

Cho, Seo-Young

Working Paper

Gender-matching school effects on girls' cognitive and non-cognitive performance: Empirical evidence from South Korea

MAGKS Joint Discussion Paper Series in Economics, No. 38-2017

Provided in Cooperation with:

Faculty of Business Administration and Economics, University of Marburg

Suggested Citation: Cho, Seo-Young (2017) : Gender-matching school effects on girls' cognitive and non-cognitive performance: Empirical evidence from South Korea, MAGKS Joint Discussion Paper Series in Economics, No. 38-2017, Philipps-University Marburg, School of Business and Economics, Marburg

This Version is available at:

<https://hdl.handle.net/10419/174334>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

MAGKS



**Joint Discussion Paper
Series in Economics**

by the Universities of
Aachen · Gießen · Göttingen
Kassel · Marburg · Siegen

ISSN 1867-3678

No. 38-2017

Seo-Young Cho

**Gender-matching School Effects on Girls' Cognitive and
Non-cognitive Performance –Empirical Evidence from
South Korea**

This paper can be downloaded from
<http://www.uni-marburg.de/fb02/makro/forschung/magkspapers>

Coordination: Bernd Hayo • Philipps-University Marburg
School of Business and Economics • Universitätsstraße 24, D-35032 Marburg
Tel: +49-6421-2823091, Fax: +49-6421-2823088, e-mail: hayo@wiwi.uni-marburg.de

Gender-matching School Effects on Girls' Cognitive and Non-cognitive Performance —Empirical Evidence from South Korea

Seo-Young Cho*
(Philipps-University Marburg)

2017

Abstract: Gender-matching school environments may provide benefits for girls to enhance their performance. By using PISA data from South Korea, this paper suggests that the effects of single-sex schooling and a student-teacher's gender matching are heterogeneous across different student groups. The gender-matching school environments are most positive to non-cognitive outcomes of girls at the highest tail of cognitive performance levels. By attending an all-girls school and being taught by a female teacher, high performing girls are as motivated and interested in pursuing careers in STEM fields as boys. However, single-sex schooling and female teachers do not produce positive effects on girls in lower performing groups. For median girls, single-sex schooling can even be detrimental to their non-cognitive performance. These results corroborate that gender-matching school environments can be a useful tool to promote female talent in STEM fields, but the effect cannot be generalized for public education for all students.

Keywords: gender-matching effects; student-teacher's gender-matching; single-sex schooling; cognitive performance; non-cognitive performance; education production functions; propensity-score matching; South Korea

JEL-codes: C31; I21; I24; J16; O53

*Contact: Junior Professor, Research Group of Empirical Institutional Economics, School of Business and Economics, Philipps-University Marburg. Barfuessertor 2, D-35037 Marburg, Germany. Tel. 49 (0)6421-28-23996. Email. seo.cho@wiwi.uni-marburg.de Web. www.uni-marburg.de/fb02/empinsti

1. Introduction

Labor market outcomes of men and women show that women are still disadvantaged in earnings and promotion for decision-making positions, despite noticeable improvement in female education and social status today. One explanation for such gender disparity is that men and women behave differently in competitive environments. Women's lack of participation in competition is arguably responsible for their underrepresentation in professions with higher recognition and remunerations (such as STEM fields). In an attempt to shed light on gender-asymmetric behaviors in competition, the recent literature has focused on how gender compositions of surroundings affect individual performance (Antonovics et al. 2009). The absence of male counterparts is often suggested as a favorable environment for women and girls to boost their performance and confidence (Niederle and Vesterlund 2007).

In this respect, single-sex schooling is considered a policy instrument to enhance educational attainment in many countries. This is not only because single-sex schools are expected to maximize academic outcomes of boys and girls by providing them instructions based on their gender-specific needs. Single-sex schooling may also improve girls' competitive attitudes. In all-girls schools, girls can be granted more opportunities to take leadership roles and adopt positive gender roles from their female teachers and peers who are more present in such environments.

Presently, however, literature provides conflicting evidence of the effects of single-sex schooling which vary across countries, school systems, students' age groups, and outcome variables (see section 2 for detailed discussions). One challenge in estimating a net effect of single-sex schooling lies in identification problems. There are two major limitations that make it difficult to isolate the effect from other compounding factors. One is self-selection biases, in that students in single-sex schools are systematically different in their characteristics from students in coeducational schools. The other is unobserved heterogeneity of schools in terms of curriculum, teacher quality, and school orientations that differ between the school types.

In this paper, I try to single-out an effect of single-sex schooling by focusing on South Korea. Data from South Korea provides an advantage of equilibrating students between single- and mixed-sex schools because single-sex schooling is more common there – about 25-30 percent of

high schools are single-sex (OECD 2015). Thus, systematic differences in students between the two types of schools are less likely salient. Also, a sufficient number of observations of single-sex school attendees can be obtained for a viable comparison. Unobserved heterogeneity of students and schools that may still persist is further addressed through different approaches. First, various educational inputs are incorporated in the empirical model in a holistic manner based on the education production function (Hanushek 1986 and Krueger 1999). Second, students are matched based on their propensity to attend a single-sex school and an average treatment effect is gauged by a propensity-score matching method. Last, the sample is limited to public schools only to minimize differences between schools.

My analysis is extended to evaluate the effects of gender-matching school environments on both cognitive and non-cognitive outcomes of students. An emphasis is given to non-cognitive performance of one's motivation, confidence, and interest in competitive study and career choices in STEM fields because gender gaps in this dimension provide an arguably important explanation for women's underrepresentation in high-profile positions. In addition, my study integrates another aspect of gender-matching school environments: matching of a student's and a teacher's gender. Such gender-matching can capture the effects of individual interactions between a teacher and a student of the same sex, while single-sex schooling reflects gender-matching environments at the school level. In the recent literature, a growing number of studies documented the positive influences of female teachers on girls' performance (Carrell et al. 2010).

Using the data of PISA 2014, my findings suggest that the effects of gender-matching environments are heterogeneous across different student groups. The positive effects of single-sex schooling and a student-teacher's gender matching are most evident among girls at the highest quartile of cognitive performance levels. By attending an all-girls school and being taught by a female teacher, they become (almost) as motivated and interested in pursuing careers in STEM fields as boys. However, single-sex schooling and female teachers do not provide as positive effects on attitudinal development of girls in lower quartiles. For median girls, single-sex schooling can even be detrimental to their non-cognitive performance. On the other hand, there is little evidence that gender-matching environments affect girls' cognitive performance, while some positive effects are suggested for boys' study outcomes. These results indicate that gender-

matching school environments can be a useful tool to promote female talent in STEM fields, however, the effect cannot be generalized for all students.

2. Literature Review

Presently, literature shows that the direction of the effect of single-sex schooling differs across countries and school levels (elementary, middle, and high schools, etc.). This observation indicates that different school systems and societal environments produce heterogeneous outcomes of single-sex schooling. On the one hand, there are several reasons to presume a positive effect of single-sex schooling. First, in single-sex schools, teachers can tailor their instruction to the particular needs of each sex. In math and science particularly, boys tend to seek and receive teachers' attention more than girls in mixed-sex classes, possibly due to different socially learned behaviors (Bracey 2006). In this case, single-sex schooling can be beneficial to girls because it minimizes environmental effects such as those observed in mixed-sex schools that are unfavorable to girls' active participation and initiatives. Second, the absence of the opposite sex may reduce possibilities for being distracted from studies and having romantic relationships instead (Hill 2015). Third, when boys are absent, girls may enhance their confidence and be willing to take more competitive educational opportunities because they can be freer of socialized gender roles of being passive and moderate (Gneezy et al. 2003; Niederle and Vesterlund 2007).

In their recent studies, Booth and Nolen (2012a, b) show that single-sex environments can positively affect girls' attitudinal development. Using controlled experiments with students from single- and mixed-sex high schools in the United Kingdom, girls in all-girls environments (either all-girls schools or all-girls groups for competition) are found to be more willing to enter competitions (2012a) and less risk-averse (2012b), compared to girls in mixed-sex environments. With this finding, they argue that observed gender differences in competitiveness and risk preferences are more attributed to nurture effects of different gender roles assigned between boys and girls than biological (nature) gender differences. A positive effect of single-sex environments is further documented in other studies that investigated other countries. Schneeweis and Zweimullter (2012) report a positive gender-matching effect on girls' choice to select male-dominated school types instead of female dominated ones in Austrian high schools. McCoy et al.

(2012) show that girls in single-sex primary schools have a more positive attitude towards math compared to others in mixed-sex schools in Ireland.

On the other hand, Jackson's (2012) analysis on Trinidad and Tobago suggests a somewhat different cognitive outcome of single-sex schooling. He finds a null average effect of attending a single-sex school on exam performance of students between 6th and 10th grades. He argues that the presumed positive effect of single-sex schooling is mainly attributed to students' preferences towards single-sex schools. However, his study further reveals that the effect of single-sex schooling is heterogeneous depending on the level of one's preferences. For instance, attending a single-sex school provides sizeable advantages for girls with strong preferences for all-girls schools. Fryer and Levitt (2010) document an overall positive effect of single-sex schooling on students' math studies, examining data of primary to high schools in the United States and comparing them with students of 30 other countries. Eisenkopf et al.'s (2015) study corroborates the finding of Fryer and Levitt. Exploiting randomized data of a secondary school in Switzerland, they find that girl-only math classes improve girls' math test scores, particularly beneficial to girls with high abilities. Their study also shows that single-sex schooling strengthens girls' self-confidence on their mathematics skills. Interestingly, Hoxby (2000) and Lavy and Schlosser (2011) report a positive impact of the presence of girls on both boys and girls. They find that increasing a fraction of girls in peer groups improve achievements of both genders.

Other studies disagree with the positive role of single-sex schooling by arguing that presumed positive outcomes are likely caused by endogenous choices of single-sex schooling. Billger (2009) shows that the effect of single-sex schooling in the United States is widely driven by students in private schools who are already likely to perform well because of their socioeconomic characteristics. Aedin et al. (2013) focused on Ireland where single-sex schools are part of the general educational system representing all socioeconomic groups. Examining the math differentials between boys and girls at the top of the distribution tail, they find no evidence that single-sex schooling reduces a gender gap in math. Furthermore, Strain (2013) suggests that single-sex math classes are negatively associated with math performance of students. Also, he finds no positive effect of single-sex reading classes on reading scores in North Carolina public schools in the United States. Halpern et al. (2011) further articulate evidence that sex segregation in schooling may exacerbate gender stereotyping. This argument is also supported by Goodkind

et al. (2013), showing that single-sex classes increase gender stereotypes and do not reduce distractions among low-income African American youth.

In the South Korean contexts, literature suggests varying effects of single-sex schooling depending on school levels, locations, and outcome variables. An advantage of using Korean data is randomized distributions of students between single- and mixed-sex schools that were implemented until 2010¹ in Seoul – the capital and the most populous city of South Korea. As randomly assigned, socioeconomic backgrounds of students across the different types of schools were comparable, thus making causal inference more plausible. Using randomized data of high school from 2009 in Seoul, Park et al. (2013) find that single-sex schooling increases Korean and English test scores and four-year college attendance rates compared to coeducational schools. This benefit is found in both girls and boys. Additionally, another study of Park et al. (2011) suggests a positive effect of single-sex schooling on choosing STEM majors in college in South Korea. But, this effect holds for boys only, but not for girls. Kim (2012) also finds supportive evidence for single-sex schooling. His findings show that coeducational schooling reduces Korean, English, and math scores in the college entrance exams. This result remains consistent for both girls and boys, but the negative effects of mixed-sex schooling are greater for girls. Moreover, mixed-sex schooling is more detrimental to better performing students in math, while, in Korean and English classes, it has a greater negative effect on worse performing students. However, the author points out that the effect can largely be explained by differences in students' socioeconomic backgrounds between the two types of schools, and thus, the results are not free of self-selection into a specific school type. The positive effect of single-sex schooling on girls' study performance is further documented by Kim and Law (2012). Through a cross-country analysis of South Korea and Hong Kong, they show that the positive gender-matching effect holds only in Korea but not in Hong Kong due to their different usage of gendered curriculum.

On the other hand, Lee et al. (2014) investigated the effect of single-sex schooling on middle-school students' non-cognitive outcomes in Seoul. In contrast to Park et al.'s (2011 and 2013) and Kim's (2012) studies, they find no positive effect of single-sex schooling. In their analysis,

¹ In 2010, the government introduced a new system, through which students and parents are allowed to choose their preferred high schools.

girls in all-girls schools are not necessarily more competitive than girls in coeducational schools. Rather, mixed-sex schooling reduces gender gaps in competitiveness by 6.5 percentage points. Such differences in findings are possibly due to different school levels (middle or high school) or different outcome variables (cognitive or non-cognitive performance) that each study examined.

There are also a growing number of studies that address another aspect of gender-matching effects on students' performance: the effects of teachers' gender. Female teachers/professors can have positive effects on female students' learning because they can employ instruction methods and communicational modes more suited for female students. Also, female teachers can provide a positive gender role for female students, motivating them to actively participate in classes. Carrell et al. (2010) show through longitudinal study records of college students in the United States that female professors have an important role in female students' studies. By being taught by female professors, girls improve their math and science scores and increase the likelihood of pursuing studies in STEM fields. This positive effect of having a professor of the same gender is particularly stronger for well-performing female students at the top of the distribution tail. However, female professors have little impact on male students' performance or their study paths. This positive effect of female professors on female students is also supported by Bettinger and Long (2005) to a large extent but their findings vary depending on subjects. Using data from public colleges in Ohio, United States, they show that being taught by female faculty, female students increase their study hours and are more likely to choose math, geology, and several social science subjects as their majors, but the effect reverses in some other disciplines.

