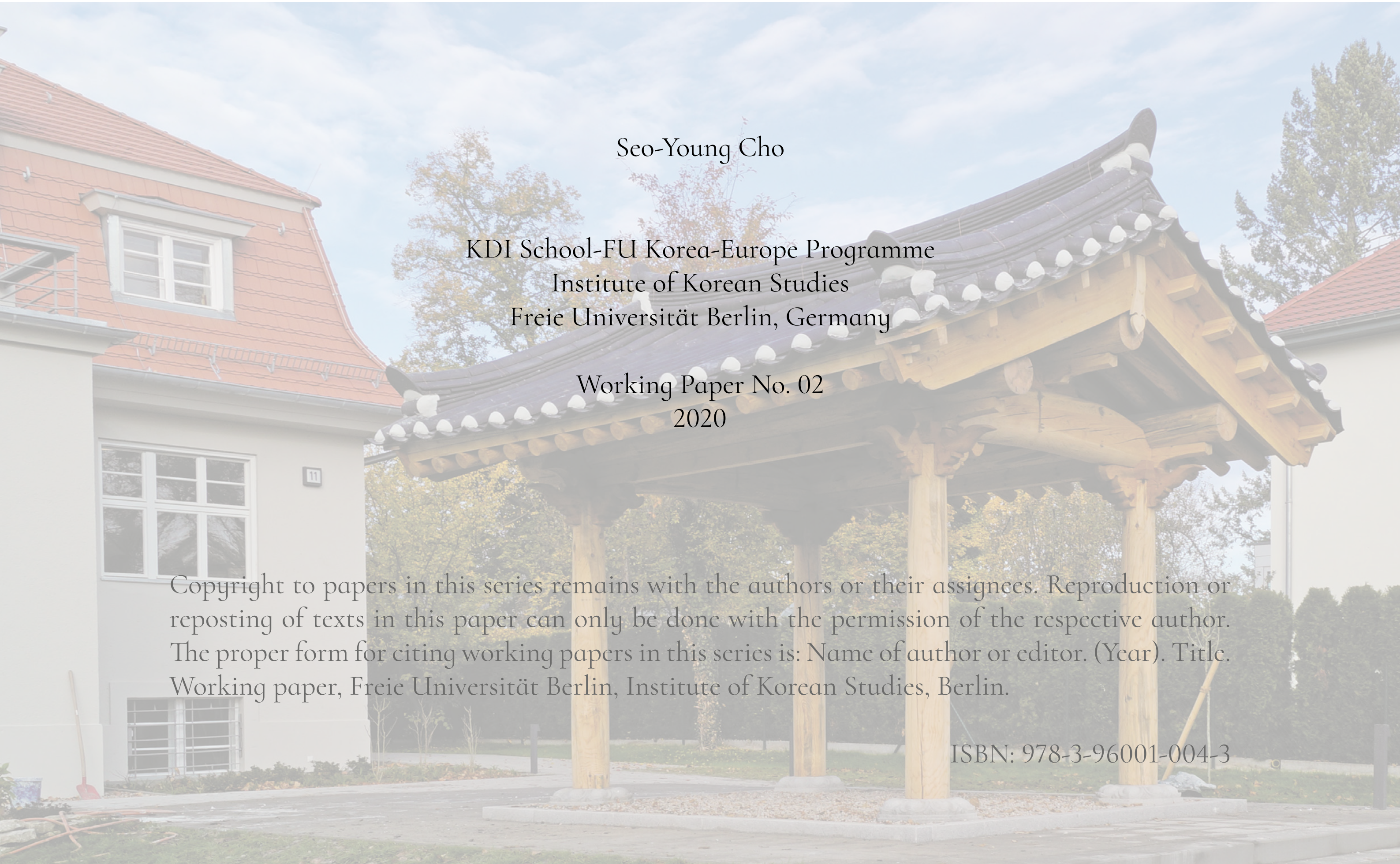
Institute of Korean Studies

Freie Universität Berlin

Korea Focus

Female Mentors and Peers

– A Heterogeneity Analysis of Gender Gaps in Attitudes towards STEM in South Korea



Seo-Young Cho

KDI School-FU Korea-Europe Programme
Institute of Korean Studies
Freie Universität Berlin, Germany

Working Paper No. 02
2020

ISBN: 978-3-96001-004-3

Female Mentors and Peers

– A Heterogeneity Analysis of Gender Gaps in Attitudes towards STEM in South Korea

Seo-Young Cho*

Seo-Young Cho is research fellow of the KDI-FU Korea-Europe Program at the Institute of Korean Studies at FU-Berlin and lecturer of Korean Economy at Tübingen University. Previously, she was junior professor of economics at the University Marburg for the last six years and senior researcher at DIW-Berlin. As an empirical economist, she has conducted extensive research on economic and institutional development in Korea. Currently, she focuses on inclusive growth in South Korea by investigating the role of SMEs in innovation economy, Millennial, female and migrant entrepreneurs, as well as agendas of fair competition. Her research extends to topics of migration, gender, and institutions in the East Asian and global economy. To the present, she has published her articles in various international peer-reviewed journals such as World Development, European Journal of Political Economy, Social Science Quarterly, International Studies Quarterly, Scandinavian Journal of Economics, International Migration, and European Journal of Law and Economics. In addition, she has completed many research projects funded by the DFG, AKS, DAAD and EU. Presently, she serves the advisory board of the Journal of Human Trafficking and the Directorate of the Korean-German Academy of Economics and Management. Seo-Young Cho received her doctorate in Economics from the University of Goettingen and a master's degree in Public Affairs from Columbia University in New York.

