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Female Mentors and Peers: *A Heterogeneity Analysis of Gender Gaps in Attitudes towards STEM in South Korea*

Seo-Young CHO

Abstract

This paper investigates whether gender-matching school environments can foster girls' interest and motivation in science. Using the 2015 PISA data for South Korea, the findings show that single-sex schooling and female teachers have positive effects on high-performing girls' attitudes in science studies. By attending an all-girls school and being taught by female science teachers, girls who are ranked in the highest quartile of the science test become as motivated and interested in pursuing studies and careers in STEM fields as boys in the same rank. In addition, female teachers also enhance competitive attitudes of average- and low-performing girls. But single-sex schooling has no positive effect on them. These heterogeneous results propose gender-matching schooling as a useful policy instrument to recruit female talent among high-performing girls into STEM fields. Yet, this effect is not universal and therefore cannot be generalized to everyone.

Keywords: Gender, STEM, gender-matching schooling, cognitive and non-cognitive performance, South Korea

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Seo-Young CHO is a senior researcher for quantitative policy research, Department of Cultural Management and Gender Studies (IKM), University of Music and Performing Arts, Vienna (MDW). E-mail: cho@mdw.ac.at.

Introduction

Statistics provided by the Program for International Student Assessment (PISA) (OECD 2015) present an interesting case of gender gaps in student performance in South Korea. While South Korean girls are as good as boys in math and science studies (they even slightly outperform boys in science), they are significantly less motivated and interested than boys in pursuing studies and careers in the fields of science, technology, engineering, and math (STEM) (see Fig. 1).[1]

Observing this incongruity, this paper aims to shed light on such gender differences in attitudes towards science. As illustrated in Figure 1, South Korean girls' low motivation and interest in science cannot be explained by their lack of cognitive abilities, given their high level of educational attainments. Instead, one may find a more convincing answer by investigating social conditions and environments that discourage girls from participating in STEM fields. For instance, girls are more likely to face challenges in establishing themselves in these fields because STEM are considered typically male-dominated areas and therefore successful women professionals and mentors who can provide positive role models for girls are rare (Bracey 2006; Hill 2015; Gneezy et al. 2003; Niederle and Vesterlund 2007). In South Korea, less than 20 percent of professionals in STEM fields are women, while women form about 40 percent of the total regular labor force in the country (Government of the Republic of Korea 2016).

With this in mind, this paper investigates school environments where girls can more easily adopt positive gender roles for themselves and estimates such school effects on girls' performance in STEM fields. In this regard, single-sex schooling and female teachers are suggested as providing school environments that can foster girls' attitudes by facilitating interactions between female mentors and peers (gender-matching schooling). In all-girls schools, girls can develop more positive and active gender identities by communicating and cooperating with other girls (especially in the absence

1. In other OECD countries, girls and boys on average exhibit the same level of motivation in science (OECD 2017).

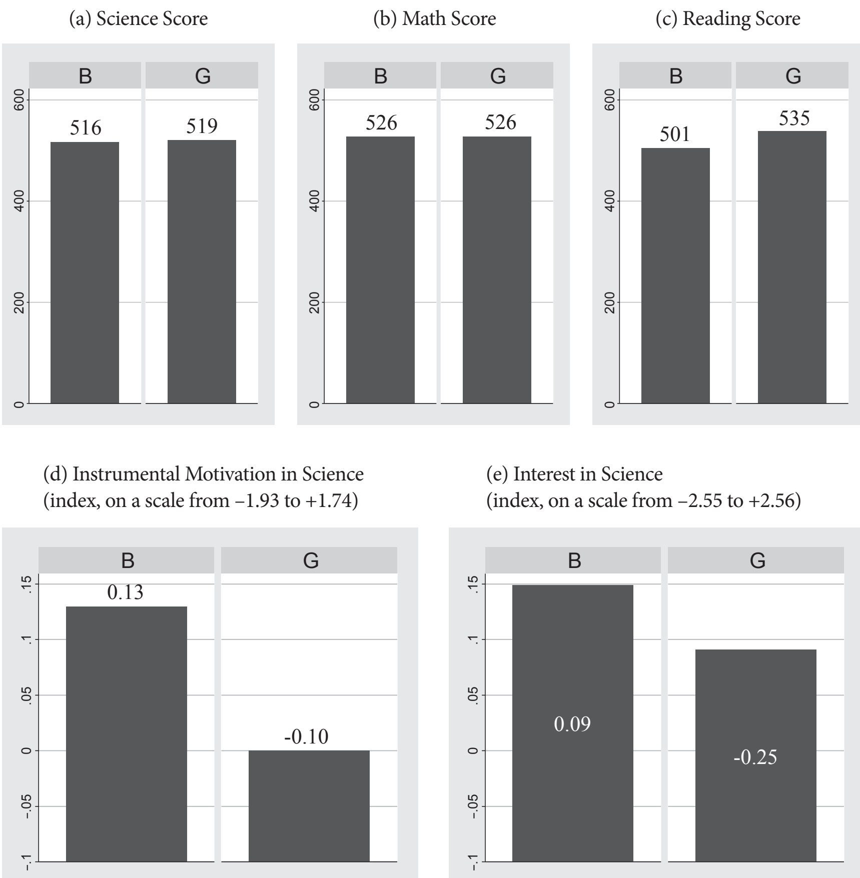

Figure 1. Gender Differences in Cognitive and Non-cognitive Performance in South Korea

Source: OECD (2015).

of boys), and thus they can more readily be driven to assume lead roles. Also, female teachers, in their role as professionals and mentors, can serve as gender role models for girls, motivating them to actively participate in class and set ambitious career goals.

To date, various studies provide supportive evidence of gender-matching schooling in many countries. The positive effect of single-sex schooling on girls' studies and attitudes are documented in: Booth and Nolen (2012) for the United Kingdom, Schneeweis and Zweimüller (2012) for Austria, McCoy et al. (2012) for Ireland, Hoxby (2000), Fryer and Levitt (2010), and Lavy and Schlosser (2011) for the United States, Eisenkopf et al. (2015) for Switzerland, and Jackson (2012) for Trinidad and Tobago. However, the role of single-sex schools is challenged in other studies that attribute the positive outcome of single-sex schools to endogenous school choices (Billger 2009; Halpern et al. 2011; Aedin et al. 2013; Strain 2013; Goodkind et al. 2013). In contrast to single-sex schooling, the literature generally suggests the positive effect of female teachers on girls (Carrell et al. 2010; Nixon and Robinson 1999; Bettinger and Long 2005; Dee 2007).

Regarding South Korea specifically, studies report generally positive results of gender-matching schooling for cognitive outcomes (Park et al. 2013; Kim 2012; Link 2012; Dustmann et al. 2018 for single-sex schooling and Lim and Meer 2017 for female teachers). However, studies on non-cognitive outcomes do not provide evidence supporting the role of all-girls schools. For example, Lee et al. (2014) find that girls in all-girls schools are not more competitive than girls in mixed-sex schools. Park et al. (2018) further show that, while single-sex schooling increases boys' interest and self-efficacy in math and science, this effect does not exist for girls.

However, such effects could be sensitive to heterogeneous types of students. Existing studies to date have focused on outcomes at the aggregate level, but gender-matching schooling may produce different results depending on students' abilities. Especially, girls with higher cognitive abilities could receive greater benefits from gender-matching environments where their abilities are more likely to be recognized, as opposed to mixed-sex environments where girls' abilities may be undervalued compared to boys. With this in mind, my study elaborates the channel of gender-matching school effects by disentangling the effects on heterogeneous groups of students based on their cognitive abilities.

