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Causal Effects of Single-Sex Schools on College Entrance Exams and College Attendance: Random Assignment in Seoul High Schools

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Abstract
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Keywords
Academic achievement, Attendance, Causal effects, Causal inferences, Causation, Coeducational schools, College attendance, College Scholastic Ability Test (CSAT), Consequences, Education, Equalization Policy, Female teachers, Four-year colleges, Gender, High school, Higher education, Korea, Korean government, Korean high schools, Learning, Male teachers, Outcomes, Public education, Public lottery, Random school assignment, Regression analysis, Same-gender teachers, Single-sex public education, Single-sex schools, Teachers, Two-year colleges, United States

Disciplines
Asian Studies | Curriculum and Instruction | Demography, Population, and Ecology | Education | Educational Administration and Supervision | Family, Life Course, and Society | Gender and Sexuality | Inequality and Stratification | International and Comparative Education | Other Education | Quantitative, Qualitative, Comparative, and Historical Methodologies

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Causal Effects of Single-Sex Schools on College Entrance Exams and College Attendance: Random Assignment in Seoul High Schools

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ABSTRACT

Despite the voluminous literature on the potentials of single-sex schools, there is no consensus on the effects of single-sex schools because of student selection of school types. We exploit a unique feature of schooling in Seoul, the random assignment of students into single-sex versus coeducational high schools, to assess causal effects of single-sex schools on college entrance exam scores and college attendance. Our validation of the random assignment shows comparable socioeconomic backgrounds and prior academic achievement of students attending single-sex schools and coeducational schools, which increases the credibility of our causal estimates of single-sex school effects. Attending all-boys schools or all-girls schools rather than attending coeducational schools is significantly associated with higher average scores on Korean and English test scores. Single-sex schools have a higher percentage of graduates who attended four-year colleges and a lower percentage of graduates who attended two-year junior colleges than coeducational schools. The positive effects of single-sex schools remain substantial, even after taking into account various school-level variables such as teacher quality, the student-teacher ratio, the proportion of students receiving lunch support, and whether the schools are public or private.

BACKGROUND

A large body of demographic research has investigated the determinants of schooling and the effects of schooling attainment on individuals' own and their children's demographic behaviors and economic outcomes, contributing to macro demographic and economic changes in both developed and developing countries. In particular, increasing women's schooling is a strategy advocated by national governments and international organizations not only to address gender equality and women's empowerment in contexts where cultural norms and structural factors considerably constrain women's economic, political, and social participation but also to attain important demographic and economic goals (UN 2000, World Bank 2000). What determines schooling and gender differentials in schooling, therefore, has broad implications for individuals (perhaps especially for women) and their children's life-course outcomes.

Single-sex schooling is one way of attempting to affect schooling attainment. Such schooling may have particular relevance for issues of policies and practices in education for gender equity (Lee and Marks 1992) but also for a range of demographic and economic outcomes. Numerous studies in the United States and other countries have examined whether single-sex schools may be more effective in enhancing students' educational outcomes than coeducational schools (Mael et al. 2005; Datnow and Hubbard 2002; AAUWEF 1998). Earlier studies were particularly interested in the extent to which all-girls schools offer educational environments conducive to academic achievement of girls. Proponents of single-sex schools highlighted several aspects of coeducational settings that reinforce, rather than reduce, traditional gender role socialization and thus ultimately discourage girls' interest in learning, especially stereotypically male subjects such as math and science (LePore and Warren 1997; AAUW 1992).

The implications of single-sex schools for students' demographic and economic outcomes through their effects on educational attainment may be important for boys as well. Indeed, researchers in the United States have become increasingly interested in potential benefits of single-sex schooling for *boys* as a way to address the educational lag of boys relative to girls (Kleinfeld 2006). Recent studies of test scores show that girls outperform boys in reading consistently across elementary, middle and high schools, though gender disparities in math are not significant (Chudowsky and Chudowsky 2010). American women have made significant improvements in their schooling attainment. Indeed since the mid 1980s women have surpassed their male counterparts in acquiring college degrees (DiPrete and Buchmann 2006; Freeman 2004). The increasing gender gaps in education favoring girls have led to increasing concern about how to increase schooling of boys, and all-boy schools are one possible means that has been advocated.

Despite the voluminous literature on single-sex schools, there is far from a consensus on their effects. Several studies report positive benefits of single-sex schools, particularly for girls in academic achievement, sex-role attitudes, self-esteem, and career aspirations (Lee and Bryk 1986; Riordan 1990). But other studies find no significant differences between single-sex and coeducational schools and thereby, question any benefits of single-sex schools (Marsh 1989; LePore and Warren 1997). Moreover, because of the earlier predominance of interest in the effects of single-sex schooling on girls, relatively few studies have examined effectiveness of all-boys schools in enhancing boys' educational outcomes (Mael et al. 2005).

A fundamental issue underlying the disagreement on single-sex school effects is that it is difficult to know what differences in test scores and other educational outcomes between students in single-sex and coeducational schools mean because the differences may reflect

selection mechanisms rather than the effects of the schools per se. In an educational system such as in the United States where some students (or their parents) choose single-sex schools over coeducational schools, the two bodies of students attending single-sex and coeducational schools are likely to differ in many aspects of observed and unobserved characteristics of students and their families. Hence, observed differences in educational outcomes between students attending single-sex and coeducational schools may be due to unobserved students' (and families') characteristics rather than reflect causal effects of single-sex schools (LePore and Warren 1997; Marsh 1989). Even though extensive controls for observed characteristics in observational data are helpful, potential biases due to selection cannot be ignored because some potentially critical factors (e.g., innate abilities, preferences) are likely to remain unobserved.

In this paper, we move beyond the associations that dominate the existing literature to draw causal inferences about the effectiveness of single-sex schools by exploiting a unique feature of high schools in Seoul, South Korea (Korea hereafter): random assignment of students to coeducational and single-sex schools in a context in which there are considerable numbers of coeducational, all-boys and all-girls schools. Seoul is the capital and largest city in Korea, with over 10 million inhabitants, accounting for about 20% of the Korean population and making Seoul one of the ten most populous cities in the world.

