Published in final edited form as:
Demography. 2013 April ; 50(2): 447–469. doi:10.1007/s13524-012-0157-1.

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

Hyunjoon Park,
Department of Sociology, University of Pennsylvania, 3718 Locust Walk, Philadelphia, PA 19104

Jere R. Behrman, and
Department of Economics and Sociology, University of Pennsylvania

Jaesung Choi
Department of Economics, University of Pennsylvania

Hyunjoon Park: hypark@sas.upenn.edu

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. The three-level hierarchical model shows that attending all-boys schools or all-girls schools, rather than coeducational schools, is significantly associated with higher average scores on Korean and English test scores. Applying the school district fixed-effects models, we find that single-sex schools produce a higher percentage of graduates who attended four-year colleges and a lower percentage of graduates who attended two-year junior colleges than do coeducational schools. The positive effects of single-sex schools remain substantial, even after we take 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.

Keywords

Single-sex schools; Random assignment; Causal inferences; College entrance; College entrance exam scores

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-level 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 (United Nations 2000; World Bank 2000). The determinants of schooling and gender differences in schooling, therefore, have 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 (AAUWEF 1998; Datnow and Hubbard 2002; Mael et al. 2005). 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 stereotypically male subjects such as math and science (AAUW 1992; LePore and Warren 1997).

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, although 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 have been proposed as one possible means.

Despite the voluminous literature on single-sex schools, there is far from a consensus on their effects. Several studies have reported 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). However, other studies have found no significant differences between single-sex and coeducational schools and thus question any benefits of single-sex schools (LePore and Warren 1997; Marsh 1989). 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 those differences may reflect selection mechanisms rather than the effects of the schools *per se*. In an educational system such as in the United States, wherein 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 (Jackson 2012; LePore and Warren 1997; Marsh 1989). Although extensive controls for observed characteristics in observational data are helpful, potential biases owing to selection cannot be ignored because some potentially critical factors (e.g., innate abilities and preferences) are likely to remain unobserved.

In this article, 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 (hereafter, Korea): namely, 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, one of the 10 most populous cities in the world, is the capital and largest city in Korea, with more than 10 million inhabitants, accounting for about 20 % of the Korean population.

Specifically, we assess causal effects of single-sex high schools on two pivotal educational outcomes: college entrance exam scores and college attendance rates. 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 attendance rates at four-year colleges and two-year junior colleges 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 64 of 93 countries in the United Nations Development Programme's Gender Empowerment Measure (UNDP 2007). 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 have suggested 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 (Goodlad 1984; Lee and Bryk 1986; Salomone 2003).

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 (Lee and Bryk 1986; UNESCO 2007). 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, but 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 typical coeducational classrooms. Female students also reported enhanced confidence in their abilities in math as a consequence of attending the single-sex math classroom (Streitmatter 2002). 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 also be generated from the nature of interactions between students and teachers. Two versions of student-teacher interaction explanations for single-sex school impacts 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 (Lee et al. 1994; Valentine 1998). 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 tend to have more female teachers than coeducational schools, while all-boys schools tend 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 (1999) 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. Studying eighth grade students and their teachers using data from the National Education Longitudinal Study, Dee (2006:71, 2007) also found that "… girls have better educational outcomes when taught by women and boys are better off when taught by men". 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 the greater effectiveness of single-sex schools 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).[1] However, this effect may not only, or may not at all, reflect role models. Mael et al. (2004), for example, summarized 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 et al. 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, some evidence suggests that single-sex schools display more ordered classroom climates and fewer 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 can teachers of a different gender. We reason that teachers' management of classroom discipline and order can be even more effective when they have 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, conducting such an experiment in the real world is extremely difficult. 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'y ongjunhwa Ch ngch'aek*) (Kim 2003; Lee et al. 1996). This policy created a *de facto* experiment in which middle school graduates were randomly assigned to high schools within their school districts.[2] The random assignment was applied regardless of whether schools are coeducational or single-sex schools so that students could not choose between coeducational and single-sex schools. Although some school districts never implemented the random assignment policy, the randomization was 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 to respond to growing concerns for limited school choice, allowing students to list the two or three schools that they prefer. Then, the school districts randomly select 30 % to 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, but 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, 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.

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

[2] In Korea, middle school students can progress into two types of high schools: academic high schools and vocational high schools. The high school equalization policy is applied only to academic high schools. In recent years, about three of four high school students in Korea have attended academic high schools. In this study, we analyze academic high schools only.

[3] Among 11 school districts in Seoul, one school district, which mainly covers downtown areas with a relatively small number of residents, does not apply the strict random assignment. In this district, students list two to three schools in order of their preference and then are assigned to one of these schools by lottery. We estimate district fixed-effects models, which to some extent should account for this difference. We also tested the robustness of our findings by excluding schools in this particular district, and the results were very robust.