In secondary schools, shares of teachers of the same sex are closely associated with single-sex schooling because all-girls schools tend to hire more female teachers (and vice-versa for all-boys schools). With the evidence from eighth-grade students in the United States, Dee (2007) argues that girls perform better when taught by female teachers and boys do better with male teachers. The positive effect of student-teacher gender matching is also found for female students in Nixon and Robinson's study (1999); a higher share of female teaching staff increases levels of girls' study attainments. On the other hand, there is also evidence against the positive influences of female teachers on female students. Eisenkopf et al. (2015) find in a Swiss secondary school that female students perform better in math if they are taught by a male teacher in a single-sex class.

3. Empirical Framework

3.1. Education Production Function

The central question for an empirical analysis is to identify net effects of gender-matching school environments on students' performance. To isolate such effects, the estimation model includes an exhaustive list of covariates that potentially have compounding effects on outcome variables. Variables are selected following the education production function suggested by Hanushek (1986) and Krueger (1999). According to the education production model, outputs (students' achievements) are determined by inputs as following.

$$Y \text{ (educational output)} = f(\text{individual; family; school; teacher; and peer inputs})$$

Here it is important to note that students' achievements include not only their study outcomes (cognitive performance) but also attitudinal development (non-cognitive performance). The above education production function is rewritten in an econometric model below in equation 1 specifying covariates and their relationship with the outcome variables.

$$\begin{aligned} \text{Performance}_i = & a + \beta_1 \text{female student}_i + \beta_2 \text{boy school}_i + \beta_3 \text{girl school}_i + \beta_4 \text{female teacher}_i \\ & + \beta_5 \text{female student}_i * \text{female teacher}_i + X_i' T + S_i' \Psi + T_i' \Pi + B_i' \Upsilon + R_i' \mathcal{N} + u_i \end{aligned} \quad (1)$$

The set of the outcome variables consists of several performance indicators that evaluate different dimensions of students' achievements. First, students' cognitive knowledge and skills are measured by their test scores in reading, math, and science subjects. Second, non-cognitive skills of students are proxied by a student's self-assessments on his/her instrumental motivation, confidence, and interest in science that are available in PISA 2015. These variables are selected as the measurements of non-cognitive performance because they reflect important individual attitudes that influence one's decision to pursue competitive career paths in STEM fields.

$$\text{Cognitive performance} = \{\text{science score, math score, reading score}\}$$

$$\text{Non-cognitive performance} = \{\text{instrumental motivation, confidence, interest in science}\}$$

In estimating the model of non-cognitive performance, a variable that reflects a student's intellectual abilities is additionally included in the model because one's knowledge level provides a basis for his/her non-cognitive performance. While science knowledge would have the closest association with attitudes towards science, the available measurement of science knowledge – science (math) scores – likely has a tautological relationship with attitudinal development in science, sharing their latent concepts to a great extent. To avoid this problem, reading scores are taken 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: $\text{corr}(\text{reading score}, \text{science score}) = 0.85$. Accordingly, the model of non-cognitive performance takes the following form.

$$\begin{aligned} \text{Performance (non-cognitive)}_i = & \alpha' + \beta'_1 \text{female student}_i + \beta'_2 \text{boy school}_i + \beta'_3 \text{girl school}_i \\ & + \beta'_4 \text{female teacher}_i + \beta'_5 \text{female student}_i * \text{female teacher}_i + \beta'_6 \text{reading score}_i \\ & + X_i' T' + S_i' \Psi' + T_i' \Pi' + B_i' \Upsilon' + R_i' \mathcal{N}' + u'_i \end{aligned} \quad (1')$$

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. Gender-matching effects for girls are captured by two variables – *girl school* and *female student_i * female teacher_i* (the interaction term of a student and a teacher's gender). Accordingly, positive gender-matching effects on girls' performance will arise as:

$$H_0: \beta_3 (\beta'_3) > 0$$

$$H_0: \beta_5 (\beta'_5) > 0$$

The model includes an exhaustive set of input variables so that biases caused by omitted variables can be minimized. Accordingly, vectors, X , S , T , B , and R incorporate 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. Hanushek (1986) emphasizes the important role of students' socioeconomic characteristics in determining their performance level. Krueger (2003) and Hanushek (2011) suggest that school variables (such as class sizes and teachers' quality) are important inputs. In addition, a student's behavioral patterns and his/her relationship with teachers and peers are also taken into consideration because these variables often mirror a

student's personality and mentalities. Therefore, accounting for such effects can reduce influences of a student's unobserved characteristics on his/her performance. The list of input variables in each vector is detailed below. Descriptive statistics of all variables used for the estimation are presented in appendix A.

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

The econometric model formulated in equation 1 and 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) model in which observations are nested within schools. This approach is to account for heterogeneous data patterns across schools. In this model, intercepts are treated as random effects considering the grouping structure of the data by school. In addition, robust standard errors clustered at the school level are applied because variations of observations in the same school are possibly correlated to one another.

In addition to the baseline model in equation 1(1'), a probit analysis is conducted with the dummy dependent variables indicating whether a student is ranked in top 25 percent in the reading, math, and science tests, respectively. Through an examination of the highest quartile of

the distribution tail, one can find whether gender-matching environments are particularly beneficial (or harmful) to best performing students. The probit model is formulated below.

$$P(Q_{75} = 1 \mid G; X; S; T; B; R) = \Phi(\cdot) \quad (2)$$

Φ : the cumulative distribution function of the standard normal distribution.

The binary choice of the dependent variable (1, 0) depends on its latent value (Y^*).

$$Y(Q_{75}) = \begin{cases} 1, & Y^* > 0 \\ 0, & otherwise \end{cases}$$

$$Y_i^* = a + \beta_1 \text{female student}_i + \beta_2 \text{boy school}_i + \beta_3 \text{girl school}_i + \beta_4 \text{female teacher}_i \\ + \beta_5 \text{female student}_i * \text{female teacher}_i + X_i' T + S_i' \Psi + T_i' \Pi + B_i' \Upsilon + R_i' N + u_i$$

The dichotomy model is estimated by probit and multilevel probit methods. In the multilevel estimation, the model is nested within schools alike the baseline model above.

Estimations are first conducted with the full sample. The full sample includes all students in 105 high schools in South Korea who took part in PISA in 2015 ($n = 3,259$). Then, the sample is limited to public schools only ($n = 2,280$; $s = 74$) because private school students tend to be systematically different in their demographic characteristics and performance. Furthermore, the full sample is decomposed by tail distributions in students' science scores through the following categorization: the 4th quartile (science score > 582); the 3rd quartile ($518 < \text{science score} < 582$); the 2nd tail ($449 < \text{science score} < 518$); and the 1st quartile (science score < 449). The sub-sample estimations are designed to estimate how differently gender-matching effects affect students' non-cognitive performance depending on their cognitive abilities.

3.2. Mechanism of Attending a Single-sex School and Propensity-score Matching

In an attempt to isolate the effect of single-sex schooling from other compounding influences, one should ask a critical question: are students in single-sex schools systematically different from others in mixed-sex schools? If students decide to attend all-girls or all-boys schools because of their backgrounds and characteristics being different from students in coeducational schools, this

choice is endogenous to their performance outcomes. Under the presence of endogeneity, a causal effect of single-sex schooling on performance cannot be identified. In this section, I will first examine whether students in single-sex schools are, indeed, different from others in mixed-sex schools. Afterwards, a method of propensity-score matching is discussed with respect to equilibrating the pools of single- and mixed-sex school students.

In South Korea, single-sex schooling is more prevalent than many other countries. In the sample of the PISA 2015, 29.4% of boys attend all-boys high schools. Among girls, the share of all-girls school attendees is 24.8%. Given the high share of single-sex schools, systematic differences between single- and mixed-sex school students may be smaller than other countries (e.g. the share of single-sex schools in the United States is less than 5 percent). Hence, risks of endogenous choices of single-sex schooling are presumably lower in South Korea.

However, the decision of attending a specific high school is primarily made by students (and their parents) in South Korea. For instance, since 2010, middle-school students in Seoul submit three names of preferred high schools and they are assigned to a school based on their preferences. According to Kim's study (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' performance in university entrance exams are lower among mixed-sex school students. Coeducational high schools have become common in South Korea since the 1990s with the goal of promoting gender equality and cooperation and social interactions between the genders (Kim 2012). However, despite the up-to-date mandates of coeducation, students and parents are reluctant to choose a mixed-sex high school due to concerns about their study records.

With this in mind, a formal analysis is conducted to identify whether students in single-sex schools have systematically different backgrounds than mixed-sex school students. To elicit a mechanism of attending a single-sex school, various ex-ante conditions of students prior to attending a single-sex high school are included in the parsimony and extended models presented in appendix C – such as students' socioeconomic status and parental characteristics. Contrary to commonly believed preferences for single-sex schools, a higher level of a student's socioeconomic status does not necessarily increase the probability of one attending an all-girls or all-boys school. For girls, father's education and home facilities (such as TV, wash machines, etc.)

reduce their probability of choosing an all-girls school instead of increasing it. Most other variables measuring students' conditions have no significant effects on single-sex schooling. However, family support for children increases the probability of attending a single-sex school. Specifically, educational resources at home have a positive effect on girls, while for boys, it is parental emotional support. In addition, the probability of attending an all-boys school is higher in larger cities – a natural consequence given that small towns may not be able to host both all-boys and all-girls schools. Weak relationship between students' conditions and single-sex schooling maintains that students are relatively comparable between the two school types in South Korea. Nonetheless, there is some tentative evidence that students whose parents are more supportive are more likely to attend a single-sex school. This observation necessitates the issue of endogenous school choices to be addressed in the empirical model.

Accordingly, a propensity-score matching (PSM) method is employed to account for self-selection into single-sex schools. In this estimation, the treatment effect is attending a single-sex school. An individual's probability of attending a single-sex school is predicted based on observed covariates and students with similar probabilities but receiving different treatments are matched to equate differences between the treatment and control groups. The average treatment effect (ATE) of attending a single-sex school is computed by imputing the missing potential outcome for each subject. This is done by using an average of the outcomes of similar subjects that receive the other treatment level. Subsequently, the PSM estimator reflects the average difference between the observed and potential outcomes for each subject (Abadie and Imbens 2011).

$$ATE = E[\text{cognitive outcome}_{\text{single-sex}} - \text{cognitive outcome}_{\text{mixed-sex}} \mid G; X; S; T; B; R] \quad (3)$$

$$ATE = E[\text{non-cognitive outcome}_{\text{single-sex}} - \text{non-cognitive outcome}_{\text{mixed-sex}} \mid G; X; S; T; B; R] \quad (3')$$

4. Results

4.1. Descriptive Differences in Performance and Behaviors by Gender and by School Types

First, we begin with descriptive differences in cognitive and non-cognitive performance between boys and girls. Appendix B shows that 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 (see appendix B1, B2, and B3, respectively). Girls outperform boys in reading. 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 do. Also, the Mann-Whitney rank-sum test places girls more right-sides of the distribution curve. In addition, figure 1 that illustrates quartile distributional plots of test scores of boys and girls, respectively, shows minimal gender differences in science in all fractions of the data – see (1), (2), and (3) of figure 1. In math, boys in the two upper quartiles of their own group perform slightly better than girls in the corresponding quartiles. In reading, girls outperform boys in the highest quartile.

However, when non-cognitive performance is concerned, the findings are different. Boys demonstrate higher levels of instrumental motivation and interests in pursuing careers in STEM fields than girls. This is evident in all tests of mean, median, and distribution differences. Also, quartile analyses depicted in (4) and (6) of figure 1 show that boys have higher levels of motivation and interest than girls in all fractions of data points. Seemingly, 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 studies.

Observing gender differences in non-cognitive outcomes, a follow-up question of whether students' performance varies between single- and mixed-sex schools arises. This question is examined accordingly, and the results are presented in appendix D. For girls, there is no evidence that their cognitive and non-cognitive outcomes are different between all-girls and coeducational schools. The only exception is math, in which girls in coeducational high schools outperform girls in all-girls schools. The mean difference is about 8 points (8 percent of its standard deviation, appendix D.1). The results of the median and tail distribution tests are also more favorable for girls in mixed-sex schools (appendix D.2 and D.3). These findings provide counter-evidence to the commonly claimed advantage of all-girls schools, in which girls can receive more female-friendly instructions and support from teachers.

Different from girls, boys in all-boys schools outperform boys in mixed-sex schools in all cognitive areas. The mean differences in these three subjects between single- and mixed-sex

school boys are 28–30 points (appendix D.1). Also, significantly more boys in all-boys schools have a score above the median than boys in mixed-sex schools (appendix D.2). Scores of boys in single-sex schools are distributed more skewed to the right sides of the curve (appendix D.3). However, differences in non-cognitive outcomes between all-boys and coeducational schools are less substantial. There is no significant difference in confidence and interest in science between the two school types. All-boys school students are weakly more motivated to pursue careers in STEM fields than boys in mixed-sex schools. But, this evidence is modest – with a significance level of 10 percent in the mean and distribution tests only.

