Together or Separate: Disentangling the Effects of Single-Sex Schooling from the Effects of Single-Sex Schools[1]

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Abstract

To separately identify the effects of single-sex "schooling" versus single-sex "schools", we exploit two unusual experiments in South Korea: students are randomly assigned to academic high schools within districts regardless of school types, and some schools changed their types from single-sex to coeducational over time. While the overall effects of attending a single-sex school are positive for both boys and girls, these are driven by the differences in resources between school types, rather than classroom gender composition *per se*. We find that coed (versus single-sex) classroom teaching itself has positive effects for boys, and neutral or negative effects for girls.

Key words: single sex schooling, coeducation, gender gap, random assignment
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1. Introduction

The effect of single-sex schooling is a subject of growing interest and continuing debate, as highlighted in a recent article by Halpern et al. (2011) and the ensuing comments and responses.[4] Single-sex schooling is of particular interest to economists as well as to education researchers due to its potential in reducing various types of gender gaps. These include boys lagging behind girls in cognitive and non-cognitive achievements (Goldin et al. 2006; Bertrand and Pan 2013; Fortin et al. 2013); the gender gap in mathematics (Fryer and Levitt 2010); and gender differences in performance and willingness to compete depending on the gender composition of the group environment (Gneezy et al. 2003; Niederle and Vesterlund 2007; Booth and Nolen 2012). Adding further relevance and importance to this question is a recent policy shift in the U.S.; namely, the passage of Title IX regulations in 2006, which made it easier for school districts to create single-sex schools within the public school system (McLane et al. 2006; Jackson 2012).

Using administrative data on college entrance exams in South Korea spanning 1998-2009, this paper estimates the overall effects of attending single-sex "schools" on student achievement and isolates the effects of single-sex "schooling" (i.e., single-sex classroom teaching) from the overall effects. We focus on students' performance on Korean, English, and math tests. For identification, we exploit two unusual experiments in South Korea: Students are randomly assigned to academic high schools within districts regardless of school types, and some schools changed their types from single-sex to coeducational over time.

There are two major challenges in estimating the effects of single-sex schooling on the achievement of students. First, students self-select into different school types, creating a classical selection bias.[5] Second, single-sex schools may differ from coed schools in many aspects (e.g., public versus private establishments, class size, pupil-teacher ratios, etc.) that have been found to affect student achievement (Behrman and Birdsall, 1983; Card and Krueger, 1996) over and above the gender composition of classrooms. Moreover, different educational production functions and organizational structures may be operative in single-sex versus coed schools (Lazear, 2001).

[4] See Kalkus (2012), Park et al. (2012a), Ford (2012), Palima (2012), and Halpern et al. (2012).

[5] See Altonji et al. (2005a) for discussion of this problem in the context of selection into Catholic schools in the U.S., and an empirical strategy to assess the degree of bias due to selection on unobservable characteristics using observable characteristics. Altonji et al. (2005b) assess the validity of various instrumental variables (religious affiliation and proximity to Catholic schools) employed in previous studies in that literature and raise doubts about the validity of those instruments.

To our knowledge, only two existing papers provide systematic evidence addressing the first problem, based on different designs.[6] Jackson (2012), using data from Trinidad and Tobago, exploits the fact that secondary school assignment is based on test outcomes and a list of school choices, which allows him to derive a rule-based IV strategy that predicts single-sex school attendance. Park et al. (2013) use random assignment of pupils to academic high schools in Seoul, South Korea, to address the sorting problem, which is the same variation we will be using in our study. The second challenge is addressed by Park et al. (2013) by conditioning on school-specific characteristics, hoping that these will eliminate all of the variations between single-sex versus coed schools that can affect achievement. Jackson (2012) uses a similar strategy, focusing only on single-sex versus coed schools that are similar in various aspects.

Notice that addressing the first problem only allows estimation of the causal effects of attending a single-sex (versus a coed) "school," but does not identify the causal effect of single-sex (versus coed) "schooling." While the first parameter may be of interest from the perspective of the country analyzed, it is usually not generalizable, as the possible quality differences between single-sex and coed schools are country- or context-specific. It is, therefore, the second parameter upon which we will focus our attention.

Our identification strategy addresses both of these problems in a novel way. As in Park et al. (2013), we use random assignment of pupils to schools within districts in Seoul to address the problem of sorting. However, while these authors use only a cross-section of data from 2009, we are in the fortunate position of having access to data ranging from 1998 to 2009. Over this period, nine single-sex male schools and four single-sex female schools changed to coed schools, which allows us to condition—besides observable school characteristics—on school fixed effects, using only the within-school variation between the older and the younger cohorts who were educated under the single-sex and the coed regimes, respectively. Additionally, the presence of other schools that remained single-sex or coed schools throughout the period analyzed, and the fact that every cohort between 1998 and 2009 is subject to random assignment to high schools, allow us to condition on cohort-specific fixed effects. Essentially, we use a difference-in-differences strategy exploiting two types of variations; first, between changed and non-changed schools and, second, between older and younger cohorts.

[6] Other studies compare student outcomes in single-sex versus coed schools without addressing student selection into schools. See, e.g., Lee and Byrk (1986); Jimenez and Lockheed (1989); Marsh (1989); LePore and Warren (1997); and Sullivan et al. (2010).

However, even that identification strategy may be problematic if the change of school types from single-sex to coeducational is accompanied by other unobserved changes in school resources. Although we are confident that the set of school-specific variables we utilize allows us to condition on most of the relevant resources (such as school size, class size, pupil-teacher ratios, number of administrators per pupil, etc.), we cannot assume that we do not miss out on additional factors, such as other possible changes in schools' organizational structures. For instance, the change from a single-sex to a coed school requires additional and separated bathrooms, teachers who deal with gender-specific problems, etc.

We therefore sharpen our identification strategy by comparing, in schools that changed from single-sex to coed status, two adjacent cohorts: those who started in a single-sex school that converted to a coed status one year later and those who started off in a coed school in that year. High school education in South Korea lasts for three years. Therefore, while the former cohort is exposed to three years of single-sex classrooms (with the last two years in a coed school or campus), the latter cohort is exposed to three years of coed classrooms in a school that will have been a coed school for three years (See Figure 1 in which we illustrate this idea using an example). Thus, it is likely that any measures undertaken as a consequence of changing a school from single-sex to coed status will affect both cohorts similarly, while the cohorts differ in their experience of classroom gender composition.

[Figure 1 here]

We find that the overall effects of attending a single-sex (versus a coed) school are positive for both boys and girls. However, once we condition on school fixed effects exploiting school-type changes over time, coed classroom teaching itself has a positive effect on boys for all subjects while having a neutral or negative effect on girls depending on subjects. These contrasting results illustrate the importance of distinguishing between resources and classroom gender composition *per se*, as potential factors responsible for the seeming advantages conferred by single-sex schools.

Besides isolating the effects of single-sex (versus coed) classroom teaching from the overall effects of attending a single-sex school, we further distinguish between the effects of exposure to coed school or campus environment (without coed classroom teaching) versus

exposure to coed classroom teaching.[7] To this end, we compare the cohort who started in a single-sex school that converted to a coed status two years later with the cohort who started in that school one year later.[8] While both cohorts are never exposed to coed classroom teaching, they are differentially exposed to coed school or campus environment, the former for one year and the latter for two years. Of course, whether these differential lengths of exposure to coed "school" or coed "campus" will have any impact on achievement is an empirical question.[9] In the data, however, we find evidence that an extra year's exposure to coed school or campus environment (without coed classroom teaching) has a negative effect on boys but not on girls. The results, at least for boys, seem to be in line with the observation in U.S. studies that often students' attention is diverted from academic learning to interpersonal relationships and physical attractiveness, etc. in coed schools (Coleman 1961; Lee and Byrk 1986; Riordan 1990). Interestingly, however, for boys who are exposed to both coed classroom teaching and coed schools or campus environments, the negative effects of coed school environments are fully offset by the positive effects of coed classroom teaching, leading to insignificant positive net effects. For girls who are exposed to both coed classroom teaching as well as coed campus environments, we find the net effects to be negative and significant for English but not for other subjects. Taken together with our findings from the between-school designs, these results suggest that if we removed the differences in resources and organizational structures between boys-only (or girls-only) schools and coed schools, there would remain little difference in the academic performance of boys (or girls) between school types.

To our knowledge, our identification strategy based on random assignment together with school-type changes over time controls for the effects of (observable and unobservable) school characteristics in the most comprehensive way available so far in the literature. Isolating the effects of coed classroom teaching from the effects of other characteristics that are associated with coed schools should have an important bearing on the assessment of policies that promote or demote single-sex schooling (i.e., single-sex classroom teaching). For instance, if there is an independent and positive effect of single-sex schooling in itself, then promotion of single-sex classrooms or single-sex schools would be justified. On the

[7] Note that coed classroom teaching necessarily implies a coed school or coed campus environment—in order to have a coed classroom in a school, at least some boys and some girls must be attending that school--but not vice versa. There can exist coed schools in which boys and girls are educated separately in different classrooms.
[8] In the example provided in Figure 1, this corresponds to the comparison between the CSAT cohorts (t^*-2) and (t^*-1).
[9] For instance, if all that matters is "any" exposure to a coed campus or coed exposure, say, in the last year of high school, then we should not find any difference between the above two cohorts.

other hand, if the better performance of students in single-sex schools is driven entirely by the fact that these schools have other characteristics more conducive to good performance than their coed counterparts, then investing in those characteristics rather than offering single-sex classrooms will be a more effective way to improve student achievement. Evidence, at least in the South Korean context, seems to point to a characteristics-based explanation, rather than to an inherent advantage of single-sex schooling itself, as to why students in single-sex schools seemingly outperform their peers in coed schools.

This study is most closely related to Jackson (2012) and Park et al. (2013) as discussed above. Jackson (2012) finds that students in single-sex schools in Trinidad and Tobago perform no better than those at similar coed schools. In our data from South Korea and based on the new identification strategy, we find qualitatively similar results. In regard to Park et al. (2013), we confirm their results for the overall effects of attending single-sex schools in a cross section of 2009 data, which show the advantage of single-sex schools over coed schools for both boys and girls. In our full sample of 1998-2009, however, in which we condition on school fixed-effects exploiting school-type changes, we find that the effect of coed classroom teaching in itself is positive for boys. We also find that this positive effect is dampened by an opposing negative effect through exposure to a coed "school" or "campus." For girls, the coed classroom effect itself is found to be negative for Korean and English; the net effects of exposure to both coed classroom and coed campus are also negative, though generally insignificant.

This paper can also be tied to the literature on gender peer effect. Hoxby (2000), Whitmore (2005), and Lavy and Schlosser (2011), within a coed school setting, have established that having more girls in a (coed) classroom improves the achievement of all pupils, according to data from the U.S. and Israel. Whether this effect, based on a small change in the proportion of girls in a classroom, will carry over into a situation in which a larger change occurs, as it does in our setting (due to school type changes from a single-sex to a coed school) is an empirical question of interest. Our finding of positive coed classroom effects on boys and negative effects on girls seems to confirm that this is indeed the case.