KDI School-FU Korea-Europe Programme
Institute of Korean Studies
Freie Univesität Berlin

2020

Abstract:
This paper investigates whether gender-matching school environments can foster girls' confidence and motivation in science. Using the PISA data from 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. However, the role of single-sex schooling is not as positive for average- and low-performing girls. On the other hand, the effect of female teachers is more generalized, in that female teachers can boost girls' competitive attitudes regardless of their study records. These findings corroborate that gender-matching schooling can be a useful policy instrument of promoting female talent in STEM fields. But the positive effect is not universal and cannot be generalized for everyone.

Keywords:
Gender, STEM Fields, Female Mentors and Peers, Education, Attitudes, All-girls Schools, South Korea

*Author: Freie Universität Berlin, Institute of Korean Studies, KDI School-FU IKS Korea and Europe Programme, Otto-von-Simson-Str. 11, 14195 Berlin, Germany. Email: seoy.cho@gmail.com

1. Introduction

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

Observing this incongruity, this paper aims to shed light on reasons for such gender differences in attitudes towards science in South Korea. As illustrated in Figure 1, Korean girls' low motivation and interest in science cannot be explained by their lack of cognitive abilities, given the high level of educational attainment. 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 likely to confront challenges in establishing themselves in these fields because STEM are considered as typical male-dominated areas and therefore, successful female professionals and mentors who can provide role models for girls are rare (Bracey 2006, Hill 2015, Gneezy et al. 2003, and 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 school environments that can foster girls' attitudes by providing more opportunities for 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 of boys), and thus they can readily be driven to assume leadership 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 the present, 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 Zweimuller (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, and Goodkind et al. 2013). On the other hand, the literature evaluates the effect of female teachers more positively in general (see Carrell et al. 2010, Nixon and Robinson 1999, Bettinger and Long 2005, and Dee 2007).

In South Korea specific, studies that investigate the effect of gender-matching schooling on study outcomes report generally positive results (see Park et al. 2013, Kim 2012, Kim and Law 2012, Link 2012, Dustmann et al. 2017 for single-sex schooling and Lim and Meer 2017 for female teachers).

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

However, studies on non-cognitive outcomes do not provide as positive of evidence supporting the role of all-girls schools in the country. 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.

Considering the findings presented in the current literature, my study elaborates the channel of gender-matching school effects by disentangling the effects on heterogeneous groups of students in their cognitive abilities. The existing studies so far focus on the outcomes at the aggregate level including all students, but gender-matching schooling may produce different results depending on students' abilities. In particular, girls with a higher level of abilities could benefit more from gender-matching environments where their abilities are likely to be more fairly valued and hence they are encouraged to be more confident and aim higher, whereas in mixed- sex environments, girls' abilities may be undervalued compared to their male counterparts'.

Through the 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 tail of the science test become as motivated and interested in pursuing studies and careers in STEM fields as high-performing boys. However, the role of single-sex schooling is not as positive for average- and low-performing girls. On the other hand, the effect of female teachers is more generalized, in that female teachers can enhance girls' competitive attitudes regardless of their study records. The results of this paper propose gender-matching schooling as a useful policy instrument to recruit female talent in STEM fields. Yet, one should note that this effect is not universal for all girls.

2. Empirical Framework

2.1. Education Production Function

The central question for 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 (students' performance) are determined as: Y (educational output) = f (individual, family, school, teacher, and peer inputs).

In this model, students' performance (Y) includes 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 in the future. 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 Korean girls demonstrate.

The education production function is rewritten in an econometric model below specifying co-variates and their relationships with the outcome variables.[2]

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

The set of the performance variables (Y) consists of several indicators that evaluate students' performance. First, students' cognitive performance is measured by their PISA test scores in reading, math, and science subjects. Second, non-cognitive performance related to STEM fields is proxied by students' self-assessments of their instrumental motivation, confidence, and interest in science (data available in the PISA survey). 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* refers to whether student i is taught by a female teacher in the respective course (i.e. reading, math, or science). *Boy school* and *girl school* represent single-sex schooling for boys and girls, respectively. Hence, gender-matching school effects for girls are estimated through two variables: *girl school* and *female student*female teacher* (i.e. a girl is taught by a female teacher). Accordingly, positive gender-matching effects on girls' performance are hypothesized as follows.

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

The model includes 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), a student's behavioral patterns (B), and his/her relationships with teachers and peers (R). The choice of input variables follows the literature. Students' socioeconomic characteristics are taken from Hanushek (1986) who emphasizes their important role in determining students' performance. The choice of school inputs follows Krueger (2003) and Hanushek (2011). They propose class sizes and teacher quality as important 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 relationship effects can reduce omitted variable biases by controlling for the influence of a student's unobserved characteristics on his/her performance.

Additionally, in estimating the model of non-cognitive performance (attitudes), a variable that measures intellectual abilities is 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.

2 Descriptive statistics of all variables used in this model (including the measurement scales of the variables) are presented in Appendix A.

The econometric model formulated in Equation 1 is estimated by two methods. First, an OLS estimation is applied, assuming the linearity of the model with 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 accounting for varying data patterns across schools. In this nested model, intercepts are treated as random effects that consider 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.

2.2. 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 with 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 backgrounds. Thus, each class includes wide ranges 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 distinguished backgrounds 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 from 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 5 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 reflected 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 a preferred school. For instance, since 2010, middle-school students in Seoul have been allowed to submit three names of preferred high schools, with school assignments following based on their preferences. According to Kim (2012), students tend 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 in university entrance exams. Thus, students (and parents) who are more concerned about studies and opportunities for higher education are more likely to choose single-sex schools.