4.2. Baseline Estimates

What determines a student's cognitive and non-cognitive performance? This question is estimated based on the baseline model (equations 1 and 1') and the results are presented in tables 1 and 2. Table 1 shows the results of cognitive outcomes estimated with the full sample. The models are first estimated without the interaction term of student-teacher's gender-matching and then include the interaction effect. As expected from the descriptive analysis, a student's gender is not a significant determinant of his/her science and math scores. But, in the reading section, being a girl brings a significant advantage of gaining additional five points (i.e. 5 percent of its standard deviation). On the other hand, a teacher's gender is widely unimportant. There is some evidence that being taught by a female science teacher increases a student's score in this subject. However, this result is suggested by the multilevel estimation only. Moreover, the estimated effect is too small to gauge an economic meaning. In addition, gender-matching environments do not influence a student's cognitive performance. Neither single-sex schooling (boy and girl schools) nor student-teacher's gender-matching (female student*female teacher) has any effect on any of the three test scores.

Several input variables suggested by the education production function have significant effects on a student's cognitive outcomes. Among school inputs, a higher student-teacher ratio deteriorates study outcomes, supporting the benefits of small classes. However, school sizes are not an important factor of a student's study results. School quality evaluated by parents has a positive effect in the OLS estimation but the size of the effect is negligible. A school's status (public or private) and location (community size, urban or rural) are also unimportant. Furthermore,

teachers' qualifications have little to do in improving students' study performance. Neither teacher's tenure nor experience has any effect on students' scores.² Limited roles of school and teachers' inputs may mirror the situation that the importance of private after-school tutoring often overshadows formal schooling in South Korea (Kim 2012).

On the contrary, a student's family backgrounds and socioeconomic status are important inputs of cognitive production. 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 adds 33–48 (ESC status), 12–27 (family spending), and 7–9 (parental support) points to the test scores. The effect of one's ESC status is greater for math scores, while that of parental support has a larger effect on science. The influence of parental education is, however, generally weak, possibly because they capture similar dimensions to parental support for children. Nonetheless, a mother's education has a positive effect on her child's math performance. A one-standard deviation increase in the level of a mother's education increments 7–9 points in her child's math score. But, a mother's education does not have a robust effect on the other two subjects. There is no evidence that a father's education affects his child's study. Probably, its effect is surpassed by the effect of a mother's education that has a high level of multi-collinearity.

In this estimation, a student's behaviors are suggested to have great explanatory power over his/her study outcomes. Particularly, frequently skipping classes and coming to school late are associated with poor study results. So does frequenting online chatting at school. However, online activities outside of the school (out-of-school online chatting and social network participation) do not harm a student's study outcomes. 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.

Regressing cognitive outcomes on various individual, family, environmental, behavioral, and relational inputs, there is little evidence of gender or gender-matching effects. However, the

² Teachers' education is not included as a teacher's input in this model because of little variations in the variable. In South Korea, nearly all teachers are certified with a bachelor degree or higher.

outlooks are different when the effects are estimated on non-cognitive outcomes. Table 2 shows the results of the non-cognitive models. Girls have a 0.24–0.35 point-lower level of instrumental motivation in science (6.7–9.5 p.p.) than boys on average. Also, being a girl reduces her interest in science by 0.35–0.47 points (6.8–9.2 p.p.). Furthermore, being taught by a female science teacher has a negative effect on boys, reducing their motivation, confidence, and interest in science by 4 p.p., 1.7 p.p., and 1.7 p.p., respectively. However, for girls, the effect of being taught by a female teacher is generally positive – i.e., the positive interaction effect of a female student-teacher pair dominates the negative effect of a female teacher. For instance, girls increase their interest in science by 2 p.p. when they are taught by a female science teacher. The positive interaction effect of a female student-teacher pair also reduces the negative effect of girls’ own gender. If a girl is taught by a female teacher, the negative influence of being a girl on her motivation reduces by 5.3–7.5 percent. For her interest in science, a female student-teacher pair decreases the negative gender effect of a girl by 20.5–21.5 percent (see columns 2 and 4; and 10 and 12 of table 2, respectively).

In contrast to student-teacher gender-matching, single-sex schooling does not influence one’s non-cognitive performance – alike its minimal role in cognitive outcomes above. Most other school inputs have no effect, except perceived school quality that is positively associated with non-cognitive performance. Teachers’ inputs are also irrelevant to a student’s motivation, confidence, and interest. Significant and robust explanatory factors are family backgrounds and behavioral patterns. In particular, a student’s ESC status increases his/her confidence and interest in science. So does parental support for learning. However, family spending on education and parents’ emotional support that were important to cognitive outcomes do not play a role in enhancing a student’s non-cognitive performance. In addition, one’s intellectual level proxied by reading scores has a significant influence on his/her non-cognitive performance, as expected. Increasing a student’s reading score by one-standard deviation raises his/her motivation, confidence, and interest by 12–13 p.p.

Among behavioral indicators, frequently coming to school late and participating in social networks signal that the student is less motivated, lacks confidence, and has little interest in science. Interestingly, chatting online at school reinforces a student’s positive attitudes towards science. Increasing one-standard deviation in the frequency of in-school online chatting raises

one's motivation, confidence, and interest levels by 1.2 p.p. This might be because online chatting inside the school mirrors active involvement in school and outgoing attitudes. In contrast, social networks may discourage active school participation as some students may use SNS as a tool to shy away from the real world. 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 renders further research. In addition, feeling belonging to school increases all of the three dimensions of non-cognitive outcomes, while the unfairness of a science teacher decreases one's interest in the subject.

4.3. Effects of Unobserved Characteristics

The baseline estimations in section 4.2 exploited a large number of control variables so that net gender-matching effects can be singled-out. Among the two gender-matching indicators, the gender-matching of a female student-teacher pair is assumed to be fairly exogenous because the allocation 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 unlikely. In South Korea, students are randomly allocated among different classes (at least in regular classes that are surveyed in the PISA), independent from their study records and/or demographic traits. Thus, each class includes wide ranges of students of different study ranks and backgrounds.

On the other hand, gender-matching environments of single-sex schooling are 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 that affect one's decision to select a single-sex school helps reduce biases arising from an endogenous choice of schools. However, a large set of controls does not necessarily ensure that no variable is left unobserved. To further address this issue of endogenous school choices, I limit the sample to public schools only. The public-school sample comprises students of more population-representative socioeconomic statuses, while private schools tend to have students with wealthier family backgrounds. Furthermore, school quality is more homogeneous among public schools than

private ones whose quality and orientation differs depending on founders and school management. Tables 3 and 4 present the results of the public-school sample. The public-school sample includes 70 percent of the full sample.

The results of cognitive outcomes in public schools (table 3) are similar to those of the full sample in table 1. There is no female disadvantage in math and science – neither from female students nor female teachers. Female students have advantages in reading, but female teachers produce neither advantages nor disadvantages in this subject. Gender-matching environments – single-sex schooling and the interaction of a female student-teacher pair – play no role in one’s cognitive performance in public schools. Among school inputs, only the student-teacher ratio has a significant (negative) effect. Different from the results of the full sample, perceived school quality has no effect in public schools. This difference refers to the observation that public schools provide relatively more homogeneous quality of education than private schools. Family backgrounds and parental supports maintain significant explanatory power, similar to the full sample. Several behavioral patterns are robust indicators of cognitive performance – skipping classes, coming to school late, and chatting online at school. The negative effect of skipping classes in public schools is different from a null effect in the full sample. Seemingly, class participation is more important in public schools than in private ones where students may be provided additional tutoring outside of regular classes. Also, the unfairness of teachers is detrimental to students’ studies.

The results of non-cognitive performance in public schools are presented in table 4. Compared the full-sample outcomes, there are two significant differences. First, all-girls schools provide a positive effect on girls’ instrumental motivation in science in public schools (no effect in the full sample). Second, a female science teacher does not have 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 the full sample. This means that gender-matching effects are more salient in ordinary environments of public schools than arguably more privileged private ones. The positive gender-matching effects also reduce the negative effect of a girl’s own gender. For instance, 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 declines to less than one-third (see columns 2 and 4). Also,

girls can reduce the negative influence of their gender on interest in science by 40 percent if taught by female teachers (columns 10 and 12).

Self-selection into a single-sex school is further examined by using a propensity-score matching method, as discussed in section 3.2. Similar to the results estimated by OLS and multilevel methods, the PSM estimators of single-sex schooling are widely insignificant (table 5). Somewhat different results here are the positive effects of attending an all-boys school. The average treatment effect is positive for boys, increasing their science and reading scores by 3.5 and 3.9 points, respectively (table 5.1). When the sample is limited to public schools only (table 5.2), the positive effect of all-boys schools disappears, however. The presumed positive effect of all-boys schools is driven by those who chose to attend a private single-sex school, so that the effects cannot be generalized among the typical population of boy students in South Korea.

The PSM estimation reveals that attending an all-girls school has no effect on girls' cognitive and non-cognitive performance (except a negative effect on girls' math scores significant at a 10 percent level only, see table 5.1). Limiting the sample to public schools does not alter the main findings. The PSM results do not reinstate the positive effect of single-sex public schooling on girls' instrumental motivation identified in the OLS and multilevel estimations. All in all, the PSM exercises provide little support to the role of single-sex schools in improving girls' performance.

4.4. Response Heterogeneity by Performance

The results so far provide some but not very robust evidence for gender-matching effects on students' performance at the aggregate level. In this section, the gender-matching effects are further investigated by disentangling the effects by students' performance levels. This approach lends insights into potentially heterogeneous responses to single-sex schooling and interaction between a female student and a female teacher.

First, I examine whether a student's gender affects one's probability of being ranked on top of cognitive performance levels and, if so, whether gender-matching environments can change the gender effect. Given that boys are often overrepresented in the upper quartiles of the distribution

in STEM subjects, it is necessary to identify whether there is, indeed, a net gender effect on the top performing group. Also, it is tested whether gender-matching environments can be a tool to reduce the presumably negative gender effect on girls. Table 6 presents the results of a binary outcome estimated based on equation 2 in section 3.1³: whether a student is ranked in top 25 percent of science, math, and reading scores, respectively. The models are estimated by probit and multilevel probit methods, and marginal effects are computed conditional on the mean values of other covariates. While a student's gender plays no role in determining one's science score, there is a significant gender effect on math and reading scores. Being a girl reduces one's probability of achieving a math score of the highest quartile by more than 20 percent. In contrast, a girl's gender provides an advantage of increasing her probability by more 25 percent. These findings suggest that a student's gender explains girls' underrepresentation in the highest quartile of math scores, and their overrepresentation in that quartile of reading scores. However, a teacher's gender does not have a decisive influence on a student's probability of performing on top in tests.⁴ Furthermore, single-sex schooling has no effect on determining top cognitive performance.

Second, potentially heterogeneous responses to non-cognitive performance are examined by subgrouping students by the level of their cognitive performance (science scores). Table 7 shows the results of this sub-sample estimation including both public and private schools.⁵ Consistent with the negative effect at the aggregate level in table 2, a girl's gender constrains her from being motivated and interested in science in all levels of science scores. Notably, the negative magnitude of a student's gender effect is largest among best performing girls in science (4th quartile). Specifically, the negative gender effect on girls' motivation is twice as large for this group of girls compared to others in the worst performing group (1st quartile). Also, the negative gender effect on interest in science is almost one-fifth greater for best performing girls than worst

³ The estimates of the control variables (school, teacher's, family, behavioral, and relational inputs) are not presented in table 6 to save the space. The results can be obtained from the author upon request.

⁴ There is moderate evidence that, in private schools, a female teacher reduces a boy's probability of being placed in the highest quartile of math scores by 13–14 percent, but increases a girl's probability by 2.4–2.7 percent. However, these effects are significant at a 10 percent level only.

⁵ In tables 7 and 8, the results of the control variables (school, teacher's, family, behavioral, and relational inputs) are not also presented to save space but can be obtained from the author upon request.

ones. This finding that a feminine gender is most detrimental to the non-cognitive development of high performing girls implies that girls' abilities are discredited instead of recognized in our society (Cho 2017).

However, the negative effect of a girl's gender is mitigated if she is taught by a female science teacher. This positive gender-matching effect is particularly salient for girls in the highest quartile of science scores. For instance, if a girl in this quartile is taught by a female teacher, the negative effect of her gender decreases by 26 percent for her instrumental motivation; and by more than 50 percent for her interest in science. There is also positive evidence for girls in the 2nd quartile of science scores. In this group, the positive effect of female student-teacher matching reduces the negative effect of a student's gender on her interest in science by 80 percent. For the other quartiles, however, the gender-matching effect of a female student-teacher pair is minimal. On the other hand, there is little evidence of the role of single-sex schooling as a tool to boost girls' non-cognitive performance.

In addition, table 8 presents the results of the public-school sample. The findings of public schools are similar to those of all schools but there are a few notable differences. First, the negative effect of a girl's gender becomes smaller in the highest quartile, and the effect loses its significance in the 3rd quartile. Second, the effect of single-sex schooling turns positive for girls in the highest quartile. Third, the effect of a female teacher is not anymore negative in almost all specifications.