The rest of the paper is organized as follows: In the next section, we provide some institutional details on the education system in South Korea. Section 3 describes our data. Section 4 discusses our identification strategy. Section 5 presents the results of our empirical analysis. Section 6 consists of some concluding comments and further discussion.

2. Background

2.1 Why South Korean Data?

The context of academic high schools in South Korea is a particularly attractive one for disentangling the effects of single-sex schooling from the effects of other characteristics associated with single-sex schools. First of all, given that random assignment of students to schools is a rare variable to come by in other developed countries, the fact that a large number of students are subject to random assignment presents an unusual experimental setting in which to address the difficult sorting issue.

Second, unlike in other countries, in which single-sex schooling tends to be confined to religious or private schools, in South Korea there is a good mixture of single-sex and coed schools both within districts and across public and private establishment types.[10] In Korea, "public" and "private" schools do not have the same connotation as in other countries; both public and private establishment types are subject to random assignment of students and they all charge the same fees and teach similar curricula, due to tight government controls and heavy subsidies. Therefore, as far as students are concerned, there is no real choice for schools within districts. Nonetheless, schools can vary in many respects even within a single district. Therefore, this environment is expedient for illustrating the relative contribution of classroom gender composition versus other school characteristics in driving the observed differences between student achievements at single-sex versus coed schools.

2.2 The Education System

In South Korea, all students go through six years of education in a primary school followed by attendance at a middle (lower-secondary) school for three years. These nine years of schooling are compulsory. After that, one can go on to pursue additional education at a high (upper-secondary) school. In the year 2009, 99.6 percent of the 674,864 South Korean middle school graduates enrolled in a high school.[11] This shows that high school education, though not required, is very common. High schools consist of three grades, "Go1," "Go2," and "Go3," which correspond to grades, 10, 11, and 12 in the U.S.[12] While the curricula at the primary and the lower-secondary levels are uniform for all individuals, starting in high school, students have to choose among three different tracks: academic, vocational, and special-

[10] As of 2009, the ratio of single-sex to coed high schools was roughly 40: 60 for both boys and girls (Appendix Table A2).
[11] Statistical Yearbook of Education, Korean Educational Development Institute, http://cesi.kedi.re.kr.
[12] In Korean, "Go" means "High (school)" and "Go1" is a common slang for a first grade (or first graders) in a high school. Likewise for "Go2" and "Go3."

purpose high schools. The primary objective of academic high schools is to prepare individuals for college admission.[13] As of 2009, about 74 percent of South Korean high school students were in academic high schools.[14]

Random assignment is used for academic high schools only, which are, therefore, the focus of our analysis. For vocational and special-purpose high schools, there is a separate admission process and random assignment is not applicable. From here on, we refer to academic high schools simply as "high schools" for brevity's sake.

2.3 Random Assignment of Students to High Schools

The random assignment of students to high schools in South Korea has been well documented in prior research that exploited this rare experiment to investigate a variety of issues in labor and public economics, see, e.g., Kang et al. (2007); Kim et al. (2008); Park et al. (2012b, 2013); and Lee (2011) and the description of the random assignment policy therein. The policy traces its roots back to the "High School Equalization Policy (HSEP)" that was instituted in 1974 (Kim, 2003). Prior to that, students were admitted to high schools based on performance on high school entrance exams. Under the exam-based regime, the hierarchy of high schools was quite evident and it was directly reflected in their performance in advancing their graduates into elite universities (Lee, 2011). With the rapid increase of South Koreans who pursued a high school education in the late 1960s and early 1970s, the competition for entry into elite high schools was intensified to the point of being deemed "unhealthy" by many. The government then mandated the abolition of exam-based sorting and instituted the HSEP, which randomly allocates qualified middle school graduates to high schools within their own districts. A lottery-based high school assignment system was first implemented in Seoul in 1974 and subsequently expanded to other metropolitan areas. This random assignment rule has since been in place in most metropolitan areas in South Korea, whereas rural areas and provincial towns use a mixture of methods to allocate students to schools.

For consistency of policies and homogeneity of the sample, we focus our analysis on students in Seoul. Seoul has over ten million residents, about a quarter of the population of South Korea. As of 2012, about 18 percent of the 1,920,097 South Korean high school students lived in Seoul.[15]

[13] It is possible to apply to colleges upon graduating from vocational or special-purpose high schools, as well. The curricula and emphasis during high school attendance differ among the three tracks, however.
[14] Statistical Yearbook of Education, Korean Educational Development Institute, http://cesi.kedi.re.kr.
[15] Statistical Yearbook of Education, Korean Educational Development Institute, http://cesi.kedi.re.kr.

There are 11 school districts in Seoul. Each district is large and has multiple single-sex and coed schools. The districts used for the high school lottery are based on the student's residential address as of the middle of the last academic year in middle school.[16] Therefore, in order for a student to take part in a high school lottery in a district different than where the middle school is located, his/her family has to move to the new district before the last year of middle school starts. Once assigned to a high school, students usually matriculate in that school. In order to attend a school different than assigned during this lottery, the student (and his/her family) has to move to a different district. However, in the new district, the student will once again be subject to randomization. Therefore, it is not possible for a student to choose a school of their preferred type with certainty.

Due to this strict enforcement of random assignment policy, the most critical decision for students and parents boils down to a residential choice among districts, as districts differ in their average school quality due to historic reasons. Tiebout sorting (Epple and Romano, 1998; Nechyba, 2000; Urquiola, 2005; Bayer et al., 2007; and Bayer and McMillan, 2012) between districts is, therefore, quite active, and naturally, this is reflected quite clearly in housing prices in Seoul districts, consistent with the strong commitment of Korean parents to the education of their children (Lee 2011). In practice, most of the sorting occurs prior to entering middle school as Korean students and parents are usually averse to changing schools after the student has already started her post-primary education. However, once conditioned on districts, the assignment between high schools is random, and this is well understood by students and parents. In our empirical analysis, we always condition on districts and do not use variation between districts.

Beginning with the cohort who started high school in 1996, there was a modification to the school assignment policy in Seoul. Due to excess capacity at schools in the "Central District" of Seoul, this district was given permission to recruit students from across Seoul prior to the random assignment procedures taking place in other districts.[17] This allows students from any part of Seoul to apply to a school of their choice in the Central District. For

[16] An academic year runs from March of one calendar year to February of the following year. The high school assignment is based on the applicant's address as of August in the last academic year during middle school.

[17] The Central District, which is a small district in the center of Seoul, has historically been the home of many high schools. However, due to its small size and its also being the center of the city's administrative and commercial activities, not many people, especially those with school-age children, live there. While some schools have relocated to different districts over time, there is still an imbalance between the joint capacity of the schools in the Central District and the supply of pupils who are residents of that district. As a remedy, the government allowed the Central District to recruit pupils, partially through preference-based applications, prior to the random assignment.

this reason, our analysis is based on students at academic high schools in the ten districts in Seoul for which assignment is purely random.

The assignment of students to academic high schools in Seoul is administered by the Seoul Metropolitan Office of Education (SMOE). Although the exact algorithm for the computerized lottery is strictly confidential, we were able to obtain some administrative details about the school assignment process through an in-depth interview with an official in the School Support Division of the SMOE, the division in charge of student assignment.[18] First, each year, the SMOE determines the number of total seats available in all academic high schools in Seoul, which varies from year to year. Second, students in their last year of middle school who have the intention of attending an academic high school (as opposed to a vocational or a special-purpose high school) send in their applications to the SMOE. Third, if the number of applicants exceeds the number of available slots for that cohort, the SMOE screens out some applicants according to their grades in middle school.[19] Importantly, beyond this screening stage, students' grades in middle school are never used in the actual assignment process; once qualified, only the individual's residential address as of the middle of his/her last year of middle school is utilized for the lottery and nothing else, not even the identity of the middle school an applicant has attended. Fourth, for students in each residential district, the computer program tentatively allocates the set of relevant high schools separately for boys and girls. Among those individuals facing a common set of potential schools, the computer program then randomly selects the student–high school matches.[20]

Ideally, we would have liked to obtain administrative data on the pre-assignment characteristics of students to check for balance between those who are assigned to single-sex versus coed high schools (within districts). Unfortunately, neither the CSAT data nor the school-level data that we use include information on the characteristics of individual students. Given the absence of administrative data that link high school students to their pre-assignment characteristics, Park et al. (2013) checked for balance on some observed characteristics of students between single-sex and coed high schools, using data from the Korean Educational Longitudinal Survey (KELS), which has tracked a nationally

[18] The interview was conducted on June 27, 2013 at the SMOE by one of the authors.

[19] According to the SOME, the number of applicants that are screened out at this stage, while varying from year to year, is at most a few hundred. Consistent with this, an "admission" to an academic high school in South Korea is not perceived as a particular "achievement" by most accounts.

[20] In the algorithm, a random number generator is involved, so one crucial thing is to fix a seed number; otherwise, the SMOE personnel in charge could potentially keep re-drawing different sets of random numbers until his/her favored outcomes are obtained. Although this is unlikely, to prevent such possibilities, each year the superintendent of the SMOE provides the seed number to the School Support Division just before the lottery and it is kept strictly confidential.

representative sample of 7th graders (the first year in middle school) since 2005. Based on a sample of 1,279 girls and 1,380 boys that started high school in 2008, Park et al. (2013) find that there is no statistically significant difference between students in single-sex versus coed high schools in terms of parental education, monthly household income, or students' academic achievement as of the last year of middle school.

While it is reassuring that the findings in Park et al. (2013) are consistent with what we have been told by the SMOE, we also conducted an additional balancing test based on an alternate dataset, the Korea Labor and Income Panel Survey (KLIPS). KLIPS is an annual panel survey of around 5000 households and their members, which started in 1998. In the 11th wave of the survey, it asked detailed questions about the educational attainment of individuals, in particular whether the high school one attended was academic or not, and whether it was single-sex versus coeducational. We then linked the "students" in the 11th wave to their parents in other waves of the survey. To be consistent with our CSAT data, we restrict our attention to the individuals who attended an academic high school in Seoul with a high school entry year falling between 1996 and 2007.[21] Conditioning on the district fixed effects and cohort fixed effects, we regress the dummy indicating whether the high school is coed (versus single-sex) on a series of student and parental characteristics. The characteristics we consider include mother's and father's educational attainment; the student's academic achievement; whether the student was living with both parents; the number of rooms in the student's house (to proxy for family wealth); and whether the student received private tutoring, all measured as of the 8th grade, the second year in middle school. The results are provided in Table 1.

[Table 1 here]

While we are limited by the small sample size, it is nevertheless useful to see that conditional on districts, assignment to a coed school is not systematically associated with more or less favorable pre-assignment characteristics of students. Similarly, no systematic pattern is found when we expand the sample and include all high school entry cohorts dating from 1974, the first year when the High School Equalization Policy (HSEP) was implemented in Seoul.[22]

[21] These are the cohorts who sat in the CSAT exams in 1998-2009.
[22] We also estimate the specifications in Table 1 by logit and probit and do not find any systematic difference either.