Through heterogeneity analysis, this paper finds an asymmetrically positive effect of gender-matching schooling on high-performing girls' attitudes towards science. By attending an all-girls school and being taught by a female science teacher, girls who are ranked at the highest quartile of the science test (measured by PISA 2015) become as motivated and interested in pursuing studies and careers in STEM fields as high-performing boys. In addition, female teachers generally enhance competitive attitudes of average- and low-performing girls. But the effect of single-sex schooling is not as positive for these girls. These heterogeneous results propose gender-matching schooling as a useful policy instrument to recruit female talent among high-performing girls into STEM fields. Yet, this effect is not universal for all girls.

Empirical Framework

Education Production Function

The central focus of the empirical analysis is to identify the net effect of gender-matching school environments on girls' performance and attitudes. To isolate this effect, the model includes an exhaustive list of covariates that have potentially compounding effects on outcome variables. The selection of variables follows the education production function suggested by Hanushek (1986) and Krueger (1999). In the education production model, outputs (student performance) are determined as: Y (educational output) = f (individual, family, school, teacher, and peer inputs).

In this model, student performance (Y) comprises not only their study outcomes (cognitive performance) but also attitudes (non-cognitive performance) as both cognitive and non-cognitive skills are important determinants of successful career development. Also, distinguishing between study and attitudinal outcomes enables us to explain the observed disparity between the high level of study achievements and the low level of motivation and interest, which South Korean girls demonstrate.

The education production function is rewritten in an econometric model below that specifies covariates and their relationships with the outcome variables. The variables used in this model are taken from the 2015 PISA test scores and accompanying surveys with students and their teachers (OECD 2015). The PISA assesses learning outcomes of students who are aged between 15 years and 3 months and 16 years and 2 months. In South Korea, the majority of this age group are high school students, but about 15 percent of PISA participants attended middle schools. In this analysis, the sample is limited to high school students only (i.e., international grade 10 or higher) in order to minimize the heterogeneity of students from different levels of schools.

$$\text{Performance}_i = a + \beta_1\text{female student}_i + \beta_2\text{boy school}_i + \beta_3\text{girl school}_i + \beta_4\text{female teacher}_i + \beta_5\text{female student}_i{*}\text{female teacher}_i + X_i'\Gamma + S_i'\Psi + T_i'\Pi + B_i'\text{Ɣ} + R_i'\text{Ɲ} + u_i \qquad (1)$$

The set of the performance variables (Y) consists of several indicators that evaluate student performance. First, student cognitive performance is measured by the PISA test scores in reading, math, and science subjects on a scale from 0 to 1,000.[2] Second, non-cognitive performance in STEM fields is proxied by student self-assessments of their instrumental motivation, confidence, and interest in science. The PISA data provides composite indices on these three dimensions of student attitudes by compiling answers of the survey questionnaire filled by students after taking the tests. The questions about instrumental motivation include the student's future plans and aspirations in STEM fields, measured on a scale from –1.93 to 1.74. The questions on interests in science refer to the degree of the student's interest in a broad spectra of science topics, measured on a scale from –2.55 to 2.56. The index of confidence in science assesses the level of the student's self-confidence and efficacy in handling science-related problems that is measured on a scale from –3.76 to 3.28. These variables reveal important individual attitudes that influence one's decision to pursue studies and careers in STEM fields.

Female student is a dummy variable indicating a student's gender. *Female teacher* shows whether student i is taught by a female teacher in the

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2. The test scores take a logarithmic form in this model for two reasons: to straightforwardly interpret coefficients as percentage-point changes and to normalize the distributions of the test scores. Without taking the logarithmic form, the distributions of the scores would be skewed on the right side, which would make it difficult to establish linearity in effects.

respective course (i.e., reading, math, and science) corresponding to the outcome variable. *Boy school* and *girl school* represent single-sex schooling for boys and girls, respectively. Hence, gender-matching school effects on girls are estimated through two variables: *girl school* and *female student*female teacher*. Accordingly, positive gender-matching effects on girls' performance are hypothesized as follows.

$$H_0: \quad \rightarrow \quad \beta_3 > 0$$
$$H_0: \quad \rightarrow \quad \beta_5 > 0$$

The model integrates various additional input variables so that omitted variable biases can be minimized. Accordingly, vectors X, S, T, B, and R consist of the following variables: a student's socioeconomic and family backgrounds (X), school characteristics (S), teacher characteristics (T), behavioral patterns (B), and his/her relationships with teachers and peers (R). The choice of input variables follows the literature. Student socioeconomic characteristics are taken from Hanushek (1986), who emphasizes the importance of demographic backgrounds in determining student performance. The choice of school inputs follows Krueger (2003) and Hanushek (2011), who propose class sizes and teacher quality as key inputs. In addition, a student's behavioral patterns and relationships with teachers and peers are incorporated in the model because these variables often mirror a student's personality and mentality. Accounting for such behavioral and relational influences can reduce omitted variable biases by controlling for the effects of a student's unobserved characteristics on his/her performance. The list of input variables in each vector is detailed below. These variables are taken from the accompanying surveys of the 2015 PISA with students and teachers. The descriptive statistics and measurement scales of all variables used for the estimation are presented in Appendix.

- G (gender and gender-matching variables) = {female student; boy school; girl school; female teacher; female student*female teacher}
- X (student's and family characteristics) = {father's education; mother's education; student's economic, social, and cultural status (ESC) index;

family spending on education; parental support for learning at home; parental emotional support; (and intellectual ability, see below)}

- S (school characteristics) = {school type (public or private school); community size where the school is located; teacher-student ratio; school size; and school quality as perceived by parents}
- T (teacher's characteristics) = {teacher's tenure; and teacher's years of experience}
- B (student's behaviors) = {frequency of skipping classes; coming to school late; chatting online at school & outside school; and participation in social networks}
- R (teacher and peer relationship) = {feeling of belonging to the school; and unfairness of teachers}

Moreover, in estimating the model of non-cognitive performance (attitudes), a variable that measures intellectual abilities is additionally included as an explanatory variable because one's knowledge level leverages his/her non-cognitive performance. Scientific knowledge can be the most crucial factor in determining attitudes towards science. However, the available measurement of scientific knowledge—science (or math) scores in the PISA test—has a tautological relationship with non-cognitive performance in science, as they share latent concepts to a great extent. To avoid this problem, reading scores are used as a proxy to capture a general level of intelligence instead. High correlation between the science and reading scores ($r = 0.85$) supports the validity of a reading score as a proxy variable.

The econometric model formulated in Equation 1 is estimated by two methods. First, an OLS estimation is applied, assuming linearity in relationships between the explanatory variables and continuous dependent variables. Second, the model is constructed as a multilevel (mixed) one in which observations are nested within schools. This approach allows us to address school-specific heterogeneity of observations by capturing varying data patterns across schools. In this nested model, intercepts are treated as random effects that account for the data structure grouped by school. In addition, robust standard errors are clustered at the school level because unobserved variations of observations in the same school are possibly correlated to one another.

Endogenous School Choice and Propensity-Score Matching

Among the two gender-matching school effects hypothesized above, the interaction between a female student and a female teacher is assumed to be fairly exogenous because the assignment of teachers inside a school is a decision of the school but not of students/parents. One may speculate that female teachers may be assigned to systematically different classes—for example, consisting of worse-performing students or those from low-income families. However, this is unlikely. In South Korea, students are randomly allocated among different classes (at least in regular classes that were surveyed in the PISA), independent of their performance or background. Thus, each class includes a wide range of students of different study ranks and demographic characteristics.