Specifically, we assess causal effects of single-sex high schools on two pivotal educational outcomes: college entrance exam scores and college attendance rates. College attendance is widely perceived to be an important outcome of primary and secondary education that has considerable influence on individuals' life chances. In Korea, students have to take the nationally-standardized entrance examination to apply for college. Therefore, college entrance exam scores are important educational outcomes to investigate for the school effects. We

supplement the analysis of college entrance exam scores of individual students with the analysis of college entrance rates at the school level. We compare single-sex and coeducational schools separately for rates of four-year college attendance and rates of two-year junior college to investigate whether single-sex schools have different impacts depending on the type of college (e.g., Lee and Marks 1990).

Examining single-sex schools in Seoul is useful not only because of the unique setting of random assignment but also because of the potential of single-sex schools for addressing persistent gender inequality in Korean society. Korea ranks 64th out of 93 countries in the United Nations Development Program's (2007) Gender Empowerment Measure. Korea has the largest earnings gender gap (favoring men) among all OECD countries that provided the data (OECD 2008). Underlying the limited economic opportunities of Korean women is a pervasive patriarchal culture (Cho 2004). In this regard, exploring whether single-sex schools can help Korean women realize their educational and occupational potentials can provide some insights into benefits of single-sex schools to researchers and policymakers in other countries where similar patriarchal culture and limited economic and social opportunities for women constrain girls' educational and occupational careers (UNESCO 2007).

WHY MIGHT SINGLE-SEX SCHOOLS BE MORE BENEFICIAL?

According to single-sex school advocates, single-sex schools may reduce influences of adolescent culture that tend to distract students' attention from academic learning and instead place emphasis on physical attractiveness and interpersonal relationships (Coleman 1961; Riordan 1985). More than four decades ago, Coleman (1961) showed that students in coeducational schools were more concerned about appearance and popularity, leading him to

conclude that coeducational schools restrained academic achievement. By reducing the influences of adolescent culture, therefore, single-sex schools may help students concentrate on academic learning. Some studies suggest that students in all-boys or all-girls schools tend to spend more time on homework and show more academically oriented attitudes than those in coeducational schools, while popularity based on physical attractiveness and excellence in sports is more highly valued in coeducational schools (Salomone 2003; Lee and Bryk 1986; Goodlad 1984).

Another potential source of single-sex school effects, especially for girls, is related to classroom dynamics that affect students' self-esteem, self-concept and confidence in academic learning (UNESCO 2007; Lee and Bryk 1986). Interviewing and observing students in single-sex math classrooms in American secondary schools, Streitmatter (2002) found that the girls in a single-sex classroom had the sense of ownership of their class, while the same girls did not feel the sense of ownership in coeducational classrooms. Girls perceived the dominance of boys in coeducational classes: "Guys yell out the answer and want to give the answers. They take up a lot of attention. It's kind of like the whole class is spinning around that guy and not math" (Streitmatter 2002: 217, interview with a girl). However, girls in a single-sex classroom reported that they were not afraid of asking and answering questions because they were no longer concerned about reactions from boys as in usual coeducational classrooms. Female students also reported enhanced confidence in their abilities in math as a consequence of attending the single-sex math classroom: "…I am not sure what it will be like in math next year, but at least I know I can do math and I'm not stupid in it" (Streitmatter 2002: 221). It is, however, questionable whether this argument for enhanced self-esteem and confidence in academic learning by removing the opposite sex should be applied to boys as well.

Single-sex school effects can be also generated from the nature of interactions between students and teachers. Two different versions of explanations for single-sex school impacts because of student-teacher interactions can be distinguished (Dee 2006; 2007). The first version focuses on how teachers treat students differently according to the gender of students. For instance, in regard to math and science education, which often are pivotal subjects for college attendance, studies have shown that teachers have higher expectations for boys than for girls and provide more encouragement for boys to take math and science courses and to pursue educational careers in math and science (Valentine 1998; Lee, Marks, and Byrd 1994). Teachers tend to have more interactions with male students than with female students in math and science classrooms, and teachers often use different instructional strategies for female and male students (Oakes 1990; Sadker and Sadker 1994). In contrast, the "chilly" climate of classrooms for female students is conjectured to lead female students, who had interests in math and science as much as did male students during their primary school years, to lose their interests in math and science, and consider these subjects as related to male careers as they go through secondary schools (Hall and Sandler 1982). This argument leads to an expectation that girls in coeducational schools, who compete with boys, should be relatively more disadvantaged than girls in all-girls schools. However, it is difficult to apply a parallel argument to the comparison between boys in all-boys schools and boys in coeducational schools. Moreover, some researchers question whether this kind of sex-bias in teacher-student interactions is still prevalent in coeducational K-12 schools in the United States and even argue for disadvantages of boys whose academic difficulties and specific needs arguably are not appropriately dealt with (Mael et al. 2004; Pollack 1998).

The second argument concerning student-teacher interactions focuses on how students respond to the gender of teachers rather than how teachers treat students differently according to

the gender of students (Dee 2007). Riordan (1990) showed that all-girls schools tended to have more female teachers than coeducational schools, while all-boys schools tended to have more male teachers. Some studies have found that students, especially girls, benefit from having a same-gender teacher. Using the National Longitudinal Survey of Youth, Nixon and Robinson (1995) found that the higher share of female teachers and professional staff in high school was significantly associated with higher levels of educational attainment of young women. In a study of 8th grade students and their teachers using data from the National Education Longitudinal Study (NELS: 88), for example, Dee (2006, 2007) found significant effects of teachers' gender on student outcomes: "Simply put, girls have better educational outcomes when taught by women and boys are better off when taught by men" (2006: 71).[1] Given the high proportion of same-gender teachers in single-sex schools in the United States and other countries, the effect of same-gender teachers may account for why single-sex schools might be more effective than coeducational schools. Moreover, this argument can be applied to explain potential advantages of single-sex schools for boys as well as girls.