2.4 The Expansion of Coeducation

South Korea is a country in which gender inequality is quite pervasive and persistent despite the nation's impressive recent economic growth and development. In the Global Gender Gap Index 2011, South Korea ranked 107 out 135 countries surveyed (World Economic Forum Gender Gap Report 2011). The liberal government that was in office in the late 1990s saw coeducation as a fundamental step towards achieving gender equality. Consequently, it actively promoted the expansion of coeducation throughout South Korea during that period both by building new coed schools and by converting some pre-existing single-sex schools—boys schools, in particular—to coed schools (Chung et al., 2009).

Consistent with national policy, there was also an expansion of coeducation in Seoul in the late 1990s and early 2000s. As a result, the ratio of boys attending coed high schools in the city increased from 22 percent in 1996 to 35 percent in 2007, and the ratio of girls increased from 24 percent to 36 percent.

[Figure 2 here]

Figure 2 shows the evolution of the percentage of boys and girls attending a coed (versus single-sex) school in Seoul for the cohorts who took the college entrance exam between 1998 and 2009 (i.e., those who started high school between 1996 and 2007). The percentage attending a coed school is higher for girls to start off with. However, by the end of the sample period, the ratio more or less equalizes and rises above 35 percent.

3. Data and Descriptives

3.1 Data

To measure students' academic achievement, we use administrative data on the national college entrance exam, the College Scholastic Aptitude Test (CSAT). The CSAT score is required for admission to any college in South Korea. Therefore, far more than 90 percent of students in academic high schools take this test whether or not they end up going to college (see Appendix Table A2). We use the standardized scores of individual students on Korean, English, and math tests. We standardize the raw CSAT scores to z-scores (to have mean 0; standard deviation 1) based on the mean and standard deviation of all examinees currently

enrolled in a high school in Seoul during each year. Our sample includes all individuals for whom the scores for Korean, English, or math are available.[23]

We use the population CSAT data from 1998 to 2009, which correspond to the cohorts who started high school between 1996 and 2007. We exclude 2007 from our analysis because for that year raw scores on the CSAT were not reported; only roughly defined intervals of scores were provided. An academic year runs from March in a calendar year to February in the following year. The CSAT test is taken usually in November, towards the end of "Go3," or grade 12. Therefore, by the time an individual takes the CSAT, he/she has already spent almost three academic years in a high school.

Besides the scores of the test, the CSAT data also provide some rudimentary information on each examinee, including gender; whether a student is currently enrolled in a high school or not; a school ID; and city and district information. Using the examinee's enrollment status and school ID, we matched the score data with the relevant school-year level characteristics.

The school-level data come from the 1996-2010 issues of the Seoul Education Statistics Annual (SESA). From this publication, we compiled school-year level information, such as establishment type (public versus private), coed versus single-sex, school size (total enrollment), class size, pupil-teacher ratio, and percentage of female teachers, among other variables.

The school-characteristics variables are constructed to reflect the average characteristics that an individual student experienced during his/her high school years. For instance, consider pupil-teacher ratios. For a student who took the CSAT at the end of calendar year 2005, we look at the pupil-teacher ratios in his/her school as of 2003, 2004, and 2005, then average them. Since this varies across years, different cohorts even in the same school will be exposed to different school characteristics. We believe this is a more accurate way to assign school characteristics to individuals than simply assigning school characteristics based on his/her final year of high school.[24]

[23] A vast majority of the students take all three subjects. However, from 2004 onward, the math section of the CSAT was no longer mandatory for admission to some colleges. Therefore, the number of observations in math is generally smaller than that for Korean and English in the data. For our empirical analysis, we use all observations available in each subject.

[24] As a robustness check, we also constructed the school characteristics variables based on school characteristics as of the student's final year of high school. Our results still obtain when we use the school characteristics as of the final year of high school.

3.2 Descriptive Statistics

Appendix Table 1A provides some descriptive statistics. Panel A shows the characteristics at the school level. For both boys and girls, single-sex schools are more likely to be of the private establishment type, older, and slightly larger. Also, boys-only schools tend to have a lower percentage of female teachers and administrators than coed schools, while girls-only schools tend to have a higher percentage. To account for these differences between school types, our analysis controls for the percentage of female teachers and administrators.[25]

Panel B of Table 1A shows the summary statistics of the CSAT scores normalized to z-scores to have a mean of 0 and a standard deviation of 1 among all CSAT takers in Seoul who are currently enrolled at any high school in each year. Consistent with the pattern observed in the U.S. (Bertrand and Pan 2013; Fortin et al. 2013), it is evident that on average girls outperform boys in all three subject areas and that this is so across school types. Also, for both boys and girls, those in single-sex schools outperform their peers in coed schools.

Appendix Table 2A provides information on schools, enrollments, and CSAT takers by year. The number of coed schools rose from 39 in 1998 to 76 by 2009, which mostly has to do with the establishment of new coed schools. Also, during the sample period (1998-2009), nine boys-only schools and four girls-only schools switched to being coed schools, which we exploit for our identification in part of our analysis. The last two columns in the table show that in all years, over 93 percent of students in academic high schools take the CSAT test and that there is no systematic difference in this rate between school types or across years.

4. Estimation and Identification Strategy

Consider an outcome of interest y_{ijkt} (CSAT scores) and the following relationship

$$y_{ijkt} = \alpha_0 + \alpha_1 X_i + \alpha_2 Z_{jt} + \alpha_3 CE_{ijt} + \psi_{kt} + \epsilon_{ijt}, \quad (1)$$

where i, j, k, and t are indices for individual, school, district, and year that the CSAT is taken, respectively. Observed individual and school characteristics are denoted by X_i and Z_{jt}, respectively, and ψ_{kt} represents district-specific time-fixed effects. The variable CE_{ijt} is an

[25] While we use female teachers as control variables in order to account for the resource differences between coed and single-sex school types, Bettinger and Long (2005), Dee (2007), and Carrell et al. (2010) investigate the effect of teacher gender itself in a context where all schools are coeducational.

indicator variable measuring whether individual i attending school j and taking the CSAT in year t has been exposed to coed classroom teaching during the three years of school attendance. Let $\epsilon_{ijt} = u_i + \phi_j + v_{jt}$, where u_i and ϕ_j are unobserved individual and school characteristics and assume for now that $E\left(v_{jt}\middle|CE_{ijt}, X_i, Z_{jt}, \psi_{kt}, u_i, \phi_j\right) = 0$.

Estimation of (1) by OLS gives an unbiased estimate of the parameter of interest α_3, the effect of exposure to coed classroom teaching, on outcomes only if

$$E\left(\epsilon_{ijt}\middle|CE_{ijt}, X_i, Z_{jt}, \psi_{kt}\right) = E\left(u_i + \phi_j + v_{it}\middle|CE_{ijt}, X_i, Z_{jt}, \psi_{kt}\right) = 0.$$

Our random assignment within districts assures that $E\left(u_i\middle|CE_{ijt}, X_i, Z_{jt}, \psi_{kt}\right) = 0$. However, the conditional expectation $E\left(\phi_j\middle|CE_{ijt}, X_i, Z_{jt}, \psi_{kt}\right)$ will be equal to zero only if observed individual and time-varying school characteristics and district-cohort fixed effects eliminate all correlation between CE_{ijt} and school fixed effects. That is the assumption in Park et al. (2013) and in Jackson (2012).

But this may well not be the case. Imagine the linear projection $L\left(\phi_j\middle|CE_{ijt}, X_i, Z_{jt}, \psi_{kt}\right) = b_0 + b_1 CE_{ijt}$ such that coed schools are different than single-sex schools in a systematic and unobserved way. In that case, the OLS regression gives $plim\ \widehat{\alpha_3} = \alpha_3 + b_1$. Thanks to random assignment, this is still a causal parameter, measuring the effect of attending a coed school and obtaining coed classroom exposure on outcomes, conditional on observed individual and school characteristics as well as on district-cohort fixed effects. However, it does not identify the pure effect of exposure to coed classroom teaching. Instead, it shows the composite effects of exposure to coed classroom teaching and every (unobservable) way in which coed schools are different from single-sex schools, conditional on observable school characteristics.

To address this issue and identify the pure effects of coed classroom teaching, we make use of the fact that some of the schools in our sample changed from single-sex to coed status, which allows us to condition on school fixed effects. Therefore, we estimate

$$y_{ijkt} = \beta_0 + \beta_1 X_i + \beta_2 Z_{jt} + \beta_3 CE_{ijt} + \psi_{kt} + \phi_j + e_{ijt}, \quad (2)$$

where ϕ_j is school fixed effects and $e_{ijt} = u_i + v_{jt}$.

However, it may still be the case that—as discussed in the introduction—changes from single-sex to coed status are accompanied by unobserved *changes* on school level that impact student achievement.[26] To address this problem, we therefore use the fact that we observe two adjacent cohorts around the time of the school type change: those who are exposed to a coed school for the last two years of their high school experience, but not to coed classroom teaching, and cohorts who are exposed to both coed schools and coed classroom teaching for their entire high school experience. In the example provided in Figure 1, this corresponds to the comparison between the CSAT cohorts (t*) and (t*-1). Thus, by separating the effects of coed school and coed classroom exposure, we obtain

$$y_{ijkt} = \gamma_0 + \gamma_1 X_i + \gamma_2 Z_{jt} + \gamma_3 CE^S_{ijt} + \gamma_4 CE^C_{ijt} + \psi_{kt} + \phi_j + \omega_{ijt}, \qquad (3)$$

where CE^S_{ijt} and CE^C_{ijt} are dummy variables indicating an individual's exposure to (any) school and classroom coeducation prior to taking the CSAT, respectively.

Differencing between the first cohort who was exposed to coed classroom teaching and the cohort just before it (who experienced only single-sex classroom teaching, but attended a coed school for their two remaining years), we obtain

$$\Delta y^1_{ijkt} = \gamma_2 \Delta Z_{jt} + \gamma_4 + \Delta\psi_{kt} + \Delta\omega_{ijt}. \qquad (4)$$

Similarly, measuring the difference between two adjacent cohorts in "non-change" schools in the same district that remain single-sex throughout, we obtain

$$\Delta y^0_{ijkt} = \gamma_2 \Delta Z_{jt} + \Delta\psi_{kt} + \Delta\omega_{ijt}.$$

Our difference-in-differences estimator then corresponds to

$$\Delta y^1_{ijkt} - \Delta y^0_{ijkt} = \gamma_4. \qquad (5)$$

Essentially, what we can identify in (5) is the effect on students of exposure to three years of coed classroom teaching and coed school exposure as compared to those who did not receive

[26] Notice that any (observed and unobserved) changes on district, city or country level are already accounted for by district-cohort (or district-year) fixed effects, ψ_{kt}.

coed classroom teaching, but were likewise exposed to a coed school.[27] We believe that this design provides a very tight identification of the effects of coed classroom teaching or coed "schooling" as distinguished from the overall effects of attendance at coed "schools"; the difference in (5) removes not only school fixed effects but also unobserved and time-varying school characteristics that are common to two adjacent cohorts within a single school.

While we have so far defined in (3) CE_{ijt}^{S} as a dummy variable indicating *any* exposure to coed "school," let us now consider a variation of (3) in which we allow differential effects of exposure to coed "school" by the length of exposure:

$$y_{ijkt} = \gamma_0 + \gamma_1 X_i + \gamma_2 Z_{jt} + \sum_{\tau=t-2}^{t} \gamma_{3\tau} CE_{ij\tau}^{S} + \gamma_4 CE_{ijt}^{C} + \psi_{kt} + \phi_j + \omega_{ijt},$$

where $CE_{ij\tau}^{S}$ indicates the individual's exposure to coed "school" in any of the three years prior to taking the CSAT.

