Just Accepted MS.
https://doi.org/10.1162/edfp_a_00352

Table 1: Comparison of three groups

	All second children in two-child families (1)	Those included in the analysis (2)	Those omitted due to missing test score information (3)	*P*-value (4)
Has an older sister (%)	44.8	46.0	40.1	0.25
	(49.8)	(49.9)	(49.2)	
Female (%)	37.6	37.7	36.9	0.87
	(48.5)	(48.5)	(48.4)	
Sibling age difference	2.9	2.8	3.1	0.20
	(2.0)	(2.0)	(1.9)	
Father – college graduate (%)	31.8	32.2	30.4	0.72
	(46.6)	(46.8)	(46.2)	
Father – high school graduate (%)	50.3	51.6	45.2	0.22
	(50.0)	(50.0)	(50.0)	
Mother – college graduate (%)	13.0	13.8	10.1	0.29
	(33.7)	(34.5)	(30.2)	
Mother – high school graduate (%)	59.8	59.8	59.7	0.97
	(49.1)	(49.1)	(49.3)	
Paternal age	48.4	48.5	48.1	0.24
	(3.3)	(2.9)	(4.3)	
Maternal age	45.5	45.5	45.4	0.92
	(2.5)	(2.5)	(2.7)	
Monthly household income (million Korean won)	3.1 (2.1)	3.1 (1.9)	3.4 (2.8)	0.23
Parents read books frequently before entering school (%)	26.3 (44.1)	27.6 (44.8)	21.3 (41.1)	0.16
Read six or more novels or books of poetry or essays during high school (%)	42.0 (49.4)	40.0 (40.0)	50.0 (50.2)	0.04
Out-of-school reading tutoring hours per week	1.2 (2.2)	1.2 (2.3)	0.9 (1.8)	0.14
Out-of-school math tutoring hours per week	2.3 (3.1)	2.5 (3.2)	1.1 (2.4)	0.00
Have a conversation with sibling frequently (%)	55.0 (49.8)	56.7 (49.6)	48.4 (50.2)	0.10
Main topic of conversation with sibling is studying, career paths, or school life (%)	39.0 (48.8)	40.0 (49.0)	35.2 (48.0)	0.34
Number of schools	100	99	63	
Maximum number of observations	595	472	123	

The *p*-value in column (4) is for the difference between columns (2) and (3). One million Korean won is approximately equal to 900 U.S. dollars.

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Table 2: The effect of parental characteristics on the first child's gender

	Dependent variable = Whether the first child is a girl
Father – college graduate (=1)	0.058
	(0.093)
Father – high school graduate (=1)	−0.054
	(0.078)
Mother – college graduate (=1)	−0.157
	(0.105)
Mother – high school graduate (=1)	−0.101
	(0.064)
Paternal age	0.007
	(0.010)
Maternal age	0.006
	(0.012)
Household income	0.003
	(0.015)
P-value of F-test	0.35
R-squared	0.00
Number of observations	420

Standard errors are in parentheses. They are clustered at the school level. The regression also includes a constant. The analysis is restricted to the analytical sample whose information on parental characteristics is available.

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Table 3: Sibling gender effects on test scores

	Dependent variable = Scores of		
	Relative reading (1)	Reading (2)	Math (3)
Has an older sister (=1)	0.170**	0.237***	0.067
	(0.082)	(0.081)	(0.085)
Female (=1)	0.184**	0.206**	0.022
	(0.093)	(0.097)	(0.091)
R-squared	0.01	0.02	0.00
Number of observations	472	472	472

Standard errors are in parentheses. They are clustered at the school level. These regressions also include a constant.
***: statistically significant at the 1% level
**: statistically significant at the 5% level

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Table 4: Parental behavior and sibling interaction based on older sibling gender

	Has an older sister (1)	Has an older brother (2)	*P*-value (3)
Parents read books frequently before entering school (%)	24.4 (43.1)	30.2 (46.0)	0.16
Students read six or more novels or books of poetry or essays during high school (%)	41.0 (49.3)	38.8 (48.8)	0.37
Out-of-school reading tutoring hours per week	1.2 (2.1)	1.2 (2.6)	0.91
Out-of-school math tutoring hours per week	2.6 (3.3)	2.5 (3.2)	0.62
Have a conversation with sibling frequently (%)	57.1 (49.6)	56.5 (49.7)	0.88
Main topic of conversation with sibling is studying, career paths, or school life (%)	43.8 (49.7)	36.4 (48.2)	0.11
Maximum number of observations	217	255	

The *p*-value is for the difference between columns (1) and (2).