One possible reason for the significant effect of same-gender teachers is that such teachers provide better role models (Bettinger and Long 2005; Nixon and Robinson 1999; Riordan 1990). However, this effect may not only, or may not at all, reflect role models. Mael et al. (2004), for example, summarize some studies suggesting that teachers are not necessarily seen as impressive role models by students and parents. An alternative explanation of the positive effect of same-gender teachers may pertain to possible advantages for same-gender teachers to manage student discipline and classroom order, especially for boys (see Sullivan, Joshi, and Leonard 2010). We are not aware of any research that provides empirical evidence that gender matching between teachers and students should facilitate student discipline and classroom order.

However, there is some evidence that single-sex schools display more ordered classroom climates and less disciplinary problems among students than coeducational schools (Riordan 1990). Students in single-sex schools are more likely to have same-gender teachers who possibly can better discipline student behaviors than do teachers of a different gender. We reason that teachers' management of classroom discipline and order can be even more effective when they deal with only either all boys or all girls.

RANDOM ASSIGNMENT TO SEOUL SCHOOLS

Although a randomized experiment may be the best option for drawing causal inferences about the effectiveness of single-sex schools, it is extremely difficult to conduct such an experiment in the real world. Interestingly, the current educational system of Seoul has the unique feature of random assignment of students into high schools. Before 1974, Korean high schools could choose their students on the basis of students' scores on entrance examinations administered by individual high schools, resulting in apparent clustering by family background and substantial between-school differences in students' academic performances. The rising concern about between-school inequality and academic pressure on students to do well on high-school entrance examinations led to a national educational reform called the 'Equalization Policy'(*P'yŏongjunhwa Chŏngch'aek*) (Kim 2003; Lee et al. 1996). This policy created a de facto experiment, in which students after middle school graduation were *randomly* assigned to high schools within their school districts.[2] The random assignment is applied regardless of whether schools are coeducational or single-sex schools so that students cannot choose between single-sex or coeducational schools. Although some school districts have never implemented the random assignment policy, the randomization has been executed using a public lottery in the

majority of school districts including Seoul and other metropolitan areas. However, in recent years some school districts have loosened the equalization policy in order to respond to growing concerns for limited school choice. They allow students to list the 2-3 schools that they prefer. Then, they randomly select 30 – 40% of enrollments in a school among those students who showed preference for that school, while the remaining enrollments are selected entirely by lottery without considering students' preferences. As of 2009, the six metropolitan areas other than Seoul and other small areas have implemented this modification of randomization to some extent and only in Seoul are the entire enrollments determined by random assignment.[3] Therefore, to maximize the utility of randomization for estimating causal effects of single-sex schools, in this study we limit our analysis to schools located in Seoul where the random assignment is fully executed rather than blended with potential selectivity as in the other metropolitan areas.

Single-sex schools in Seoul are predominantly private: about 80 percent of all-boys and all-girls schools, respectively, are private, while only 30 percent of coeducational schools are private. Private schools are also subject to the random assignment of students. Therefore, there is no significant difference in students' socioeconomic background between students attending private and public schools (Park, 2010). The Korean government also imposes uniform curriculum and tuition on public and private schools. However, private schools are owned by individuals and have rights to select teachers. Teacher selection and appointment into public schools is governed by national or provincial governments and is subject to open, severe competition of which the major factor is the applicant's score on the standardized teacher examination, while each private school is in charge of selection and appointment of teachers (Seo et al. 2003). Moreover, teachers in public schools have to move to a different school within the province every 4-5 years, while teachers in private schools can stay in the same school more

than 4-5 years. Therefore teacher characteristics of single-sex schools, which are heavily private, can differ from those of coeducational schools, which are heavily public. However, as will be seen later, the quality of teachers, at least with respect to measures used in our study, is not higher among single-sex schools that are more likely to be private than coeducational schools that are more likely to be public.

Compliance issues in the random assignment deserve some discussion. If students (or their families) move their residences to a new school district for any reason including their dissatisfaction with the school assignment, students are subject to another random assignment in the new district. In other words, there is no guarantee that a student can attend a single-sex or coeducational school as she or he wants in the new district. Because most school districts in Seoul have several single-sex and coeducational schools, it is unlikely that moving to a new school district significantly changes the probability of being assigned to a single-sex school over a coeducational school or vice versa.[4]

Moreover, the proportion of students moving to a different school district during the period of transition to high school seems very small. Using the 2000 Korean Census data, we identified the places of current residence and residence one year ago among those aged 14 to 16 in 2000 whose age range corresponds to the age of transition to high school. Among those who had lived in Seoul one year earlier, only 4.5 percent moved into a new school district either within Seoul or outside Seoul. The remaining 95.5 percent remained in the same location or moved in a new place within the same school district.

Finally, students can avoid the random assignment by applying for specialized high schools including foreign language, science, and art schools that are not subject to the high school equalization policy and thus can select students on the basis of their own criteria.

However, the number of those specialized high schools is very small (see note 6 below) and thus specialized high schools are not much of an option for the majority of high school students. In short, non-compliance with the random assignment among students in Seoul seems at most very limited, suggesting that any bias in our estimates caused by non-compliance probably is small.

High school seniors can apply to either four-year colleges or two-year junior colleges for tertiary education. For either type of college, two major elements for admission are scores on the national college entrance examination, College Scholastic Ability Test (CSAT) and high school records. In the senior year of high school, students take the CSAT, which is administered by the government and offered only once a year (usually in November) (MEST 2009). The government is responsible for grading the test for every student and sending back the score to each student. Typically, higher CSAT scores and better high school records are required for four-year colleges than two-year junior colleges. Given the importance of the CSAT score for college admission, high school curricula and learning are heavily directed toward preparing students for the CSAT.

DATA AND METHODS

Data

The CSAT score is probably more reliable and valid than any other test scores of academic achievement in Korean schools. Going through the application process, we obtained the permission to use data of CSAT scores of all individual high school seniors who took the test in November 2009. The CSAT consists of several subjects including Korean, English, mathematics, science, social studies/history, and a second-foreign language. There are uniform tests for Korean and English that almost every student takes. But for other subjects, there are multiple tests from which students select a subset. Therefore, to facilitate comparison, in this

study we use only Korean and English scores that are available for every student. The Ministry of Education has scaled Korean and English scores to have a mean of 100 points and a standard deviation of 20 points. The numbers of male students for the analysis of Korean and English are 46,191 and 45,879, respectively, who are nested within 68 all-boys schools and 68 coeducational schools within the 11 school districts in Seoul. The numbers of female students for the analysis of Korean and English are 42,162 and 42,042, respectively, nested within 60 all-girls schools and 68 coeducational schools.