By differencing between the cohort who started in a single-sex school that converted to coed status one year later with the cohort who started in that school one year earlier (e.g., the CSAT cohorts (t*-1) and (t*-2) in Figure 1), we obtain

$$\Delta y_{ijkt}^{3} = \gamma_2 \Delta Z_{jt} + \gamma_{3t} + \Delta\psi_{kt} + \Delta\omega_{ijt}.$$

Similarly, measuring the difference between two adjacent cohorts in "non-change" schools in the same district that remain single-sex throughout, we obtain

$$\Delta y_{ijkt}^{2} = \gamma_2 \Delta Z_{jt} + \Delta\psi_{kt} + \Delta\omega_{ijt}.$$

Taking difference in the differences, we obtain

$$\Delta y_{ijkt}^{3} - \Delta y_{ijkt}^{2} = \gamma_{3t}. \qquad (6)$$

Essentially, what we can identify in (6) is the effect of two years' exposure to a coed school (in calendar years t-1 and t) as compared to one year's exposure (in calendar year t-1) for

[27] We are ignoring here that the first cohort exposed to three years of coed classroom teaching has had one more year of exposure to a coed school environment than the previous cohort, but we address this in our empirical analysis below. To be precise, what we are estimating here is the combined effects of three years of exposure to a coed classroom and one extra year's exposure to a coed campus.

those who did not receive any coed classroom teaching. This allows us to identify a parameter that we can cautiously interpret as coed "school" or "campus" effects.[28]

5. Results

5.1 Between-School Estimates of the Effects of Attending a Coed School

Table 2 presents "between-school" estimates of the effects of attending a coed (versus single-sex) school, as estimated by OLS. Results for boys are presented in Panel A. Columns 1-3 are based on cross-section data from 2009, which is the same sample that Park et al. (2013) used for their paper. Based on this cross-section data, we repeat Park et al. (2013)'s analysis including district fixed effects. Standard errors are clustered at the school level. As expected, the estimated coefficients are very similar to what Park et al. (2013) found for Korean and English, the two academic subjects that are common to that paper and the present paper. Specifically, our estimates show that attending a coed (versus a single-sex) school decreases boys' performance on the CSAT test by 9.4 percent of one standard deviation for Korean; by 14.4 for English; and by 7.9 for math. Park et al. (2013)'s estimates for a comparable specification show that attending a coed (versus a single-sex) school decreases boys' performance on the CSAT test by 11 percent of one standard deviation for Korean and 15 for English.[29]

[Table 2 here]

Columns 4-9 are based on a panel of 2001-2009 CSAT data, for which we have all of the control variables available. In all specifications, we include district-year fixed effects. Even-numbered columns show the "overall" effects of coed school attendance. In odd-numbered columns, we control for a comprehensive list of school-level time-varying characteristics. These include private (versus public) establishment; years since establishment; school size; class size; pupil-teacher ratio; pupil-administrator ratio; percentage of female teachers; and percentage of female administrators (in Appendix Table A3, we provide the correlation between the coed school dummy and all of the control variables included above).

[28] As pointed out earlier, if all that matters is "any" exposure to a coed campus, or coed exposure in the last year of high school, then we may not find any difference between the two cohorts used above. Therefore, whether these differential lengths of exposure to coed "school" or coed "campus" will have any impact on achievement is an empirical question.

[29] Park et al. (2013) did not look at math as an outcome variable. Also, our estimates are slightly different from those in Park et al. (2013) since the authors used all eleven districts whereas we use ten districts excluding the Central District (see Section 2.3 for discussion).

The estimate in Column 4 shows that the overall effect of coed (versus single-sex) school attendance on Korean continues to be negative in the 2001-2009 panel, as was the case in the cross-section of 2009, although the magnitude is smaller. In Column 5, we see that once we control for various school characteristics, the coefficient on the coed school dummy changes sign and is no longer significant (The coefficients on the control variables are suppressed, but they are presented in Appendix Table A4). This is compatible with the hypothesis that the negative effect of coed schools is due to coed schools being associated with characteristics less conducive to student achievement than their single-sex counterparts, but that once these characteristics are controlled for, the direct effects of coed classroom exposure itself may be positive. We also find a similar reversal of signs for English and math, as indicated in columns 6 and 7, and columns 8 and 9.

Panel B in Table 2 presents the results of parallel analyses as above for girls. In columns 1-3, we confirm the results in Park et al. (2013) in cross-section data from 2009 for Korean and English. Specifically, our estimates show that attending a coed (versus a single-sex) school decreases girls' performance on the CSAT test by 4.8 percent of one standard deviation for Korean; by 5.9 for English; and by 5 for math. Park et al. (2013)'s estimates for a comparable specification show that attending a coed (versus a single-sex) school decreases girls' performance on the CSAT test by 6 percent of one standard deviation for Korean and 7 percent for English. In columns 4-9, we present the between-school estimates based on the 2001-2009 panel. Column 4 shows that the overall effects of coed (versus single-sex) school attendance are still negative and statistically significant. However, once we control for a variety of school characteristics (Column 5), coed school coefficients become positive, although not statistically significant (The coefficients on the control variables are presented in Appendix Table A4). Columns 6-9 show similar qualitative results for English and math.

What the results in Table 2 illustrate is that the effects of attending single-sex "schools" may be radically different from the effects of single-sex "schooling" (i.e., single-sex classroom teaching) *per se*. This may be driven by the fact that many characteristics other than classroom gender composition alone are at variance between single-sex and coed schools. In the analyses that follow, we further investigate this finding and attempt to isolate the effects of single-sex schooling from the effects of other school characteristics that are associated with single-sex schools.

5.2 Diff-in-diff Estimates of the Effects of Coed Classroom Exposure

Table 3 presents the difference-in-differences estimates of the effects of single-sex schooling for boys based on the sample of 1998-2009 data (equation (2) in Section 4). In these analyses, nine schools that switched type from boys-only to coed, and schools that remain boys-only schools throughout are included. The former corresponds to our "treatment" group and the latter to our "control" group. The presence of this control group allows us to condition on cohort-specific time-fixed effects. For the control group, the coed dummy is always zero. For the treatment group, the coed dummy is 1 only if the cohort is exposed to three years of coed classroom teaching.

[Table 3 here]

For these analyses, we focus on eight cohorts around school-type changes, four cohorts who did not receive any coed classroom teaching and four cohorts who did. Given that our panel is rather short and school-type changes do not necessarily occur in the middle of the sample period (1998-2009) for all switching schools, using a window wider than eight cohorts would have left us with no variation with which to identify the coefficients on event years further away from the school-type changes. On the other hand, if we chose narrower windows around school type changes, we might have missed out on some interesting patterns before and after the school type change while the school environment facing the included cohorts was more comparable and the point estimates more precise. Here, we keep the event window as wide as possible; later, we consider a very narrow window and look at the cohorts just before and after school-type changes only.

In all specifications in Table 3, we include school fixed effects to control for (observable and unobservable) school characteristics as well as time-varying school-level controls including school size, class size, pupil-teacher ratio, and pupil-administrator ratio. The diff-in-diff parameter is identified due to the fact that nine schools changed their type during the sample period. We also include district-year (or district-cohort) fixed effects in all specifications. Standard errors are clustered at the school level.

In columns 1 and 2, we compare four cohorts who did not receive any coed classroom teaching with four cohorts who did. Column 1 shows that for Korean, the effect of three years' exposure to coed classroom teaching relative to no exposure is positive for boys, though not statistically significant. Column 2 includes differential trends for pre- and post-switch schools

to account for the fact that, potentially, switching schools may have different pre-switch trends. The coefficient becomes larger in magnitude.

In Column 3, we estimate a variation of equation (2), in which we allow different coefficients for different cohorts around the school-type change. We define the first cohort who received the full three-year coed classroom treatment as event year 1. Event years 2-4 correspond to cohorts who also received the three-year coed classroom teaching, but 1-3 years after the first cohort, respectively. Event years -3, -2, -1, and 0 correspond to the older cohorts who entered (and graduated) that high school 4, 3, 2 and 1 year prior to the cohort whom we define as event year 1, respectively. Notice that these cohorts were never exposed to coed classroom teaching during their high school years, although cohorts who correspond to event years -1 and 0 were exposed to coed "school" or "campus" environments for one and two years, respectively, during the latter part of their high school educations. In Column 3, the reference category is event years -3 and -2, the cohorts who were exposed to neither coed classroom teaching nor coed campus environments during their high school years. The estimates show that relative to the base category, the cohorts who were exposed to coed schools or campus environments but not to coed classroom teaching (event years -1 and 0) perform worse. Interestingly, when it comes to the cohorts who were exposed to both coed classroom teaching and (therefore) to coed schools or campus environments, namely event years 1, 2, 3, and 4, we find no significant difference in performance relative to the reference cohorts. We conduct similar analyses for English and math; these estimates are provided in columns 4-6 and columns 7-9, respectively. The results are qualitatively similar to those for Korean.

Overall, the results in Table 3 for boys show that relative to the four cohorts who did not receive any coed classroom teaching, the four cohorts who did perform better in all subjects (columns 1-2, 4-5, and 7-8), which is suggestive of positive coed classroom effects for boys. Next, by allowing different coefficients for different cohorts around the school-type change (columns 3, 6, and 9), we find the effects of exposure to coed schools or campus environments (without exposure to coed classroom teaching) to be negative. This seems to be consistent with the observation in U.S. studies that often students' attention is diverted from academic learning to interpersonal relationships and physical attractiveness, etc. in coed schools (Coleman 1961; Lee and Byrk 1986; Riordan 1990). However, for boys who are exposed to both coed classroom teaching and coed schools or campus environments, the negative effects of coed school environments seem to be fully offset by the positive effects of coed classroom teaching, leading to insignificant positive net effects.

Table 4 presents the results of parallel analyses as Table 3 for girls. The analyses are based on four girls-only schools that switched to coed at any point during this period and girls-only schools that remain single-sex throughout the sample period.

Column 1 shows that for Korean, the effect of three years' exposure to coed classroom teaching relative to no exposure is negative for girls. Column 2 includes differential trends for pre- and post-switch schools and the coefficient becomes larger in magnitude. In Column 3, we allow different coefficients for different cohorts around the school-type change. The reference category is the cohorts who were exposed to neither coed classroom teaching nor coed campus environments (event years -3 and -2). We find no difference between the base category and the cohorts who correspond to event years -1 and 0. This means that for girls who were exposed to coed campus environments only (without coed classroom teaching), there is no strong evidence for "distraction effects" of coed campus exposure. However, for the cohorts who were exposed to both coed classroom teaching and to coed schools or campus environments (event years 1, 2, 3, and 4), the net effects are generally negative although not statistically significant in most cases. For English, we find both the coed classroom effects (columns 4 and 5) and the net effects of coed classroom and coed campus environments (Column 6) to be negative. For math, we do not find any strong effects of coed classroom exposure (columns 7 and 8). The net effects of exposure to both coed classroom and coed school are negative although generally insignificant.

