Gender-matching School Effects on Girls' Cognitive and Non-cognitive Performance in South Korea

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Abstract:
This paper investigates whether gender-matching school environments can improve girls' interest and motivation in science. Using the PISA data from South Korea, the empirical results of this paper show that gender-matching school environments have the most positive effect on the attitudinal development of girls who are at the highest quartile in science studies. By attending an all-girls school and being taught by a female science teacher, high-performing girls become as motivated and interested in pursuing science studies and careers as boys. Additionally, female teachers have a generally positive effect on developing girls' competitive attitudes regardless of their study records. However, the effect of single-sex schooling is heterogeneous depending on levels of students' cognitive performance. While maintaining its positive effect on high- and low-performing girls, attending an all-girls school can be detrimental to the attitudinal development of median girls. These findings corroborate that gender-matching school environments can be a useful policy instrument that promotes female talent in STEM fields, but the positive effect is not universal and thus cannot be generalized for everyone.

Keywords: student-teacher gender-matching; single-sex schooling; cognitive performance; non-cognitive performance; propensity-score matching; South Korea
JEL-codes: I21; I24; J16; O53

Note:
Figures, tables and appendices of this paper can be found in its discussion paper version available online (https://www.uni-marburg.de/fb02/makro/forschung/magkspapers/paper_2017/38-2017_cho.pdf). Figure 1, Tables 6 and 8 are presented in this paper.

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1. Introduction

Despite noticeable improvement in recent female education and their social status, labor market outcomes show that women are still disadvantaged in earnings and are promoted less frequently to decision-making positions. One explanation for such gender disparity is that men and women behave differently in competitive environments. Women's underperformance and underrepresentation in competition could explain gender wage differentials and gender gaps in decision-making positions. In an attempt to shed light on the causes of gender-asymmetric behaviors in competition, recent literature has focused on how the gender composition of one's surroundings influences individual performance. The empirical evidence suggested in the literature reveals that women tend to underperform when they have to compete with men, and a higher presence of female peers (or the absence of male counterparts) can therefore create a favorable environment for women and girls to boost their performance and competitiveness (Antonovics et al. 2009; Niederle and Vesterlund 2007).

In this respect, single-sex schooling is often considered a policy instrument in education to improve girls' performance. This is not only because single-sex schools are expected to maximize boys' and girls' academic performance by providing them with instructions based on their gender-specific needs, but also because single-sex schooling can strengthen girls' competitive attitudes. In all-girls schools, girls can be freer from traditional gender roles and can adopt more positive and active gender identities by interacting with female peers who are more present and driven towards lead roles that become more available in the absence of boys (see Bracey 2006; Hill 2015; Gneezy et al. 2003; and Niederle and Vesterlund 2007 for detailed discussions). In literature, various studies provide empirical evidence that single-sex schooling has a positive effect on girls' studies and attitudes in different countries: see Booth and Nolen (2012a, b) 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.[1]

However, other studies challenge the idea that single-sex schooling can improve girls' performance (see Billger 2009; Halpern et al. 2011; Aedin et al. 2013; Strain 2013; and Goodkind et al. 2013). These studies argue that the presumed positive outcome of single-sex schools is likely caused by endogenous school choices, in that students in single-sex schools are systematically different in their characteristics and performance records from students in coeducational schools.

In addition to single-sex schooling, literature also focuses on another important type of gender-matching in school environments: interactions between students and teachers of the same sex. A growing number of studies have documented that female teachers/professors have a positive influence on female students' performance (Carrell et al. 2010; Nixon and Robinson 1999; Bettinger and Long 2005; Dee 2007). This is likely because they can employ teaching methods and forms of communication that are more suited for girls due to their own gender knowledge. Furthermore, female teachers represent active female professionalism and mentorship for girls and therefore can become positive gender role models for girls, motivating them to actively participate in class and set ambitious career goals.

Considering these arguments, this paper investigates single-sex schooling and interactions of a female student and a female teacher as crucial gender-matching school environments that influence girls' performance and attitudes by focusing on South Korea. Statistics suggested by the Program for International Student Assessment (PISA, OECD 2015) illustrates an interesting case of gender gaps in students' performance in South Korea. Namely, South Korean girls outperform boys in cognitive studies including science, however, they are less motivated and interested than boys in pursuing competitive

[1] Jackson (2012) finds an overall null effect of attending a single-sex school, however, his study further reveals that single-sex schools provide sizeable advantages for girls with strong preferences for attending an all-girls school.

study and career paths in science, technology, engineering, and math (STEM) – see Figure 1.[2] This disparity signals that girls' low level of motivation and interest in science cannot be explained by their supposed lack of abilities. Rather, it can be attributed to societal environments that discourage women's participation in STEM fields. In this paper, STEM fields are at the forefront of the investigative analysis because science and engineering are among the most male-dominated areas that exacerbate gender wage differentials and women's underrepresentation in competitive labor markets.