The findings on heterogeneous responses to single-sex schooling are further checked by propensity-score matching estimations, as discussed in section 3.2. After balancing out students' characteristics between the treatment and control groups, the effects now vary across different quartiles (see table 9.1). The PSM estimation identifies a positive effect of single-sex schooling exclusively for the highest quartile of girls. The effect on this group of girls remains positive for all three non-cognitive indicators. The magnitudes of the effects are considerably large, thus the negative effect of a girl's gender can be (almost) cancelled out if a girl attends an all-girls school

and is taught by a female science teacher.⁶ However, for low performing girls, this positive effect does not hold – except a positive effect on motivation of girls in the lowest quartile. Also, there is no evidence that single-sex schooling improves boys’ performance. For best performing boys and median girls, the effect of single-sex schooling is even detrimental. Attending an all-girls school reduces a girl’s confidence and/or interest in science, if she belongs to the 3rd or 2nd quartile. Single-sex schooling negatively affects the confidence level of boys in the highest quartile. When the sample is limited to public schools (table 9.2), the positive effect of single-sex schooling on top performing girls remains unchanged. Also, outcomes on girls in lower quartiles and boys in all quartiles are similar to those of the all school sample. Single-sex schooling has no positive effect on them.⁷ In some cases, it produces negative consequences on their non-cognitive performance.

5. Conclusion

If gender-matching environments can create a positive effect on female performance and attitudes, this can be used as a policy instrument to reduce gender inequality in society. My analysis, however, posits complex implications to this question. It shows that outcomes of gender-matching environments are heterogeneous across students’ performance levels and genders. Single-sex schooling and female teachers have most positive effects on facilitating motivation and interest of best performing girls in science. However, this does not come without costs on median girls, as well as boys, who do not benefit (or even worse-off) from such environments.

These mixed results complicate policy-making. If a policy priority is to promote female talent in STEM fields, gender-matching environments can be a viable policy option. However, for the interest of general education that does not leave any student behind, single-sex schooling may not necessarily be the best choice. With this in mind, one may consider introducing single-sex school systems specifically targeting best performing girls in science, while maintaining coeducational schools for the rest.

⁶ For instance, the net effect of gender and gender-matching environments on the instrumental motivation of a girl in the highest quartile is: $-0.494 - 0.243 + 0.373 + 0.443 = 0.079$ (see column 1 of table 7 and column 2 of table 9.1).

⁷ An exception is a positive effect on confidence of boys in the 2nd quartile.

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.
- Akerlof, George and Rachel Kranton 2000. Economics and Identity. *Quarterly Journal of Economics* 115: 715-753.
- Antonovics, Kate, Peter Arcidiacono, and Randall Walsh. 2009. The Effects of Gender Interactions in the Lab and in the Field. *Review of Economics and Statistics* 91: 152-162.
- 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(a). Choosing to Compete: How Different are Girls and Boys? *Journal of Economic Behaviour and Organization* 81: 542-555.
- Booth, Alison and Patrick Nolen. 2012(b). Gender Differences in Risk Behaviour: Does Nurture Matter? *Economic Journal* 122: 56-78.
- 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.
- Cho, Seo-Young. 2017. Explaining Gender Differences in Confidence and Overconfidence in Math. 2017. MAGKS DP No. 01-2017.
- Dee, Thomas. 2007. Teachers and the Gender Gaps in Student Achievement. *Journal of Human Resources* 42: 528-554.
- 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(2): 210-240.

- 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(3): 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(3): 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.
- Huguet, Pascal and Isabelle Regner. 2007. Stereotype Threat Among School Girls in Quasi-Ordinary Classroom Circumstances. *Journal of Educational Psychology* 99: 545-560.
- 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.
- Korea Education Development Institute. 2016. Brief Statistics on Korean Education (written in Korean). Ministry of Education of the Republic of Korea: Seoul.
- 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 (2): 1-33.
- Lee, Soohyung, Muriel Niederle and Namwook Kang. 2014. Do Single-sex Schools Make Girls More Competitive? *Economics Letters* 124: 474-477.
- 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(3): 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) 2014. OECD: Paris.
- Park, Hyunjoon, Jere Behrman and Jaesung Choi. 2011. Causal Effects of Single-Sex Schools on Students' STEM Outcomes by Gender and Parental SES. University of Pennsylvania Working Paper.
- 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.
- 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.

Table 1. Effects of Gender and Gender-Matching Environments 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		-0.002		-0.011		0.020		0.014		0.009		0.008
*Female Teacher		(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 (0.0005)	-0.0001 (0.0005)	0.0004 (0.0004)	0.0004 (0.0004)	-0.0005 (0.0005)	-0.001 (0.001)	0.00006 (0.0004)	0.00005 (0.0004)	-0.0005 (0.0005)	-0.0006 (0.0005)	-0.0002 (0.0004)	-0.0002 (0.0004)
Father's Education	0.0003 (0.005)	0.0003 (0.005)	-0.004 (0.005)	-0.004 (0.005)	0.004 (0.005)	0.003 (0.005)	-0.0006 (0.005)	-0.0006 (0.005)	0.0006 (0.005)	0.0006 (0.005)	-0.004 (0.005)	-0.004 (0.005)
Mother's Education	0.008* (0.005)	0.008* (0.005)	0.007 (0.004)	0.007 (0.004)	0.008** (0.004)	0.009** (0.004)	0.007* (0.004)	0.007* (0.004)	0.007 (0.005)	0.007 (0.004)	0.006 (0.004)	0.006 (0.004)
Economic, Social and Cultural Status	0.061*** (0.008)	0.061*** (0.008)	0.043*** (0.007)	0.043*** (0.007)	0.069*** (0.008)	0.069*** (0.007)	0.052*** (0.007)	0.052*** (0.007)	0.067*** (0.008)	0.067*** (0.008)	0.048*** (0.007)	0.048*** (0.007)
Family Spending on Education	0.016*** (0.003)	0.016*** (0.003)	0.009*** (0.002)	0.009*** (0.002)	0.020*** (0.003)	0.020*** (0.003)	0.013*** (0.003)	0.013*** (0.003)	0.019*** (0.003)	0.019*** (0.003)	0.012*** (0.002)	0.012*** (0.002)
Parental Support for Learning at Home	0.007* (0.004)	0.007* (0.004)	0.005 (0.004)	0.005 (0.004)	0.002 (0.003)	0.001 (0.003)	-0.0004 (0.003)	-0.0005 (0.003)	0.006* (0.004)	0.006* (0.004)	0.004 (0.003)	0.004 (0.003)
Parental Emotional Support	0.008** (0.003)	0.008** (0.003)	0.007** (0.003)	0.007** (0.003)	0.007** (0.003)	0.007** (0.003)	0.006* (0.003)	0.006* (0.003)	0.007** (0.003)	0.007** (0.003)	0.006* (0.003)	0.006* (0.003)
Skipping (some) Classes	-0.068*** (0.025)	-0.068*** (0.025)	-0.051** (0.024)	-0.051** (0.024)	-0.062*** (0.022)	-0.062*** (0.022)	-0.043** (0.020)	-0.043** (0.020)	-0.087*** (0.027)	-0.087*** (0.027)	-0.070*** (0.026)	-0.070*** (0.026)
Coming to School Late	-0.027*** (0.006)	-0.027*** (0.006)	-0.023*** (0.006)	-0.023*** (0.006)	-0.032*** (0.006)	-0.032*** (0.006)	-0.028*** (0.006)	-0.028*** (0.006)	-0.026*** (0.006)	-0.026*** (0.006)	-0.022*** (0.006)	-0.022*** (0.006)
Chatting Online (Outside of School)	-0.001 (0.002)	-0.001 (0.002)	0.001 (0.002)	0.001 (0.002)	-0.0007 (0.002)	-0.001 (0.002)	-0.001 (0.002)	0.001 (0.002)	-0.002 (0.002)	-0.002 (0.002)	0.00004 (0.002)	0.00005 (0.002)
Participation in Social Networks	-0.004* (0.002)	-0.004* (0.002)	-0.003 (0.002)	-0.003 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.001 (0.002)	-0.001 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.001 (0.002)	-0.001 (0.002)
Chatting Online (School)	-0.027*** (0.005)	-0.027*** (0.005)	-0.026*** (0.003)	-0.026*** (0.004)	-0.023*** (0.005)	-0.023*** (0.005)	-0.022*** (0.004)	-0.022*** (0.004)	-0.029*** (0.006)	-0.030*** (0.006)	-0.030*** (0.004)	-0.030*** (0.004)
Feeling Belonging to School	0.001 (0.004)	0.001 (0.004)	-0.003 (0.003)	-0.003 (0.003)	0.012*** (0.004)	0.012*** (0.004)	0.009*** (0.003)	0.009*** (0.003)	0.0003 (0.004)	0.003 (0.004)	-0.003 (0.003)	-0.003 (0.003)
Unfairness of Teacher	-0.008***	-0.008***	-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 Chi2			462.3***	469.3***			631.8***	629.8***			507.7***	511.4***

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

Table 2. Effects of Gender and Gender-Matching Environments on Non-cognitive Performance, full sample

Dependent Variable	Instrumental Motivation in Science				Confidence in Science				Interest in Science			
Method	OLS		Multilevel		OLS		Multilevel		OLS		Multilevel	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Female Student	-0.244*** (0.046)	-0.349*** (0.055)	-0.221*** (0.044)	-0.306*** (0.053)	0.038 (0.046)	-0.007 (0.073)	0.038 (0.045)	-0.005 (0.073)	-0.355*** (0.038)	-0.465*** (0.055)	-0.351*** (0.036)	-0.454*** (0.054)
Boy School	0.017 (0.058)	-0.004 (0.057)	0.030 (0.058)	0.011 (0.059)	-0.017 (0.061)	-0.026 (0.063)	-0.017 (0.061)	-0.026 (0.063)	0.021 (0.057)	-0.001 (0.058)	0.028 (0.057)	0.006 (0.058)
Girl School	0.091 (0.076)	0.093 (0.072)	0.079 (0.075)	0.080 (0.071)	-0.095 (0.079)	-0.094 (0.078)	-0.094 (0.079)	-0.094 (0.078)	0.056 (0.057)	0.057 (0.053)	0.055 (0.056)	0.057 (0.052)
Public School	0.039 (0.067)	0.040 (0.066)	0.027 (0.067)	0.030 (0.066)	0.033 (0.052)	0.034 (0.051)	0.032 (0.051)	0.033 (0.051)	0.027 (0.049)	0.029 (0.048)	0.021 (0.048)	0.024 (0.048)
Community Size	0.018 (0.035)	0.022 (0.034)	0.017 (0.035)	0.020 (0.034)	-0.008 (0.029)	-0.007 (0.029)	-0.008 (0.029)	-0.007 (0.029)	0.005 (0.024)	0.008 (0.023)	0.006 (0.024)	0.009 (0.023)
Student-Teacher Ratio	-2.037 (2.156)	-2.234 (2.117)	-1.932 (2.113)	-2.096 (2.074)	-1.128 (1.879)	-1.213 (1.869)	-1.157 (1.882)	-1.231 (1.869)	-1.637 (1.797)	-1.854 (1.765)	-1.699 (1.818)	-1.899 (1.776)
School Size	-0.0001 (0.0001)	-0.0001 (0.0001)	-0.0001 (0.0001)	-0.0001 (0.0001)	-0.00001 (0.00009)	-0.00001 (0.00009)	-0.00001 (0.00009)	-0.00001 (0.00009)	-0.00007 (0.00009)	-0.00008 (0.00009)	-0.00008 (0.00009)	-0.00008 (0.00009)
Perceived School Quality	0.072*** (0.021)	0.071*** (0.021)	0.070*** (0.022)	0.069*** (0.021)	0.037 (0.027)	0.037 (0.027)	0.037 (0.027)	0.037 (0.027)	0.070*** (0.022)	0.070*** (0.022)	0.071*** (0.023)	0.071*** (0.022)
Female Teacher	-0.071* (0.040)	-0.158*** (0.053)	-0.059 (0.038)	-0.131*** (0.048)	-0.083* (0.044)	-0.119** (0.059)	-0.082* (0.043)	-0.118** (0.059)	-0.005 (0.037)	-0.094* (0.053)	0.003 (0.035)	-0.084* (0.051)
Female Student*Female Teacher		0.184*** (0.070)		0.146** (0.066)		0.078 (0.088)		0.075 (0.088)		0.190*** (0.068)		0.177*** (0.067)
Teacher's Tenure	0.013 (0.057)	0.010 (0.058)	-0.023 (0.057)	-0.025 (0.058)	0.032 (0.057)	0.030 (0.057)	0.034 (0.057)	0.032 (0.057)	-0.056 (0.045)	-0.059 (0.045)	-0.053 (0.046)	-0.056 (0.046)