[Table 4 here]

Overall, the results in Table 4 indicate that the switch from girls-only to coed schools has a mixed effect on achievement. Unlike for boys, we do not find evidence for the "distraction effects" of coed campus environments for girls. However, we find suggestive evidence for negative coed classroom effects for girls' performance on Korean and English as well as negative net effects of coed classroom and coed campus environments for English.

5.3 Mechanism and Sensitivity Analysis

Next we further sharpen our identification strategy and explore the mechanism underlying the results above. We also present the results of several sensitivity analyses.

5.3.1 The Effects of Coed School Environment versus Coed Classroom Teaching

In Tables 3 and 4, we considered eight cohorts around school type changes. Although we control for school fixed effects and some observable time-varying school characteristics, the

school environment facing those eight cohorts may not be comparable. To address this concern, in Table 5, as our most restrictive specification, we compare two adjacent cohorts who are plausibly subject to highly similar school environment. Essentially, we are interested in the parameters in equations (5) and (6) of Section 4.

In Table 5, the sample includes schools that remain single-sex throughout, which serves as our control group, and schools that switch from single-sex to coed, which serves as our treatment group. All specifications include district-year fixed effects as well as school fixed effects. The results for boys are presented in Panel A. In Column 1, the base category is the cohort corresponding to event year 0 who is exposed to two years of coed "school" environment while never exposed to coed classroom teaching. The cohort in event year 1 is exposed to three years of coed "school" treatment plus three years of coed "classroom" treatment. Therefore, what is identified in Column 1 is the effect of three years of coed classroom teaching plus one extra year's exposure to coed school or campus environment, relative to two years of coed school or campus environment, but no coed classroom teaching. This effect is found to be positive (16 percent of one standard deviation) and significant at the 10 percent level (this corresponds to γ_4 in equation (5)).

[Table 5 here]

Next, we further distinguish the effects of exposure to coed "school" or "campus" from the effects of exposure to coed "classroom." In Column 2, we consider three adjacent cohorts, event years -1, 0 and 1. The reference category is the cohort corresponding to event year -1, who was exposed to one year of coed "school" treatment but never to coed "classroom" teaching. The coefficient on (Switching school*Event year 0) shows that an extra year's exposure (or exposure during the second year of high school) to coed "school" treatment is negative (-0.054), although not statistically significant (this corresponds to γ_3 in equation (6)). The coefficient on (Switching school*Event year 1) shows that the effects of three years of coed classroom teaching plus two extra years of coed school exposure are positive (0.114)—this can be roughly interpreted as γ_4 in (5) plus γ_3 in (6)—although smaller in magnitude than what is estimated in Column 1 (0.160). This is quite intuitive: If the effects of coed "school" and "classroom" treatment operate additively, given that the effect of coed school environment itself is negative (-0.054), two years' exposure to that should dampen the positive effect of coed classroom teaching more than one year's exposure would (0.114 <

0.160).[30] In columns 3 and 4, we repeat the analyses in columns 1 and 2 with additional school-level controls that are time-varying. The results do not change in any significant way, which is reassuring as this indicates that for these adjacent cohorts, the school environments they are facing are highly comparable in (observable and unobservable) ways, making the extra controls redundant.

For English and math, we conduct analyses parallel to those for Korean (columns 5-8 and 9-12). The overall picture looks quite similar to that for Korean except that for English and math, the negative effect of an extra year's exposure to coed "school" treatment is statistically significant, i.e., coefficients on (Switching school*event year 0) are significant in columns 6 and 8 for English and columns 10 and 12 for math. However, the net effects of three years' exposure to coed classroom teaching and two extra years' exposure to coed "school" are positive for all three subjects (0.105, 0.083, and 0.076), although these numbers are not statistically significantly different from zero.

To summarize, our results show that for boys, the pure effects of coed classroom teaching are positive for all subjects, while these positive effects are dampened by the opposing negative effects of exposure to coed campus environments, leading to positive but insignificant net effects.

The results for girls are presented in Panel B in Table 5. We find a negative and significant effect of coed classroom treatment for Korean and English, but not for math (columns 3, 7, and 11). Looking at columns 4, 8, and 12, we do not find any evidence for "distraction effects" of coed campuses for girls, i.e. coefficients on (Switching school*event year 0), which is in contrast to the results for boys. As the coefficients on (Switching school*event year 1) indicate, the net effects of exposure to coed classrooms and to coed campuses for girls are negative and significant for English (-0.080 in Column 8) but not for the other subjects.

The fact that coed classroom effects for girls are negative for Korean and English (subjects stereotyped in favor of girls), but not for math (subject stereotyped in favor of boys), suggests that the gender stereotype threat (Spencer et al., 1999) is unlikely to be dominant here, if present. Rather, these results seem to be driven mainly by the fact that girls are simply better peers academically: girls outperform boys in Korean and English by wide margins

[30] Column 1 shows the effects of three years of coed classroom teaching plus one extra year's exposure to coed campus. If we assume that the coed "school" effects operate linearly and that the effects of coed "school" and "classroom" treatment operate additively, then the "pure" effects of coed classroom teaching (without exposure to coed campus) will be roughly 0.160 – (-0.054) = 0.214, which is positive. Of course, this exercise is only hypothetical as in reality, coed classroom necessarily implies coed campus, though not vice versa.

while less so in math (See Panel B in Appendix Table A1). In addition, the fact that for boys, coed classroom effects are positive for all three subjects is suggestive of the fact that the presence of girls in a classroom may exert a positive behavioral influence on other pupils, over and above the positive effects of girls' being academically better peers (Lavy and Schlosser, 2011). This is because academic peer effects alone will be unable to reconcile with the fact that positive coed classroom effects for boys are equally strong in all three subjects while in math girls do not outperform boys as much as they do in the other subjects. Moreover, the fact that coed classroom effects for boys are positive, not negative, even for subjects stereotyped against boys, namely Korean and English, suggests that the gender stereotype threat with respect to these subjects is unlikely to be dominant, if present, similarly to our interpretation of the parallel results for girls.

5.3.2 Sorting into Districts

Although random assignment is within districts and we condition on districts for all of our analyses, one possible concern is that there may be a systematic sorting of students into districts. For instance, students with a strong desire for a single-sex school may have selected themselves into a district in which the share of coed schools is relatively low to minimize the "risk" of being assigned to a coed school.

[Figure 3 here]

Figure 3 shows the number of coed versus single-sex schools by districts separately for boys and girls. Indeed, there are districts in which the distribution of single-sex versus coed schools is skewed toward one type. In particular, the district denoted by h has a relatively low percentage of coed schools for both boys and girls. In contrast, the districts denoted by d and i have a relatively high percentage of coed schools for boys, and districts d and f for girls.

To examine whether the potential sorting of students into districts plays any role, we estimate the diff-in-diff coefficients in a sample of districts with a relatively even proportion of single-sex and coed schools only. To this end, we exclude districts h, d, and i for boys and districts h, d, and f for girls.

Table 6 presents the results for our most restrictive specification (specifications in columns 3-4 in Table 5), diff-in-diff between schools and between two adjacent cohorts, in a sample of schools that switched and schools that remain single-sex throughout. Panel A

shows the results for boys and Panel B for girls. We find that restricting the sample to districts with a relatively even proportion of single-sex and coed schools does not change our main findings. Panel A shows that in this sub-sample, the estimated coefficients are slightly larger than what we found in Table 5. For girls, the results remain virtually the same as in the full sample including all ten districts.

[Table 6 here]

5.3.3 Public versus Private Schools

Next, we examine whether our main results might be driven by the difference between public versus private establishment types, taking into account the fact that there is a strong correlation between a school's establishment type and its single-sex or coed status. As noted earlier, in South Korea, private schools are subject to the same random assignment policy as public schools within districts, and students cannot choose which establishment type they will attend. Despite the random assignment, however, it is worthwhile to examine whether the estimated coed effects vary depending on whether the schools are public versus private.

[Table 7 here]

Table 7 shows some interesting heterogeneity between public and private schools. While the positive coed "classroom" effect is common between public and private schools, the negative coed "school" effect, namely the negative coefficient on (Switching School*Event year 0), is present only for public schools. This seems to suggest that private schools are better equipped to deal with the "distraction effect" of coed campuses than their public counterparts. The net effects of exposure to coed "school" environments and coed "classroom" teaching— coefficients on (Switching School*Event year 1) in even-numbered columns—are positive for private schools while negative for public schools although these numbers are not always significant.

For girls, there are no switching schools among the public schools analyzed. Therefore, when we restrict the sample to private schools only, the only thing that changes is the set of schools included in the control group, namely the non-switching schools. When we do this, our earlier findings based on the full sample remain virtually the same.[31]

[31] The results are available upon request.

6. Discussion and Conclusion

In this paper, we attempted to isolate the effects of single-sex "schooling" (i.e., single-sex classroom teaching) from the overall effects of attending a single-sex "school." This distinction should be particularly important for situations in which many characteristics other than classroom gender composition alone are at variance between single-sex and coed schools. For identification, we used two unusual experiments with schooling policies occurring in South Korea: one in which students are randomly assigned to high schools within districts and one in which some schools changed types from single-sex to coed. Taking advantage of the school-type change, we were able to control for the effects of (observable and unobservable) school characteristics in the most comprehensive way available so far in the literature in order to isolate the effects of single-sex "schooling" from the composite effects. In addition, we also sought to understand the effects of exposure to coed schools or campus environments only (without exposure to coed classroom teaching), as distinguished from the effects of exposure to coed classroom teaching.

Our main findings show that while the overall effects of attending a single-sex school are positive for both boys and girls, once we condition on the various factors that characterize single-sex schools, the effects of coed (versus single-sex) classroom teaching itself are positive for boys while having neutral or negative effects for girls.

These divergent findings from the between-school and within-school estimates should have important implications for educational policies with regards to single-sex schooling. According to our data, it is specifically coed classroom teaching that has a consistent positive effect for boys across subjects while the effects for girls are mixed. The seeming advantage of single-sex schools seems to be driven by the better resources or inputs that characterize these schools, rather than classroom gender composition *per se*. Therefore, creating single-sex schools or classrooms without adequate resources or inputs is unlikely to lead to improvement in the achievement of pupils. Of course, the difference in characteristics or resources between single-sex and coed schools is highly country-specific. In the South Korean context, at least, single-sex schools have been shown to have better resources and organizational advantages over coed schools.

In our data, we also found evidence that exposure to coed schools or campus environments alone (without coed classroom teaching) has a negative effect on boys, although this "distraction effect" seems to be fully offset by the positive effects of coed classroom teaching. For girls who were exposed to both coed classroom as well as coed

campus treatments, we find the net effects to be negative and significant for English but not for other subjects. Taken together with our findings from the between-school differences, these results then suggest that if we removed the differences in resources and organizational structures between single-sex schools and coed schools, there would remain little difference in the academic performance of boys or girls between school types.

One implication of our findings is that single-sex classroom teaching within a coed school is unlikely to benefit boys because in this case boys are exposed to the negative effect of a coed (versus single-sex) campus while not being exposed to the positive effect of coed (versus single-sex) classroom teaching. In contrast, for girls, single-sex classroom teaching within a coed school has the potential to improve the performance of girls compared to the counterfactual in which girls are educated in coed classroom within the same coed school.