By examining the case of South Korea, this paper aims to find whether gender-matching school environments can be instrumental to reduce gender gaps in competitive attitudes in STEM fields. To the present, literature reports a generally positive effect of attending an all-girls school in South Korea, but most analyses focus on the effect on cognitive outcomes (Park et al. 2013; Kim 2012; Kim and Law 2012; Link 2012; Dustmann et al. 2017). In addition to single-sex schooling, Lim and Meer (2017) document that female teachers have a positive influence on girls' studies in South Korea. On the other hand, studies on the effect of single-sex schooling on non-cognitive outcomes in South Korea so far do not provide positive evidence supporting the role of all-girls schools. Through an analysis of middle-schools in Seoul, Lee et al. (2014) find that girls in all-girls schools are not more competitive than girls in mixed-sex schools, and coeducation rather reduces gender gaps in competition. Using a sample of high school students in Seoul, Park et al. (2018) further show that single-sex schooling increases boys' interest and self-efficacy in math and science, but the effect does not exist for girls. Given the scarcity of empirical evidence of gender-matching school effects on attitudes in South Korea, their studies provide seminal analyses with which findings should be coupled with data of different school levels, heterogeneous student groups, and wider ranges of regions. Keeping this in mind, my paper builds on evidence of gender-matching school effects on girls' non-cognitive performance in science by extending the analysis to high school students in different regions throughout South Korea. Furthermore, my study adds a new dimension of investigation by distinguishing heterogeneous effects of gender-matching schooling on non-cognitive outcomes that differ depending on students' cognitive performance levels.

Using the 2015 PISA data for South Korea, the findings of this paper show that gender-matching school environments can promote high-performing girls' motivation and interest in science. By attending an all-girls school and being taught by a female science teacher, girls who are 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. In addition, female teachers generally have a positive effect on developing competitive attitudes of girls regardless of their study records. However, the effect of single-sex schooling is not as positive for girls in the 2nd and 3rd quartiles of their science scores because attending an all-girls school can be detrimental to the attitudinal development of median girls in this group. This finding is consistent with Lee et al. (2014) and Park et al. (2018) and indicates that no positive effect of single-sex schooling on girls' attitudes is possibly driven by average girls. The results of my paper corroborate that gender-matching school environments can be a useful policy instrument to motivate female talent to pursue careers in STEM fields. However, one should also note that this positive effect is not universal for all students.

2. Empirical Framework

2.1. Education Production Function

The central question for the empirical analysis of this paper is to identify the net effect of gender-matching school environments on girls' performance. To isolate this effect, the estimation 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 by the following input:

[2] Figures, tables and appendices of this paper can be found in its discussion paper version available online (https://www.uni-marburg.de/fb02/makro/forschung/magkspapers/paper_2017/38-2017_cho.pdf). Figure 1, Tables 6 and 8 are presented in this paper.

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) because both cognitive and non-cognitive skills are important determinants of successful career development. The above education production function is rewritten in an econometric model below specifying covariates and their relationships with the outcome variables:

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

The set of the outcome variables consists of several indicators that evaluate different dimensions of students' performance. First, students' cognitive performance is measured by their PISA test scores in reading, math, and science subjects. Second, the non-cognitive performance of students is proxied by a student's self-assessment of his/her instrumental motivation, confidence, and interest in science that are available in the PISA survey. These variables reflect important individual attitudes that influence one's decision to pursue studies and careers in STEM fields:

Cognitive performance = {science score, math score, reading score}
Non-cognitive performance = {instrumental motivation, confidence, interest in science}

In estimating the model of non-cognitive performance, a variable that reflects a student's 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 important factor of 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, sharing their latent concepts to a great extent. To avoid this problem, PISA reading scores are used as a proxy to capture a general level of intelligence instead. High correlation between the two scores strengthen the validity of a reading score as a proxy variable: corr. (reading score´science score) = 0.85. Accordingly, the model of non-cognitive performance takes the following form:

$$\text{Performance (non-cognitive)}_i = a' + \beta'_1 \text{female student}_i + \beta'_2 \text{boy school}_i + \beta'_3 \text{girl school}_i + \beta'_4 \text{female teacher}_i + \beta'_5 \text{female student}_i * \text{female teacher}_i + \beta'_6 \text{reading score}_i + X_i{'}\Gamma' + S_i{'}\Psi' + T_i{'}\Pi' + B_i{'}\Upsilon' + R_i{'}N' + u'_i \qquad (1')$$

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. *Boy school* and *girl school* represent single-sex schooling for boys and girls, respectively. Hence, gender-matching 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 following.

$$H_0: \quad \beta_3 (\beta`_3) > 0$$
$$H_0: \quad \beta_5 (\beta`_5) > 0$$

The model includes various 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), teachers' characteristics (T), a student's behavioral factors (B), and teacher and peer relationship (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 level. The choice of school inputs follows Krueger (2003) and Hanushek (2011) who propose class sizes and teachers' 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 mentalities. Therefore, accounting for such effects can reduce the influence of a student's unobserved characteristics on his/her performance. The list of input variables in each vector is detailed below and the descriptive statistics of all variables used for the estimations are presented in Appendix A.