In contrast, single-sex schooling is more likely endogenous to students' performance outcomes if students decide to attend a same-sex school because of their personal background and characteristics. Under the presence of such self-selection biases, a causal effect of single-sex schooling on students' performance cannot be identified. Hence, a critical question remains to be examined: are students in single-sex schools systematically different from those in mixed-sex ones?

In this respect, the data of South Korea provides a comparative advantage in equilibrating students between single- and mixed-sex schools because single-sex schooling is more common there than in most other countries—for instance, less than five percent of all high schools in the United States provide single-sex education. In South Korea, more than a quarter of high school students attend single-sex schools, as seen in the sample of the PISA 2015—30 percent of boys and 25 percent of girls. Thus, systematic differences in students between single- and mixed-sex schools are less salient there. Also, the large share of single-sex schools enables a sufficient number of observations for a viable comparison.

However, the South Korean sample is not completely free of selection biases because students are not randomly assigned to schools, instead having the option to designate preferred schools. For instance, since 2010, middle-school students in Seoul have been allowed to submit the names of three preferred high schools, with school assignments following based on their preferences. According to Kim (2012), students have tended to avoid mixed-sex schools after the introduction of this policy. One of the main reasons for preferring single-sex schools is that students in all-boys and all-girls schools outperform those in mixed-sex schools on university entrance exams. Thus, students (and parents) who are more concerned about studies and opportunities for higher education may choose single-sex schools. On the other hand, counterarguments are also plausible. Girls may not necessarily prefer single-sex schooling because competition for grades has become more intensive in all-girls schools with girls' outperformance in studies over boys in recent years. Therefore, girls in all-girls schools may receive disadvantages from single-sex schooling because it would be more difficult for them to secure higher school scores so important for college admission.

Considering both the arguments and counterarguments of single-sex schooling, self-selection into a specific type of schools remains in question. Therefore, various methods are employed here to account for the endogenous relationship between school choices and student performance. First, a number of educational inputs are incorporated in the empirical model in a holistic manner. Including an extensive set of covariates helps reduce biases arising from an endogenous school choice. However, a large set of controls may not fully ensure that no covariate remains unobserved. For instance, unobserved family values and students' personality may affect their performance and school choice simultaneously. With this in mind, a propensity-score matching (PSM) analysis is conducted to further address unobserved heterogeneity.

The PSM estimations take the following procedures. First, an individual's probability of choosing single-sex schooling is predicted based on one's observed characteristics, and students with similar probabilities but receiving different treatments (single- or mixed-sex schooling) are matched to equate differences between treatment and control groups. Then, the average treatment effect (ATE) of attending a single-sex school is computed by imputing the missing potential outcome for each subject (see Equation 2 below). This is done by averaging outcomes of similar subjects that receive the other treatment. Thus, the PSM estimator captures the average difference between the observed and potential outcomes for each subject (Abadie and Imbens 2011).

$$ATE = E\,[outcome_{single\text{-}sex} - outcome_{mixed\text{-}sex} \mid G, X, S, T, B, R] \qquad (2)$$

The PSM model is based on the implicit assumption that an individual unobserved heterogeneity is correlated with his/her observed characteristics, which are used to equate students with different school choices. This assumption is reasonable given that individuals' values and personalities are likely determined through interactions with their socioeconomic conditions and other demographic traits. In this model, the student's behavioral and relational characteristics in particular are explicitly observed and these variables are likely to interact with unobserved values and beliefs. Nonetheless, a PSM method may not produce fully unbiased estimators if observed and unobserved characteristics are only weakly correlated.

Recognizing this limitation, an additional approach is employed by conducting the PSM estimations with observations in public schools only in order to further address the endogeneity of school choices. Limiting the sample to public schools can minimize unobserved heterogeneity because students in private schools tend to be different in their backgrounds and orientations (including values and religions, as some private schools have certain religious, pedagogical, or philosophical directions) from others in public schools. Also, given that private schools have different school quality, curriculum, and teacher recruitment processes,[3] excluding them from the sample can reduce biases caused by unobserved heterogeneity at the school level.

3. In public schools, teachers must pass the national teacher exam to be employed, but this exam is not required for teachers in private schools. Also, teachers in public schools are regularly rotated to different schools within the province/city (e.g., every five years), while teachers in private schools are not subject to obligatory relocation.

Findings

Estimating the Average Effects of Gender and Gender-matching Schooling

This section presents the average effects of gender and gender-matching schooling on all students.[4] First, regarding the findings of students' cognitive performance (Table 1), there is no effect on math and science scores based on a student's own gender, as expected from the descriptive findings in Figure 1. However, in reading, girls have a significant advantage that their average score is five percentage points (p.p.) higher than boys'. On the other hand, gender-matching schooling is widely unimportant in explaining study outcomes in all subjects—for both boys and girls. Attendance at all-boys or all-girls schools has no effect on test scores. Being taught by a female science teacher increases student scores in this subject to some extent. However, this result is found in the multilevel estimations only, and the estimated effect is too small in size to draw a meaningful interpretation.[5]

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4. The maximum number of the sample for the PISA 2015 for South Korea is 5,581, and this is reduced to 3,259 in this analysis because of: (i) the exclusion of middle-school students (about 15 percent) and (ii) missing observations in the student and teacher surveys due to the inclusion of an exhaustive set of covariates constructed by using these survey questions (additional 30 percent).
5. In addition, the results of the control variables (Table 1) are presented separately here. Among school and teacher inputs, a higher student-teacher ratio deteriorates study outcomes, supporting the benefits of smaller classes. Nonetheless, most other variables have no effect on student test scores: school size, school's status (public or private), community size, or teacher's tenure and experience. Also, the effect of school quality as evaluated by parents is negligible (despite the statistical significance of its effect to some extent). The limited roles of school and teacher inputs underscore the importance of private after-school tutoring that often overshadows formal schooling in South Korea (Kim 2012). Instead, family background and socioeconomic status are important inputs for student cognitive performance. A student's economic, social, and cultural (ESC) status, family spending on education, and parental emotional support have positive effects on all of science, math, and reading scores. Also, a mother's education positively influences a student's math and science scores. Furthermore, student behavior has great explanatory power over his/her cognitive performance. Frequently skipping classes and coming to school late result in low test scores, as does frequenting online chatting at school. Additionally, a student's relationship with teachers—(dis)trust in the fairness of a teacher—

The analysis of cognitive performance suggests little support of gender or gender-matching effects on science and math studies. However, the outlooks are different when the effects are estimated on non-cognitive outcomes—student attitudes towards science (Table 2). First, the effect of the student's own gender is negative for girls. Girls' instrumental motivation in science is lower than that of boys by 6.5–9.5 p.p. and their interest in science is also lower by 6.8–9.2 p.p. Furthermore, a teacher's gender has a significant effect on student attitude, but the effect is different between boys and girls. Female science teachers reduce boys' motivation, confidence, and interest in science by 4.0, 1.7, and 1.7 p.p., respectively. However, for girls, the effect of being taught by a female teacher is positive, as the positive interaction effect of a female student-teacher pair outweighs the negative effect of a female teacher. Girls increase their motivation for and interest in science by 0.7 and 2 p.p., respectively when they are taught by a female science teacher. In addition, this positive interaction effect of a female student-teacher pair also reduces the negative effect of a girl's own gender on her attitudes. If a girl is taught by a female teacher, the negative effect of her own gender on her motivation decreases by 5.3–7.5 percent, and the effect on her interest by 20.5–21.5 percent (see columns 2, 4, 10, and 12 of Table 2).[6]

In contrast to the positive gender-matching effect between a female student and a female teacher, single-sex schooling has no influence on a student's non-cognitive performance—for either girls or boys. Most other school inputs also have no effect, except for perceived school quality, which is positively associated with one's motivation and interest levels. Teacher

is an important factor in the student's cognitive learning.