Our findings are based on one particular population—high school students in South Korea, in which girls on average outperform boys in terms of academic achievement while the gender gap (in favor of men) in the overall society is highly prevalent. Therefore, caution needs to be taken when extending our findings to other populations and contexts. Nonetheless, we believe that the key finding of this study, that the effects of single-sex schooling (i.e., single-sex classroom teaching) can look radically different from the overall effects of attending single-sex schools, is more generally applicable and thus can provide useful insight on the current debate about the effectiveness of single-sex schooling in the U.S. and elsewhere.

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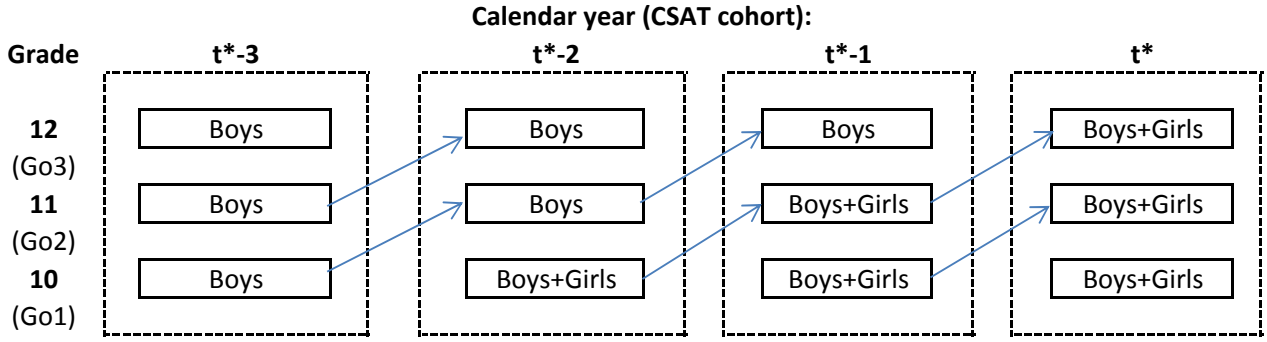
Figure 1: Example of a boys-only school that switched to a coed school in year t*-2.



Notes: CSAT is taken towards the end of grade 12. Therefore, CSAT cohort t refers to those who are in grade 12 as of year t*, CSAT cohort t*-1 to those who are in grade 12 as of year t*-1, etc.*
Boxes in dotted line indicate the sex composition at the school level.
Boxes in solid line indicate the sex composition at the classroom level.
CSAT cohort t is exposed to three years of coed classroom teaching and three years of coed campus.*
CSAT cohort t-1 is exposed to coed campus for two years but not to coed classroom.*
CSAT cohort t-2 is the cohort exposed to coed campus for one year but not to coed classroom.*

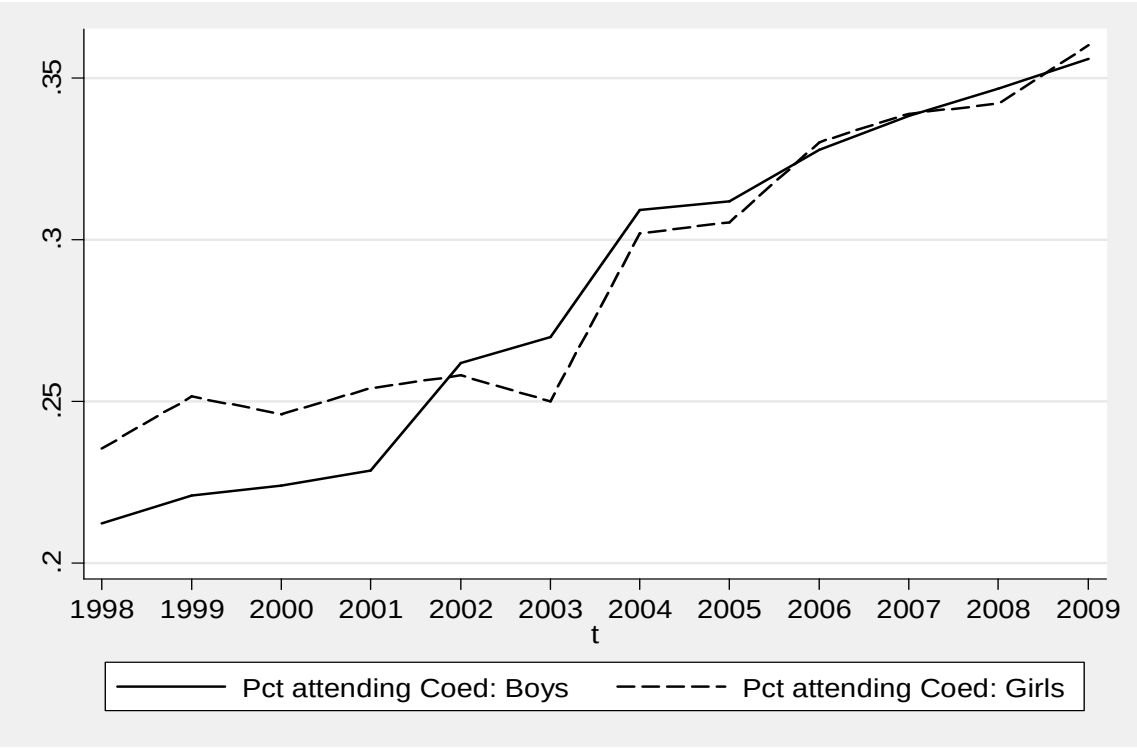


Figure 2: The percentage of boys and girls attending coed high schools in Seoul, 1998-2009

Notes: The horizontal axis refer to the calendar year in which each cohort took the CSAT.

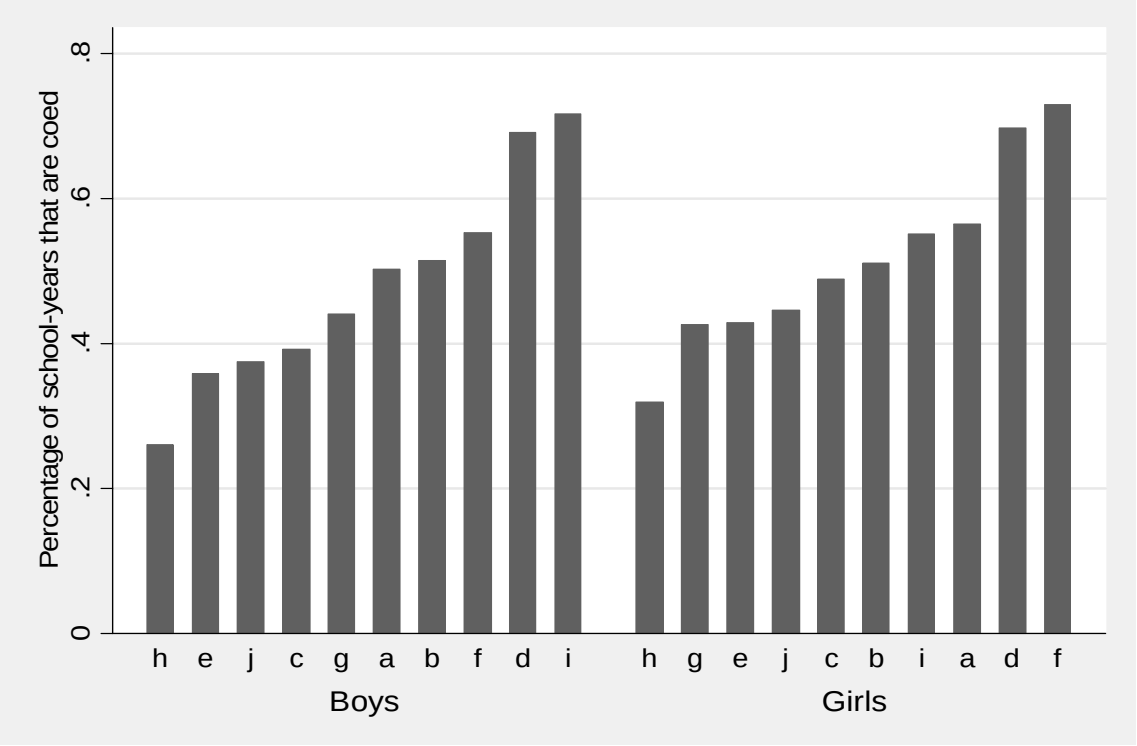


Figure 3: Distribution of coed schools by districts

Notes: Based on ten districts excluding the Central district. Includes all school-years during 1998-2009 except 2007.

Table 1: Assignment to a coed high school in Seoul and pre-assignment characteristics of individuals

	Dependent var.: Assigned to a coed (versus single-sex) high school											
	Post-1996 sample						**Post-1974 sample**					
	Boys			***Girls***			***Boys***			***Girls***		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	-0.001	0.003	-0.028	0.023	0.018	0.052	0.020	0.019	-0.005	0.031	0.030	0.011
	(0.063)	(0.064)	(0.088)	(0.061)	(0.044)	(0.075)	(0.025)	(0.026)	(0.053)	(0.025)	(0.025)	(0.030)
Father's education	0.011	0.007	0.015	0.031	0.035	0.092**	0.003	0.003	0.011	-0.004	-0.004	0.035
	(0.046)	(0.046)	(0.059)	(0.029)	(0.027)	(0.035)	(0.024)	(0.024)	(0.039)	(0.014)	(0.014)	(0.026)
Student's academic score at 8th grade	-0.033	-0.038	-0.041	0.027	0.028	0.097	0.001	0.002	-0.017	0.006	0.007	0.017
	(0.055)	(0.060)	(0.070)	(0.043)	(0.044)	(0.057)	(0.025)	(0.025)	(0.036)	(0.019)	(0.019)	(0.030)
Cohabit with both of parent at 8th grade		0.063	-0.031		0.062	0.200		-0.009	0.083		0.024	-0.043
		(0.069)	(0.189)		(0.110)	(0.224)		(0.044)	(0.139)		(0.075)	(0.131)
Number of rooms in the house at 8th grade			0.028			-0.132			0.013			-0.018
			(0.077)			(0.094)			(0.038)			(0.052)
Indicator of receiving private tutoring at 8th grade			-0.046			0.024			-0.013			0.105
			(0.149)			(0.193)			(0.075)			(0.062)
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	154	154	135	127	127	84	417	417	248	424	424	207
R-squared	0.075	0.077	0.094	0.205	0.207	0.307	0.075	0.077	0.147	0.165	0.166	0.202

Robust standard errors clustered by school district are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
Post-1996 sample includes the cohorts that started high school in 1996 or after.
Post-1974 sample includes cohorts that started high school in 1974 or after.
High school equalization policy was implemented starting in 1974.
There is a substantial drop in the number of observations when the number of rooms (proxy for family wealth) is included.