- G (gender and gender-matching variables) = {female student; boy school; girl school; female teacher; and female student*female teacher}
- X (student's and family characteristics) = {father's education; mother's education; student's economic, social, and cultural status; family spending on education; parental support for learning at home; parental emotional support; and intellectual ability (in the model of non-cognitive performance)}
- S (school characteristics) = {public school; community size; student-teacher ratio; school size; and school quality perceived by parents}
- T (teacher's characteristics) = {teacher's tenure; and teacher's years of teaching experience}
- B (student's behaviors) = {frequency of skipping classes; coming to school late; chatting online at school and outside of the school; and participation in social networks}
- R (teacher and peer relationships) = {degree of feeling belonging to school; and unfairness of teachers}

The econometric models formulated in Equation 1 and 1′ are estimated by two methods. First, an OLS estimation is applied, assuming the linearity of the models with continuous dependent variables. Second, the models are constructed as a multilevel (mixed) one in which observations are nested within schools. This approach allows us to account for heterogeneous data patterns across schools. In this model, intercepts are treated as random effects considering 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.

Estimations are first conducted with the full sample. The full sample includes 3,259 students in 105 high schools in South Korea who took part in PISA in 2015 (n = 3,259; s = 105). Then, the sample is limited to public schools (n = 2,280; s = 74). The sample of public schools can reduce unobserved heterogeneity of students and schools because students in private schools tend to be different in their socioeconomic backgrounds from others in public schools, and private schools have different school management systems including own recruitment processes of teachers.[3]

2.2. Self-selection into a Single-sex School and Propensity-score Matching

In identifying the net effect of single-sex schooling from other compounding influences, a critical question remains to be answered: *are students in single-sex schools systematically different from others in mixed-sex schools?* If students decide to attend an all-girls or all-boys school because of their distinguished backgrounds and characteristics, the choice of school is endogenous to their performance outcomes. Under the presence of such self-selection biases, a causal effect of single-sex schooling on students' performance cannot be identified. Furthermore, unobserved heterogeneity of schools in terms of curriculum, teachers' quality, and school orientations that may differ between the school types also makes it difficult to isolate the gender-matching effect of single-sex schools.

In this respect, the data from South Korea provides a comparative advantage of equilibrating students between single- and mixed-sex schools because single-sex schooling is more common there than most other countries – for instance, less than 5 percent of all high schools in the USA provide single-sex education. In the sample of the PISA 2015, 29.4 percent of boys and 24.8 percent of girls attend single-sex high schools. Thus, systematic differences in students between the two types of schools are less salient in South Korea. Furthermore, a sufficient number of observations of single-sex school attendees can be obtained for a viable comparison. However, the South Korean sample is also not completely free of selection biases because students are not randomly assigned to schools but they can select a preferred

[3] In public schools, teachers have to pass the national teacher exam (implemented at the provincial level) to be employed, but this exam is not required for teachers in private schools. Also, teachers in public schools are rotated to different schools regularly (e.g. every five years), while teachers in private schools are not subject to obligatory relocation.

one to attend. For instance, since 2010, middle-school students in Seoul have been allowed to submit three names of preferred high schools and they are assigned to a school based on their preferences. According to Kim (2012), students clearly 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 others in mixed-sex schools in university entrance exams. Thus, students (and parents) who are more concerned about their study records and opportunities for higher education are more likely to choose single-sex schools.