Hence, various methods are employed to account for endogenous relationship between school choices and performance in this paper. First, a number of educational inputs are incorporated in the empirical model in a holistic manner (see Section 2.1 for details). 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. Hence, a propensity-score matching (PSM) method is used 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 the 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).

$$\text{ATE} = \text{E}\left[\text{outcome}_{\text{single-sex}} - \text{outcome}_{\text{mixed-sex}} \,\middle|\, \text{G, X, S, T, B, R}\right] \tag{2}$$

The PSM model is formed based on an 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. Particularly, students' behavioral and relational characteristics are explicitly observed in this model 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 method is employed by conducting the PSM estimations with observations in public schools only in order to further minimize the endogeneity of school choices. Limiting the sample with public schools can reduce 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] including them in the sample can exacerbate biases in estimation by adding unobserved heterogeneity at the school level.

3. Findings

3.1. Estimating the Average Effects of Gender and Gender-matching Schooling

In this section, we discuss the average effects of gender and gender-matching schooling for all students. First, regarding the findings on students' cognitive performance (see Table 1), there is no (students' own) gender effect on math and science scores, as expected from the descriptive findings in Figure 1.

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 rotated to different schools within the province/city regularly (e.g. every five years), while teachers in private schools are not subject to obligatory relocation.

However, in reading, girls have a significant advantage in having a score that is five percentage-points (p.p.) higher than boys' average score. On the other hand, gender-matching schooling is widely unimportant in explaining study outcomes in all subjects – for both boys and girls. Neither all-boys nor all-girls schools have any effect on the test scores. There is some evidence that being taught by a female science teacher increases students' scores in this subject. However, this result is found in the multilevel estimations only, and the estimated effect is too small to draw a meaningful interpretation.

Among school and teacher inputs, a higher student-teacher ratio deteriorates study outcomes, supporting the benefits of small classes. Nonetheless, most other variables have no effect on students' test scores: school size, school's status (public or private), community size, as well as teacher's tenure and experience. Also, the effect of school quality evaluated by parents is negligible in its size (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, students' family backgrounds and socioeconomic status are important inputs for their 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. In addition, a mother's education positively influences a student's math and science scores. Furthermore, a student's behaviors are suggested to have 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. In addition, a student's relationship with teachers – (dis)trust in the fairness of a teacher – is important for the student's cognitive learning.

So far, the analysis of cognitive performance suggests little support of gender or gender-matching effects in the fields of science and math studies. However, the outlooks are different when the effects are estimated on non-cognitive outcomes, namely students' attitudes towards science (see Table 2). First, the effect of students' own gender is negative for girls. The level of girls' instrumental motivation in science is lower than that of boys by 6.5–9.5 p.p. and interest in science is also lower by 6.8–9.2 p.p. Furthermore, a teacher's gender has a significant effect on students' attitudes, 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 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 and 4 and 10 and 12 of Table 2, respectively).

In contrast to the positive gender-matching effect between a female student and a female teacher, single-sex schooling has no influence on students' non-cognitive performance – neither for girls nor for 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. Teachers' inputs are also unimportant for a student's non-cognitive performance. However, students' family backgrounds and their behavioral patterns provide significant explanations for their attitudes – similar to their effects on cognitive study outcomes presented above.

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.

3.2. Self-Selection Effects

The baseline results above suggest that female teachers have positive effects on girls' attitudes towards science, while all girls-schools are not important for their cognitive and non-cognitive outcomes. As discussed in Section 2.2, 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 (see Section 2.2. for detailed reasons for limiting the sample).

Table 3 presents the PSM results, in that the effect of an all-girls school remains generally minimal in determining girls' performance. This is similar to the findings of the baseline estimations shown in Section 3.1. 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 for girls' confidence only, but it is significant just at a 10 percent level.

As presented here, the PSM analysis provides little support to the role of all-girls schools in fostering girls' attitudes and study outcomes, but attending an all-boys school has a more significant effect on boys' cognitive performance. 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.

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

The results above provide mixed evidence for 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 for all girls but affect girls differently depending on their academic aptitudes. This hypothesis is articulated because female abilities are often less valued when male counterparts are present and thus, highly able girls are more challenged than average ones (Niederle and Vesterlund 2007). Such challenges tend to be intensified in typically male-dominated fields – such as STEM. 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. With this argument, the gender-matching school effects are further examined 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 4^{th} (score ≥ 582), 3^{rd} (518 ≤ score < 582), 2^{nd} (449 ≤ score < 518), and 1^{st} (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 results at the average level shown in Table 2. But the negative gender effect is largest among high-performing girls in the 4th quartile. This negative effect on a girl's motivation is twice as large for high-performing girls as low-performing ones (1st quartile). Also, it is 20 percent larger on high-performing girls' interest in science than that of others in the 1st quartile. The finding that a girl's gender has the most detrimental effect on high-performing group of girls implies that a high level of female abilities is discredited instead of being recognized.

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 most prominent for 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 are also benefit by interactions with 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 provides more heterogenous effects depending on girls' study records. For high-performing girls (4th quartile), all-girls schools further moderate the negative effect of their own gender to a large extent. Estimated by a PSM method (Table 5.1), the negative gender effect 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 with public schools only (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 certain extents (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, but this effect maintains in private schools only. On the boys' side, the effect of single-sex schooling is insignificant by and large – except 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 do not benefit from or even are disadvantaged by single-sex schooling.

4. Conclusion

The findings of this paper highlight the positive effect of gender-matching schooling on girls' attitudes in South Korea. Particularly, 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 reduced. Furthermore, the finding that high-performing girls are the largest beneficiaries of gender-matching schooling suggests a way of recruiting female talent in a typically male-dominated field like STEM. However, one should also note that gender-matching schooling – especially single-sex schools – does not produce universally positive effects but its gains for high-performing girls accompany costs to average-performing ones who do not benefit in 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' development over school-level environments (i.e. all-girls schools).