For college attendance, we rely on a school-level database compiled by the Korean government with a variety of information on high schools, as reported by each school in accordance with educational law. The compiled data are publicly available at a governmental webpage, www.schoolinfo.go.kr. For our study, we use data of the total number of senior students and the numbers of those seniors who were enrolled in four-year colleges and in two-year junior colleges, separately, one year after high school graduation as well as other school-level variables such as the number of (female and male) teachers and the number of students receiving lunch support (which is provided to students from low-income families). For coeducational schools, the data provide the number of high school seniors and college attendants by gender. Compared to data only of one cohort for college entrance exam scores, we use data of college entrance rates for two separate cohorts per school: the 2008 senior cohort and the 2009 senior cohort.[5] However, because this dataset does not include any measures for teacher quality, using school names as identifiers we have further attached to this dataset two teacher quality measures (average years of teaching experience and schooling attainment of teachers in each school) available from school data gathered for the Statistical Yearbook of Education by the Korean Educational Development Institute (http://cesi.kedi.re.kr). These two additional measures

are useful to compare school quality between single-sex and coeducational schools. After deleting some specialized schools such as foreign language, science, and art schools for which the high school equalization policy is not applied, the final sample consists of 196 high schools across 11 school districts per year (i.e. a total of 392 observations; none of the schools did not change its single-sex or coeducational status).[6] Among these 196 high schools, 68 are all-boys, 60 are all-girls, and 68 are coeducational.

The random assignment of students into single-sex or coeducational schools should result in comparable socioeconomic conditions of students attending single-sex and coeducational schools within school districts. However, the school-level data used in this study do not have detailed information on socioeconomic background of students attending the schools. The only variable available to represent schools' socioeconomic composition is the proportion of students in a school that receive lunch support. Similarly, the student-level data of the CSAT scores do not include any information on individual students' socioeconomic background. The only individual-level variable available in the CSAT dataset is gender of a student.

To check for balances on the observed characteristics of parents between students in single-sex and coeducational schools, we use another dataset, the Korean Educational Longitudinal Survey (KELS) that has tracked a nationally representative sample of 7th graders (1st year in middle school) every year since 2005 (Kim et al. 2006). By the fourth wave of KELS, almost all those 7th original graders had become first-year high school students. Importantly, the third wave of KELS provides respondents' scores on standardized math, Korean, and English tests administered in the last year of middle school (i.e. one year before entering high school). Therefore, using the third and fourth waves of KELS, we can test whether two groups of students attending single-sex and coeducational high schools have balance not only on their

socioeconomic backgrounds but also on their prior academic achievement. Restricting analysis to students who resided in the areas of high school equalization policy, the final sample consists of 1,380 male and 1,279 female students for which we have information on their socioeconomic backgrounds (parental education and household income) and prior academic achievement (composite score of math, Korean, and English tests) as well as whether they attended single-sex or coeducational high schools.[7]

Analytic Strategy

Analysis of College Entrance Exam Scores

For college entrance exam (CSAT) scores, we use three-level hierarchical linear models to take into account the nested structure of the data: individual students are nested within schools, which are in turn nested into school districts (Raudenbush and Bryk 2002). We estimate the three-level models for girls and boys, separately. Note that we do not have any student-level predictor but have school-level predictors (including the indicator of single-sex school) for school mean scores. The level-1 model is:

$$Y_{ijk} = \pi_{0jk} + e_{ijk}$$

Where

Y_{ijk} is the (either Korean or English) exam score of student *i* in school *j* and district *k*;

π_{0jk} is the intercept (mean) for school *j* in district *k*; and

e_{ijk} is a level-l (student) random effect.

The level 2 (school-level) model is:

$$\pi_{0jk} = \beta_{00k} + \beta_{01k}(Single-Sex\,Sch) + \sum_{q=2}^{6} \beta_{0qk} X_{qjk} + r_{0jk}$$

In this school-level model, school mean scores (π_{0jk}) are predicted by our focal variable, the indicator for a single-sex school, and five additional school-level variables: the senior students-teacher ratio, average years of teaching experience, schooling attainment of teachers, the proportion of students receiving lunch support, and a dummy variable for private schools. We pointed out above that reduced adolescent social culture and enhanced self-esteem and confidence in learning are potential explanations of single-sex school effects. Our school-level dataset lacks variables that directly measure school disciplinary climates or sociopsychological states for students, which would be useful to test these hypotheses on adolescent culture and self-esteem. Therefore, we do not attempt to address mechanisms through which single-sex school effects might be generated. Instead, we focus on estimating the overall magnitude of single-sex school effects. However, in estimating the overall effects of single-sex schools, we carefully control for major school characteristics such as teacher quality, the socioeconomic composition of student bodies (as measured by the proportion of students receiving lunch support), student-teacher ratios, and private vs. public, which are known to have influences on student outcomes and could be potentially correlated with, but not necessarily caused by, single-sex/coeducational schools.

Finally, the level-3 (district-level) model is

$$\beta_{00k} = \gamma_{000} + u_{00k}$$

$$\beta_{01k} = \gamma_{010}$$

$$\beta_{0qk} = \gamma_{0q0} \ (q = 2 \text{ to } 6)$$

In this district-level model, we allow district mean scores to randomly vary around the grand mean (γ_{000}), but postulate the effects of single-sex schools (γ_{010}) and five school-level variables ($\gamma_{020} - \gamma_{060}$) to be constant across districts.