With this in mind, a formal analysis is conducted to find whether students in single-sex schools have systematically different characteristics compared to those in mixed-sex schools. To identify a mechanism of attending a single-sex school, various ex-ante conditions of students prior to entering a high school are included in the parsimony and extended models and the effects are estimated by using a probit method (with a binary dependent variable that has a value of 1 if student i attends a single-sex school). The results are presented in Appendix C. Contrary to commonly-held beliefs of single-sex schools, a higher socioeconomic status of a student does not increase the probability of one attending a single-sex school. Further, higher levels of a father's education and home possessions (e.g. TV and wash machines) even reduce a girl's probability of choosing an all-girls school. Most other variables reflecting students' characteristics have no significant effects on single-sex schooling. An exception is family support for children that has a positive effect on single-sex education. Educational resources available at home increase a girl's probability to attend an all-girls school, and parental emotional support increases a boy's single-sex schooling chances. In addition, living in a larger city positively affects attendance in an all-boys school – a logical consequence given that small towns may not be able to host both all-boys and girls schools. Weak relationships between students' socioeconomic conditions and single-sex schooling show that students are relatively comparable across the two school types in South Korea. Nonetheless, there is some evidence that students whose parents are more supportive are more likely to choose a single-sex school. This finding necessitates the utilization of a method that can empirically address the endogenous school choice. Accordingly, the following approaches are employed in this paper. First, various educational inputs are incorporated in the empirical model in a holistic manner based on the education production function (Hanushek 1986; Krueger 1999) – see Section 2.1 for details. Second, the sample is limited to public schools only to minimize school heterogeneity. Third, students are matched based on their propensity to attend a single-sex school and an average treatment effect is computed by a propensity-score matching method (PSM).

In the PSM estimations, attending a single-sex school is designated as a treatment effect. An individual's probability of choosing single-sex schooling is predicted based on observed covariates, 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. The average treatment effect (ATE) of attending a single-sex school is then computed by imputing the missing potential outcome for each subject (see Equation 2/2′ below). This is done by averaging outcomes of similar subjects that receive the other treatment level. Hence, the PSM estimator captures the average difference between the observed and potential outcomes for each subject (Abadie and Imbens 2011).

$$\text{ATE} = E[\text{cognitive outcome}_{\text{single-sex}} - \text{cognitive outcome}_{\text{mixed-sex}} \mid G; X; S; T; B; R] \quad (2)$$
$$\text{ATE} = E[\text{non-cognitive outcome}_{\text{single-sex}} - \text{non-cognitive outcome}_{\text{mixed-sex}} \mid G; X; S; T; B; R] \quad (2')$$

3. Results

3.1. Baseline Estimates

In investigating gender gaps in cognitive and non-cognitive performance, descriptive differences between boys and girls are first compared. Overall, South Korean girls do not perform worse than boys in their studies. There is no gender difference in science and math scores measured by mean, median, and distribution differences, while girls outperform boys in reading significantly (see Appendix B).[4] In

[4] The mean reading score of girls is 34 points (a third of its standard deviation) higher than that of boys. Furthermore, 57 percent of girls have a reading score above the median, while only 44 percent of boys

addition to the overall comparisons presented in Appendix B, Figure 2 illustrates quantile distributional plots of performance of boys and girls that show minimal gender differences in science and math test scores in all fractions of the data.

However, the findings are quite different in non-cognitive performance. Boys express higher levels of instrumental motivation and interest in pursuing careers in STEM fields than girls.[5] This is evident in all of mean, median, and distribution differences (Appendix B). Also, the quantile analyses depicted in (4) and (6) of Figure 2 reveal that boys have higher levels of motivation and interest in science in all fractions of data points. These descriptive gender differences in cognitive and non-cognitive performance tentatively suggest that boys are overly motivated and interested in science compared to girls although there is little evidence that they actually outperform girls in this field of study.

With this in mind, the gender (in)differences in cognitive and non-cognitive performance in science are further investigated through systematic analyses. In doing so, the following questions are specifically addressed: (i) dose a student's gender influence his/her performance?, and (ii) can gender-matching school environments reduce the suggested gender gaps in non-cognitive performance?

The results of cognitive outcomes estimated with the full sample are first presented in Table 1. As expected from the descriptive analysis, a student's gender is not a significant determinant of his/her science and math scores. However, in reading, girls have a significant advantage of having a score that is five percentage-points (p.p.) higher than boys' on average. On the contrary, a teacher's gender is widely unimportant to students' cognitive performance. There is some evidence that being taught by a female science teacher increases both girls' and boys' test scores in this subject. However, this result is found in the multilevel estimations only, and the estimated effect is too small to draw an economic meaning. Furthermore, gender-matching environments do not influence a student's cognitive performance. Neither single-sex schooling nor the interaction of a female student and a female teacher has an effect on any of the three test scores.

Among school inputs, a higher student-teacher ratio deteriorates study outcomes, supporting the benefits of small classes. However, a school size (the number of students) is not an important determinant of a student's study results. School quality evaluated by parents has a positive effect in the OLS estimations but the size of the effect is negligible. A school's status (public or private) and location (community size, indicating urban or rural) are also unimportant. Moreover, teachers' credentials have little to do in improving students' study performance. Neither teacher's tenure nor experience has any effect on test scores.[6] Limited roles of school and teachers' inputs mirror the importance of private after-school tutoring that often overshadows formal schooling in South Korea (Kim 2012).