6. One can also interpret the positive gender-matching effect of a female student-teacher pair in another way by comparing the (student's own) gender effect between girls taught by female teachers and others by male teachers. Let's take the example of column 2 in Table 2. For girls who are taught by male teachers, the negative gender effect of being a girl is –0.349 (or their motivation level is 9.5 percent lower than that of boys). By comparison, for girls taught by female teachers, this negative gender effect is mitigated by the gender-matching effect of a female student-teacher pair (–0.158+0.184 = 0.026). Therefore, their gender effect of being a girl becomes smaller: –0.349 + 0.026 = –0.323 (or their motivation level is 8.8 percent lower than that of boys). That being said, female teachers reduce girls' negative gender effects by 7.5 percent (from a negative effect of 9.5 percent to 8.8 percent).

input is also unimportant for a student's non-cognitive performance. However, a student's family background and behavioral patterns provide significant explanations for his/her attitudes. In addition, one's intelligence level (proxied by reading scores) has a positive effect on attitudes, as to be expected, but the magnitude of the effect is trivial—about a tenth of 1 p.p.

Self-Selection Effects

The baseline results above suggest that female teachers have an overall positive effect on girls' attitudes towards science, while all-girls schools are not important for their cognitive and non-cognitive outcomes. As discussed in above, the choice of a single-sex school is likely endogenous to students' performance and thus, its effect is further examined by employing a propensity-score matching method. In this analysis, the sample is further disentangled by school types. First, the sample includes all schools, and then it is limited to public schools that represent 70 percent of the full sample.

Table 3 presents the PSM results, in that the effect of an all-girls school remains generally minimal in determining girls' cognitive and non-cognitive performance. In the full sample, the only significant effect arises in girls' math scores, but the effect is negative and marginally significant at a 10 percent level only. Furthermore, this effect does not hold in the public-school sample. In public schools, the effect of single-sex schooling is positive on girls' confidence only, but it is significant just at a 10 percent level.

As presented here, the PSM analysis provides little evidence of all-girls schools fostering girls' attitudes and study outcomes, while showing that attending an all-boys school has a more significant effect on boys' study outcomes. It increases boys' science and reading scores by 3.5 and 3.9 p.p., respectively (Table 3.1). However, when the sample is limited to public schools, the effect disappears. This positive effect is indeed driven by those who selected private all-boys schools, but not by the general population of male high school students in South Korea.

Is Gender-matching Schooling More Beneficial to High-performing Girls?

The results above provide mixed evidence regarding the effects of gender-matching schooling on girls. On average, female teachers influence girls' attitudes positively but all-girls schools do not. Yet, gender-matching schooling may not produce homogeneous effects on all girls but affect girls differently depending on their academic aptitudes. This hypothesis is articulated because women's abilities are often less valued when male counterparts are present and especially, highly able women and girls are more challenged than average ones in male-dominated fields such as STEM (Niederle and Vesterlund 2007). In contrast, girls' abilities can be more fairly recognized in gender-matching school environments with female mentors and peers and therefore, talented girls can be more encouraged to be confident and motivated to aim higher. With this argument, the gender-matching school effects are further examined here by decomposing the sample of students based on their study records. This decomposition analysis is designed to identify if single-sex schools and female teachers have more positive effects on high-performing girls' attitudes in the field of science.

To estimate the hypothesized heterogeneous effects of gender-matching schooling, students are sub-grouped by their science scores: the 4th (score $\geq$ 582), 3rd (518 $\leq$ score < 582), 2nd (449 $\leq$ score < 518), and 1st (score < 449) quartiles. The findings presented in Table 4 show that a girl's own gender constrains her from being motivated and interested in science regardless of her science score—consistent with the aggregate results shown in Table 2. But the negative gender effect is largest among high-performing girls in the 4th quartile. This negative effect on girls' motivation is twice as large for high-performing girls as low-performing ones (1st quartile). Also, it is 20 percent larger for high-performing girls' interest in science than that for others in the 1st quartile. This finding of the most detrimental gender effect on high-performing girls implies that women's high level of ability is discredited instead of being recognized by society.

However, this negative gender effect on girls can be mitigated through gender-matching schooling. Considering the interaction effect of female students and teachers, female teachers influence most girls positively, but the effect is greatest on high-performing girls. If a girl in the 4th quartile is taught by a female science teacher, the negative effect of her own gender decreases by 26 percent for her instrumental motivation, and by nearly 50 percent for her interest in science (columns 1 and 9, Table 4). In addition to high-performing girls, girls in the 1st and 2nd quartiles also receive benefits from female teachers. Being taught by a female teacher, girls in the 1st quartile become more motivated to pursue science studies and careers than boys in the same quartile (column 4). Similarly, for girls in the 2nd quartile, the positive interaction effect reduces the negative effect of their own gender on interest in science by 80 percent (column 11). However, female teachers play no significant role for girls in the 3rd quartile.

Different from the generally positive effects of female teachers on girls (except those in the 3rd quartile), single-sex schooling has more heterogenous effects depending on a girl's study record. For high-performing girls (4th quartile), all-girls schools further moderate the negative gender effect to a large extent. Estimated by a PSM method (Table 5.1), the negative effect of girls' own gender is reduced by 50–90 percent in all three dimensions of non-cognitive performance, if a high-performing girl attends an all-girls school. Moreover, combining both single-sex schooling and a female student-teacher pair, girls in this best performing group can be more motivated than boys in the same rank, and they can also be (almost) as interested in science as boys. When the sample is limited to public schools (Table 5.2), the effect of all-girls schools on this group of girls remains positive.

For other girls in the lower quartiles of science studies, single-sex schools create mixed outcomes. Attending an all-girls school increases low-performing girls' motivation and confidence in science to some extent (1st quartile, Table 5.1). However, this positive effect is applied to private all-girls schools only because it is no longer significant in public schools (Table 5.2). On the other hand, for average-performing girls (in the 2nd and 3rd quartiles), single-sex schooling produces negative outcomes. Most notably, attending an all-girls school negatively affects girls in the 3rd quartile by lowering the level of their interest in science by 4–6 p.p. (in both public and private schools). Also, single-sex schooling reduces the confidence of girls in the 2nd and 3rd quartiles who attend private schools. On the boys' side, the effect of single-sex schooling is insignificant by and large—except for a negative effect on the confidence of boys in the 3rd and 4th quartiles.

The heterogeneous responses found in this section corroborate that gender-matching schooling is more beneficial to high-performing girls. The positive effect of female teachers is greater for high-performing girls. All-girls schools also provide a positive stimulus for girls in this best group. However, such benefits are accompanied by costs to average girls (and better-performing boys) who are disadvantaged by single-sex schooling.