References

Abadie, Alberto and Guido W. Imbens. 2011. Bias-corrected Matching Estimators for Average Treatment Effects. *Journal of Business and Economic Statistics* 29: 1-11.

Aedin, Doris, Donal O'Neill and Olive Sweetman. 2013. Gender, Single-sex Schooling and Maths Achievement. *Economics of Education Review* 35: 104-119.

Bettinger, Eric and Bridget Terry Long. 2005. Do Faculty Serve as Role Models? The Impact of Instructor Gender on Female Students. *American Economic Review: Papers and Proceedings* 95: 152-157.

Billger, Sherrilyn. 2009. On Reconstructing School Segregation: The Efficacy and Equity of Single-Sex Schooling. *Economics of Education Review* 28: 393-402.

Booth, Alison and Patrick Nolen. 2012. Choosing to Compete: How Different are Girls and Boys? *Journal of Economic Behaviour and Organization* 81: 542-555.

Bracey, Gerald. 2006. Separate but Superior? A Review of Issues and Data Bearing on Single-sex Education. Tempe: Educational Policy Research Unit.

Carrell, Scott, Marianne Page, and James West. 2010. Sex and Science: How Professor Gender Perpetuates the Gender Gap. *Quarterly Journal of Economics* 1101–1144.

Dee, Thomas. 2007. Teachers and the Gender Gaps in Student Achievement. *Journal of Human Resources* 42: 528-554.

Dustmann, Christian, Hyejin Ku, and Do Won Kwak. 2017. Why are Single-sex Schools Successful? CESifo Working Papers No. 6535.

Eisenkopf, Gerald, Zohal Hessami, Urs Fischbacher, and Heinrich W. Ursprung. 2015. Academic Performance and Single-sex Schooling: Evidence from a Natural Experiment in Switzerland. *Journal of Economic Behavior and Organization* 115: 123-143.

Fryer, Roland G. Jr. and Steven D. Levitt. 2010. An Empirical Analysis of the Gender Gap in Mathematics. *American Economic Journal: Applied Economics* 2: 210-240.

Government of the Republic of Korea. 2016. Korea Statistics: Seoul.

Goodkind, Sara, Lisa Schelbe, Andrea A. Joseph, Daphne E. Beers, Stephanie L. Pinsky. 2013. *Children and Youth Services Review* 35: 1174-1181.

Gneezy, Uri, Muriel Niederle and Aldo Rustichini. 2003. Performance in Competitive Environments: Gender Differences. *Quarterly Journal of Economics* 118: 1049-1073.

Halpern, Diane, Lise Eliot, Rebecca Bigler, Richard Fabes, Laura Hanish, Janet Hyde, Lynn Liben, and Carol Martin. 2011. *The Pseudoscience of Single-sex Schooling. Science* 333: 1706-1707.

Hanushek, Eric. 1986. The Economics of Schooling: Production and Efficiency in Public Schools. *Journal of Economic Literature* 24:1141-1177.

Hanushek, Eric. 2011. The Economic Value of Higher Teacher Quality. *Economics of Education Review* 30: 466-479.

Hill, Andrew. 2015. The Girl Next Door: The Effect of Opposite Gender Friends on High School Achievement. *American Economic Journal: Applied Economics* 7: 147-177.

Hoxby, Caroline. 2000. Peer Effects in the Classroom: Learning from Gender and Race Variation. National Bureau of Economic Research Working Paper No. 7867.

Jackson, C. Kirabo. 2012. Single-sex Schools, Student Achievement, and Course Selection: Evidence from Rule-based Student Assignments in Trinidad and Tobago. *Journal of Public Economics* 96: 173-187.

Kim, Hisam. 2012. Estimation of Education Production Function Focusing on School Effects and Policy Directions for Primary and Secondary Education (written in Korean). *KDI Research Monograph* 2012-09 (Korea Development Institute): Seoul.

Kim, Doo Hwan and Helen Law. 2012. Gender Gap in Maths Test Scores in South Korea and Hong Kong: Role of Family Background and Single-sex Schooling. *International Journal of Education Development* 32: 92-103.

Krueger, Alan. 1999. Experimental Estimates of Education Production Functions. *Quarterly Journal of Economics* 114: 497-532.

Krueger, Alan. 2003. Economic Considerations and Class Size. *Economic Journal* 113: 34-63.

Lavy, Victor and Analía Schlosser. 2011. Mechanisms and Impacts of Gender Peer Effects at School. *American Economic Journal: Applied Economics* 3: 1-33.

Lee, Soohyung, Muriel Niederle and Namwook Kang. 2014. Do Single-sex Schools Make Girls More Competitive? *Economics Letters* 124: 474-477.

Lim, Jaegeum and Jonathan Meer. 2017. The Impact of Teacher-Student Gender Matches: Random Assignment Evidence from South Korea. *Journal of Human Resources* 52: 979-997.

Link, Susanne. 2012. Single-sex Schooling and Student Performance: Quasi-Experimental Evidence from South Korea. Ifo Working Paper No. 146, University of Munich.

McCoy, Selina, Emer Smyth and Joanne Banks. 2012. The Primary Classroom: Insights from the ‚Growing Up in Ireland' Study. Economics and Social Research Institute Working Paper: Dublin.

Niederle, Muriel and Lise Vesterlund. 2007. Do Women Shy Away from Competition? Do Men Compete Too Much? *Quarterly Journal of Economics* 122: 1065–1101.

Nixon, Lucia and Michael D. Robinson. 1999. The Educational Attainment of Young Women: Role Model Effects of Female High School Faculty. *Demography* 36: 185-194.

Organization for Economic Cooperation and Development (OECD). 2015. Program for International Student Assessment (PISA). OECD: Paris.

Organization for Economic Cooperation and Development (OECD). 2017. PISA 2015 Technical Report. OECD: Paris.