Table 2: Between-school estimates of the effects of attending a coed (versus a single-sex) school on the academic performance

	Dependent var.: CSAT score in								
	Korean	English	Math	Korean		English		Math	
	2009 sample			***2001-2009 panel***					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Boys									
Coed school	-0.094***	-0.144***	-0.079**	-0.058**	0.029	-0.080**	0.025	-0.054*	0.034
	(0.030)	(0.038)	(0.033)	(0.026)	(0.034)	(0.034)	(0.043)	(0.028)	(0.034)
Observations	42,054	41,764	40,015	325,734	316,475	324,885	315,654	311,566	302,771
R-squared	0.036	0.072	0.044	0.034	0.039	0.062	0.069	0.037	0.042
Panel B: Girls									
Coed school	-0.048	-0.059	-0.050	-0.050*	0.017	-0.063	0.019	-0.057*	0.006
	(0.032)	(0.044)	(0.036)	(0.029)	(0.044)	(0.039)	(0.057)	(0.032)	(0.048)
Observations	38,539	38,422	35,247	282,157	276,544	281,614	276,015	260,941	256,000
R-squared	0.025	0.058	0.031	0.026	0.028	0.050	0.054	0.031	0.033
School characteristics	No	No	No	No	Yes	No	Yes	No	Yes
District FE	Yes	Yes	Yes	No	No	No	No	No	No
District-year FE	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors clustered by school are in parentheses.

**** p<0.01, ** p<0.05, * p<0.1*

CSAT scores are in z-scores with mean 0 and standard deviation 1.

2009 is the sample used in Park et al. (2013).

Sample includes schools that remain single-sex, schools that remain coed, and schools that switch from single-sex to coed.

School characteristics include private (versus public) establishment; years since establishment; log school size; class size; pupil-teacher ratio; pupil-administrator ratio; percentage of female teachers; and percentage of female administrators.

Table 3: Diff-in-diff estimates of the effects of coed classroom teaching on boys' CSAT scores

	Dependent var.: CSAT score in								
	Korean			English			Math		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Switching school*Post	0.073	0.139*		0.084	0.125		0.090	0.115	
	(0.075)	(0.079)		(0.069)	(0.082)		(0.068)	(0.086)	
Switching school*Event yr (-1)			-0.119*			-0.093			-0.062
			(0.070)			(0.058)			(0.062)
Switching school*Event yr (0)			-0.177**			-0.157**			-0.145**
			(0.069)			(0.060)			(0.063)
Switching school*Event yr 1			-0.038			-0.020			0.005
			(0.058)			(0.062)			(0.074)
Switching school*Event yr 2			-0.003			0.020			0.006
			(0.053)			(0.047)			(0.055)
Switching school*Event yr 3			0.005			0.028			0.082
			(0.074)			(0.073)			(0.070)
Switching school*Event yr 4			-0.013			0.021			0.025
			(0.076)			(0.063)			(0.078)
Pre- and Post-switch linear trends		Yes			Yes			Yes	
School FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
School characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	348,623	348,623	348,623	347,958	347,958	347,958	339,526	339,526	339,526
R-squared	0.052	0.053	0.053	0.085	0.085	0.085	0.058	0.058	0.058

Robust standard errors clustered by school are in parentheses.
**** p<0.01, ** p<0.05, * p<0.1*
CSAT scores are in z-scores with mean 0 and standard deviation 1.
Sample includes schools that remain single-sex and schools that switch from single-sex to coed.
Switching school dummy is 1 for schools that switch type from single-sex to coed; 0 for schools that remain single-sex throughout.
Post dummy is 1 for cohorts that received coed classroom treatment for three year.
Event yr 1 is defined as the first cohort that received the coed classroom teaching for three years.
Event yr 0 is the cohort that started high school one year before the cohort that corresponds to event yr 1.
In columns 1-2, 4-5, and 7-8, the base category is those with Post=0, cohorts who were never exposed to coed classroom teaching.
In columns 3, 6, and 9, the base category is event years (-3) and (-2), cohorts who were exposed to neither coed classroom nor coed campus during their high school attendance.
School characteristics include log school size, class size, pupil-teacher ratio, and pupil-administrator ratio.

Table 4: Diff-in-diff estimates of the effects of coed classroom teaching on girls' CSAT scores

	Dependent var.: CSAT score in								
	Korean			English			Math		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Switching school*Post	-0.057**	-0.088**		-0.105***	-0.127***		-0.051	-0.018	
	(0.023)	(0.039)		(0.037)	(0.038)		(0.042)	(0.069)	
Switching school*Event yr (-1)			-0.005			-0.087			-0.013
			(0.080)			(0.053)			(0.034)
Switching school*Event yr (0)			0.003			-0.045			-0.024
			(0.069)			(0.054)			(0.043)
Switching school*Event yr 1			-0.060			-0.168***			-0.058
			(0.057)			(0.052)			(0.037)
Switching school*Event yr 2			-0.098			-0.179**			-0.042
			(0.081)			(0.085)			(0.101)
Switching school*Event yr 3			-0.164**			-0.273***			-0.118***
			(0.066)			(0.053)			(0.030)
Switching school*Event yr 4			0.016			-0.073			-0.076*
			(0.063)			(0.061)			(0.042)
Pre- and Post-switch linear trends		Yes			Yes			Yes	
School FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
School characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	276,539	276,539	276,539	276,171	276,171	276,171	261,672	261,672	261,672
R-squared	0.035	0.035	0.035	0.068	0.068	0.068	0.042	0.042	0.042

Robust standard errors clustered by school are in parentheses.
**** p<0.01, ** p<0.05, * p<0.1*
CSAT scores are in z-scores with mean 0 and standard deviation 1.
Sample includes schools that remain single-sex and schools that switch from single-sex to coed.
Switching school dummy is 1 for schools that switch type from single-sex to coed; 0 for schools that remain single-sex throughout.
Post dummy is 1 for cohorts that received coed classroom treatment for three years.
Event yr 1 is defined as the first cohort that received the coed classroom teaching for three years.
Event yr 0 is the cohort that started high school one year before the cohort that corresponds to event yr 1.
In columns 1-2, 4-5, and 7-8, the base category is those with Post=0, cohorts who were never exposed to coed classroom teaching.
In columns 3, 6, and 9, the base category is event years (-3) and (-2), cohorts who were exposed to neither coed classroom nor coed campus during their high school attendance.
School characteristics include log school size, class size, pupil-teacher ratio, and pupil-administrator ratio.

Table 5: Diff-in-diff estimates of the effects of coed school (campus) versus classroom treatments on CSAT scores

	Dependent var.: CSAT score											
	Korean				English				Math			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Boys												
Switching school*Event yr 0		-0.054		-0.052		-0.072**		-0.069**		-0.092**		-0.089**
		(0.035)		(0.033)		(0.033)		(0.033)		(0.046)		(0.044)
Switching school*Event yr 1	0.160*	0.114	0.152*	0.105	0.154*	0.090	0.147*	0.083	0.167*	0.082	0.160*	0.076
	(0.086)	(0.091)	(0.084)	(0.083)	(0.088)	(0.089)	(0.086)	(0.084)	(0.091)	(0.098)	(0.090)	(0.091)
Observations	329,407	333,341	329,407	333,341	328,763	332,692	328,763	332,692	320,818	324,719	320,818	324,719
R-squared	0.043	0.047	0.044	0.047	0.077	0.080	0.077	0.080	0.050	0.053	0.050	0.053
Panel B: Girls												
Switching school*Event yr 0		0.011		0.025		0.047		0.049		-0.029		-0.021
		(0.016)		(0.022)		(0.030)		(0.033)		(0.037)		(0.042)
Switching school*Event yr 1	-0.053*	-0.059*	-0.064**	-0.057	-0.120***	-0.078***	-0.125***	-0.080***	-0.030	-0.039	-0.040	-0.040
	(0.029)	(0.030)	(0.031)	(0.035)	(0.037)	(0.028)	(0.037)	(0.027)	(0.042)	(0.048)	(0.042)	(0.050)
Observations	284,606	286,342	271,554	273,290	284,248	285,984	271,199	272,935	270,127	271,730	257,085	258,688
R-squared	0.034	0.034	0.035	0.035	0.066	0.066	0.069	0.068	0.042	0.042	0.043	0.043
Additional controls	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes
District*Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
School FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors clustered by school in parentheses.
**** p<0.01, ** p<0.05, * p<0.1*
CSAT scores are in z-scores with mean 0 and standard deviation 1.
Sample includes schools that remain single-sex and schools that switch from single-sex to coed.
Switching school dummy is 1 for schools that Switching type from single-sex to coed; 0 for schools that remain single-sex throughout.
Event yr 1 is defined as the first cohort that received the coed classroom teaching for three years.
Event yr 0 is the cohort that started high school one year before the cohort that corresponds to event yr 1.
Event yr -1 is the cohort that started high school two years before the cohort that corresponds to event yr 1.
Sample includes cohorts that correspond to event years 0 and 1 in odd numbered columns and -1, 0, and 1 in even numbered columns.
Omitted category is event year (0) in odd numbered columns and event year (-1) in even numbered columns.
Additional controls at the school-year level include log school size, class size, pupil-teacher ratio, and pupil-administrator ratio.

Table 6: Robustness - districts with relatively even distribution of coed versus single-sex schools

	Dependent var.: CSAT score in					
	Korean		English		Math	
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A: Boys			
Switching school*Event yr 0		-0.037		-0.058		-0.085
		(0.044)		(0.038)		(0.062)
Switching school*Event yr 1	0.198*	0.167	0.201*	0.148	0.206*	0.127
	(0.106)	(0.117)	(0.109)	(0.117)	(0.114)	(0.129)
Observations	261,890	264,198	261,395	263,699	255,368	257,648
R-squared	0.042	0.046	0.077	0.081	0.047	0.051
			Panel B: Girls			
Switching school*Event yr 0		0.023		0.046		-0.024
		(0.025)		(0.036)		(0.044)
Switching school*Event yr 1	-0.068**	-0.061	-0.129***	-0.086***	-0.041	-0.043
	(0.032)	(0.036)	(0.036)	(0.028)	(0.042)	(0.051)
Observations	212,728	214,464	212,457	214,193	201,339	202,942
R-squared	0.034	0.034	0.066	0.066	0.042	0.042
School FE	Yes	Yes	Yes	Yes	Yes	Yes
District*Year FE	Yes	Yes	Yes	Yes	Yes	Yes
School characteristics	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors clustered by school in parentheses.
**** p<0.01, ** p<0.05, * p<0.1*
CSAT scores are in z-scores with mean 0 and standard deviation 1.
Sample includes schools that remain single-sex and schools that switch from single-sex to coed.
Switching school dummy is 1 for schools that Switching type from single-sex to coed; 0 for schools that remain
Event yr 1 is defined as the first cohort that received the coed classroom teaching for three years.
Event yr 0 is the cohort that started high school one year before the cohort that corresponds to event yr 1.
Event yr -1 is the cohort that started high school two years before the cohort that corresponds to event yr 1.
Sample includes cohorts that correspond to event years 0 and 1 in odd numbered columns and -1, 0, and 1 in even numbered columns.
Omitted category is event year (0) in odd numbered columns and event year (-1) in even numbered columns.
School characteristics include log school size, class size, pupil-teacher rato, and pupil-administrator ratio.
Boys: drop districts h, d, and i.
Girls: drop districts h, d, and f.

