Do single-sex schools make girls less interested in predominantly male majors?

Jihye Kam and Yuseob Lee

This study estimates the impact of single-sex schooling on the gender gap in students' choice of college major. Potential endogeneity concerns are mitigated by homogeneous application behavior under the Boston mechanism-type assignment into high schools and college-major-specific admissions policies in South Korea. Single-sex schooling is found to widen the gender gap in the choice of predominantly male majors by attracting girls to gender-balanced majors and boys to predominantly male majors. Recruiting more male mathematics and science teachers, while maintaining the share of female teachers at a certain level, could encourage girls in single-sex schools to pursue predominantly male majors.

Keywords: College major choice, Gender gap, Single-sex schools, Teacher gender
JEL Classification: C39; I20; J16

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This paper is based on, but with significant revised on, the third chapter, "Do single-sex schools make girls less interested in science and engineering majors?," of Yuseob Lee's doctoral dissertation titled "Three Essays in Labor Economics" (2018, Department of Economics, University of Wisconsin-Madison). We thank conference participants at the American Economic Association, Association for Education Finance and Policy, and Southern Economic Association for helpful comments and suggestions. All remaining errors are our own. Authors contributed equally to this paper.

[**Seoul Journal of Economics** 2023, Vol. 36, No. 4]
DOI: 10.22904/sje.2023.36.4.002

I. Introduction

Although more women in most countries are going to college than ever before, they are still making less money than their male counterparts (*e.g.*, Barres 2006; Goldin *et al.* 2006; Kim 2005; McDonald & Thornton 2007; Turner & Bowen 1999). A growing body of research provides evidence that the choice of college major explains a substantial portion of gender pay gap (*e.g.*, Brown & Corcoran 1997; Cho et al. 2018; Gill & Leigh 2000; O'Neill 2003; Xie & Shauman 2003; Zafar 2013). Hence, by understanding why the majority of women continue to choose less profitable majors, policy implications can be drawn for addressing the gender gap in labor market outcomes.

As a policy aimed at reducing the gender gap, single-sex schools in secondary education have been promoted. A large set of empirical studies has found significant effects of classroom or school gender composition on the educational outcomes of students in both primary and secondary education (*e.g.*, Choi *et al.* 2015; Eisenkopf *et al.* 2015; Hoxby 2002; Lavy & Schlosser 2011; Lu & Anderson 2015; Whitmore 2005). The positive effects of same-gender peers on academic achievement, especially for women, have been explained by the argument that single-sex schools, where opposite-gender counterparts are absent, may help mitigate negative gender stereotyping and rigid gender roles (Kessels & Hannover 2008; Pahlke, Bigler *et al.* 2014; Patterson 2012).

Despite extensive literature on the benefits of single-sex schooling, the effects are still under debate regarding whether single-sex schooling has persistent long-term effects (Anelli & Peri 2019; Carrell *et al.* 2018; Lu & Anderson 2015) and whether the potential endogeneity of school choice is corrected (Angrist 2014; Evans *et al.* 1992; Lee 2007; Manski 1993; Moffitt 2001). If single-sex schooling affects test scores but not long-term outcomes, such as career paths and earnings, the growing concerns over school gender composition may be overstated. In contrast, if its effects do not diminish over time, single-sex schooling can explain a significant portion of the gender gap in the choice of college majors and, consequently, labor market outcomes. In this study, we bridge the gap between the literature on single-sex schooling and that on the gender gap in college major choice by examining to what extent the gender composition of high school peers influences the choice of a college major.

In this research setting, the key analytical challenge for endogeneity lies in two potential sources of correlation: one between student and school characteristics, and the other between students' college experience and their choice of major. To mitigate this potential endogeneity concern, this study takes advantage of the unique educational system in South Korea, which possesses two critical features essential for developing an estimable model of the effects of single-sex schooling.[1] First, students in South Korea exhibit homogeneous application behavior under the Boston mechanism-type assignment system, which is effectively akin to random assignment in equalized education districts consisted of multiple all-boys, all-girls, and coeducational schools. In other words, some students may be assigned to a single-sex school without regard for their preference as a result of a lottery administered by each Regional Office of Education.[2] The induced randomness in the assignment of students to either single-sex or coeducational schools helps alleviate endogeneity concerns to some extent.