In contrast, a student's family backgrounds and socioeconomic status are important inputs of one's 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. Increasing one-standard deviation in these variables increases the test scores by 3.3–4.8 p.p. (ESC status), 1.2–2.7 p.p. (family spending), and 0.7–0.9 p.p. (parental emotional support). The effects of one's ESC status and family spending on education are greater for math scores, while that of parental emotional support has a larger effect on science. In addition, a mother's education positively influences a student's math score. A one-standard deviation increase in the level of a mother's education increases her child's math score by 0.7–0.9 p.p. Also, evidence suggests a positive effect of a mother's education on her child's science score (but the effect is significant in the OLS model only). On the other hand, a father's education does not affect his child's study outcomes in any of the three subjects. Its effect is possibly surpassed by the effect of a mother's education that tends to share similar features.

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do. Also, the Mann-Whitney rank-sum test places more girls on the right-side of the distribution curve (i.e. higher scores) than boys.

[5] On the other hand, there is no difference in the level of confidence between boys and girls.

[6] Teachers' education is not included as a teacher's input because of little variations in the variable. In South Korea, nearly all teachers are certified with a bachelor degree or higher.

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. However, online activities outside of the school (online chatting out-of-school and social network participation) do not harm a student's study performance. In addition, a student's relationship with teachers is important to the cognitive learning of the student. Increasing distrust in the fairness of a teacher by one standard deviation reduces a student's test scores by more than 2 points (0.2 p.p.) in all three subjects.

So far, the analysis of cognitive performance suggests little support to gender or gender-matching effects. However, the outlooks are different when the effects are estimated on non-cognitive outcomes (see Table 2). First, the gender effect becomes negative for girls. Being a girl, the level of her instrumental motivation in science is lower than boys by 6.5–9.5 p.p. and that of her interest in science by 6.8–9.2 p.p. On the other hand, a teacher's gender has a conflicting effect on boys and girls. Female science teachers reduce boys' motivation, confidence, and interest in science by 4, 1.7, and 1.7 p.p., respectively. However, for girls, the effect of a female teacher is generally positive, as the positive interaction effect of a female student-teacher pair outweighs the negative effect of a female teacher. Specifically, 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. This positive interaction effect also reduces the negative effect of a girl's own gender. If a girl is taught by a female teacher, the negative effect of being a girl on her motivation decreases by 5.3–7.5 percent and that on her interest in science 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 of a female student-teacher pair, single-sex schooling does not influence one's non-cognitive performance – similar to its minimal role in cognitive outcomes. Most other school inputs also have no effect, except perceived school quality that is positively associated with one's motivation and interest levels. Teachers' inputs are also irrelevant to a student's non-cognitive performance. On the other hand, students' family backgrounds and their behavioral patterns provide significant explanations for their attitudinal performance. In particular, a student's ESC status increases his/her confidence and interest in science, and parental support for learning improves students' non-cognitive performance in all three dimensions. However, family spending on education and parents' emotional support that were important to cognitive outcomes do not play a significant role in enhancing students' non-cognitive performance. In addition, one's intelligence level (proxied by log reading scores) has a significant effect on his/her non-cognitive performance, as expected, but the magnitude of the effect is trivial – about a tenth of 1 p.p.

Among behavioral patterns, frequently coming to school late and participating in social networks negatively influence non-cognitive performance in all three dimensions. Increasing frequency in late coming by one-standard deviation decreases a student's non-cognitive outcomes by 0.9–1.1 p.p. Frequenting in social networks by the same margin reduces one's motivation, confidence, and interest levels by 2.34, 0.8, and 1.74 p.p., respectively. Online social networks are negatively associated with students' attitudes possibly because some students may use SNS as a tool to shy away from activities in the real world. In contrast, chatting online at school reinforces a student's positive attitudes. Increasing one-standard deviation in the frequency of in-school online chatting improves one's non-cognitive performance by 1.1–1.2 p.p. One plausible interpretation on this result is that online chatting inside the school mirrors a student's outgoing involvement in school activities. Examining detailed mechanisms of online activities and their effects on one's attitudes is beyond the scope of this paper. However, given the rising importance of online behaviors on cognitive and non-cognitive development of the youth today, this finding certainly requires further research. In addition to online behaviors, feeling belonging to school increases all three dimensions of non-cognitive outcomes, while the unfairness of a science teacher decreases one's interest in this subject.

3.2. Effects of Unobserved Heterogeneity

Among the two gender-matching indicators, the interaction of a female student-teacher pair 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 family backgrounds. However, this is less likely. In South Korea, students are randomly allocated among different classes (at least in regular classes that are surveyed in the PISA), independent of their performance or characteristics. Thus, each class includes wide ranges of students of different study ranks and backgrounds. On the other hand, single-sex schooling is more likely endogenous to students' performance given that students/parents can select a list of preferred schools and are assigned to one of them. Including an extensive set of covariates as presented in Section 3.1. helps reduce biases arising from an endogenous school choice. However, a large set of controls does 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, the endogenous choice of single-sex schooling (self-selection) is further examined by employing the following approaches in this section.