Experience of Teacher	-0.003 (0.002)	-0.003 (0.002)	-0.001 (0.002)	-0.001 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)	0.0005 (0.002)	0.0003 (0.0017)	0.0006 (0.002)	0.0004 (0.002)
Cognitive Abilities (log reading score)	0.441*** (0.122)	0.445*** (0.120)	0.416*** (0.121)	0.421*** (0.120)	0.904*** (0.134)	0.906*** (0.134)	0.900*** (0.134)	0.903*** (0.134)	0.596*** (0.099)	0.599*** (0.099)	0.595*** (0.098)	0.599*** (0.099)
Father's Education	-0.006 (0.021)	-0.006 (0.021)	-0.005 (0.021)	-0.005 (0.021)	-0.048* (0.028)	-0.048* (0.028)	-0.048* (0.028)	-0.048* (0.028)	-0.006 (0.024)	-0.007 (0.024)	-0.007 (0.024)	-0.007 (0.024)
Mother's Education	0.010 (0.022)	0.010 (0.022)	0.008 (0.021)	0.007 (0.022)	-0.026 (0.028)	-0.026 (0.028)	-0.026 (0.028)	-0.026 (0.028)	-0.027 (0.021)	-0.028 (0.021)	-0.027 (0.021)	-0.028 (0.021)
Economic, Social and Cultural Status	0.062 (0.042)	0.063 (0.042)	0.063 (0.041)	0.064 (0.041)	0.293*** (0.051)	0.294*** (0.052)	0.294*** (0.051)	0.294*** (0.051)	0.130*** (0.042)	0.131*** (0.042)	0.132*** (0.041)	0.132*** (0.041)
Family Spending on Education	0.022 (0.014)	0.022 (0.014)	0.017 (0.014)	0.017 (0.014)	-0.004 (0.016)	-0.004 (0.016)	-0.004 (0.016)	-0.004 (0.016)	0.005 (0.014)	0.004 (0.014)	0.002 (0.014)	0.002 (0.014)
Parental Support for Learning at Home	0.131*** (0.018)	0.131*** (0.018)	0.127*** (0.018)	0.127*** (0.018)	0.101*** (0.024)	0.102*** (0.024)	0.101*** (0.024)	0.102*** (0.024)	0.094*** (0.018)	0.094*** (0.018)	0.093*** (0.018)	0.093*** (0.018)
Parental Emotional Support	-0.011 (0.019)	-0.012 (0.019)	-0.009 (0.019)	-0.009 (0.019)	0.019 (0.020)	0.019 (0.020)	0.019 (0.020)	0.019 (0.020)	-0.014 (0.017)	-0.014 (0.018)	-0.013 (0.017)	-0.013 (0.018)
Skipping (some) Classes	0.016 (0.082)	0.018 (0.08)	0.032 (0.083)	0.033 (0.084)	-0.005 (0.133)	-0.004 (0.133)	-0.003 (0.132)	-0.003 (0.133)	0.117 (0.087)	0.119 (0.088)	0.123 (0.085)	0.124 (0.087)
Coming to School Late	-0.069** (0.034)	-0.069** (0.034)	-0.074** (0.033)	-0.073** (0.033)	-0.112** (0.0489)	-0.111** (0.048)	-0.112** (0.048)	-0.112** (0.048)	-0.099** (0.040)	-0.098** (0.041)	-0.096** (0.040)	-0.096** (0.040)
Chatting Online (Outside of School)	0.008 (0.012)	0.010 (0.012)	0.010 (0.011)	0.011 (0.011)	0.005 (0.014)	0.006 (0.014)	0.005 (0.014)	0.006 (0.014)	0.022** (0.011)	0.024** (0.011)	0.023** (0.010)	0.024** (0.011)
Participation in Social Networks	-0.058*** (0.013)	-0.059*** (0.013)	-0.056*** (0.013)	-0.056*** (0.013)	-0.039*** (0.015)	-0.040*** (0.015)	-0.039*** (0.015)	-0.040*** (0.015)	-0.060*** (0.012)	-0.061*** (0.012)	-0.059*** (0.012)	-0.060*** (0.011)
Chatting Online (School)	0.047*** (0.017)	0.045*** (0.016)	0.045*** (0.016)	0.043*** (0.016)	0.087*** (0.022)	0.086*** (0.023)	0.087*** (0.022)	0.086*** (0.023)	0.061*** (0.020)	0.058*** (0.020)	0.063*** (0.020)	0.060*** (0.020)
Feeling 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 Chi2			347.3***	399.6***			534.6***	547***			623***	614.1***

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

Table 3. Effects of Gender and Gender-Matching Environments on Cognitive Performance, public schools

Dependent Variable	Log Science Score				Log Math Score				Log Reading Score			
	OLS		Multilevel		OLS		Multilevel		OLS		Multilevel	
Method	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Female Student	-0.001 (0.012)	-0.002 (0.015)	-0.007 (0.010)	0.001 (0.013)	-0.004 (0.010)	-0.021 (0.014)	-0.011 (0.008)	-0.025** (0.012)	0.051*** (0.010)	0.043*** (0.015)	0.043*** (0.008)	0.033*** (0.011)
Boy School	0.004 (0.028)	0.003 (0.028)	0.0003 (0.029)	0.002 (0.029)	0.007 (0.024)	0.004 (0.024)	0.002 (0.026)	-0.001 (0.025)	0.007 (0.029)	0.006 (0.029)	-0.001 (0.031)	-0.003 (0.031)
Girl School	-0.007 (0.019)	-0.007 (0.019)	-0.004 (0.022)	-0.004 (0.022)	-0.029 (0.024)	-0.028 (0.023)	-0.024 (0.028)	-0.024 (0.027)	0.007 (0.017)	0.007 (0.017)	0.010 (0.020)	0.011 (0.020)
Community Size	-0.003 (0.011)	-0.003 (0.011)	-0.001 (0.012)	-0.002 (0.012)	0.0004 (0.011)	0.001 (0.011)	0.003 (0.012)	0.003 (0.012)	-0.0005 (0.011)	-0.0002 (0.011)	0.002 (0.012)	0.003 (0.012)
Student-Teacher Ratio	-1.266* (0.725)	-1.268* (0.724)	-1.596** (0.793)	-1.574** (0.799)	-1.163 (0.737)	-1.221* (0.736)	-1.582** (0.796)	-1.626** (0.794)	-0.865 (0.763)	-0.892 (0.765)	-1.311 (0.826)	-1.343 (0.828)
School Size	0.00002 (0.00003)	0.00002 (0.00003)	0.00003 (0.00003)	0.00003 (0.00003)	0.00004 (0.00003)	0.00004 (0.00003)	0.00004 (0.00003)	0.00004 (0.00003)	0.00003 (0.00003)	0.00003 (0.00003)	0.00003 (0.00004)	0.00003 (0.00004)
Perceived School Quality	0.006 (0.006)	0.006 (0.006)	-0.001 (0.005)	-0.001 (0.005)	0.007 (0.006)	0.007 (0.006)	-0.0001 (0.005)	-0.0003 (0.005)	0.007 (0.006)	0.006 (0.006)	-0.0009 (0.005)	-0.001 (0.005)
Female Teacher	0.009 (0.010)	0.009 (0.015)	0.018** (0.008)	0.024** (0.011)	0.006 (0.011)	-0.006 (0.015)	0.009 (0.008)	-0.0007 (0.011)	0.001 (0.011)	-0.004 (0.015)	0.0009 (0.008)	-0.006 (0.011)
Female Student*Female Teacher		0.001 (0.015)		-0.012 (0.013)		0.027 (0.015)		0.021 (0.015)		0.012 (0.017)		0.015 (0.014)
Teacher's Tenure	-0.005 (0.013)	-0.005 (0.013)	-0.006 (0.010)	-0.006 (0.010)	-0.009 (0.015)	-0.009 (0.015)	-0.011 (0.011)	-0.011 (0.011)	-0.021 (0.014)	-0.021 (0.014)	-0.015 (0.011)	-0.015 (0.011)
Experience of Teacher	-0.0001	-0.0001	0.0004	0.0004	-0.0004	-0.0004	9.04e-06	-0.00002	-0.0005	-0.0005	-0.0004	-0.0004

	(0.0005)	(0.0005)	(0.0004)	(0.0004)	(0.0006)	(0.0006)	(0.0005)	(0.0005)	(0.0006)	(0.0006)	(0.0005)	(0.0005)
Father's Education	0.007	0.007	0.003	0.003	0.009	0.009	0.005	0.005	0.006	0.006	0.001	0.001
	(0.006)	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	(0.006)
Mother's Education	0.008	0.008	0.006	0.006	0.008	0.009*	0.007	0.007	0.008	0.008	0.007	0.007
	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Economic, Social and Cultural Status	0.046***	0.046***	0.033***	0.033***	0.057***	0.057***	0.047***	0.047***	0.057***	0.057***	0.044***	0.044***
	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)
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)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)
Parental Support for Learning at Home	0.006	0.006	0.005	0.005	0.0002	0.00001	-0.0007	-0.0009	0.005	0.005	0.004	0.003
	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)
Parental Emotional Support	0.010**	0.010**	0.009**	0.009**	0.010***	0.010***	0.009***	0.009***	0.0077*	0.008*	0.007*	0.007*
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.0043)	(0.004)	(0.004)	(0.004)
Skipping (some) Classes	-0.074**	-0.074**	-0.060**	-0.060**	-0.062**	-0.062**	-0.046**	-0.046**	-0.093***	-0.093***	-0.077***	-0.077***
	(0.029)	(0.029)	(0.028)	(0.028)	(0.024)	(0.024)	(0.022)	(0.022)	(0.030)	(0.030)	(0.030)	(0.030)
Coming to School Late	-0.019***	-0.019***	-0.018***	-0.018***	-0.025***	-0.024***	-0.023***	-0.023***	-0.019***	-0.019***	-0.017**	-0.017***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)
Chatting Online (Outside of School)	-0.0002	-0.0001	0.001	0.001	0.001	0.001	0.002	0.002	-0.0004	-0.0004	0.0007	0.0007
	(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	-0.003	-0.003	-0.003	-0.003	-0.0004	-0.0003	-0.0006	-0.0006	-0.0009	-0.0009	-0.0008	-0.0008
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Chatting Online (School)	-0.028***	-0.028***	-0.024***	-0.024***	-0.027***	-0.027***	-0.022***	-0.021***	-0.033***	-0.033***	-0.029***	-0.029***
	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Feeling Belonging to School	0.003	0.003	0.001	0.0001	0.013***	0.013***	0.011***	0.011***	0.002	0.002	0.0007	0.0006
	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)
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	2,280	2,280	2,280	2,280	2,280	2,280	2,280	2,280	2,280	2,280	2,280	2,280
Number of Schools	74	74	74	74	74	74	74	74	74	74	74	74
R ²	0.217	0.217			0.250	0.251			0.255	0.255		
Wald Chi2			364.1***	367.1***			553***	568.7***			363.2***	376.1***

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

Table 4. Effects of Gender and Gender-Matching Environments on Non-cognitive Performance, public schools

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	-0.222*** (0.056)	-0.354*** (0.145)	-0.212*** (0.054)	-0.335*** (0.072)	0.023 (0.051)	-0.031 (0.098)	0.022 (0.050)	-0.030 (0.097)	-0.330*** (0.043)	-0.448*** (0.068)	-0.326*** (0.040)	-0.434*** (0.066)
Boy School	0.021 (0.060)	-0.005 (0.060)	0.035 (0.061)	0.008 (0.061)	-0.045 (0.078)	-0.056 (0.080)	-0.044 (0.078)	-0.055 (0.080)	0.057 (0.079)	0.033 (0.079)	0.070 (0.078)	0.046 (0.079)
Girl School	0.193** (0.082)	0.193** (0.079)	0.187** (0.082)	0.188** (0.079)	-0.154 (0.095)	-0.154 (0.093)	-0.153 (0.094)	-0.153 (0.093)	0.068 (0.063)	0.068 (0.061)	0.067 (0.062)	0.067 (0.060)
Community Size	0.020 (0.030)	0.025 (0.029)	0.019 (0.030)	0.022 (0.029)	-0.011 (0.037)	-0.009 (0.037)	-0.011 (0.037)	-0.009 (0.037)	0.006 (0.032)	0.010 (0.031)	0.006 (0.032)	0.009 (0.031)
Student-Teacher Ratio	-2.141 (2.117)	-2.500 (2.072)	-2.167 (2.101)	-2.500 (2.047)	-2.591 (2.045)	-2.738 (2.044)	-2.624 (2.045)	-2.759 (2.040)	-1.265 (1.931)	-1.599 (1.913)	-1.260 (1.974)	-1.567 (1.937)
School Size	-0.0001 (0.0001)	-0.0001 (0.0001)	-0.00008 (0.0001)	-0.0001 (0.0001)	-5.79e-06 (0.0001)	-8.94e-06 (0.0001)	-5.52e-06 (0.001)	-8.66e-06 (0.0001)	-0.00007 (0.0001)	-0.00008 (0.0001)	-0.00007 (0.0001)	-0.00007 (0.0001)
Perceived School Quality	0.070*** (0.025)	0.069*** (0.025)	0.071*** (0.025)	0.070*** (0.025)	0.070** (0.032)	0.070** (0.032)	0.070** (0.032)	0.069** (0.032)	0.082*** (0.023)	0.081*** (0.023)	0.083*** (0.023)	0.082*** (0.023)
Female Teacher	-0.053 (0.045)	-0.145*** (0.055)	-0.036 (0.044)	-0.126** (0.054)	-0.113** (0.052)	-0.151* (0.078)	-0.112** (0.051)	-0.149* (0.077)	-0.013 (0.044)	-0.096 (0.062)	0.004 (0.043)	-0.075 (0.061)
Female Student*Female Teacher		0.202** (0.079)		0.186** (0.077)		0.081 (0.116)		0.079 (0.115)		0.180** (0.084)		0.163** (0.061)
Teacher's Tenure	-0.016 (0.002)	-0.015 (0.064)	-0.046 (0.063)	-0.043 (0.064)	0.024 (0.070)	0.024 (0.070)	0.025 (0.070)	0.025 (0.070)	-0.065 (0.056)	-0.064 (0.056)	-0.063 (0.057)	-0.063 (0.056)
Experience of Teacher	-0.002	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.0004	0.0001	0.0004	0.0002