Analysis of College Attendance Rates

Using the number of college attendants, we calculate the percentage of high school graduates who were enrolled in college one year after graduation from each high school for each of 2008 and 2009 senior cohorts. For coeducational schools we calculate the percentages for boys and the percentages for girls, separately. Then, we compare college attendance rates for boys between all-boys schools and coeducational schools as well as college attendance rates for girls between all-girls schools and coeducational schools. Specifically, we conduct regression analysis to predict college attendance rates among boys (girls) by an indicator (dummy variable) that distinguishes single-sex schools from coeducational schools. In each regression analysis, we include a dummy variable to distinguish the 2009 senior cohort from the 2008 cohort, and 10 dummy variables for school districts to control for differences across the 11 school districts so these are district fixed-effects regressions. As mentioned earlier, students are randomly assigned within school districts, though school districts may differ in their socioeconomic environments and other observed and unobserved characteristics. We estimate the regressions for four-year college attendance rates and for two-year junior college attendance rates, separately. Similar to the models for college entrance exam scores, we control for five characteristics of schools: senior students-teacher ratio, average years of teaching experience and schooling attainment of teachers, the proportion of students receiving lunch support, and private/public schools.[8]

RESULTS

Checking the Randomness of School Assignment

To verify the randomness of student assignment among Seoul high schools, we use the student-level data of KELS to estimate logit models that predict the likelihood of attending a single-sex school (as compared to attending a coeducational school) among current first-year high school students by two socioeconomic characteristics of parents (parental education and household income) and student's prior academic achievement, which were all measured one year before entering high school. Table 1 reveals that none of socioeconomic and academic background measures is associated with the likelihood for students to attend single-sex schools for either boys or girls. In other words, the results highlight balances on the two observed characteristics of parents and student's prior academic achievement between students currently attending single-sex and their peers attending coeducational high schools. This balance strengthens the claim that the student distribution among Seoul high schools is really close to the random assignment. In contrast, studies in the United States and other countries, where students (and their families) choose single-sex schools over coeducational schools, have found more advantaged background characteristics among students in single-sex schools than their counterparts in coeducational schools (Lee and Bryk 1986; Riordan 1990; Lee and Marks 1992).

TABLE 1 ABOUT HERE

Differences in School Characteristics by School Type

Although the comparisons in Table 1 show that single-sex and coeducational schools do not differ in their students' socioeconomic and academic backgrounds, single-sex and coeducational schools can still differ in other important school characteristics that have been

found to significantly affect student learning such as student-teacher ratios, teacher quality (often measured by years of teaching experience and schooling attainment among teachers) (Arum and LaFree 2008; Akiba, LeTendre and Scribner 2007; Card and Krueger 1996; Behrman and Birdsall 1983). As pointed our earlier, the system of teacher selection and appointment differs between private and public schools. Due to correlations between private and single-sex school status, therefore, teacher-related characteristics, which are not necessarily caused by single-sex school status, can differ between single-sex and coeducational schools.

TABLE 2 ABOUT HERE

Table 2 presents OLS regressions comparing the level of each school quality measure among all-boys, all-girls, and coeducational schools. For the analysis, we use measures for the same school year, 2009, that is used for the analysis of national college entrance exam scores.[9] The first column shows the difference in the senior students-teacher ratio by school type. The intercept of the model indicates that coeducational schools have 5.8 senior students per teacher on average, which is not much different from the ratio for all-boys schools. Interestingly, the coefficient of all-girls schools is significantly positive, indicating that the average senior students-teacher ratio is even larger among all-girls schools than coeducational schools. A similar pattern is found for teachers' experience. The average year of teaching experience among teachers in coeducational schools is 18.3, which is not significantly different from the average years among teachers in all-boys schools but significantly higher than the average years among teachers in all-girls schools. Turning to teachers' average years of schooling, both all-girls and all-boys schools are disadvantaged. In sum, these comparisons highlight that single-sex schools in Korea are not advantaged over coeducational schools in these measured aspects of school quality; in fact single-sex schools, especially all-girls schools are somewhat disadvantaged.

In Table 1, we have already showed balances in major family background characteristics of individual students between those attending single-sex and coeducational schools. The result of the proportion of students receiving lunch support in Table 2 confirms the earlier finding: there is no significant difference in the proportion by school type. Overall, the results in Table 2 suggest that if students in single-sex schools do better than their counterparts in coeducational schools, it is not likely because single-sex schools have teachers of better quality, smaller numbers of students per teacher, or students from wealthier families.

Causal Effects of Single-Sex Schools on the College Entrance Exam (CSAT)

TABLE 3 ABOUT HERE

Table 3 presents the estimates for Korean and English, separately, for the effects of single-sex schools on college entrance exam (CSAT) scores among high school senior girls. We estimate two models for each test score: Model 1 for the gross effect and Model 2 for the net effect controlling for the other school characteristics discussed above. In Model 1-1 for Korean, high school female seniors who attend all-girls schools show significantly higher mean scores than their peers who attend coeducational schools. Because these test scores were standardized to have a mean of 100 points and a standard deviation of 20 points, the coefficient of 1.3 corresponds to 6.5 percent of one standard deviation.[10] In Model 2-1 for English, the coefficient of all-girls schools is similar to that for Korean in Model 1-1, but is not statistically significant.

In Models 1-2 and 2-2, we control for the proportion of students receiving lunch support, teaching experience and years of schooling among teachers, the senior students-teacher ratio, and private schools. Controlling for these five school-level variables hardly affects the estimated effects of all-girls schools on college entrance exam scores. Because of reduced standard errors,

the coefficient estimate for English even becomes significant in Model 2-2. For coefficients of other variables, noteworthy is that being a private school is not significantly associated with either Korean or English performance. Schools with a higher proportion of students receiving lunch support have a lower mean score for both Korean and English tests.

TABLE 4 ABOUT HERE

Table 4 gives parallel estimates for boys. Boys attending all-boys schools have average scores for Korean that are 2.2 points higher than their counterparts attending coeducational schools (about 10 percent of one standard deviation) (Model 1-1). The corresponding advantage of all-boys schools for English is 3 points (15 percent of one standard deviation) (Model 2-1). Controlling for the five school-level variables reduces somewhat the estimated effect of all-boys schools on Korean in Model 1-2. However, the estimate is still significant at the 90 percent level. Moreover, the estimated effect on English in Model 2-2 remains substantial. A couple of points difference in the total score of CSAT can be of critical significance in affecting college admission especially when competition for a specific university or department is severe (Kim 2011).