In estimating the effect of single-sex schools, it is important to consider whether single-sex and coeducational schools may differ in teacher quality and other school characteristics as well as students' selection into each type of schools (Jackson 2012). Single-sex schools in Seoul are predominantly private: about 80 % of all-boys and all-girls schools, respectively, are private, and only 30 % of coeducational schools are private. Private schools are also subject to the random assignment of students. Therefore, students attending private and public schools do not differ significantly in terms of socioeconomic background (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 in which the major factor is the applicant's score on the standardized teacher examination; on the other hand, 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 to 5 years, whereas teachers in private schools can stay in the same school for unspecified periods. Therefore, teacher characteristics of single-sex schools, which are heavily private, can differ from those of coeducational schools, which are heavily public. However, as we discuss later, the quality of teachers, at least with respect to measures used in our study, is not higher among single-sex schools (more likely to be private) than coeducational schools (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 instead of 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 % moved into a new school district either within Seoul or outside Seoul. The remaining 95.5 % 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 and science schools, which 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 students attending those specialized high schools is very small (about 3 % of the total student enrollment in academic high schools in Seoul in 2009) and thus specialized high schools are not much of an option for the majority of high school students. In short, noncompliance with the random assignment among students in Seoul seems at most very limited, suggesting that any bias in our estimates caused by noncompliance 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

[4] The mean proportion of coeducational schools within districts among 11 school districts in Seoul is .35, with a standard deviation of .48.

on the national college entrance examination (the 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 per year (usually in November). The government is responsible for grading the test for every student and sending the score to each student. Typically, higher CSAT scores and better high school records are required for four-year colleges than for 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. 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. For other subjects, though, there are multiple tests from which students select a subset. Therefore, to facilitate comparison in this study, we use only Korean and English scores, which are available for every student. Korean and English scores were scaled 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 online (www.schoolinfo.go.kr). 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 teachers (female and male) and the number of students receiving lunch support (provided to students from low-income families). For coeducational schools, the data provide the number of high school seniors and college attendants by gender. Whereas our data for college entrance exam scores cover only one cohort, our data for college entrance rates cover two separate cohorts per school: the 2008 senior cohort and the 2009 senior cohort.[5] However, because this data set does not include any measures for teacher quality, using school names as identifiers, we further attach to this data set 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 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; no school changed its single-sex or coeducational status).[6] Among these 196 high schools, 68 are all-boys, 60 are all-girls, and 68 are coeducational.

[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.

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 data set is student's gender.

To check for balance on the observed characteristics of parents between students in single-sex and coeducational schools, we use another data set, the Korean Educational Longitudinal Survey (KELS), which has tracked a nationally representative sample of 7th graders (the first year in middle school) every year since 2005 (Kim et al. 2006). By the fourth wave of KELS, almost all those original 7th 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., the 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 similar socioeconomic backgrounds and prior academic achievement. When we restrict our 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 whom 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 score on the language exam (either Korean or English) of student i in school j and district k; $\pi_{0\ jk}$ 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

[6] Among a total of 217 academic high schools in Seoul in 2008, we exclude 21 high schools from the analysis. 14 of these schools are excluded because they are foreign language, science schools, and other kinds of special schools that are mostly not subject to the high school equalization policy. The remaining 7 schools are excluded because of missing data (no seniors) or other data problems.

[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 with this national-level data set, including Seoul and other equalization policy areas with some modifications, shows that family characteristics and prior achievement of students attending single-sex schools and those coeducational schools are similar. 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.

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

In this school-level model, school mean scores ($\pi_{0\ jk}$) 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 noted earlier in this article that reduced adolescent social culture and enhanced self-esteem and confidence in learning are potential explanations of single-sex school effects. Our school-level data set 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 versus public, which are likely to have influences on student outcomes and could be potentially correlated with, but not necessarily caused by, single-sex/coeducational schools (cf. Jackson 2012).

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 (γ_{020} – γ_{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 the 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 that these are district fixed-effects regressions. As mentioned earlier, students are randomly assigned within school districts, although 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. As with the models for college entrance exam scores, here 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 student-level data from the KELS to estimate logit models that predict the likelihood of attending a single-sex school (vs. 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 that students attend single-sex schools for either boys or girls. In other words, the results suggest no significant difference in the two observed characteristics of parents and student's prior academic achievement between students currently attending single-sex schools and their peers attending coeducational high schools. This similarity strengthens the claim that the student distribution among Seoul high schools is close to the random assignment. In contrast, studies in the United States and other countries, where students (and their families) may 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; Lee and Marks 1992; Riordan 1990).

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 and also teacher quality, which is often measured by years of teaching experience and schooling attainment among teachers (Akiba et al. 2007; Arum and LaFree 2008; Behrman and Birdsall 1983; Card and Krueger 1996). As we noted earlier, the system of teacher selection and appointment differs between private and public schools. Because of 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 presents ordinary least squares (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, on average, 5.8 senior students per teacher, 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 years 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

[8] Except for the dummy variable for private schools, the four school-level variables are centered on grand means.
[9] The estimates do not change significantly if data from 2008 are also included in these estimates.

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.