First, the sample is limited to public schools. Students in private schools are likely different from those in public schools because the former tend to come from more selected family backgrounds. Furthermore, private schools have more heterogeneous school quality and curricula decided by their founders and management instead of the state. Thus, limiting the sample to public schools can reduce unobserved heterogeneity of students and schools that influences students' performance. The public-school sample represents 70 percent of the full sample.

The results of cognitive outcomes in public schools are presented in Table 3. The results are largely similar to those of the full sample in Table 1. Most importantly, the gender-matching school environments play no role in any of the three subjects in public schools. Also, there is no negative gender effect on cognitive performance. Neither being a female student nor being taught by a female teacher reduces a student's study outcomes. Instead, being a girl has a positive effect on her reading score. The effects of school, family and behavioral inputs remain similar to those of the full sample. However, perceived school quality loses its significant effect in public schools. This finding implies that public schools offer more homogeneous quality of education than private ones.

On the other hand, the results of non-cognitive performance in public schools have three noticeable differences compared to the full-sample estimations (see Table 4). First, single-sex schooling increases girls' motivation in science in public schools – different from no effect in the full sample. Second, a female science teacher has no longer a negative effect on boys' interest in science. Third, the positive effect of a female science teacher is twice as large for girls in public schools as in the full sample. These differences suggest that the gender-matching effects are more important in ordinary environments of public schools than arguably more privileged private ones. Furthermore, while the effect of a girl's own gender remains negative in public schools, the positive gender-matching effects with larger magnitudes significantly reduce the negative gender effect. For example, if a girl attends an all-girls school and is taught by a female science teacher, the negative effect of her gender on her motivation in science decreases by 70–80 percent (Columns 2 and 4). Also, the positive interaction effect of a female student-teacher pair reduces the negative gender effect on a girl's interest in science by 40 percent (Columns 10 and 12).

In addition to the sampling of public schools, propensity-score matching is conducted, as a second method of addressing unobserved heterogeneity. Table 5 presents the PSM results, in that the effect of an all-girls school is generally minimal in determining girls' 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 positive effect of attending all-girls schools on girls' motivation that was found in Table 4 also loses its significance in the PSM analysis. The effect of single-sex schooling becomes positive for girls' confidence in this estimation, but it is significant at a 10 percent level only.

As seen here, the PSM analysis provides little support to the role of all-girls schools, but attending an all-boys school has a more significant effect on boys' cognitive performance. The average treatment effect is positive for boys, increasing their science and reading scores by 3.5 and 3.9 p.p., respectively (Table 5.1). However, when the sample is limited to public schools, the positive effect of all-boys schools disappears. This positive effect is indeed driven by those who selected private boy schools, but not by the general population of boy students in South Korea.

3.3. Response Heterogeneity by Cognitive Performance

The results above provide some but not very robust evidence for gender-matching effects on girls' performance. The interaction of a female student-teacher pair maintains its positive effect on girls' motivation and interest in science. However, the effect of all-girls schools is not consistent, particularly losing its significance after taking into account self-selection effects.

While the analysis has so far focused on the gender-matching effects at the aggregate level, the effects may be heterogeneous depending on students' study performance. Specifically, girls with higher cognitive abilities would benefit more from gender-matching environments because in such surroundings, girls' abilities are likely fairly valued and thus high performing girls would be encouraged to be confident and aim high. This argument is plausible because the absence of male counterparts enables girls and women to be freer of their traditionally defined gender role of being modest, and therefore they can develop more competitive attitudes (Niederle and Vesterlund 2007). With this mind, the effect of gender-matching schooling is further investigated by disentangling the effect based on students' study outcomes. This approach lends insights into potentially heterogeneous responses to single-sex schooling and the interaction of a female student and a female teacher.

To estimate heterogeneous gender-matching effects, students are sub-grouped based on the quartiles of their science scores: the 4th (science score > 582); the 3rd (518 < science score < 582); the 2nd (449 < science score < 518); and the 1st (science score < 449) quartiles. Table 6 shows the results of the sub-sample estimations including both public and private schools.[7] Consistent with the results at the aggregate level in Table 2, a girl's own gender constrains her from being motivated and interested in science regardless of her science score. Notably, the negative gender effect is largest among the best performing girls (the 4th quartile). For instance, the negative effect of being a girl on a girl's motivation is twice as large for the best performing girls as the worst performing ones (the 1st quartile). Also, this negative effect is 20 percent larger on the interest of girls in the 4th quartile than that of others in the 1st quartile. The finding that a girl's gender has the most detrimental influence on the best performing group of girls implies that female abilities are discredited in society instead of being recognized (Cho 2017).