Conclusion

This paper has addressed the role of gender-matching schooling in reducing gender gaps in non-cognitive performance in STEM fields in South Korea. In this regard, female teachers play a significant role in motivating and fostering girls' interest in science. These results render the importance of promoting gender role models for girls, through which the gap between their study outcomes and attitudes can be closed. Furthermore, the finding that high-performing girls are the largest beneficiaries of gender-matching schooling suggests a way of recruiting female talent in typically male-dominated fields like STEM. However, one should also note that gender-matching schooling—especially single-sex schools—does not produce universally positive effects. Its advantages for high-performing girls are accompanied by costs to average-performing ones who do not gain benefits from all-girls schools.

Such heterogeneous outcomes of single-sex schooling complicate policymaking. If a policy priority is given to promote female talent in STEM fields, all-girls schools can be a viable option. However, for the purpose of universal education that should leave no one behind, it may not be the best choice. Instead, one may more favorably consider the recruitment of female teachers for girls, as they can create more positive influences. This emphasizes the importance of individual-level interactions between female mentors and students for girls' non-cognitive development over the importance of school-level environments (i.e., all-girls schools).

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Table 1. Gender and Gender-Matching Effects on Cognitive Performance, Full Sample

Dependent variable	Log science score				Log math score				Log reading score			
Method	OLS		Multilevel		OLS		Multilevel		OLS		Multilevel	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Female student	-0.0001 (0.010)	0.001 (0.013)	-0.005 (0.008)	0.001 (0.010)	-0.003 (0.010)	-0.015 (0.013)	-0.01 (0.006)	-0.018** (0.008)	0.053*** (0.011)	0.048*** (0.014)	0.048*** (0.007)	0.043*** (0.009)
Boys school	0.022 (0.021)	0.023 (0.021)	0.022 (0.023)	0.023 (0.023)	0.016 (0.020)	0.014 (0.020)	0.016 (0.022)	0.015 (0.021)	0.017 (0.022)	0.016 (0.022)	0.016 (0.024)	0.015 (0.023)
Girls school	0.001 (0.015)	0.001 (0.015)	0.003 (0.018)	0.003 (0.018)	-0.027 (0.017)	-0.026 (0.017)	-0.022 (0.019)	-0.022 (0.019)	0.011 (0.014)	0.011 (0.014)	0.013 (0.016)	0.013 (0.016)
Public school	-0.017 (0.016)	-0.017 (0.016)	-0.025 (0.019)	-0.025 (0.019)	-0.020 (0.017)	-0.021 (0.017)	-0.026 (0.020)	-0.026 (0.020)	-0.023 (0.019)	-0.024 (0.018)	-0.031 (0.021)	-0.031 (0.021)
Community size	-0.011 (0.009)	-0.011 (0.009)	-0.011 (0.011)	-0.011 (0.011)	-0.010 (0.009)	-0.010 (0.009)	-0.010 (0.011)	-0.010 (0.011)	-0.010 (0.010)	-0.010 (0.010)	-0.010 (0.011)	-0.009 (0.011)
Student-teacher ratio	-1.54** (0.690)	-1.53** (0.684)	-2.02*** (0.774)	-2.01*** (0.777)	-1.55** (0.701)	-1.58** (0.698)	-2.12*** (0.80)	-2.14*** (0.795)	-1.22* (0.731)	-1.23* (0.732)	-1.79** (0.833)	-1.80** (0.835)
School size	0.00001 (0.00003)	0.00001 (0.00003)	0.00002 (0.00003)	0.00002 (0.00003)	0.00003 (0.00003)	0.00003 (0.00003)	0.00004 (0.00003)	0.00003 (0.00003)	0.00002 (0.00003)	0.00002 (0.00003)	0.00003 (0.00003)	0.00003 (0.00003)
Perceived school quality	0.011** (0.004)	0.011** (0.004)	0.001 (0.004)	0.001 (0.004)	0.011*** (0.004)	0.011*** (0.004)	0.0007 (0.004)	0.0007 (0.004)	0.011** (0.005)	0.011** (0.005)	0.001 (0.004)	0.001 80.004)
Female teacher	0.006 (0.008)	0.007 (0.012)	0.013** (0.006)	0.018** (0.009)	0.002 (0.009)	-0.008 (0.012)	0.005 (0.007)	-0.002 (0.009)	-0.001 (0.009)	-0.006 (0.012)	0.001 (0.007)	-0.003 (0.009)
Female student* female teacher		-0.002 (0.014)		-0.011 (0.011)		0.020 (0.014)		0.014 (0.012)		0.009 (0.014)		0.008 (0.012)

Teacher's tenure	-0.008 (0.011)	-0.008 (0.011)	-0.007 (0.009)	-0.007 (0.009)	-0.005 (0.013)	-0.005 (0.013)	-0.005 (0.009)	-0.005 (0.009)	-0.019 (0.013)	-0.019 (0.013)	-0.015 (0.009)	-0.015 (0.009)
Experience of teacher	-0.0001 (0.0005)	-0.0001 (0.0005)	0.0004 (0.0004)	0.0004 (0.0004)	-0.0005 (0.0005)	-0.001 (0.001)	0.00006 (0.0004)	0.00005 (0.0004)	-0.0005 (0.0005)	-0.0006 (0.0005)	-0.0002 (0.0004)	-0.0002 (0.0004)
Father's education	0.0003 (0.005)	0.0003 (0.005)	-0.004 (0.005)	-0.004 (0.005)	0.004 (0.005)	0.003 (0.005)	-0.0006 (0.005)	-0.0006 (0.005)	0.0006 (0.005)	0.0006 (0.005)	-0.004 (0.005)	-0.004 (0.005)
Mother's education	0.008* (0.005)	0.008* (0.005)	0.007 (0.004)	0.007 (0.004)	0.008** (0.004)	0.009** (0.004)	0.007* (0.004)	0.007* (0.004)	0.007 (0.005)	0.007 (0.004)	0.006 (0.004)	0.006 (0.004)
Economic, social and cultural status	0.061*** (0.008)	0.061*** (0.008)	0.043*** (0.007)	0.043*** (0.007)	0.069*** (0.008)	0.069*** (0.007)	0.052*** (0.007)	0.052*** (0.007)	0.067*** (0.008)	0.067*** (0.008)	0.048*** (0.007)	0.048*** (0.007)
Family spending on education	0.016*** (0.003)	0.016*** (0.003)	0.009*** (0.002)	0.009*** (0.002)	0.020*** (0.003)	0.020*** (0.003)	0.013*** (0.003)	0.013*** (0.003)	0.019*** (0.003)	0.019*** (0.003)	0.012*** (0.002)	0.012*** (0.002)
Parental support for learning at home	0.007* (0.004)	0.007* (0.004)	0.005 (0.004)	0.005 (0.004)	0.002 (0.003)	0.001 (0.003)	-0.0004 (0.003)	-0.0005 (0.003)	0.006* (0.004)	0.006* (0.004)	0.004 (0.003)	0.004 (0.003)
Parental emotional support	0.008** (0.003)	0.008** (0.003)	0.007** (0.003)	0.007** (0.003)	0.007** (0.003)	0.007** (0.003)	0.006* (0.003)	0.006* (0.003)	0.007** (0.003)	0.007** (0.003)	0.006* (0.003)	0.006* (0.003)
Skipping (some) classes	-0.068*** (0.025)	-0.068*** (0.025)	-0.051** (0.024)	-0.051** (0.024)	-0.062*** (0.022)	-0.062*** (0.022)	-0.043** (0.020)	-0.043** (0.020)	-0.087*** (0.027)	-0.087*** (0.027)	-0.070*** (0.026)	-0.070*** (0.026)
Coming to school late	-0.027*** (0.006)	-0.027*** (0.006)	-0.023*** (0.006)	-0.023*** (0.006)	-0.032*** (0.006)	-0.032*** (0.006)	-0.028*** (0.006)	-0.028*** (0.006)	-0.026*** (0.006)	-0.026*** (0.006)	-0.022*** (0.006)	-0.022*** (0.006)
Chatting online (outside of school)	-0.001 (0.002)	-0.001 (0.002)	0.001 (0.002)	0.001 (0.002)	-0.0007 (0.002)	-0.001 (0.002)	-0.001 (0.002)	0.001 (0.002)	-0.002 (0.002)	-0.002 (0.002)	0.00004 (0.002)	0.00005 (0.002)
Participation in social networks	-0.004* (0.002)	-0.004* (0.002)	-0.003 (0.002)	-0.003 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.001 (0.002)	-0.001 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.001 (0.002)	-0.001 (0.002)
Chatting online (in school)	-0.027*** (0.005)	-0.027*** (0.005)	-0.026*** (0.003)	-0.026*** (0.004)	-0.023*** (0.005)	-0.023*** (0.005)	-0.022*** (0.004)	-0.022*** (0.004)	-0.029*** (0.006)	-0.030*** (0.006)	-0.030*** (0.004)	-0.030*** (0.004)