Park, Hyunjoon, Jere Behrman and Jaesung Choi. 2013. Causal Effects of Single-Sex Schools on College Entrance Exams and College Attendance: Random Assignment in Seoul High Schools. *Demography* 50: 447-469.

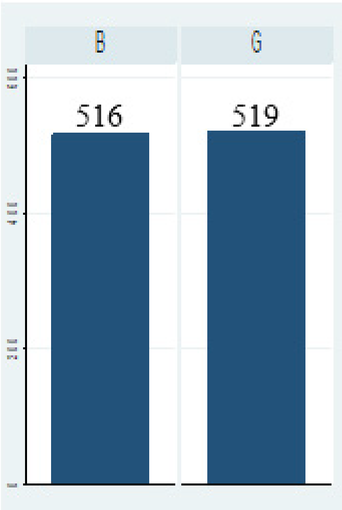
Park, Hyunjoon, Jere Behrman and Jaesung Choi. 2018. Do Single-sex Schools Enhance Students' STEM Outcomes? *Economics of Education Review* 62: 35-47.

Schneeweis, Nicole and Martina Zweimuller. 2012. Girls, Girls, Girls: Gender Composition and Female School Choice. *Economics of Education Review* 31: 482-500.

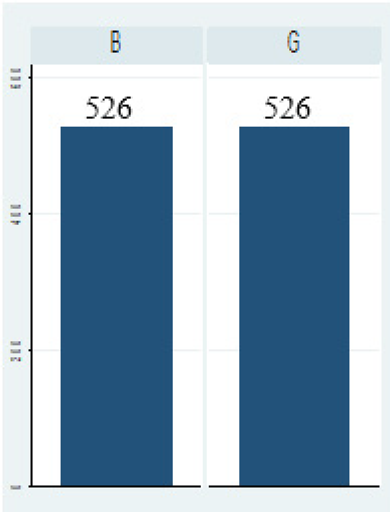
Strain, Michael. 2013. Single-sex Classes & Student Outcomes: Evidence from North Carolina. *Economics of Education Review* 36: 73-87.

Figure 1
Gender Differences in Cognitive and Non-cognitive Performance in South Korea
(PISA 2015, OECD)

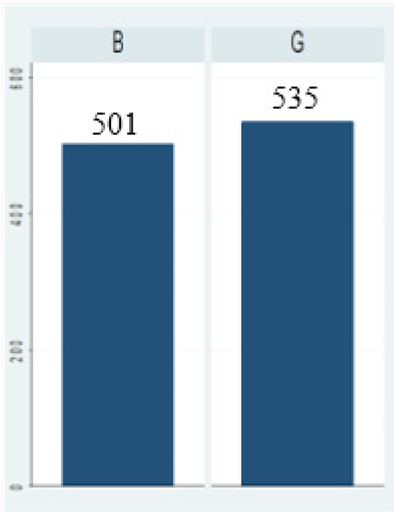
(a) Science Score



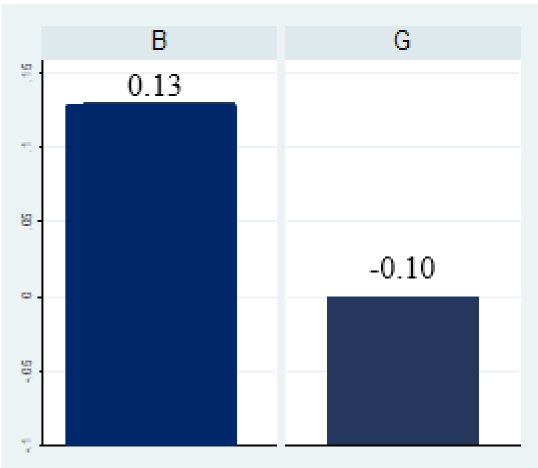
(b) Math Score



(c) Reading Score



(d) Instrumental Motivation in Science
(index, on a scale from –1.93 to +1.74)



(e) Interest in Science
(index, on a scale from –2.55 to +2.56)