However, this negative gender effect on a girl can be mitigated through the gender-matching effects that are most positive for the best performing girls in science. For instance, if a girl in the 4th quartile is taught by a female teacher, the negative gender effect decreases by 26 percent for her instrumental motivation, and by nearly 50 percent for her interest in science (Columns 1 and 9). Also, there is evidence of the positive interaction effect of a female student-teacher pair on girls in the 1st and 2nd quartiles. Being taught by a female teacher suppresses the negative gender effect on girls in the 1st quartile and they become more motivated than boys in the same group (Column 4). Similarly, the positive interaction effect reduces the negative gender effect on the interest of girls in the 2nd quartile by 80 percent (Column 11). However, there is no such gender-matching effect found in median girls in the 3rd quartile.

In addition to the interaction effect of female students and teachers, single-sex schooling further moderates the negative gender effect on girls – particularly on the best performing ones. Heterogeneous responses to single-sex schooling are identified by a propensity-score matching method (see Table 8.1). The effect is positive for girls in the 4th quartile and this effect maintains in all three dimensions of non-cognitive performance. The magnitudes of the effect are considerably large (0.154–0.443), thus the negative effect of a girl's own gender can be reduced to a great extent (by 50–90 percent). Moreover, combining both gender-matching effects of single-sex schooling and female student-teacher's interactions, the best performing girls can be more motivated than the best performing boys, and also they can be (almost) as interested in science as boys in the same group. For example, by attending an all-girls school and being taught by a female teacher, the net gender effect of a girl in the 4th quartile on

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[7] In Tables 6 and 7, 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.

her instrumental motivation become +0.079,[8] in that her motivation level is about 2.2 p.p. higher than a boy in the same quartile. Also, the negative gender effect on her interest in science is nearly nullified in such gender-matching environments.

Moreover, single-sex schooling has a positive effect on the motivation and confidence of the worst performing girls. The negative gender effect on the motivation of a girl in the 1st quartile is almost offset by the positive effect of single-sex schooling. Furthermore, if she is taught by a female teacher in an all-girls school, her motivation level is 6.5 p.p. higher than a boy in the same quartile. Also, by attending an all-girls school, the confidence level of the worst performing girls becomes 3.4 p.p. higher than the worst performing boys. But, the gender-matching environments do not influence the interest level of the worst performing girls, different from the positive effect on the best performing ones.

On the other hand, for median girls who are ranked in the 3rd and 2nd quartiles in their science scores, single-sex schooling has an opposite effect. Attending an all-girls school negatively affects the confidence and interest levels of girls in the 3rd quartile. While there is generally no gender difference in confidence, girls in this quartile who attend an all-girls school have a confidence level that is 10 p.p. lower than that of boys and girls in the same quartile who are in coeducational schools. Also, the negative gender effect on girls' interest in science becomes more than twice larger if a girl in this quartile attends an all-girls school – i.e. from –4.5 to −10.8 p.p. For girls in the 2nd quartile, single-sex schooling is less detrimental than others in the 3rd quartile, but it still reduces their confidence level by 5 p.p.

On the boys' side, the effect of single-sex schooling is insignificant to a large extent. However, there is evidence that attending an all-boys school decreases the confidence level of better performing boys who are ranked in the 4th and 3rd quartiles. These results suggest that gender-matching schooling is more beneficial to the attitudinal development of girls – particularly the best and worst performing ones, but such benefits accompany costs on median girls and better performing boys who are rather disadvantaged by single-sex schooling.

The heterogeneous responses to gender-matching school environments are further evidenced when the sample is limited to public schools only (Tables 7 and 8.2). The findings in public schools are largely similar to those of the full sample, but there are several differences to be noted. First, while the positive effect of a female student-teacher pair generally remains consistent, it loses significance on the interest level of the best performing girls. Second, the positive effect of all girls-schools on the best performing girls is consistent in public schools, but the effect is no longer significant in the worst performing group. Third, single-sex public schooling has no negative effect on median girls' confidence (in the 3rd and 2nd quartiles), but maintains its negative influence on the interest level of girls in the 3rd quartile. Despite these differences, by and large, the evidence in public schools corroborates the heterogeneous gender-matching effects that are more beneficial to the best performing girls.

4. Conclusion

If gender-matching environments can create a positive effect on female performance and attitudes, that can be used as a policy instrument to reduce gender inequality in society. My analysis, however, posits complex implications to this question. The effect of gender-matching school environments is not universal but produces heterogeneous outcomes across different student groups. High performing girls are the largest beneficiaries of single-sex schooling and female teachers, through which their motivation, confidence, and interest in science are promoted. However, such gains accompany costs on median girls who do not benefit in these environments.