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Table 5: Possible mechanisms

	Dependent variable =				
	Parents read books frequently before entering school (1)	Read six or more novels or books of poetry or essays during high school (2)	Number of reading tutoring hours minus number of math tutoring hours (3)	Have a conversation with sibling frequently (4)	Main topic of conversation with sibling is studying, career paths, or school life (5)
Panel A: Restricted to the first children in two-child families					
Female (=1)	0.053	0.019	−0.018	0.002	0.071*
	(0.041)	(0.044)	(0.283)	(0.041)	(0.038)
R-squared	0.00	0.00	0.00	0.00	0.01
Number of observations	608	608	609	610	610
Panel B: Restricted to the analytical sample					
Has an older sister (=1)	−0.034	0.019	0.014	−0.002	0.108**
	(0.043)	(0.046)	(0.352)	(0.041)	(0.051)
Female (=1)	0.099*	−0.012	0.571	−0.037	0.145***
	(0.048)	(0.055)	(0.365)	(0.053)	(0.042)
R-squared	0.02	0.00	0.01	0.00	0.03
Number of observations	472	472	472	472	472

Standard errors are in parentheses. They are clustered at the school level. The analysis in panel A is restricted to the first children with both subjects test scores in two-child families, and the analysis in panel B is restricted to the analytical sample of this study. These regressions also include a constant.
***: statistically significant at the 1% level
**: statistically significant at the 5% level
*: statistically significant at the 10% level

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Table 6: The effect of first child gender on the total number of children (panel A) and sibling gender effects on relative test scores including families with ≥2 children (panel B)

	Dependent variable = Whether a family has	
Panel A	Only child (1)	More than two children (2)
First child is a girl (=1)	−0.082***	0.260***
	(0.012)	(0.019)
R-squared	0.02	0.09
Number of observations	1,914	1,764

Panel B	Dependent variable = Relative reading scores
Has an older sister (=1)	0.164**
	(0.072)
Female (=1)	0.144*
	(0.088)
R-squared	0.01
Number of observations	556

Standard errors are in parentheses. Those in panel B are clustered at the school level. These regressions also include a constant. Column (2) of panel A does not include one child family, and panel B includes the second child from all families. Lastly, the regression in panel B includes dummy variables for the total number of children.
***: statistically significant at the 1% level
**: statistically significant at the 5% level
*: statistically significant at the 10% level

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Table 7: Heterogeneous analysis

	Dependent variable = Relative reading scores
Has an older sister (=1)	0.177*
	(0.098)
Female (=1)	0.192
	(0.119)
Has an older sister (=1)	−0.021
× Female (=1)	(0.161)
R-squared	0.01
Number of observations	472

Standard errors are in parentheses. They are clustered at the school level. The regression also includes a constant.
*: statistically significant at the 10% level

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Appendix

Figure A1: Map of Korea

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Table A1: Sibling gender effects after controlling for school characteristics

	Dependent variable = Relative reading scores
Has an older sister (=1)	0.175**
	(0.081)
Female (=1)	−0.237**
	(0.102)
Proportion of teachers with graduate degrees	−0.001
	(0.004)
Proportion of teachers having fewer than 10 years of experience	0.002
	(0.004)
Proportion of female teachers	−0.005
	(0.004)
Proportion of contract teachers	−0.010*
	(0.006)
Class size	0.020**
	(0.009)
Coeducational school	0.094
	(0.065)
R-squared	0.03
Number of observations	472

Standard errors are in parentheses. They are clustered at the school level. These regressions also include a constant. Contract teachers mean teachers with fixed-term (non-renewable) contracts.
**: statistically significant at the 5% level
*: statistically significant at the 10% level