Dependent variable	Log science score				Log math score				Log reading score			
Method	OLS		Multilevel		OLS		Multilevel		OLS		Multilevel	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Feeling of belonging to School	0.001 (0.004)	0.001 (0.004)	-0.003 (0.003)	-0.003 (0.003)	0.012*** (0.004)	0.012*** (0.004)	0.009*** (0.003)	0.009*** (0.003)	0.0003 (0.004)	0.003 (0.004)	-0.003 (0.003)	-0.003 (0.003)
Unfairness of teacher	-0.008*** (0.001)	-0.008*** (0.001)	-0.007*** (0.001)	-0.007*** (0.001)	-0.007*** (0.001)	-0.007*** (0.001)	-0.007*** (0.001)	-0.007*** (0.001)	-0.008*** (0.001)	-0.008*** (0.001)	-0.007*** (0.001)	-0.007*** (0.001)
Number of observations	3,259	3,259	3,259	3,259	3,258	3,258	3,258	3,258	3,258	3,258	3,258	3,258
Number of schools	105	105	105	105	105	105	105	105	105	105	105	105
R2	0.246	0.246			0.281	0.281			0.277	0.277		
Wald Chi2			462.3***	469.3***			631.8***	629.8***			507.7***	511.4***

Note: Robust standard errors are in parentheses. Robust standard errors are clustered at the school level in the linear estimations.
* $p< .10$, ** $p< .05$, *** $p< .001$.

Table 2. Gender and Gender-Matching Effects on Non-cognitive Performance, Full Sample

Dependent Variable	Instrumental motivation in science				Confidence in science				Interest in science			
Method	OLS		Multilevel		OLS		Multilevel		OLS		Multilevel	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Female student	-0.244*** (0.046)	-0.349*** (0.055)	-0.221*** (0.044)	-0.306*** (0.053)	0.038 (0.046)	-0.007 (0.073)	0.038 (0.045)	-0.005 (0.073)	-0.355*** (0.038)	-0.465*** (0.055)	-0.351*** (0.036)	-0.454*** (0.054)
Boys school	0.017 (0.058)	-0.004 (0.057)	0.030 (0.058)	0.011 (0.059)	-0.017 (0.061)	-0.026 (0.063)	-0.017 (0.061)	-0.026 (0.063)	0.021 (0.057)	-0.001 (0.058)	0.028 (0.057)	0.006 (0.058)
Girls school	0.091 (0.076)	0.093 (0.072)	0.079 (0.075)	0.080 (0.071)	-0.095 (0.079)	-0.094 (0.078)	-0.094 (0.079)	-0.094 (0.078)	0.056 (0.057)	0.057 (0.053)	0.055 (0.056)	0.057 (0.052)
Public school	0.039 (0.067)	0.040 (0.066)	0.027 (0.067)	0.030 (0.066)	0.033 (0.052)	0.034 (0.051)	0.032 (0.051)	0.033 (0.051)	0.027 (0.049)	0.029 (0.048)	0.021 (0.048)	0.024 (0.048)
Community size	0.018 (0.035)	0.022 (0.034)	0.017 (0.035)	0.020 (0.034)	-0.008 (0.029)	-0.007 80.029)	-0.008 (0.029)	-0.007 (0.029)	0.005 (0.024)	0.008 (0.023)	0.006 (0.024)	0.009 (0.023)
Student-teacher ratio	-2.037 (2.156)	-2.234 (2.117)	-1.932 (2.113)	-2.096 (2.074)	-1.128 (1.879)	-1.213 (1.869)	-1.157 (1.882)	-1.231 (1.869)	-1.637 (1.797)	-1.854 (1.765)	-1.699 (1.818)	-1.899 (1.776)
School size	-0.0001 (0.0001)	-0.0001 (0.0001)	-0.0001 (0.0001)	-0.0001 (0.0001)	-0.00001 (0.00009)	-0.00001 (0.00009)	-0.00001 (0.00009)	-0.00001 (0.00009)	-0.00007 (0.00009)	-0.00008 (0.00009)	-0.00008 (0.00009)	-0.00008 (0.00009)
Perceived school quality	0.072*** (0.021)	0.071*** (0.021)	0.070*** (0.022)	0.069*** (0.021)	0.037 (0.027)	0.037 (0.027)	0.037 (0.027)	0.037 (0.027)	0.070*** (0.022)	0.070*** (0.022)	0.071*** (0.023)	0.071*** (0.022)
Female teacher	-0.071* (0.040)	-0.158*** (0.053)	-0.059 (0.038)	-0.131*** (0.048)	-0.083* (0.044)	-0.119** (0.059)	-0.082* (0.043)	-0.118** (0.059)	-0.005 (0.037)	-0.094* (0.053)	0.003 (0.035)	-0.084* (0.051)
Female student*female teacher		0.184*** (0.070)		0.146** (0.066)		0.078 (0.088)		0.075 (0.088)		0.190*** (0.068)		0.177*** (0.067)