The mixed outcomes of single-sex schooling complicate policy-making. If a policy priority is given to promote female talent in STEM fields, gender-matching school environments can be a viable policy option. However, for the purpose of general education that should leave no one behind, single-sex schooling may not be the best choice.

[8] −0.494−0.243+0.373+0.443 = +0.079 (computed based on Column 1 of Table 6 and Table 8.1).

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

(PISA 2015, OECD)

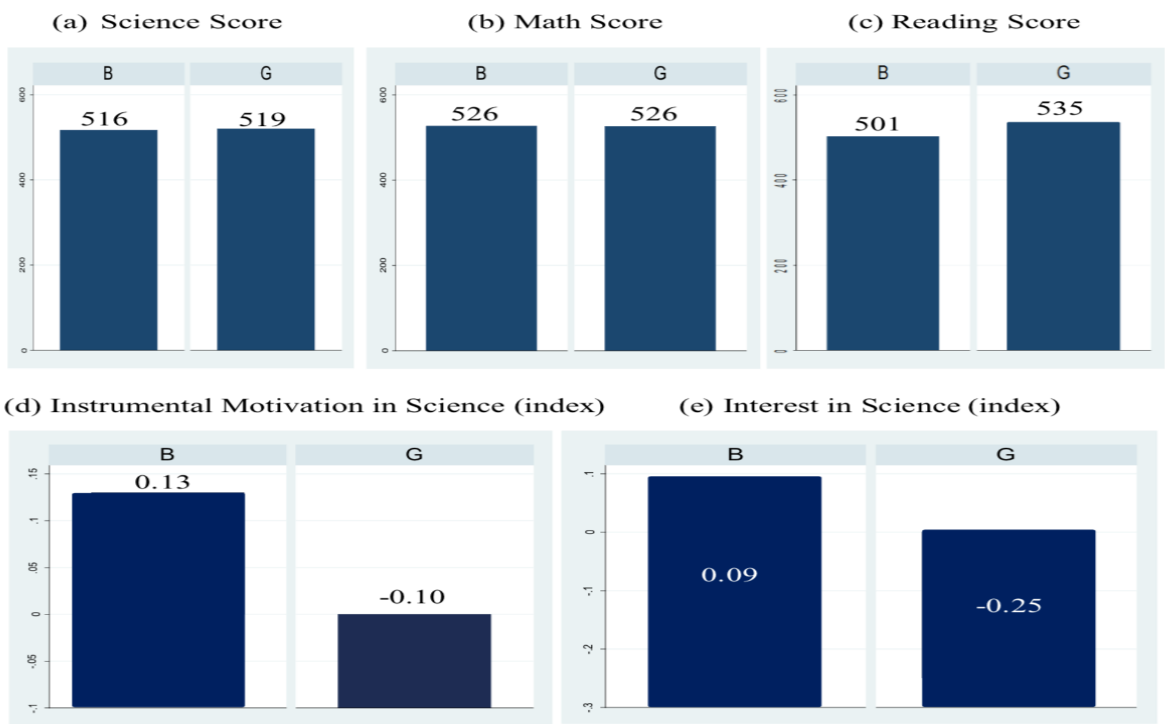

Table 6. Gender and Gender-Matching Effects on Non-cognitive Performance, heterogeneous responses by science scores
OLS, including both public and private schools

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 8. Average Treatment Effects (ATE) of Single-sex Schooling on Non-cognitive Performance, heterogeneous responses by science scores, propensity-score matching

Table 8.1. (including both public and private schools)

DV	Instrumental Motivation in Science							
Quartile	4th (score > 582)		3rd (518 < score < 582)		2nd (449 < score < 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
Number of Obs.	496	365	427	407	390	394	474	320
DV	Confidence in Science							
Quartile	4th (score > 582)		3rd (518 < score < 582)		2nd (449 < score < 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
Number of Obs.	496	365	427	408	389	394	476	321
DV	Interest in Science							
Quartile	4th (score > 582)		3rd (518 < score < 582)		2nd (449 < score < 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
Number of Obs.	494	365	426	408	389	392	468	321

Table 8.2. (public schools only)

DV	Instrumental Motivation in Science							
Quartile	4th (score > 582)		3rd (518 < score < 582)		2nd (449 < score < 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
Number of Obs.	292	223	300	282	293	292	368	232
DV	Confidence in Science							
Quartile	4th (score > 582)		3rd (518 < score < 582)		2nd (449 < score < 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
Number of Obs.	292	223	300	283	292	292	370	243
DV	Interest in Science							
Quartile	4th (score > 582)		3rd (518 < score < 582)		2nd (449 < score < 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
Number of Obs.	291	223	299	283	292	290	363	243