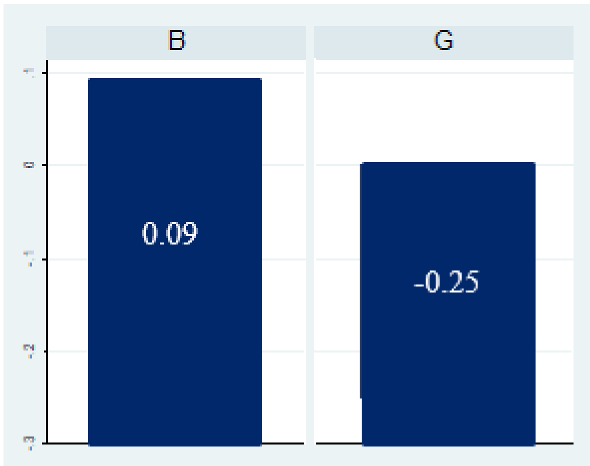


Table 1
Gender and Gender-Matching Effects on Cognitive Performance, full sample

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	0.001	-0.005	0.001	-0.003	-0.015	-0.01	-0.018**	0.053***	0.048***	0.048***	0.043***
	(0.010)	(0.013)	(0.008)	(0.010)	(0.010)	(0.013)	(0.006)	(0.008)	(0.011)	(0.014)	(0.007)	(0.009)
Boy School	0.022	0.023	0.022	0.023	0.016	0.014	0.016	0.015	0.017	0.016	0.016	0.015
	(0.021)	(0.021)	(0.023)	(0.023)	(0.020)	(0.020)	(0.022)	(0.021)	(0.022)	(0.022)	(0.024)	(0.023)
Girl School	0.001	0.001	0.003	0.003	-0.027	-0.026	-0.022	-0.022	0.011	0.011	0.013	0.013
	(0.015)	(0.015)	(0.018)	(0.018)	(0.017)	(0.017)	(0.019)	(0.019)	(0.014)	(0.014)	(0.016)	(0.016)
Public School	-0.017	-0.017	-0.025	-0.025	-0.020	-0.021	-0.026	-0.026	-0.023	-0.024	-0.031	-0.031
	(0.016)	(0.016)	(0.019)	(0.019)	(0.017)	(0.017)	(0.020)	(0.020)	(0.019)	(0.018)	(0.021)	(0.021)
Community Size	-0.011	-0.011	-0.011	-0.011	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010	-0.009
	(0.009)	(0.009)	(0.011)	(0.011)	(0.009)	(0.009)	(0.011)	(0.011)	(0.010)	(0.010)	(0.011)	(0.011)
Student-Teacher Ratio	-1.54**	-1.53**	-2.02***	-2.01***	-1.55**	-1.58**	-2.12***	-2.14***	-1.22*	-1.23*	-1.79**	-1.80**
	(0.690)	(0.684)	(0.774)	(0.777)	(0.701)	(0.698)	(0.80)	(0.795)	(0.731)	(0.732)	(0.833)	(0.835)
School Size	0.00001	0.00001	0.00002	0.00002	0.00003	0.00003	0.00004	0.00003	0.00002	0.00002	0.00003	0.00003
	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)
Perceived School Quality	0.011**	0.011**	0.001	0.001	0.011***	0.011***	0.0007	0.0007	0.011**	0.011**	0.001	0.001
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	80.004)
Female Teacher	0.006	0.007	0.013**	0.018**	0.002	-0.008	0.005	-0.002	-0.001	-0.006	0.001	-0.003
	(0.008)	(0.012)	(0.006)	(0.009)	(0.009)	(0.012)	(0.007)	(0.009)	(0.009)	(0.012)	(0.007)	(0.009)
Female Student* Female Teacher		-0.002		-0.011		0.020		0.014		0.009		0.008
		(0.014)		(0.011)		(0.014)		(0.012)		(0.014)		(0.012)
Teacher's Tenure	-0.008	-0.008	-0.007	-0.007	-0.005	-0.005	-0.005	-0.005	-0.019	-0.019	-0.015	-0.015

	(0.011)	(0.011)	(0.009)	(0.009)	(0.013)	(0.013)	(0.009)	(0.009)	(0.013)	(0.013)	(0.009)	(0.009)
Experience of Teacher	-0.0001	-0.0001	0.0004	0.0004	-0.0005	-0.001	0.00006	0.00005	-0.0005	-0.0006	-0.0002	-0.0002
	(0.0005)	(0.0005)	(0.0004)	(0.0004)	(0.0005)	(0.001)	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0004)	(0.0004)
Father's Education	0.0003	0.0003	-0.004	-0.004	0.004	0.003	-0.0006	-0.0006	0.0006	0.0006	-0.004	-0.004
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Mother's Education	0.008*	0.008*	0.007	0.007	0.008**	0.009**	0.007*	0.007*	0.007	0.007	0.006	0.006
	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)
Economic, Social and Cultural Status	0.061***	0.061***	0.043***	0.043***	0.069***	0.069***	0.052***	0.052***	0.067***	0.067***	0.048***	0.048***
	(0.008)	(0.008)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.007)	(0.007)
Family Spending on Education	0.016***	0.016***	0.009***	0.009***	0.020***	0.020***	0.013***	0.013***	0.019***	0.019***	0.012***	0.012***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)
Parental Support for Learning	0.007*	0.007*	0.005	0.005	0.002	0.001	-0.0004	-0.0005	0.006*	0.006*	0.004	0.004
at Home	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)
Parental Emotional Support	0.008**	0.008**	0.007**	0.007**	0.007**	0.007**	0.006*	0.006*	0.007**	0.007**	0.006*	0.006*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Skipping (some) Classes	-0.068***	-0.068***	-0.051**	-0.051**	-0.062***	-0.062***	-0.043**	-0.043**	-0.087***	-0.087***	-0.070***	-0.070***
	(0.025)	(0.025)	(0.024)	(0.024)	(0.022)	(0.022)	(0.020)	(0.020)	(0.027)	(0.027)	(0.026)	(0.026)
Coming to School Late	-0.027***	-0.027***	-0.023***	-0.023***	-0.032***	-0.032***	-0.028***	-0.028***	-0.026***	-0.026***	-0.022***	-0.022***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Chatting Online (outside of School)	-0.001	-0.001	0.001	0.001	-0.0007	-0.001	-0.001	0.001	-0.002	-0.002	0.00004	0.00005
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Participation in Social Networks	-0.004*	-0.004*	-0.003	-0.003	-0.002	-0.002	-0.001	-0.001	-0.002	-0.002	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Chatting Online (in School)	-0.027***	-0.027***	-0.026***	-0.026***	-0.023***	-0.023***	-0.022***	-0.022***	-0.029***	-0.030***	-0.030***	-0.030***
	(0.005)	(0.005)	(0.003)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.006)	(0.006)	(0.004)	(0.004)
Feeling Belonging to School	0.001	0.001	-0.003	-0.003	0.012***	0.012***	0.009***	0.009***	0.003	0.003	-0.003	-0.003