	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Cognitive Abilities	0.375***	0.379***	0.359***	0.364***	0.819***	0.820***	0.815***	0.817***	0.629***	0.631***	0.623***	0.626***
(log reading score)	(0.137)	(0.135)	(0.137)	(0.135)	(0.136)	(0.135)	(0.135)	(0.135)	(0.120)	(0.120)	(0.118)	(0.118)
Father's Education	-0.022	-0.022	-0.022	-0.022	-0.032	-0.032	-0.032	-0.032	-0.001	-0.001	-0.002	-0.001
	(0.020)	(0.020)	(0.020)	(0.020)	(0.029)	(0.029)	(0.030)	(0.029)	(0.029)	(0.028)	(0.028)	(0.028)
Mother's Education	0.003	-0.0001	-0.0001	-0.002	-0.069**	-0.070**	-0.069**	-0.070**	-0.039*	-0.041*	-0.039*	-0.042*
	(0.025)	(0.024)	(0.025)	(0.024)	(0.034)	(0.034)	(0.033)	(0.034)	(0.022)	(0.022)	(0.022)	(0.022)
Economic, Social and Cultural Status	0.067	0.067	0.072	0.071	0.328***	0.328***	0.328***	0.328***	0.141***	0.141***	0.146***	0.146***
	(0.047)	(0.047)	(0.047)	(0.047)	(0.060)	(0.060)	(0.059)	(0.059)	(0.048)	(0.022)	(0.047)	(0.047)
Family Spending on Education	0.027*	0.026*	0.022	0.022	-0.005	-0.005	-0.005	-0.005	0.020	0.020	0.019	0.019
	(0.014)	(0.015)	(0.014)	(0.014)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.017)	(0.017)
Parental Support for Learning at Home	0.118***	0.119***	0.115***	0.116***	0.071**	0.071**	0.071**	0.071**	0.075***	0.077***	0.074***	0.075***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.028)	(0.029)	(0.028)	(0.028)	(0.022)	(0.022)	(0.022)	(0.022)
Parental Emotional Support	0.011	0.011	0.011	0.011	0.022	0.022	0.022	0.022	-0.017	-0.017	-0.017	-0.017
	(0.023)	(0.023)	(0.023)	(0.023)	(0.025)	(0.025)	(0.024)	(0.025)	(0.020)	(0.021)	(0.020)	(0.020)
Skipping (some) Classes	0.026	0.026	0.032	0.032	0.009	0.010	0.011	0.011	0.132	0.132	0.132	0.133
	(0.091)	(0.093)	(0.093)	(0.093)	(0.146)	(0.146)	(0.015)	(0.146)	(0.095)	(0.096)	(0.093)	(0.095)
Coming to School Late	-0.069*	-0.067*	-0.067*	-0.065*	-0.121**	-0.120**	-0.121**	-0.120**	-0.119***	-0.116***	-0.112***	-0.110***
	(0.038)	(0.039)	(0.037)	(0.038)	(0.055)	(0.055)	(0.054)	(0.054)	(0.043)	(0.043)	(0.042)	(0.043)
Chatting Online (Outside of School)	0.018	0.019	0.018	0.019	-0.008	-0.007	-0.008	-0.007	0.031**	0.032***	0.031***	0.032***
	(0.013)	(0.012)	(0.012)	(0.012)	(0.017)	(0.017)	(0.017)	(0.017)	(0.012)	(0.012)	(0.012)	(0.012)
Participation in Social Networks	-0.053***	-0.055***	-0.054***	-0.055***	-0.050***	-0.051**	-0.050***	-0.051***	-0.058***	-0.059***	-0.058***	-0.059***
	(0.015)	(0.015)	(0.014)	(0.014)	(0.018)	(0.018)	(0.017)	(0.018)	(0.013)	(0.013)	(0.013)	(0.013)
Chatting Online (School)	0.030*	0.029	0.033*	0.032*	0.104***	0.104***	0.104***	0.104***	0.071***	0.070***	0.072***	0.071***
	(0.018)	(0.018)	(0.017)	(0.017)	(0.027)	(0.027)	(0.026)	(0.027)	(0.023)	(0.023)	(0.023)	(0.023)
Feeling Belonging to School	0.119***	0.119***	0.113***	0.113***	0.190***	0.190***	0.189***	0.189***	0.131***	0.131***	0.128***	0.129***

	(0.026)	(0.026)	(0.026)	(0.026)	(0.032)	(0.033)	(0.032)	(0.032)	(0.028)	(0.028)	(0.028)	(0.028)
Unfairness of Teacher	-0.004	-0.004	-0.004	-0.004	0.010	0.010	0.010	0.010	-0.016**	-0.016**	-0.017**	-0.016**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.008)	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)
Number of Observations	2,273	2,273	2,273	2,273	2,276	2,276	2,276	2,276	2,265	2,265	2,265	2,265
Number of Schools	74	74	74	74	74	74	74	74	74	74	74	74
R ²	0.083	0.085			0.106	0.106			0.117	0.119		
Wald Chi2			328.7***	378.5***			390.6***	403.2***			456.4***	467.9***

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

Table 5. Average Treatment Effects (ATE) of Single-sex Schooling
on Cognitive and Non-cognitive Performance, propensity-score matching

Table 5.1. (including both public and private schools)

Dependent Variable	Sample	ATE (single-sex school)	AI Robust Std.Err.	Number of Obs.
(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 5.2. (public schools only)

Dependent Variable	Sample	ATE (single-sex school)	AI Robust Std.Err.	Number of Obs.
(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

Table 6. Effects of Gender and Gender-Matching Environments on Cognitive Performance, probability of being ranked in the highest quartile

Dependent Variable	Top 25% in Science				Top 25% in Math				Top 25% in Reading			
	Probit		Multilvel Probit		Probit		Multilevel Probit		Probit Probit		Multilevel Estimation	
School Type	All	Public	All	Public	All	Public	All	Public	All	Public	All	Public
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Female Student	-0.100 (0.097)	-0.123 (0.122)	-0.099 (0.096)	-0.131 (0.123)	-0.260* (0.102)	-0.214* (0.114)	-0.253*** (0.086)	-0.234** (0.114)	0.259** (0.119)	0.290*** (0.109)	0.290** (0.102)	0.275** (0.109)
Boy School	0.162 (0.110)	0.095 (0.128)	0.172 (0.125)	0.098 (0.146)	0.001 (0.124)	-0.045 (0.125)	0.028 (0.138)	-0.044 (0.141)	0.013 (0.121)	0.046 (0.114)	0.031 (0.139)	0.040 (0.136)
Girl School	-0.087 (0.108)	-0.215 (0.142)	-0.094 (0.127)	-0.220 (0.160)	-0.187 (0.119)	-0.189 (0.145)	-0.183 (0.131)	-0.181 (0.156)	-0.055 (0.101)	-0.105 (0.132)	-0.061 (0.117)	-0.102 (0.147)
Female Teacher	-0.017 (0.083)	0.009 (0.102)	0.011 (0.081)	0.047 (0.098)	-0.156* (0.080)	-0.158* (0.092)	-0.138* (0.072)	-0.152* (0.087)	0.010 (0.076)	0.028 (0.089)	0.003 (0.074)	0.009 (0.089)
Female Student*Female Teacher	-0.009 (0.103)	0.027 (0.125)	-0.051 (0.103)	-0.018 (0.129)	0.180* (0.100)	0.162 (0.123)	0.165* (0.093)	0.161 (0.128)	0.062 (0.113)	0.027 (0.131)	0.040 (0.115)	0.038 (0.139)
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	3,259	2,280	3,259	2,280	3,258	2,280	3,258	2,280	3,258	2,280	3,258	2,280
Number of Schools	105	74	105	74	105	74	105	74	105	74	105	74
pseudo R ²	0.128	0.114			0.145	0.130			0.139	0.131		
Wald Chi2			342.1***	203***			316.5***	346.6***			302.9***	238.38***

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

Table 7. Effects of Gender and Gender-Matching Environments 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 (Science Scores)	4 th (>582)	3 rd (518–582)	2 nd (449–518)	1 st (<449)	4 th (>582)	3 rd (518–582)	2 nd (449–518)	1 st (<449)	4 th (>582)	3 rd (518–582)	2 nd (449–518)	1 st (<449)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Female Student	-0.494*** (0.102)	-0.209* (0.122)	-0.220* (0.117)	-0.234** (0.112)	-0.145 (0.119)	0.070 (0.113)	0.111 (0.176)	0.171 (0.182)	-0.474*** (0.095)	-0.229** (0.109)	-0.495*** (0.113)	-0.395*** (0.113)
Boy School	-0.045 (0.093)	0.004 (0.100)	-0.013 (0.134)	0.051 (0.103)	-0.257** (0.100)	-0.214* (0.112)	0.204 (0.180)	0.145 (0.148)	-0.082 (0.073)	0.005 (0.086)	0.047 (0.109)	0.034 (0.111)
Girl School	0.202 (0.204)	0.014 (0.095)	0.154 (0.114)	0.063 (0.125)	0.110 (0.093)	-0.160 (0.112)	-0.413** (0.161)	0.121 (0.148)	0.176 (0.131)	-0.034 (0.085)	0.088 (0.088)	0.089 (0.108)
Female Teacher	-0.243** (0.099)	-0.177* (0.090)	-0.040 (0.111)	-0.107 (0.096)	-0.253** (0.100)	0.006 (0.100)	0.0001 (0.148)	-0.133 (0.145)	-0.060 (0.075)	-0.043 (0.107)	-0.184 (0.126)	-0.022 (0.105)
Female Student*Female Teacher	0.373** (0.145)	0.091 (0.125)	-0.018 (0.111)	0.254* (0.139)	0.199 (0.150)	-0.058 (0.133)	-0.001 (0.199)	0.076 (0.218)	0.222** (0.107)	-0.071 (0.134)	0.390*** (0.141)	0.154 (0.150)
School Inputs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Teacher's Inputs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Family Inputs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Behavioral Factors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Relational Factors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	855	832	775	787	855	833	774	790	853	832	772	782
Number of Schools	98	104	104	97	98	104	104	98	98	104	104	98
R ²	0.122	0.090	0.077	0.070	0.120	0.080	0.125	0.072	0.152	0.115	0.087	0.088

Note: Parentheses are robust standard errors clustered at the school level. * $p < .10$, ** $p < .05$, *** $p < .001$.

Table 8. Effects of Gender and Gender-Matching Environments on Non-cognitive Performance,
heterogeneous responses by science scores, OLS, public schools only

Dependent Variable	Instrumental Motivation in Science				Confidence in Science				Interest in Science			
Quartile (Science Scores)	4 th (>582)	3 rd (518–582)	2 nd (449–518)	1 st (<449)	4 th (>582)	3 rd (518–582)	2 nd (449–518)	1 st (<449)	4 th (>582)	3 rd (518–582)	2 nd (449–518)	1 st (<449)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Female Student	-0.395*** (0.142)	-0.232 (0.155)	-0.242* (0.142)	-0.441*** (0.129)	-0.114 (0.184)	0.058 (0.157)	0.062 (0.197)	-0.010 (0.228)	-0.434*** (0.118)	-0.170 (0.124)	-0.469*** (0.145)	-0.521*** (0.152)
Boy School	-0.025 (0.101)	-0.040 (0.129)	0.051 (0.167)	0.030 (0.122)	-0.279** (0.121)	-0.354** (0.158)	0.215 (0.245)	0.205 (0.177)	-0.125 (0.078)	0.013 (0.104)	0.164 (0.122)	0.061 (0.141)
Girl School	0.565*** (0.138)	-0.020 (0.117)	0.171 (0.136)	0.229* (0.132)	0.283** (0.136)	-0.159 (0.155)	-0.513*** (0.159)	-0.152 (0.210)	0.362*** (0.099)	-0.115 (0.106)	0.105 (0.095)	0.156 (0.144)
Female Teacher	-0.229** (0.105)	-0.094 (0.110)	-0.041 (0.124)	-0.175 (0.109)	-0.181 (0.149)	-0.004 (0.139)	-0.102 (0.180)	-0.280 (0.170)	-0.053 (0.084)	-0.048 (0.136)	-0.200 (0.150)	-0.050 (0.135)
Female Student*Female Teacher	0.256* (0.154)	0.153 (0.148)	-0.0004 (0.172)	0.392** (0.170)	0.020 (0.222)	-0.105 (0.186)	-0.093 (0.241)	0.290 (0.247)	0.145 (0.123)	-0.108 (0.157)	0.387** (0.175)	0.262 (0.192)
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	510	580	577	606	510	581	576	609	509	580	574	602
Number of Schools	69	73	73	71	69	73	73	72	69	73	73	72
R ²	0.166	0.080	0.105	0.077	0.134	0.072	0.146	0.085	0.169	0.119	0.113	0.102

Note: Parentheses are robust standard errors clustered at the school level. * $p < .10$, ** $p < .05$, *** $p < .001$.