Causal Effects of Single-Sex Schools on College Attendance

TABLE 5 ABOUT HERE

Tables 5 presents district fixed effects regression results for college attendance rates by school types for girls. Similar to the analysis for college entrance exam scores, we estimate two models of gross and net effects. Model 1-1 in Table 5 shows that the four-year college attendance rate for female graduates is 3.1 percentage points higher for all-girls schools than for coeducational schools. Considering that one standard deviation of four-year college attendance

rates for female graduates is 6.8, the effect of all-girls schools is equivalent to 0.5 standard deviations of the rate of four-year college attendance for female graduates. Therefore, the advantage of all-girls schools over coeducational schools in sending female students to four-year colleges is fairly substantial. In contrast to the positive effect of all-girls schools on four-year college attendance, Model 2-1 suggests that female students from all-girls schools are less likely to attend two-year junior colleges.

Controlling for five school characteristics in Model 1-2 reduces the estimated effect of all-girls schools on four-year college attendance rates. However, the estimate is still significant at least at the 90 percent level with a magnitude that corresponds to 23 percent of one standard deviation. Moreover, compared to Model 2-1, the negative estimated effect of all-girls schools on two-year junior college attendance rates hardly changes in Model 2-2. In short, the results for college attendance among girls in Table 5 are consistent with the results for college entrance exam scores in Table 3 showing substantial effects of all-girls schools even after taking into account other school level characteristics correlated with single-sex school status.

TABLE 6 ABOUT HERE

In Table 6 for boys, Model 1-1 shows that the rate for male students to attend four-year colleges is 5.6 percentage points higher for all-boys schools than for coeducational schools. Given that one standard deviation of boys' four-year college attendance rates among all schools is 7.3, the effect size of 5.6 is quite large (about 0.8 standard deviations). Similar to girls, Model 2-1 suggests that all-boys schools have a negative effect on two-year junior college attendance: the rate of junior college attendance is 3 percentage points lower for all-boys schools than for coeducational schools.

Similar to the results for girls, the estimated effect of all-boys schools for four-year college attendance rates is reduced after taking into account five school characteristics in Model 1-2. However, the estimate still remains substantial (0.3 standard deviations) and significant. The estimated effect of all-boys schools on two-year junior college is also reduced but remains significant at the 90 percent level (Model 2-2). As for girls in Table 5, schools with a larger proportion of students receiving lunch support show a lower rate of four-year college attendance but a higher rate of two-year junior college attendance.

DISCUSSION

There has been renewed interest in the potential benefits of single-sex schools. For instance, since the United States Department of Education established new regulations on single-sex education at the end of 2006, a rapidly growing number of school districts in the United States have experimented with single-sex classrooms within coeducational settings or single-sex schools in search for a way to improve students' academic achievement (Medina 2009; Weil 2008). Despite the accelerated interest of the public and of educational practitioners, however, there is far from a consensus on causal effects of single-sex schooling, particularly because of the difficulty of controlling for effects of unobserved characteristics of students and families who choose single-sex education over coeducational education. Observed relationships between single-sex schools and better educational outcomes, some researchers argue, often are spurious resulting from unobserved characteristics of students and their families that affect both attendance at single-sex schools and educational outcomes (LePore and Warren 1997; March 1989).

In this study, we have assessed causal effects of single-sex schools on college entrance exam scores and college attendance rates by exploiting a unique feature of education in Seoul, Korea in which students are randomly assigned to single-sex or coeducational high schools. Our study is the first to assess causal links between single-sex schools and educational outcomes rather than associations that may in substantial part reflect student selection of school types. We have investigated the random nature of student assignment and found comparable socioeconomic backgrounds and prior academic achievement of students attending single-sex high schools and coeducational high schools. Our analyses show that single-sex schools are causally linked with both college entrance exam scores and college-attendance rates for both boys and girls. Attending all-boys schools or all-girls schools rather than attending coeducational schools is significantly associated with higher average scores on Korean and English test scores. Single-sex schools have a higher percentage of graduates who moved to four-year colleges and a lower percentage of graduates who moved to two-year junior colleges than coeducational schools. Although the previous literature often showed positive associations of all-girls schools with educational outcomes, significant associations of all-boys schools with such outcomes have not been robust (Mael et al. 2005).

In interpreting our findings, an important caveat is notable. The distribution of students into high schools is close to a random assignment. But the distribution of teachers is not. Many single-sex schools in Seoul are private, with a different system of teacher selection and appointment than public schools. The majority of coeducational schools, in contrast, are public. However, we have carefully examined how single-sex and coeducational schools differ in some key characteristics of their teachers, such as the senior students-teacher ratio, average teaching experience and average years of schooling among teachers. These are the best teacher quality

measures available in our data and comparable to such measures used in a number of other studies though not a complete set of quality measures. Our results show that single-sex schools are not so much different from coeducational schools in those key school characteristics. Actually, single-sex schools are slightly disadvantaged, which suggests that our estimates of single-sex school effects could be underestimated. We acknowledge that there might be some differences between single-sex and coeducational schools other than our three measured school characteristics, which could not be considered in our study. To somewhat address this concern, however, we have also taken into account whether schools are private for which a dummy variable can capture other possible differences between single-sex schools, which are mostly private, and coeducational schools, which are mostly public.

Our comparisons of socioeconomic and academic backgrounds of students, and major school characteristics increase the credibility of our causal estimates of single-sex school effects. Then, what causes the better outcomes of single-sex schools? Given that this is the first attempt to establish the causal effect of single-sex schools, in the current study we have not attempted to address the mechanisms of single-sex school effects. However, our preliminary analysis (not shown) indicates that all-boys schools in Seoul have a much larger proportion of male teachers than coeducational schools, and that the effect of all-boys schools is substantially reduced especially for college entrance exam scores, with controlling for the share of male teachers. However, we could not find the same effect of the share of female teachers for girls. Moreover, the mediation analysis should be conducted with caution, even when treatment (single-sex schools) is randomly assigned (Bullock, Green, and Ha 2010; Green, Ha, and Bullock 2010). We just note the gender composition of teachers to be potentially a mechanism through which single-sex schools affect students. This reasoning is also supported by prior research suggesting the

positive effect of gender matching between teachers and students (Dee 2006; 2007). Because little research has not so much focused on the gender composition as a potential mechanism of the single-sex school effect, we suggest that future studies look at this issue more systematically.