Dependent Variable	Instrumental motivation in science				Confidence in science				Interest in science			
Method	OLS		Multilevel		OLS		Multilevel		OLS		Multilevel	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Teacher's tenure	0.013 (0.057)	0.010 (0.058)	-0.023 (0.057)	-0.025 (0.058)	0.032 (0.057)	0.030 (0.057)	0.034 (0.057)	0.032 (0.057)	-0.056 (0.045)	-0.059 (0.045)	-0.053 (0.046)	-0.056 (0.046)
Experience of teacher	-0.003 (0.002)	-0.003 (0.002)	-0.001 (0.002)	-0.001 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)	0.0005 (0.002)	0.0003 (0.0017)	0.0006 (0.002)	0.0004 (0.002)
Intellectual abilities (log reading score)	0.441*** (0.122)	0.445*** (0.120)	0.416*** (0.121)	0.421*** (0.120)	0.904*** (0.134)	0.906*** (0.134)	0.900*** (0.134)	0.903*** (0.134)	0.596*** (0.099)	0.599*** (0.099)	0.595*** (0.098)	0.599*** (0.099)
Father's education	-0.006 (0.021)	-0.006 (0.021)	-0.005 (0.021)	-0.005 (0.021)	-0.048* (0.028)	-0.048* (0.028)	-0.048* (0.028)	-0.048* (0.028)	-0.006 (0.024)	-0.007 (0.024)	-0.007 (0.024)	-0.007 (0.024)
Mother's education	0.010 (0.022)	0.010 (0.022)	0.008 (0.021)	0.007 (0.022)	-0.026 (0.028)	-0.026 (0.028)	-0.026 (0.028)	-0.026 (0.028)	-0.027 (0.021)	-0.028 (0.021)	-0.027 (0.021)	-0.028 (0.021)
Economic, social and cultural status	0.062 (0.042)	0.063 (0.042)	0.063 (0.041)	0.064 (0.041)	0.293*** (0.051)	0.294*** (0.052)	0.294*** (0.051)	0.294*** (0.051)	0.130*** (0.042)	0.131*** (0.042)	0.132*** (0.041)	0.132*** (0.041)
Family spending on education	0.022 (0.014)	0.022 (0.014)	0.017 (0.014)	0.017 (0.014)	-0.004 (0.016)	-0.004 (0.016)	-0.004 (0.016)	-0.004 (0.016)	0.005 (0.014)	0.004 (0.014)	0.002 (0.014)	0.002 (0.014)
Parental support for learning at home	0.131*** (0.018)	0.131*** (0.018)	0.127*** (0.018)	0.127*** (0.018)	0.101*** (0.024)	0.102*** (0.024)	0.101*** (0.024)	0.102*** (0.024)	0.094*** (0.018)	0.094*** (0.018)	0.093*** (0.018)	0.093*** (0.018)
Parental emotional support	-0.011 (0.019)	-0.012 (0.019)	-0.009 (0.019)	-0.009 (0.019)	0.019 (0.020)	0.019 (0.020)	0.019 (0.020)	0.019 (0.020)	-0.014 (0.017)	-0.014 (0.018)	-0.013 (0.017)	-0.013 (0.018)
Skipping (some) classes	0.016 (0.082)	0.018 (0.08)	0.032 (0.083)	0.033 (0.084)	-0.005 (0.133)	-0.004 (0.133)	-0.003 (0.132)	-0.003 (0.133)	0.117 (0.087)	0.119 (0.088)	0.123 (0.085)	0.124 (0.087)
Coming to school late	-0.069** (0.034)	-0.069** (0.034)	-0.074** (0.033)	-0.073** (0.033)	-0.112** (0.0489	-0.111** (0.048)	-0.112** (0.048)	-0.112** (0.048)	-0.099** (0.040)	-0.098** (0.041)	-0.096** (0.040)	-0.096** (0.040)

Chatting online (outside of school)	0.008 (0.012)	0.010 (0.012)	0.010 (0.011)	0.011 (0.011)	0.005 (0.014)	0.006 (0.014)	0.005 (0.014)	0.006 (0.014)	0.022** (0.011)	0.024** (0.011)	0.023** (0.010)	0.024** (0.011)
Participation in social networks	-0.058*** (0.013)	-0.059*** (0.013)	-0.056*** (0.013)	-0.056*** (0.013)	-0.039*** (0.015)	-0.040*** (0.015)	-0.039*** (0.015)	-0.040*** (0.015)	-0.060*** (0.012)	-0.061*** (0.012)	-0.059*** (0.012)	-0.060*** (0.011)
Chatting online (in school)	0.047*** (0.017)	0.045*** (0.016)	0.045*** (0.016)	0.043*** (0.016)	0.087*** (0.022)	0.086*** (0.023)	0.087*** (0.022)	0.086*** (0.023)	0.061*** (0.020)	0.058*** (0.020)	0.063*** (0.020)	0.060*** (0.020)
Feeling of belonging to school	0.116*** (0.023)	0.116*** (0.023)	0.105*** (0.022)	0.105*** (0.022)	0.178*** (0.025)	0.177*** (0.025)	0.176*** (0.025)	0.177*** (0.026)	0.127*** (0.023)	0.126*** (0.023)	0.123*** (0.023)	0.123*** (0.023)
Unfairness of teacher	-0.003 (0.005)	-0.003 (0.005)	-0.004 (0.005)	-0.004 (0.005)	0.008 (0.007)	0.008 (0.007)	0.008 (0.007)	0.008 (0.007)	-0.010* (0.006)	-0.010* (0.006)	-0.011* (0.006)	-0.011* (0.006)
Number of observations	3,249	3,249	3,249	3,249	3,252	3,252	3,252	3,252	3,239	3,239	3,239	3,239
Number of schools	105	105	105	105	105	105	105	105	105	105	105	105
R^2	0.092	0.094			0.114	0.114			0.118	0.120		
Wald Chi^2			347.3***	399.6***			534.6***	547***			623***	614.1***

Note: Robust standard errors are in parentheses. Robust standard errors are clustered at the school level in the linear estimations.
* $p< .10$, ** $p< .05$, *** $p< .001$

Table 3. Average Treatment Effects of Single-sex Schooling on Cognitive and Non-cognitive Performance, Propensity-score Matching

Table 3.1. (all schools, including both public and private)

Dependent variable	Sample	ATE (single-sex school)	AI robust std. error	Observations
(log) Science score	Boys	0.035***	0.013	1,793
(log) Science score	Girls	-0.010	0.013	1,485
(log) Math score	Boys	0.031	0.013	1,786
(log) Math score	Girls	-0.021*	0.012	1,492
(log) Reading score	Boys	0.039***	0.014	1,786
(log) Reading score	Girls	0.010	0.010	1,492
Instrumental motivation	Boys	0.039	0.062	1,786
Instrumental motivation	Girls	-0.008	0.069	1,482
Confidence in science	Boys	0.033	0.069	1,787
Confidence in science	Girls	-0.105	0.076	1,484
Interest in science	Boys	0.021	0.068	1,776
Interest in science	Girls	0.021	0.069	1,482

Table 3.2. (public schools only)

Dependent variable	Sample	ATE (single-sex school)	AI robust std. error	Observations
(log) Science Score	Boys	0.019	0.018	1,256

(log) Science score	Girls	-0.094	0.071	1,039
(log) Math score	Boys	0.016	0.015	1,237
(log) Math score	Girls	-0.011	0.052	1,025
(log) Reading score	Boys	0.013	0.017	1,237
(log) Reading score	Girls	-0.012	0.070	1,025
Instrumental motivation	Boys	-0.039	0.071	1,252
Instrumental motivation	Girls	0.250	0.202	1,036
Confidence in science	Boys	-0.046	0.089	1,253
Confidence in science	Girls	0.430*	0.244	1,038
Interest in science	Boys	0.103	0.079	1,244
Interest in science	Girls	0.007	0.075	1,036

Note: ATE refers to average treatment effects and AI robust std. err. Abadie Imbens robust standard errors.