Table 1 shows similarities in major family background characteristics of individual students between those attending single-sex schools and those attending coeducational schools. In Table 2, the proportion of students receiving lunch support 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 fare 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 presents the estimates for Korean and English exam scores, 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 earlier. 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 % of 1 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, the teaching experience and years of schooling among teachers, the senior students-teacher ratio, and private/public schools. Controlling for these five school-level variables minimally 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 performance on either the Korean or the English exam. Schools with a higher proportion of students receiving lunch support have a lower mean score for both Korean and English tests.

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 % of 1 standard deviation) (Model 1-1). The corresponding advantage of all-boys schools for English is 3 points (15 % of 1 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 .10 level. Moreover, the estimated effect on English scores shown in Model 2-2 remains substantial. A difference of a few points 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).

[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.

Causal Effects of Single-Sex Schools on College Attendance

Table 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 1 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 the .10 level, with a magnitude that corresponds to 23 % of 1 standard deviation. Moreover, compared with Model 2-1, the negative estimated effect of all-girls schools on two-year junior college attendance rates changes little 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.

In Table 6 for boys, Model 1-1 shows that male students' rate of attending four-year colleges is 5.6 percentage points higher for those who attended all-boys schools than for those who attended coeducational schools. Given that 1 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 the model for 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 2.7 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 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 .10 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 U.S. 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 of 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 (Jackson 2012; LePore and Warren 1997; March 1989).

In this study, we assess 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 were randomly assigned to single-sex or coeducational high schools until 2009. In estimating the effect of single-sex schools, our study significantly overcomes the limitation of previous studies based on associations that may substantially reflect student selection of school types. We 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. Compared with coeducational schools, single-sex schools have a higher percentage of graduates who moved on to four-year colleges and a lower percentage of graduates who moved on to two-year junior colleges. 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 may be 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 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 measures of teacher quality available in our data and are comparable with such measures used in a number of other studies albeit not a complete set of quality measures. Our results show that single-sex schools are not so different from coeducational schools in those key school characteristics. Actually, single-sex schools are slightly disadvantaged in terms of those school characteristics. We acknowledge that single-sex schools and coeducational schools might differ in other ways that could not be considered in our study. To somewhat address this concern, however, we also took into account whether schools are private, for which a dummy variable can capture other possible differences between single-sex schools (mostly private) and coeducational schools (mostly public). Even after controlling for private (vs. public) schools in addition to key school characteristics, the causal effects of single-sex schools remain significant.

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? Considering limitations of our data, we did not attempt in the current study to address specific 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, when the share of male teachers is controlled for. However, we did not find a comparable effect of the share of female teachers on girls. Moreover, the mediation analysis should be conducted with caution, even when treatment (attendance at single-sex schools) is randomly assigned (Bullock et al. 2010; Green et al. 2010). We just note that gender composition of teachers may be a potential 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 research has not focused on the gender composition of teachers 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. However, to our knowledge, there currently 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 studying U.S. 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 that are 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), 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 as well as their entrance into 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 with female-dominant majors than women who attended coeducational schools (Thompson 2003). The finding is not conclusive, however, regarding causality because of selection into single-sex versus coeducational schools. 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.

Acknowledgments

We acknowledge support from the National Academy of Education/Spencer Postdoctoral Fellowship (for Hyunjoon Park), the Spencer Foundation (#20110030), and from the Eunice Kennedy Shriver National Institute of Child Health & Human Development (R03HD066018). The views and opinions expressed herein are those of the authors.

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Table 1

Logit models of attending a single-sex school by socioeconomic backgrounds and prior academic achievement

	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 Achievement 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 Pseudo-Likelihood	− 863.6	− 912.5
N	1,279	1,380

Note: Values in parentheses are standard errors.

Source: Korean Educational Longitudinal Survey (KELS), 3rd–4th waves.

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** (0.089)	−1.119* (0.444)	−0.157** (0.047)	0.004 (0.009)
All-boys schools	0.112 (0.086)	0.297 (0.430)	−0.206*** (0.045)	0.000 (0.009)
Intercept	5.796*** (0.061)	18.296*** (0.304)	16.949*** (0.032)	0.087*** (0.006)
R^2	0.039	0.055	0.104	0.001

Notes: Values in parentheses are standard errors. $N = 196$ (all-boys school, 68; all-girls school, 60; coeducational schools, 68).

* $p < .05$;

** $p < .01$;

*** $p < .001$

Demography. Author manuscript; available in PMC 2014 April 01.

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

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

$^{\dagger}p < .10$;

$^{*}p < .05$;

$^{**}p < .01$;

$^{***}p < .001$

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

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

$^{\dagger}p < .10$;

$^{*}p < .05$;

$^{**}p < .01$;

$^{***}p < .001$

Table 5

Causal effects of single-sex schools on college attendance for girls

	Four-Year College		Two-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

Notes: 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.

$^{\dagger}p < .10$;

$^{*}p < .05$;

$^{**}p < .01$;

$^{***}p < .001$

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

Notes: 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.

† $p < .10$;

* $p < .05$;

** $p < .01$;

*** $p < .001$