Of course, generalization from the Seoul experience to other contexts may be difficult because of other differences. But currently, to our knowledge, there is no other random assignment to single-sex versus coeducational schools on a large scale that could be used to test the external validity of our results. Therefore, our estimated causal relationships between single-sex schools and college attendance and college exam performance established in this study are a useful reference for considering effects of single-sex schools reported in other studies using observational data. Although several researchers of United States education have attributed significant associations between single-sex schools and educational outcomes to the selection bias (LePore and Warren 1997; March 1989), our finding of significant effects of single-sex schools in the Korean setting of random assignment suggests that single-sex schools may produce positive outcomes, not attributable to differences in characteristics of students and their families. The difficult issue for assessing the external validity of our results is how to evaluate the impact of possibly important cross-country differences versus the implications of not controlling for possibly important selectivity in who attends single-sex schools in other countries.

Finally, although we have limited our focus of single-sex schools on college entrance exam scores and college attendance rates, it would be desirable to extend this research to examine other educational outcomes. For instance, it would be useful to examine the effect of single-sex schools on attending top-tier four-year colleges rather than any kind of four-year colleges. Given the persistent underrepresentation of women in Science, Technology, Engineering, and Mathematics (STEM) areas (Freeman 2004; NCES 2007), furthermore we plan

to undertake in future studies an important extension to examine whether single-sex schools enhance female students' expectations and actual choices of a STEM major in college, and their entrance to STEM occupations. There is limited evidence showing that women who attended all-girls high schools in the United States are more likely to choose sex-integrated college majors compared to female-dominant majors than women who attended coeducational schools (Thompson 2002), but the associations in these studies do not control for selection into single-sex versus coeducational schools. So they are suggestive of the potential for important research on this topic, even if they are not conclusive regarding causality. Moreover, the implications of single-sex school effects can be extended to many outcomes -- including risky behaviors, family formation, fertility, mortality, health, nutrition, migration, communication skills and social interactions -- given the widely-perceived strong causal effects of schooling on these outcomes.

ENDNOTES

[1] In addition to role models, another explanation of the effect of the same-gender teacher offered by Dee (2007) is "stereotype threat" that "refers to a situation where student performance suffers when they fear being viewed through the lens of a negative stereotype threat" (533) (see also Steel 1997). For example, female students may experience stereotype threat in their math classrooms if the teachers are male.

[2] In Korea, middle school students can proceed into two different types of high schools: academic high schools and vocational high schools. Vocational high schools, which aim to prepare students for the post-high school job market, are considered less prestigious than academic high schools, which prepare students for higher education. The high school equalization policy is applied only to academic high schools. In recent years, about three out of four high school students in Korea have attended academic high schools. In this study, we refer to academic high schools when saying "high schools" unless specified otherwise.

[3] Among 11 school districts in Seoul, one school district, which mainly covers downtown areas that have a relatively small number of residents, does not apply the strict random assignment. In this district, students list 2-3 schools in order of their preference and then are assigned to one of these schools by lottery. As will be described later, we estimate district-fixed effect models, which to some extent should take care of this difference. We also tested the robustness of our findings by excluding schools in this particular district and the results were hardly different from what we present in the current paper.

[4] The mean of the proportions of coeducational schools within districts among 11 school districts in Seoul is 0.35, while the standard deviation is 0.48.

[5] The 2008 and 2009 senior cohorts refer to those who were high school seniors in 2008 and 2009, respectively. The academic year in Korea begins in March. The data on college attendance were collected in April 2009 for the 2008 cohort and in April 2010 for the 2009 cohort.

[6] The list of high schools provided by the Seoul Metropolitan Office of Education includes a total of 224 high schools for the 2008 senior cohort. We exclude 28 high schools of which the majorities are specialized schools for foreign languages, science, and arts because these specialized schools select students based on their middle school grades and other records. A handful of high schools did not report the relevant information or did not have seniors in 2008.

[7] Ideally, we would like to include students only in Seoul to make these comparisons on the basis of student-level data comparable to our school-level analysis. However, the number of students only in Seoul is not large enough for reliable estimation. Our analysis below with this national-level dataset including Seoul and other equalization policy areas with some modifications, shows good balance on observed family characteristics between students attending single-sex and coeducational schools. The results suggest that students' sorting into single-sex or coeducational schools may not be so selective even in the areas of modified randomization. Also note that the KELS survey did not administer academic tests after respondents entered high schools.

[8] Except for the dummy variable for private schools, the four school-level variables are centered around grand means.

[9] The estimates do not change significantly if data from 2008 are also included in these estimates.

[10] In the bottom of the table, the statistics of random effects show residual variances among students within schools, among schools within districts, and among districts, respectively. The results generally indicate that the variability in test scores among schools and among districts is relatively small, consistent with the effect of randomized school assignment aimed to reduce between-school inequality.

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Table 1. Logit Models of Attending a Single-Sex School by Socioeconomic Backgrounds and Prior Academic Achivement

	Girls Attending Single-Sex vs. Girls Attending Coed Schools	Boys Attending Single-Sex vs. Boys Attending Coed Schools
Parental education (years of schooling)	-0.022 (0.056)	0.019 (0.054)
Monthly household income (logged, Korean Won)	-0.118 (0.106)	0.032 (0.109)
Student's academic achivement in 9th grade (last year in middle school)	0.059 (0.063)	0.008 (0.057)
Constant	1.136 (0.579)	0.250 (0.593)
Log pseudolikelihood	-863.6	-912.5
N	1279	1380

Souce: Korean Educational Longitudinal Survey (KELS), 3rd - 4th waves

Note : Values in parentheses are standard errors.

Table 2. OLS Regression of a School Characteristic by School Type

	Seniors-Teacher Ratio	Average Years of Teaching Experiences of Teachers	Average Years of Schooling Attained of Teachers	Proportion of Students Receiving Lunch Support
School Type (ref: coeducational)				
All-girls schools	0.247 **	-1.119 *	-0.157 **	0.004
	(0.089)	(0.444)	(0.047)	(0.009)
All-boys schools	0.112	0.297	-0.206 ***	0.000
	(0.086)	(0.430)	(0.045)	(0.009)
Intercept	5.796 ***	18.296 ***	16.949 ***	0.087 ***
	(0.061)	(0.304)	(0.032)	(0.006)
R^2	0.039	0.055	0.104	0.001

Note : Values in parentheses are standard errors.