Table 9. Average Treatment Effects of Single-sex Schooling on Non-cognitive Performance,
heterogeneous responses by science scores, propensity-score matching

Table 9.1. (including both public and private schools)

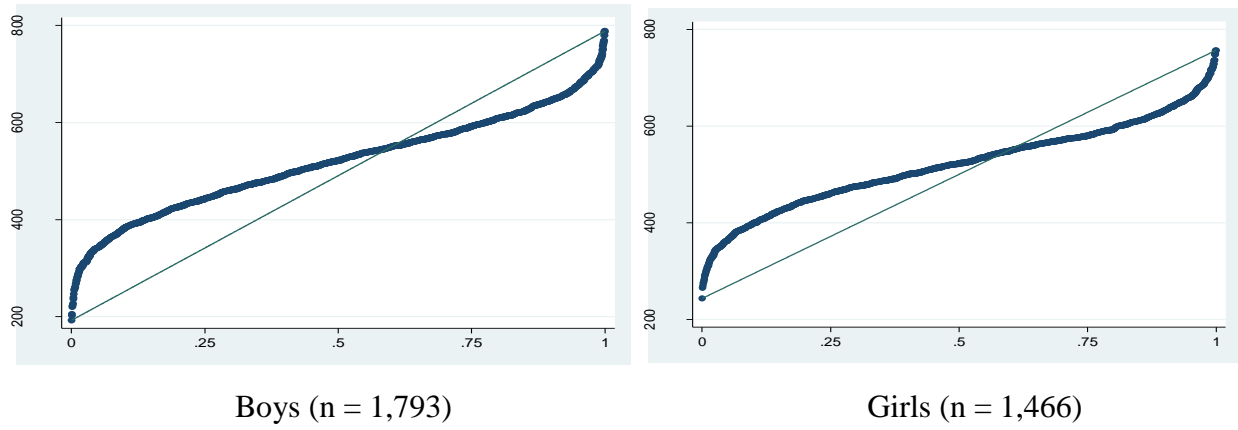
DV	Instrumental Motivation in Science							
Quartile	4 th (score > 582)		3 rd (518 < score < 582)		2 nd (449 < score < 518)		1 st (score < 449)	
Gender of Students	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
ATE	-0.044	0.443***	-0.048	-0.129	0.056	0.050	0.062	0.220**
AI Robust Std.Err.	0.069	0.116	0.115	0.124	0.093	0.146	0.141	0.101
Number of Obs.	496	365	427	407	390	394	474	320
DV	Confidence in Science							
Quartile	4 th (score > 582)		3 rd (518 < score < 582)		2 nd (449 < score < 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
Number of Obs.	496	365	427	408	389	394	476	321
DV	Interest in Science							
Quartile	4 th (score > 582)		3 rd (518 < score < 582)		2 nd (449 < score < 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
Number of Obs.	494	365	426	408	389	392	468	321

Table 9.2. (public schools only)

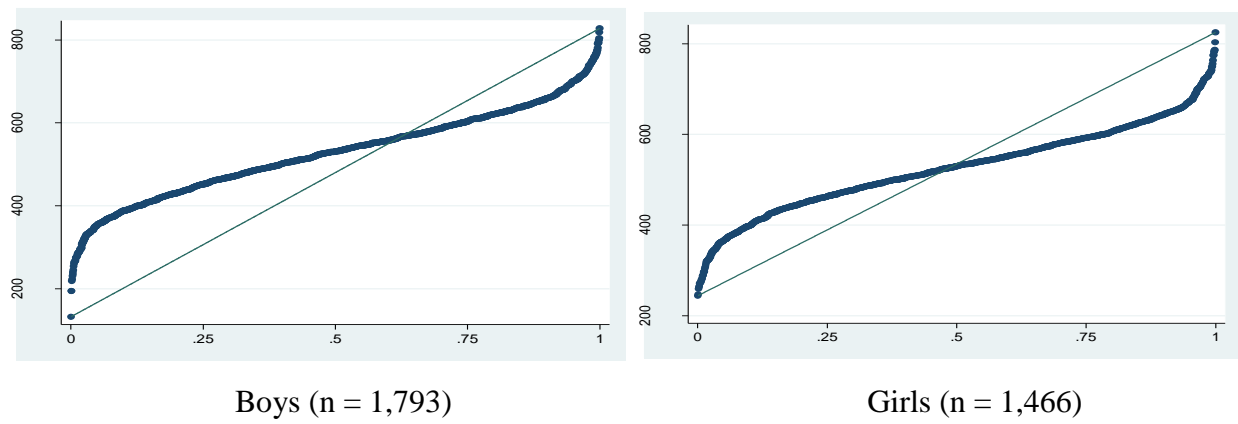
DV	Instrumental Motivation in Science							
Quartile	4 th (score > 582)		3 rd (518 < score < 582)		2 nd (449 < score < 518)		1 st (score < 449)	
Gender of Students	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
ATE	-0.017	0.642***	-0.123	0.127	0.207	0.220	-0.047	-0.048
AI Robust Std.Err.	0.111	0.157	0.119	0.103	0.259	0.619	0.234	0.136
Number of Obs.	292	223	300	282	293	292	368	232
DV	Confidence in Science							
Quartile	4 th (score > 582)		3 rd (518 < score < 582)		2 nd (449 < score < 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
Number of Obs.	292	223	300	283	292	292	370	243
DV	Interest in Science							
Quartile	4 th (score > 582)		3 rd (518 < score < 582)		2 nd (449 < score < 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
Number of Obs.	291	223	299	283	292	290	363	243

Figure 1. Quantile Distribution of Cognitive and Non-Cognitive Performance, by gender

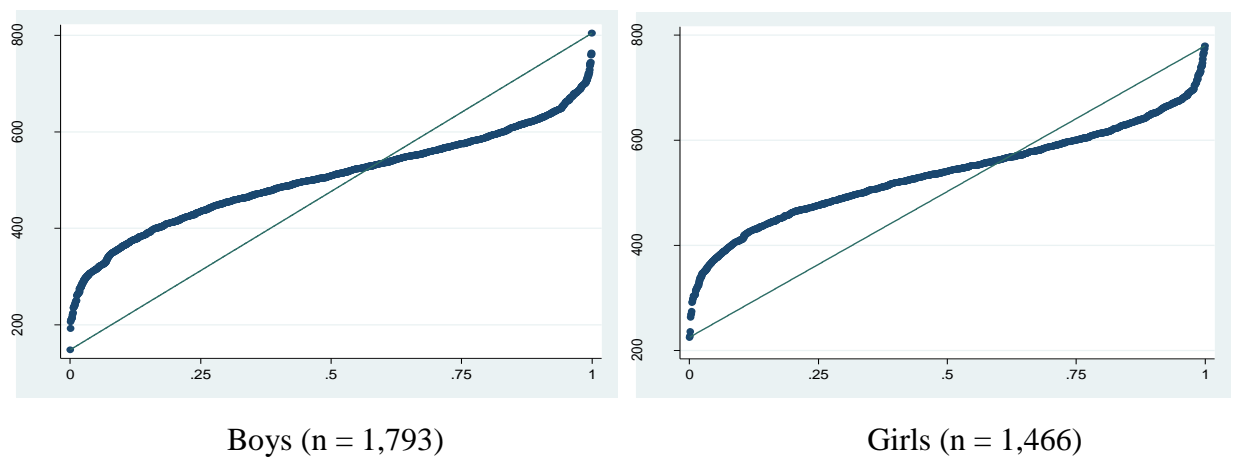
(1) Science Scores



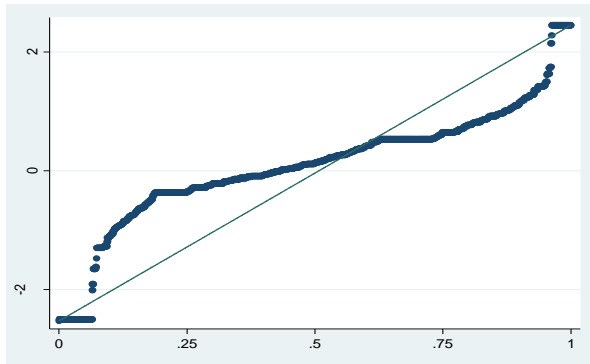
(2) Math Scores



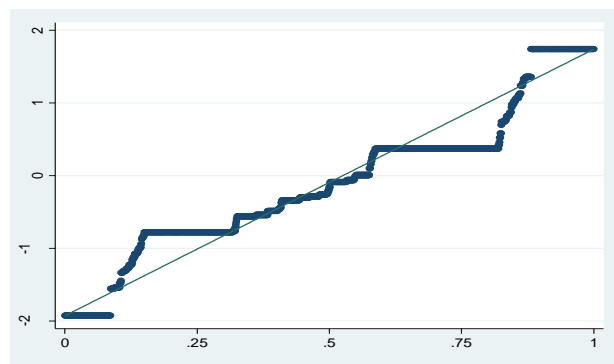
(3) Reading Scores



(4) Instrumental Motivation in Science

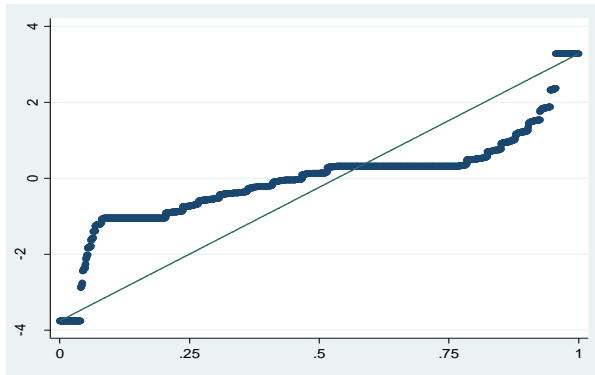


Boys (n = 1,786)

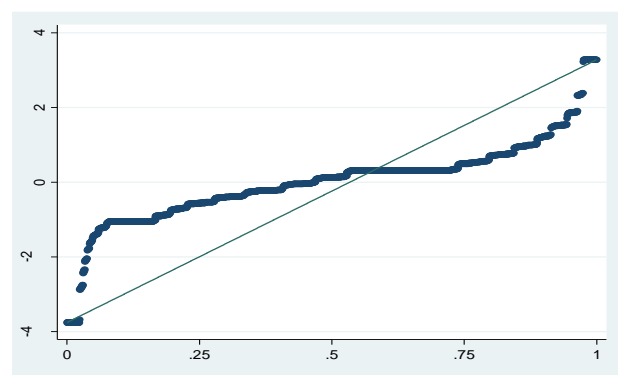


Girls (n = 1,463)

(5) Confidence in Science

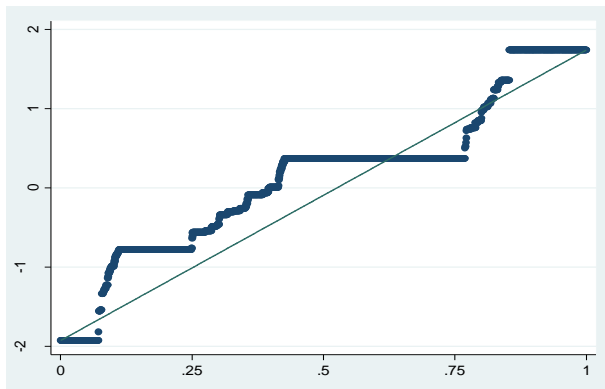


Boys (n = 1,787)

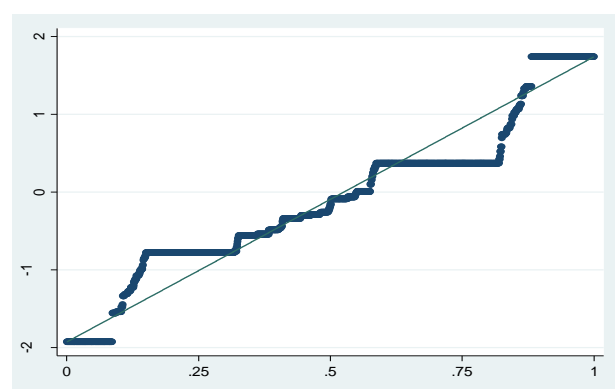


Girls (n = 1,465)

(6) Interest in Science



Boys (n = 1,776)



Girls (n = 1,463)

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 (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

Appendix B. Differences in Performance by Gender

B.1. Mean Differences

	Observations	Mean	Std.Dev.	Min.	Max.
Science Scores (boys)	1,793	516.46	102.43	192.38	825.03
Science Scores (girl)	1,466	519.78	89.36	243.14	757.16
T-statistics			-0.98		
Math Scores (boys)	1,793	526.46	106.60	132.19	827.77
Math Scores (girls)	1,466	526.08	94.97	243.73	825.03
T-statistics			0.10		
Reading Scores (boys)	1,793	501.98	102.73	148.47	804.33
Reading Scores (girls)	1,466	535.48	91.51	224.77	779.75
T-statistics			-9.73***		
Instrumental Motivation (boys)	1,786	0.13	1.00	-1.93	1.74
Instrumental Motivation (girls)	1,463	-0.10	1.01	-1.93	1.74
T-statistics			6.66***		
Confidence in Science (boys)	1,787	-0.03	1.29	-3.76	3.28
Confidence in Science (girls)	1,465	0.01	1.13	-3.76	3.28
T-statistics			-1.09		
Interest in Science (boys)	1,776	0.09	1.02	-2.53	2.45
Interest in Science (girls)	1,463	-0.25	0.91	-2.55	2.56
T-statistics			9.91***		