Table 4. Gender and Gender-Matching Effects on Non-cognitive Performance, Heterogeneous Responses by Science Scores, OLS

Dependent variable	Instrumental motivation in science				Confidence in science				Interest in science			
Quartile (Science scores)	4th (≥ 582)	3rd (518–582)	2nd (449–518)	1st (<449)	4th (≥ 582)	3rd (518–582)	2nd (449–518)	1st (<449)	4th (≥ 582)	3rd (518–582)	2nd (449–518)	1st (<449)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Female student	-0.494*** (0.102)	-0.209* (0.122)	-0.220* (0.117)	-0.234** (0.112)	-0.145 (0.119)	0.070 (0.113)	0.111 (0.176)	0.171 (0.182)	-0.474*** (0.095)	-0.229** (0.109)	-0.495*** (0.113)	-0.395*** (0.113)
Boys school	-0.045 (0.093)	0.004 (0.100)	-0.013 (0.134)	0.051 (0.103)	-0.257** (0.100)	-0.214* (0.112)	0.204 (0.180)	0.145 (0.148)	-0.082 (0.073)	0.005 (0.086)	0.047 (0.109)	0.034 (0.111)
Girls school	0.202 (0.204)	0.014 (0.095)	0.154 (0.114)	0.063 (0.125)	0.110 (0.093)	-0.160 (0.112)	-0.413** (0.161)	0.121 (0.148)	0.176 (0.131)	-0.034 (0.085)	0.088 (0.088)	0.089 (0.108)
Female teacher	-0.243** (0.099)	-0.177* (0.090)	-0.040 (0.111)	-0.107 (0.096)	-0.253** (0.100)	0.006 (0.100)	0.0001 (0.148)	-0.133 (0.145)	-0.060 (0.075)	-0.043 (0.107)	-0.184 (0.126)	-0.022 (0.105)
Female student*female teacher	0.373** (0.145)	0.091 (0.125)	-0.018 (0.111)	0.254* (0.139)	0.199 (0.150)	-0.058 (0.133)	-0.001 (0.199)	0.076 (0.218)	0.222** (0.107)	-0.071 (0.134)	0.390*** (0.141)	0.154 (0.150)
School inputs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Teacher's inputs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Family inputs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Behavioral factors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Relational factors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	855	832	775	787	855	833	774	790	853	832	772	782
Number of schools	98	104	104	97	98	104	104	98	98	104	104	98
R^2	0.122	0.090	0.077	0.070	0.120	0.080	0.125	0.072	0.152	0.115	0.087	0.088

Note: Robust standard errors are in parentheses. Parentheses are robust standard errors clustered at the school level. The results of the control variables (school, teacher's, family, behavioral, and relational inputs) are not presented to save space but can be obtained from the author upon request.
* $p < .10$, ** $p < .05$, *** $p < .001$.

Table 5. Average Treatment Effects of Single-sex Schooling on Non-cognitive Performance, Heterogeneous Responses by Science Scores, Propensity-score Matching

Table 5.1. (all schools including both public and private)

Dependent variable	**Instrumental motivation in science**							
Quartile	**4th (score ≥ 582)**		**3rd (518–582)**		**2nd (449–518)**		**1st (score < 449)**	
Gender of students	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
ATE	-0.044	0.443***	-0.048	-0.129	0.056	0.050	0.062	0.220**
AI robust std. err.	0.069	0.116	0.115	0.124	0.093	0.146	0.141	0.101
observations	496	365	427	407	390	394	474	320
Dependent variable	**Confidence in science**							
Quartile	**4th (score ≥ 582)**		**3rd (518–582)**		**2nd (449–518)**		**1st (score < 449)**	
Gender of students	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
ATE	-0.319***	0.154*	-0.233**	-0.690***	0.302	-0.367***	0.072	0.235*
AI robust std. err.	0.096	0.079	0.095	0.224	0.149	0.135	0.152	0.120
observations	496	365	427	408	389	394	476	321
Dependent variable	**Interest in science**							
Quartile	**4th (score ≥ 582)**		**3rd (518–582)**		**2nd (449–518)**		**1st (score < 449)**	
Gender of students	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
ATE	-0.069	0.235***	-0.068	-0.325**	0.291	0.249	0.139	0.053
AI robust std. err.	0.044	0.062	0.103	0.138	0.194	0.189	0.120	0.110
observations	494	365	426	408	389	392	468	321

Table 5.2. (public schools only)

Dependent variable	Instrumental motivation in science							
Quartile	4th (score ≥ 582)		3rd (518–582)		2nd (449–518)		1st (score < 449)	
Gender of Students	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
ATE	-0.017	0.642***	-0.123	0.127	0.207	0.220	-0.047	-0.048
AI robust std. err.	0.111	0.157	0.119	0.103	0.259	0.619	0.234	0.136
observations	292	223	300	282	293	292	368	232
Dependent variable	Confidence in science							
Quartile	4th (score ≥ 582)		3rd (518–582)		2nd (449–518)		1st (score < 449)	
Gender of students	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
ATE	-0.335**	0.402**	-0.382**	-0.014	0.348**	-0.090	0.222	0.047
AI robust std. err.	0.142	0.198	0.158	0.106	0.167	0.209	0.235	0.121
observations	292	223	300	283	292	292	370	243
Dependent variable	Interest in science							
Quartile	4th (score ≥ 582)		3rd (518–582)		2nd (449–518)		1st (score < 449)	
Gender of students	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
ATE	-0.050	0.330**	0.039	-0.192**	0.021	-0.081	0.226	-0.607
AI robust std. err.	0.128	0.129	0.133	0.091	0.212	0.179	0.151	0.516
observations	291	223	299	283	292	290	363	243

Note: ATE refers to average treatment effects and AI robust std. err. Abadie Imbens robust standard errors.

Appendix: Descriptive Statistics

Variable	Observations	Mean	Std. Dev.	Min.	Max.
Science score	3,259	517.95	96.77	192.38	788.37
Math score	3,259	526.29	101.52	132.19	827.77
Reading score	3,259	517.05	99.24	148.47	804.33
Instrumental motivation (index)	3,249	0.03	1.01	-1.93	1.74
Confidence in science (index)	3,252	-0.01	1.22	-3.76	3.28
Interest in science (index)	3,239	-0.07	0.99	-2.55	2.56
Female student (dummy)	3,259	0.45	0.50	0	1
Public school (dummy)	3,259	0.70	0.46	0	1
Community size (index)	3,259	4.27	0.85	1	5
Student-teacher ratio	3,259	14.32	2.57	7.2	20.83
School size	3,259	989.81	343.68	72	1,679
Perceived school quality (index)	3,259	-0.05	0.867	-3.55	2.53
Female teacher (science, dummy)	3,259	0.52	0.50	0	1
Female teacher (main, dummy)	3,220	0.53	0.50	0	1
Teacher's tenure (science, dummy)	3,259	0.83	0.38	0	1
Teacher's tenure (main, dummy)	3,224	0.83	0.38	0	1
Teacher's experience (science)	3,259	16.38	10.05	0	40
Teacher's experience (main)	3,209	16.42	10.04	0	40
Father's education (index)	3,259	5.38	1.01	1	7
Mother's education (index)	3,259	5.24	0.99	1	7
Economic, social and cultural status (index)	3,259	-0.19	0.69	-4.08	1.91
Family spending on education (index)	3,259	3.34	1.37	1	6
Parental support for learning at home (index)	3,259	-0.58	1.01	-5.01	3.74
Parental emotional support (index)	3,259	-0.72	1.11	-3.82	0.75
Skipping (some) classes (index)	3,259	1.03	0.23	1	4
Coming to school late (index)	3,259	1.24	0.59	1	4
Chatting online (outside of school, index)	3,259	2.64	1.66	1	5
Participation in social networks (index)	3,259	3.71	1.46	1	5
Chatting online (in school, index)	3,259	1.45	0.98	1	5
Feeling belonging to school (index)	3,259	0.14	0.86	-3.13	2.59
Unfairness of teacher (index)	3,259	8.34	3.14	2	24