N = 196 (all-boys school - 68, all-girls school - 60, coeducational schools - 68)

*** p < .001 ** p < .01 * p < .05

Table 3. Three-Level Models of Single-Sex School Effects on College Entrance Exam Scores for Girls

	Korean		English	
	M1-1	M1-2	M2-1	M2-2
Fixed Effect				
All-girls school (vs. coed)	1.267 (0.600)*	1.392 (0.479)**	1.318 (0.883)	1.441 (0.640)*
Proportion of students receiving lunch support (0.01 unit)		-0.624 (0.055)**		-0.978 (0.075)***
Average years of teaching experience of teachers		-0.171 (0.094)^		-0.152 (0.128)
Average years of schooling attained of teachers		1.495 (0.937)		2.228 (1.253)^
Seniors-teacher ratio		0.157 (0.481)		0.530 (0.645)
Private school (vs. public)		0.442 (0.611)		0.784 (0.814)
Intercept, γ_{000}	100.966 (0.813)***	100.988 (0.517)***	100.935 (1.371)***	101.008 (0.810)***
Random Effect				
Students (level 1), e_{ijk}	299.2	299.2	333.2	333.2
Schools (level 2), r_{0jk}	9.3	3.8	21.0	7.4
Districts (level 3), u_{00k}	5.3	1.4	16.4	4.4

Note: The analysis was conducted for data of 42,162 female students (42,042 for English) who are nested withtin 60 all-girls schools and 68 coeducational schools, which are, in turn, nested within 11 school districts. Values in parentheses are standard errors.

*** $p < .001$ ** $p < .01$ * $p < .05$ ^ $p < .10$

Table 4. Three-Level Models of Single-Sex School Effects on College Entrance Exam Scores for Boys

	Korean		English	
	M1-1	M1-2	M2-1	M2-2
Fixed Effect				
All-boys school (vs. coed)	2.181 (0.635)**	1.309 (0.739)^	3.047 (0.827)**	2.472 (0.955)*
Proportion of students receiving lunch support (0.01 unit)		-0.141 (0.048)**		-0.225 (0.062)**
Average years of teaching experience of teachers		0.040 (0.138)		-0.023 (0.178)
Average years of schooling attained of teachers		0.139 (1.237)		0.983 (1.600)
Seniors-teacher ratio		0.980 (0.667)		1.092 (0.861)
Private school (vs. public)		1.439 (0.834)^		1.276 (1.076)
Intercept, γ_{000}	94.821 (0.986)***	94.492 (0.936)***	94.646 (1.473)***	94.301 (1.384)***
Random Effect				
Students (level 1), e_{ijk}	411.6	411.6	377.5	377.5
Schools (level 2), r_{0jk}	10.1	9.1	18.2	16.1
Districts (level 3), u_{00k}	8.5	6.4	20.1	15.7

Note : The analysis was conducted for data of 46,191 male students (45,879 for English) who are nested withtin 68 all-boys schools and 68 coeducational schools, which are, in turn, nested within 11 school districts. Values in parentheses are standard errors.

*** $p < .001$ ** $p < .01$ * $p < .05$ ^ $p < .10$

Table 5. Causal Effects of Single-Sex Schools on College Attendance for Girls

	4-Year College		2-Year Junior College	
	M1-1	M1-2	M2-1	M2-2
All-girls school (vs. coed)	3.114 (0.902)**	1.560 (0.856)^	-3.252 (1.194)**	-3.151 (1.070)**
Proportion of students receiving lunch support (0.01 unit)		-0.643 (0.153)***		1.045 (0.167)***
Average years of teaching experience of teachers		-0.115 (0.197)		0.160 (0.205)
Average years of schooling attained of teachers		-2.444 (1.835)		-1.105 (1.885)
Seniors-teacher ratio		-0.038 (0.974)		-0.832 (1.029)
Private school (vs. public)		2.649 (1.230)*		-0.271 (1.346)
School district	*Controlled*		*Controlled*	
2009 seniors (vs. 2008 seniors)	*Controlled*		*Controlled*	
Constant	46.873 (1.269)***	43.148 (1.786)***	13.372 (1.210)***	18.293 (1.636)***
R^2	0.280	0.423	0.496	0.656

Note : The analysis was conducted for data of 60 all-girls schools and 68 coeducational schools that are nested within 11 school districts per cohort.

Values in parentheses are robust standard errors taking into account two cohorts per school.

*** p < .001 ** p < .01 * p < .05 ^ p < .10

Table 6. Causal Effects of Single-Sex Schools on College Attendance for Boys

	4-Year College		2-Year Junior College	
	M1-1	M1-2	M2-1	M2-2
All-boys school (vs. coed)	5.605 (0.892)***	2.435 (0.918)**	-2.719 (0.847)**	-1.712 (1.035)^
Proportion of students receiving lunch support (0.01 unit)		-0.157 (0.087)^		0.305 (0.153)*
Average years of teaching experience of teachers		-0.062 (0.169)		-0.199 (0.163)
Average years of schooling attained of teachers		-0.940 (1.676)		-1.087 (1.411)
Seniors-teacher ratio		-2.719 (0.745)***		0.599 (0.914)
Private school (vs. public)		7.198 (1.018)***		-2.214 (1.182)^
School district	*Controlled*		*Controlled*	
2009 seniors (vs. 2008 seniors)	*Controlled*		*Controlled*	
Constant	41.595 (1.249)***	37.313 (1.379)***	10.145 (0.929)***	13.333 (1.380)***
R^2	0.317	0.456	0.496	0.538

Note : The analysis was conducted for data of 68 all-boys schools and 68 coeducational schools that are nested within 11 school districts per cohort. Values in parentheses are robust standard errors taking into account two cohorts per school.

*** p < .001 ** p < .01 * p < .05 ^ p < .10