	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)
Unfairness of Teacher	-0.008***	-0.008***	-0.007***	-0.007***	-0.007***	-0.007***	-0.007***	-0.007***	-0.008***	-0.008***	-0.007***	-0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(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
R^2	0.246	0.246			0.281	0.281			0.277	0.277		
Wald Chi^2			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***	-0.349***	-0.221***	-0.306***	0.038	-0.007	0.038	-0.005	-0.355***	-0.465***	-0.351***	-0.454***
	(0.046)	(0.055)	(0.044)	(0.053)	(0.046)	(0.073)	(0.045)	(0.073)	(0.038)	(0.055)	(0.036)	(0.054)
Boy School	0.017	-0.004	0.030	0.011	-0.017	-0.026	-0.017	-0.026	0.021	-0.001	0.028	0.006
	(0.058)	(0.057)	(0.058)	(0.059)	(0.061)	(0.063)	(0.061)	(0.063)	(0.057)	(0.058)	(0.057)	(0.058)
Girl School	0.091	0.093	0.079	0.080	-0.095	-0.094	-0.094	-0.094	0.056	0.057	0.055	0.057
	(0.076)	(0.072)	(0.075)	(0.071)	(0.079)	(0.078)	(0.079)	(0.078)	(0.057)	(0.053)	(0.056)	(0.052)
Public School	0.039	0.040	0.027	0.030	0.033	0.034	0.032	0.033	0.027	0.029	0.021	0.024
	(0.067)	(0.066)	(0.067)	(0.066)	(0.052)	(0.051)	(0.051)	(0.051)	(0.049)	(0.048)	(0.048)	(0.048)
Community Size	0.018	0.022	0.017	0.020	-0.008	-0.007	-0.008	-0.007	0.005	0.008	0.006	0.009
	(0.035)	(0.034)	(0.035)	(0.034)	(0.029)	80.029)	(0.029)	(0.029)	(0.024)	(0.023)	(0.024)	(0.023)
Student-Teacher Ratio	-2.037	-2.234	-1.932	-2.096	-1.128	-1.213	-1.157	-1.231	-1.637	-1.854	-1.699	-1.899
	(2.156)	(2.117)	(2.113)	(2.074)	(1.879)	(1.869)	(1.882)	(1.869)	(1.797)	(1.765)	(1.818)	(1.776)
School Size	-0.0001	-0.0001	-0.0001	-0.0001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00007	-0.00008	-0.00008	-0.00008
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.00009)	(0.00009)	(0.00009)	(0.00009)	(0.00009)	(0.00009)	(0.00009)	(0.00009)
Perceived School Quality	0.072***	0.071***	0.070***	0.069***	0.037	0.037	0.037	0.037	0.070***	0.070***	0.071***	0.071***
	(0.021)	(0.021)	(0.022)	(0.021)	(0.027)	(0.027)	(0.027)	(0.027)	(0.022)	(0.022)	(0.023)	(0.022)
Female Teacher	-0.071*	-0.158***	-0.059	-0.131***	-0.083*	-0.119**	-0.082*	-0.118**	-0.005	-0.094*	0.003	-0.084*
	(0.040)	(0.053)	(0.038)	(0.048)	(0.044)	(0.059)	(0.043)	(0.059)	(0.037)	(0.053)	(0.035)	(0.051)
Female Student*Female Teacher		0.184***		0.146**		0.078		0.075		0.190***		0.177***
		(0.070)		(0.066)		(0.088)		(0.088)		(0.068)		(0.067)
Teacher's Tenure	0.013	0.010	-0.023	-0.025	0.032	0.030	0.034	0.032	-0.056	-0.059	-0.053	-0.056

	(0.057)	(0.058)	(0.057)	(0.058)	(0.057)	(0.057)	(0.057)	(0.057)	(0.045)	(0.045)	(0.046)	(0.046)
Experience of Teacher	-0.003	-0.003	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	0.0005	0.0003	0.0006	0.0004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.0017)	(0.002)	(0.002)
Intellectual Abilities	0.441***	0.445***	0.416***	0.421***	0.904***	0.906***	0.900***	0.903***	0.596***	0.599***	0.595***	0.599***
(log reading score)	(0.122)	(0.120)	(0.121)	(0.120)	(0.134)	(0.134)	(0.134)	(0.134)	(0.099)	(0.099)	(0.098)	(0.099)
Father's Education	-0.006	-0.006	-0.005	-0.005	-0.048*	-0.048*	-0.048*	-0.048*	-0.006	-0.007	-0.007	-0.007
	(0.021)	(0.021)	(0.021)	(0.021)	(0.028)	(0.028)	(0.028)	(0.028)	(0.024)	(0.024)	(0.024)	(0.024)
Mother's Education	0.010	0.010	0.008	0.007	-0.026	-0.026	-0.026	-0.026	-0.027	-0.028	-0.027	-0.028
	(0.022)	(0.022)	(0.021)	(0.022)	(0.028)	(0.028)	(0.028)	(0.028)	(0.021)	(0.021)	(0.021)	(0.021)
Economic, Social and Cultural Status	0.062	0.063	0.063	0.064	0.293***	0.294***	0.294***	0.294***	0.130***	0.131***	0.132***	0.132***
	(0.042)	(0.042)	(0.041)	(0.041)	(0.051)	(0.052)	(0.051)	(0.051)	(0.042)	(0.042)	(0.041)	(0.041)
Family Spending on Education	0.022	0.022	0.017	0.017	-0.004	-0.004	-0.004	-0.004	0.005	0.004	0.002	0.002
	(0.014)	(0.014)	(0.014)	(0.014)	(0.016)	(0.016)	(0.016)	(0.016)	(0.014)	(0.014)	(0.014)	(0.014)
Parental Support for Learning at Home	0.131***	0.131***	0.127***	0.127***	0.101***	0.102***	0.101***	0.102***	0.094***	0.094***	0.093***	0.093***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.024)	(0.024)	(0.024)	(0.024)	(0.018)	(0.018)	(0.018)	(0.018)
Parental Emotional Support	-0.011	-0.012	-0.009	-0.009	0.019	0.019	0.019	0.019	-0.014	-0.014	-0.013	-0.013
	(0.019)	(0.019)	(0.019)	(0.019)	(0.020)	(0.020)	(0.020)	(0.020)	(0.017)	(0.018)	(0.017)	(0.018)
Skipping (some) Classes	0.016	0.018	0.032	0.033	-0.005	-0.004	-0.003	-0.003	0.117	0.119	0.123	0.124
	(0.082)	(0.08)	(0.083)	(0.084)	(0.133)	(0.133)	(0.132)	(0.133)	(0.087)	(0.088)	(0.085)	(0.087)
Coming to School Late	-0.069**	-0.069**	-0.074**	-0.073**	-0.112**	-0.111**	-0.112**	-0.112**	-0.099**	-0.098**	-0.096**	-0.096**
	(0.034)	(0.034)	(0.033)	(0.033)	(0.0489	(0.048)	(0.048)	(0.048)	(0.040)	(0.041)	(0.040)	(0.040)
Chatting Online (outside of School)	0.008	0.010	0.010	0.011	0.005	0.006	0.005	0.006	0.022**	0.024**	0.023**	0.024**
	(0.012)	(0.012)	(0.011)	(0.011)	(0.014)	(0.014)	(0.014)	(0.014)	(0.011)	(0.011)	(0.010)	(0.011)
Participation in Social Networks	-0.058***	-0.059***	-0.056***	-0.056***	-0.039***	-0.040***	-0.039***	-0.040***	-0.060***	-0.061***	-0.059***	-0.060***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.015)	(0.015)	(0.015)	(0.015)	(0.012)	(0.012)	(0.012)	(0.011)
Chatting Online (in School)	0.047***	0.045***	0.045***	0.043***	0.087***	0.086***	0.087***	0.086***	0.061***	0.058***	0.063***	0.060***