B.2. Non-parametric Equality-of-medians test

Science Scores	Boys	Girls	Total
Lower than the Median	899	731	1,630
Higher than the Median	894	735	1,629
Total	1,793	1,466	3,259
Corrected Pearson Chi2(1)		0.01	
Math Scores	Boys	Girls	Total
Lower than the Median	894	736	1,630
Higher than the Median	899	730	1,629
Total	1,793	1,466	3,259
Corrected Pearson Chi2(1)		0.03	
Reading Scores	Boys	Girls	Total
Lower than the Median	1,002	628	1,630
Higher than the Median	791	838	1,629
Total	1,793	1,466	3,259
Corrected Pearson Chi2(1)		54.39***	
Instrumental Motivation	Boys	Girls	Total
Lower than the Median	1,374	1,200	2,574
Higher than the Median	412	263	675
Total	1,786	1,463	3,249
Corrected Pearson Chi2(1)		12.36***	
Confidence in Science	Boys	Girls	Total
Lower than the Median	899	746	1,645
Higher than the Median	888	719	1,607
Total	1,787	1,465	
Corrected Pearson Chi2(1)		0.10	
Interest in Science	Boys	Girls	Total
Lower than the Median	728	896	1,624
Higher than the Median	1,048	567	1,615
Total	1,776	1,463	3,239
Corrected Pearson Chi2(1)		130.81***	

B.3. Two-sample Wilcoxon Rank-sum (Mann-Whitney) Test

Science Scores	Observations	Rank Sum	Expected
Boys	1,793	2904255	2922590
Girls	1,466	2407915	2389580
Combined	3,259	5312170	5312170
Z-statistics		-0.69	
Math Scores	Observations	Rank Sum	Expected
Boys	1,793	2929408.5	2922590
Girls	1,466	2382761.5	2389580
Combined	3,259	5312170	5312170
Z-statistics		0.26	
Reading Scores	Observations	Rank Sum	Expected
Boys	1,793	2680827.5	2922590
Girls	1,466	2631342.5	2389580
Combined	3,259	5312170	5312170
Z-statistics		-9.05***	
Instrumental Motivation in Science	Observations	Rank Sum	Expected
Boys	1,786	3094890	2902250
Girls	1,463	2184735	2377375
Combined	3,249	5279625	5279645
Z-statistics		7.36***	
Confidence in Science	Observations	Rank Sum	Expected
Boys	1,787	2865384.5	2906555.5
Girls	1,465	2423993.5	2382822.5
Combined	3,252	5289378	5289378
Z-statistics		-1.55	
Interest in Science	Observations	Rank Sum	Expected
Boys	1,776	3193867	2877120
Girls	1,463	2053313	2370060
Combined	3,239	5247180	5247180
Z-statistics		11.97***	

Appendix C. Determinants of Attending a Single-sex School, probit analysis

	Attending an All-Girls School		Attending an All-Boys School	
	(1)	(2)	(3)	(4)
Mother's Education	-0.005 (0.038)	0.020 (0.040)	0.027 (0.033)	0.024 (0.035)
Economic, Social and Cultural Status	-0.172*** (0.058)	0.066 (0.087)	0.078 (0.051)	0.090 (0.075)
Family Spending on Education	-0.003 (0.025)	0.008 (0.025)	0.031 (0.022)	0.033 (0.022)
Parental Support for Learning at Home	-0.046 (0.035)	-0.044 (0.035)	-0.012 (0.029)	-0.014 (0.030)
Parental Emotional Support	-0.038 (0.030)	-0.032 (0.030)	0.092*** (0.028)	0.088*** (0.028)
Community Size	-0.004 (0.034)	-0.008 (0.034)	0.395*** (0.042)	0.395*** (0.043)
Father's Education		-0.120*** (0.043)		0.001 (0.037)
Cultural Possession at Home		-0.016 (0.059)		0.022 (0.055)
Home Educational Resources		0.110** (0.045)		0.060 (0.039)
Home Possessions		-0.368** (0.160)		-0.103 (0.138)
Family Wealth		0.211 (0.138)		0.041 (0.115)
Number of Observations	1,980	1,965	2,334	2,302
Log pseudo likelihood	-1,103.05	-1,082.30	-1,344.00	-1,325.80

Note: Parentheses are robust standard errors. * $p < .10$, ** $p < .05$, *** $p < .001$.

Appendix D. Differences in Performance between Single- and Mixed-sex Schools

D.1. Mean Differences

Girls	Observations	Mean	Std.Dev.	Min.	Max.
Science Scores (mixed-sex)	1,081	519.68	89.42	243.14	757.16
Science Scores (all-girls schools)	385	520.06	89.32	291.89	735.09
T-statistics			-0.07		
Math Scores (mixed-sex)	1,081	529.28	95.31	246.97	825.03
Math Scores (all-girls schools)	385	517.12	93.56	243.73	784.73
T-statistics			2.16**		
Reading Scores (mixed-sex schools)	1,081	533.85	93.59	224.77	779.75
Reading Scores (all-girls schools)	385	540.05	85.38	298.50	774.73
T-statistics			-1.14		
Instrumental Motivation (mixed-sex)	1,078	-0.12	1.02	-1.93	1.74
Instrumental Motivation (all-girls schools)	385	-0.05	0.96	-1.93	1.74
T-statistics			-1.19		
Confidence in Science (mixed-sex)	1,080	0.04	1.13	-3.76	3.28
Confidence in Science (all-girls schools)	385	-0.06	1.14	-3.76	3.28
T-statistics			1.50		
Interest in Science (mixed-sex)	1,078	-0.26	0.93	-2.5	2.56
Interest in Science (all-girls schools)	385	-0.23	0.86	-2.55	2.45
T-statistics			-0.71		
Boys	Observations	Mean	Std.Dev.	Min.	Max.
Science Scores (mixed-sex)	1,190	506.55	102.32	192.38	779.33
Science Scores (all-boys schools)	603	536.00	99.90	286.82	788.37
T-statistics			-5.80***		
Math Scores (mixed-sex)	1,190	516.43	109.02	132.19	827.77
Math Scores (all-boys schools)	603	546.25	98.80	239.48	818.11
T-statistics			-5.65***		
Reading Scores (mixed-sex)	1,190	492.54	105.22	148.47	804.33
Reading Scores (all-boys schools)	603	520.62	94.99	220.28	763.14
T-statistics			-5.51***		
Instrumental Motivation (mixed-sex)	1,184	0.10	0.99	-1.93	1.74
Instrumental Motivation (all-boys schools)	602	0.20	1.00	-1.93	1.74
T-statistics			-1.92*		
Confidence in Science (mixed-sex)	1,185	-0.07	1.35	-3.76	3.28
Confidence in Science (all-boys schools)	602	0.03	1.18	-3.76	3.28
T-statistics			-1.56		
Interest in Science (mixed-sex)	1,174	0.06	1.05	-2.53	2.45
Interest in Science (all-boys schools)	602	0.14	0.95	-2.5	2.45
T-statistics			-1.59		

D.2. Non-parametric Equality-of-medians test

Science Scores	Girls in mixed-sex schools	Girls in all-girls schools	Total
Lower than the Median	546	187	733
Higher than the Median	535	198	733
Total	1,081	385	1,466
Corrected Pearson Chi2(1)		0.35	
Science Scores	Boys in mixed-sex schools	Boys in all-boys schools	Total
Lower than the Median	648	249	897
Higher than the Median	542	354	896
Total	1,190	603	1,793

Corrected Pearson Chi2(1)	27.20***		
Math Scores	Girls in mixed-sex schools	Girls in all-girls schools	Total
Lower than the Median	524	209	733
Higher than the Median	557	176	733
Total	1,081	385	1,466
Corrected Pearson Chi2(1)	3.61*		
Math Scores	Boys in mixed-sex schools	Boys in all-boys schools	Total
Lower than the Median	641	256	897
Higher than the Median	549	347	896
Total	1,190	603	1,793
Corrected Pearson Chi2(1)	20.39***		
Reading Scores	Girls in mixed-sex schools	Girls in all-girls schools	Total
Lower than the Median	544	189	733
Higher than the Median	537	196	733
Total	1,081	385	1,466
Corrected Pearson Chi2(1)	0.13		
Reading Scores	Boys in mixed-sex schools	Boys in all-boys schools	Total
Lower than the Median	646	251	897
Higher than the Median	544	352	896
Total	1,190	603	1,793
Corrected Pearson Chi2(1)	25.16***		
Instrumental Motivation in Science	Girls in mixed-sex schools	Girls in all-girls schools	Total
Lower than the Median	558	175	733
Higher than the Median	520	210	730
Total	1,078	385	1,463
Corrected Pearson Chi2(1)	4.27**		
Instrumental Motivation in Science	Boys in mixed-sex schools	Boys in all-boys schools	Total
Lower than the Median	924	450	1,374
Higher than the Median	260	152	412
Total	1,184	602	1,786
Corrected Pearson Chi2(1)	2.25		
Confidence in Science	Girls in mixed-sex schools	Girls in all-girls schools	Total
Lower than the Median	547	199	746
Higher than the Median	533	186	719
Total	1,080	385	1,465
Corrected Pearson Chi2(1)	0.08		
Confidence in Science	Boys in mixed-sex schools	Boys in all-boys schools	Total
Lower than the Median	590	309	899
Higher than the Median	595	293	888
Total	1,185	602	1,787
Corrected Pearson Chi2(1)	0.32		
Interest in Science	Girls in mixed-sex schools	Girls in all-girls schools	Total
Lower than the Median	568	197	765
Higher than the Median	510	188	698
Total	1,078	385	1,463
Corrected Pearson Chi2(1)	0.21		
Interest in Science	Boys in mixed-sex schools	Boys in all-boys schools	Total
Lower than the Median	603	285	888
Higher than the Median	571	317	888
Total	1,174	602	1,776
Corrected Pearson Chi2(1)	2.41		

D.3. Two-sample Wilcoxon Rank-sum (Mann-Whitney) Test

Science Scores	Observations	Rank Sum	Expected
Girls in mixed-sex schools	1,081	792510	792913.5
Girls in all-girls Schools	385	282801	282397.5
Combined	1,466	1075311	1075311
Z-statistics		-0.06	
Science Scores	Observations	Rank Sum	Expected
Boys in mixed-sex schools	1,190	1008262.5	1067430
Boys in all-boys Schools	603	600058.5	540891
Combined	1,793	1608321	1608321
Z-statistics		-5. 71***	
Math Scores	Observations	Rank Sum	Expected
Girls in mixed-sex schools	1,081	809383.5	792913.5
Girls in all-girls Schools	385	265927.5	282397.5
Combined	1,466	1075311	1075311
Z-statistics		-2.31**	
Math Scores	Observations	Rank Sum	Expected
Boys in mixed-sex schools	1,190	1009839	1067430
Boys in all-boys Schools	603	598482	540891
Combined	1,793	1608321	1608321
Z-statistics		-5. 56***	
Reading Scores	Observations	Rank Sum	Expected
Girls in mixed-sex schools	1,081	786472	792913.5
Girls in all-girls Schools	385	288839	282397.5
Combined	1,466	1075311	1075311
Z-statistics		-0.90	
Reading Scores	Observations	Rank Sum	Expected
Boys in mixed-sex schools	1,190	1009377.5	1067430
Boys in all-boys Schools	603	598943.5	540891
Combined	1,793	1608321	1608321
Z-statistics		-5. 61***	
Instrumental Motivation in Science	Observations	Rank Sum	Expected
Girls in mixed-sex schools	1,078	778144.5	789096
Girls in all girls Schools	385	292771.5	281820
Combined	1,463	1070916	1070916
Z-statistics		-1.56	
Instrumental Motivation in Science	Observations	Rank Sum	Expected
Boys in mixed-sex schools	1,184	103992	1057904
Boys in all-boys Schools	602	556399	537887
Combined	1,786	1595791	1595791
Z-statistics		-1.84*	
Confidence in Science	Observations	Rank Sum	Expected
Girls in mixed-sex schools	1,080	797015	791640
Girls in all-girls Schools	385	276830	282205
Combined	1,465	1073845	1073845
Z-statistics		-0.76	
Confidence in Science	Observations	Rank Sum	Expected
Boys in mixed-sex schools	1,185	1049541	1059390
Boys in all-boys Schools	602	548037	538188
Combined	1,787	1597578	1597578
Z-statistics		-0.96	
Interest in Science	Observations	Rank Sum	Expected
Girls in mixed-sex schools	1,078	783540.5	789096

Girls in all-girls Schools	385	287375.5	281820
Combined	1,463	1075311	1070916
Z-statistics		-0.78	
Interest in Science	Observations	Rank Sum	Expected
Boys in mixed-sex schools	1,174	1028894.5	1043099
Boys in all-boys Schools	602	549081.5	534877
Combined	1,776	1577976	1577976
Z-statistics		-1.39	