Table 7: Robustness - public versus private establishment types for boys

	Dependent var.: CSAT score in											
	Korean		English		Math		Korean		English		Math	
	Public schools only						***Private schools only***					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Switching school*Event yr (0)		-0.167***		-0.296***		-0.176***		-0.002		-0.022		-0.014
		(0.047)		(0.034)		(0.045)		(0.044)		(0.038)		(0.058)
Switching school*Event yr (1)	0.108*	-0.088	0.163**	-0.140**	0.167***	-0.003	0.232*	0.238*	0.233*	0.218	0.234*	0.229
	(0.057)	(0.064)	(0.057)	(0.057)	(0.031)	(0.038)	(0.119)	(0.141)	(0.125)	(0.142)	(0.133)	(0.156)
School FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
School characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	51,495	53,731	51,382	53,613	49,824	52,051	277,912	279,610	277,381	279,079	270,994	272,668
R-squared	0.052	0.053	0.092	0.092	0.060	0.061	0.042	0.046	0.075	0.078	0.049	0.052

Robust standard errors clustered by schools in parentheses.

**** p<0.01, ** p<0.05, * p<0.1*

CSAT scores are in z-scores with mean 0 and standard deviation 1.

Sample includes schools that remain single-sex and schools that switch types from single-sex to coed.

Switching school dummy is 1 for schools that switch type from single-sex to coed; 0 for schools that remain single-sex throughout.

Event yr 1 is defined as the first cohort that received the coed classroom teaching for three years.

Event yr 0 is the cohort that started high school one year before the cohort that corresponds to event yr 1.

Event yr -1 is the cohort that started high school two years before the cohort that corresponds to event yr 1.

Sample includes cohorts that correspond to event years 0 and 1 in odd numbered columns and -1, 0, and 1 in even numbered columns.

Omitted category is event year (0) in odd numbered columns and event year (-1) in even numbered columns.

School characteristics include log school size, class size, pupil-teacher ratio, and pupil-administrator ratio.

Table A1: Descriptives - characteristics of schools and individuals by school types

	Boys						***Girls***					
	Boys only schools			Coed schools			Girls only schools			Coed schools		
	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
Panel A: School-level characteristics												
School average CSAT score: Korean	655	-0.158	0.284	595	-0.220	0.264	538	0.141	0.190	595	0.023	0.353
School average CSAT score: English	655	-0.141	0.339	595	-0.214	0.325	538	0.119	0.258	595	-0.008	0.406
School average CSAT score: Math	655	-0.081	0.291	595	-0.132	0.273	538	0.040	0.213	594	-0.064	0.325
Private	655	0.837	0.370	595	0.329	0.470	538	0.796	0.404	595	0.329	0.470
Years since establishment	655	40	25	595	24	17	538	41	26	595	24	17
School size (total students of all grades in school)	652	1684	394	592	1487	422	523	1677	438	592	1487	422
Class size	652	41.238	7.003	592	39.848	7.371	523	42.222	8.157	592	39.848	7.371
Pupil-teacher ratio	652	20.709	3.565	592	18.839	3.613	523	21.230	4.440	592	18.839	3.613
Pupil-administrator ratio	652	245.684	59.546	591	233.660	50.623	523	262.486	76.000	591	233.660	50.623
Percent female teachers[a]	462	0.158	0.117	472	0.424	0.133	402	0.514	0.118	472	0.424	0.133
Percent female administrators[a]	442	0.219	0.132	467	0.330	0.147	390	0.269	0.162	467	0.330	0.147
Panel B: Individual-level CSAT scores												
z-score: Korean	343,424	-0.145	1.010	147,625	-0.206	0.995	291,683	0.149	0.937	129,523	0.083	0.947
z-score: English	342,768	-0.125	1.015	147,280	-0.200	1.002	291,321	0.132	0.929	129,268	0.053	0.945
z-score: Math	334,878	-0.064	1.022	141,546	-0.116	1.007	277,187	0.050	0.936	121,973	-0.017	0.946

Sample includes all academic high schools in Seoul in ten districts excluding Central district, spanning the CSAT cohorts 1998-2009.
The school-characteristics variables in Panel A are constructed to reflect the average characteristics that an individual student experienced during his/her high school years. For instance, consider pupil-teacher ratios. For a student who took the CSAT at the end of calendar year 2005, we look at the pupil-teacher ratios in his/her school as of 2003, 2004, and 2005, then average them.
[a] SES reports gender-specific info from 1999 edition only.
z-scores were constructed based on the mean and the standard deviations of the CSAT scores of all CSAT takers currently enrolled in any high school in Seoul each year.

Table A2: Descriptives - schools, enrollments and CSAT takers by school types

	No. schools		No. students		No. CSAT takers		CSAT takers (%)	
	Single-sex	Coed[a]	Single-sex	Coed	Single-sex	Coed	Single-sex	Coed
				Panel A: Boys				
1998	65	39	NA	NA	43,531	13,302	NA	NA
1999	64	42 (1)	41,889	13,574	41,036	13,285	0.98	0.98
2000	64	42	39,620	13,090	38,747	12,741	0.98	0.97
2001	64	43	37,847	12,742	36,372	12,222	0.96	0.96
2002	60	48 (4)	31,923	12,999	30,539	12,495	0.96	0.96
2003	58	50 (2)	31,480	13,634	30,068	12,909	0.96	0.95
2004	56	56 (2)	27,748	14,603	26,523	13,782	0.96	0.94
2005	56	60	27,426	14,579	25,818	13,551	0.94	0.93
2006	56	66	26,983	15,339	25,277	14,337	0.94	0.93
2007	56	69	26,221	15,738	24,601	14,626	0.94	0.93
2008	56	73	25,397	15,752	23,818	14,592	0.94	0.93
2009	56	76	28,156	18,063	27,179	17,393	0.97	0.96
				Panel B: Girls				
1998	45	39	NA	NA	32,080	11,592	NA	NA
1999	45	42	32,224	12,564	30,971	12,242	0.96	0.97
2000	46	42	31,682	11,892	30,780	11,593	0.97	0.97
2001	47	43	30,204	11,832	28,895	11,189	0.96	0.95
2002	48	48	26,751	10,661	25,761	10,156	0.96	0.95
2003	50	50	27,367	10,428	26,177	9,858	0.96	0.95
2004	52	56	25,240	12,208	24,097	11,466	0.95	0.94
2005	52	60 (2)	25,669	12,658	24,424	11,859	0.95	0.94
2006	51	66 (1)	24,751	13,756	23,575	12,842	0.95	0.93
2007	52	69	24,032	13,806	23,074	13,117	0.96	0.95
2008	51	73 (1)	23,458	13,602	22,500	12,912	0.96	0.95
2009	51	76	26,081	16,373	25,392	15,795	0.97	0.96

Sample includes all academic high schools in 10 districts in Seoul. The central district is excluded as in that district, students are not randomly assigned to high schools.

Number of CSAT takers are based on the CSAT dataset. Numbers of schools and students are based on the Seoul Educational Statistics (SES). Student information for 1998 is missing as the SES started to break out the number of students by sex since 1999 only.

[a] In this column, the numbers in parentheses refer to the number of formerly SS schools that were converted Coed school.

Table A3: Correlation between coed (versus single-sex) school status and various school characteristics

	Dependent var.: Coed (versus single-sex) school			
	Boys		***Girls***	
	(1)	(2)	(3)	(4)
Private	0.352***	0.271**	-0.691***	-0.537***
	(0.130)	(0.113)	(0.119)	(0.096)
Years since establishment*100	-0.287*	-0.148	-0.316	-0.344**
	(0.148)	(0.128)	(0.199)	(0.146)
Log (school size)	-0.751***	-0.490**	-0.005	-0.037
	(0.246)	(0.199)	(0.344)	(0.216)
Class size*10	0.594**	0.339***	-0.526*	-0.420***
	(0.270)	(0.106)	(0.314)	(0.133)
Pupil-teacher ratio*10	-0.557*	-0.184	0.711	0.052
	(0.333)	(0.208)	(0.629)	(0.278)
Pupil-teacher ratio sq* 100	0.140	0.065	-0.036	-0.054
	(0.112)	(0.078)	(0.148)	(0.051)
Female teacher percentage	2.217***	2.463***	-1.943***	-2.144***
	(0.266)	(0.259)	(0.391)	(0.256)
Female administrator percentage	0.116	0.128	0.163	0.387*
	(0.251)	(0.212)	(0.239)	(0.205)
District FE	Yes	No	Yes	No
District*Year FE	No	Yes	No	Yes
Observations	128	896	118	801
R-squared	0.657	0.645	0.527	0.583

Robust standard errors clustered by school in parentheses.
**** p<0.01, ** p<0.05, * p<0.1*
Columns 1 and 3 are based on 2009 data.
Columns 2 and 4 include 2001-2009.

Table A4: Between-school estimates of the effects of attending a coed (versus a single-sex) school on the academic performance

	Dependent var.: CSAT score in					
	Korean	English	Math	Korean	English	Math
	Corresponding to Table 2's					
	Panel A, column:			***Panel B, column:***		
	(5)	(7)	(9)	(5)	(7)	(9)
Coed school	0.029	0.025	0.034	0.017	0.019	0.006
	(0.034)	(0.043)	(0.034)	(0.044)	(0.057)	(0.048)
Private	-0.086*	-0.111*	-0.103**	-0.007	-0.026	-0.022
	(0.048)	(0.063)	(0.051)	(0.046)	(0.060)	(0.051)
Years since establishment*100	0.048	0.124	0.080	0.135**	0.192**	0.101
	(0.064)	(0.091)	(0.073)	(0.056)	(0.093)	(0.073)
Log (school size)	0.071	0.042	0.055	-0.059	-0.079	-0.012
	(0.089)	(0.108)	(0.096)	(0.056)	(0.078)	(0.067)
Class size*10	0.117	0.106	0.121	0.089*	0.103*	0.083
	(0.092)	(0.095)	(0.084)	(0.046)	(0.061)	(0.053)
Pupil-teacher ratio*10	0.176**	0.236**	0.205**	0.189***	0.274***	0.223**
	(0.073)	(0.104)	(0.086)	(0.070)	(0.101)	(0.087)
Pupil-teacher ratio sq* 100	0.013	0.012	0.013	0.025	0.026	0.021
	(0.028)	(0.034)	(0.031)	(0.015)	(0.018)	(0.016)
Female teacher percentage	-0.327*	-0.388*	-0.354*	0.141	0.166	0.113
	(0.170)	(0.225)	(0.186)	(0.114)	(0.157)	(0.134)
Female administrator percentage	-0.170	-0.173	-0.136	0.013	-0.003	-0.053
	(0.109)	(0.123)	(0.108)	(0.065)	(0.090)	(0.082)
District FE	No	No	No	No	No	No
District-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	316,475	315,654	302,771	276,544	276,015	256,000
R-squared	0.039	0.069	0.042	0.028	0.054	0.033

Robust standard errors clustered by school are in parentheses.
**** p<0.01, ** p<0.05, * p<0.1*
CSAT scores are in z-scores with mean 0 and standard deviation 1.
2009 is the sample used in Park et al.(2013).
Sample includes schools that remain single-sex, schools that remain coed, and schools that switch from single-sex to coed.