	(0.017)	(0.016)	(0.016)	(0.016)	(0.022)	(0.023)	(0.022)	(0.023)	(0.020)	(0.020)	(0.020)	(0.020)
Feeling Belonging to School	0.116***	0.116***	0.105***	0.105***	0.178***	0.177***	0.176***	0.177***	0.127***	0.126***	0.123***	0.123***
	(0.023)	(0.023)	(0.022)	(0.022)	(0.025)	(0.025)	(0.025)	(0.026)	(0.023)	(0.023)	(0.023)	(0.023)
Unfairness of Teacher	-0.003	-0.003	-0.004	-0.004	0.008	0.008	0.008	0.008	-0.010*	-0.010*	-0.011*	-0.011*
	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)	(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 schools)

Dependent Variable	Sample	ATE (single-sex school)	AI Robust Std.Err.	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.Err.	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	4th	3rd	2nd	1st	4th	3rd	2nd	1st	4th	3rd	2nd	1st
(Science Scores)	(≥ 582)	(518-582)	(449-518)	(<449)	(≥ 582)	(518-582)	(449-518)	(<449)	(≥ 582)	(518-582)	(449-518)	(<449)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Female Student	-0.494***	-0.209*	-0.220*	-0.234**	-0.145	0.070	0.111	0.171	-0.474***	-0.229**	-0.495***	-0.395***
	(0.102)	(0.122)	(0.117)	(0.112)	(0.119)	(0.113)	(0.176)	(0.182)	(0.095)	(0.109)	(0.113)	(0.113)
Boy School	-0.045	0.004	-0.013	0.051	-0.257**	-0.214*	0.204	0.145	-0.082	0.005	0.047	0.034
	(0.093)	(0.100)	(0.134)	(0.103)	(0.100)	(0.112)	(0.180)	(0.148)	(0.073)	(0.086)	(0.109)	(0.111)
Girl School	0.202	0.014	0.154	0.063	0.110	-0.160	-0.413**	0.121	0.176	-0.034	0.088	0.089
	(0.204)	(0.095)	(0.114)	(0.125)	(0.093)	(0.112)	(0.161)	(0.148)	(0.131)	(0.085)	(0.088)	(0.108)
Female Teacher	-0.243**	-0.177*	-0.040	-0.107	-0.253**	0.006	0.0001	-0.133	-0.060	-0.043	-0.184	-0.022
	(0.099)	(0.090)	(0.111)	(0.096)	(0.100)	(0.100)	(0.148)	(0.145)	(0.075)	(0.107)	(0.126)	(0.105)
Female Student*Female Teacher	0.373**	0.091	-0.018	0.254*	0.199	-0.058	-0.001	0.076	0.222**	-0.071	0.390***	0.154
	(0.145)	(0.125)	(0.111)	(0.139)	(0.150)	(0.133)	(0.199)	(0.218)	(0.107)	(0.134)	(0.141)	(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. * $p< .10$, ** $p< .05$, *** $p< .001$.

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.

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 schools)

Dependent Variable	Instrumental Motivation in Science							
Quartile	4^{th} (score ≥ 582)		3^{rd} (518–582)		2^{nd} (449–518)		1^{st} (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	4^{th} (score ≥ 582)		3^{rd} (518–582)		2^{nd} (449–518)		1^{st} (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	4^{th} (score ≥ 582)		3^{rd} (518–582)		2^{nd} (449–518)		1^{st} (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)

Note: ATE refers to average treatment effects and AI Robust Std.Err. Abadie Imbens robust standard errors.

Dependent Variable	Instrumental Motivation in Science							
Quartile	4^{th} (score ≥ 582)		3^{rd} (518–582)		2^{nd} (449–518)		1^{st} (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	4^{th} (score ≥ 582)		3^{rd} (518–582)		2^{nd} (449–518)		1^{st} (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	4^{th} (score ≥ 582)		3^{rd} (518–582)		2^{nd} (449–518)		1^{st} (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 A. 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