Second, South Korea employs college[3]-major-specific admissions policies, which require a student to make a joint application decision for a college-major pair.[4] Changing a major is allowed for only a few

[1] Many studies examined the impact of single-sex schooling (often interpreted as "peer effect") using the South Korean educational setting. Most of them, however, focused on academic outcomes (*e.g.*, Kang 2007; Kim *et al.* 2008; Lee *et al.* 2015; Pahlke, Hyde *et al.* 2014; Park *et al.* 2013; Sohn 2016).

[2] The Regional Office of Education is primarily responsible for establishing, administering, and coordinating education policies and practices to promote equity and quality in education throughout its administrative districts. There are a total of 17 Regional Offices of Education, which include seven Metropolitan Offices of Education (Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, and Ulsan), eight Provincial Offices of Education (Gyeonggi-do, Gangwon-do, Chungcheongbuk-do, Chungcheongnam-do, Jeollabuk-do, Jeollanam-do, Gyeongsangbuk-do, and Gyeongsangnam-do), and two Metropolitan Autonomous City Offices of Education (Jeju and Sejong).

[3] In South Korea, the term "*college*" refers to both two-year colleges and universities, while "*university*" refers to both four-year colleges and universities. It's important to note that there are no liberal arts colleges in South Korea. In this paper, the term "college" is used to encompass both colleges and universities.

[4] The term "college-major-specific admissions policies" is defined by Bordon and Fu (2015), who examined the equilibrium effects of postponing student

students when the enrollment capacity for a particular program is not met due to student dropout and leaves of absence. Consequently, the majority of students complete their degree in the major they selected during the application process, relying on information collected during their secondary education. This admissions system allows for the documentation of potential long-term effects of single-sex schooling by establishing a connection between the gender composition of high school peers and the choice of major in college.

Our estimation results show that single-sex schooling does not narrow the gender gap in the choice of college majors. More male students choose predominantly male majors (*e.g.*, Engineering) or predominantly female majors (*e.g.*, Medicine/Public Health, Humanities/Social Science, Education, and Arts/Athletics) rather than gender-balanced majors (*e.g.*, Science and Business/Economics) in the context of single-sex schooling. On the contrary, relatively fewer female students choose predominantly male majors in single-sex schooling. These results contradict the findings of Billger (2009) that single-sex schools yield the least segregated college major choices within the U.S. educational setting, where endogeneity might confound the results due to preference-based school choice. As a measure of segregation, Billger (2009) used the Duncan index (Duncan, O.D. & Duncan, B. 1955) to aggregate the absolute difference between male and female students across college majors. To decrease the gender gap as defined by the Duncan index in our setting, female students should be reallocated away from predominantly female majors, while male students should be reallocated toward predominantly female majors. However, the observed reallocation pattern due to single-sex schooling does not make notable differences in terms of the Duncan index.

A possible interpretation of the results is that the imbalanced gender distribution of peers and teachers in single-sex schools induces a stereotype threat, which shapes rigid gender roles. This is in line with Halpern *et al.*'s (2011) argument that sex segregation increases gender stereotyping and legitimizes institutional sexism. This hypothesis is examined in reference to differences in teacher gender composition by school type. The share of female teachers within a school is shown to

choice of major using the Chilean educational setting. For more detailed information about Korean college admissions policies, please refer to Cho *et al.* (2018).

influence the magnitude of the effect size for the causal relationship between single-sex schooling and the gender gap in major choice.

The results have policy implications for the debate on single-sex schooling. Despite its positive effect on academic achievement, particularly for female students, single-sex schooling contributes to widening the gender gap in college major choice. The findings of this study provide insight into one potential mechanism underlying this effect by addressing the imbalanced teacher gender ratio in favor of female teachers at all-girls high schools. The value of single-sex education will be further enhanced if a policy intervention effectively encourages a school to recruit more male mathematics and science teachers while increasing the overall proportion of female teachers. This policy will ultimately lead to the promotion of gender equity in science, mathematics, engineering, and mathematics (STEM) disciplines, which are predominantly male fields in most countries.

The rest of this paper proceeds as follows: Section 2 provides institutional background information about the educational system in South Korea, which guides the development of the baseline model of this study. Section 3 describes the data and empirical framework. Section 4 presents estimates from the regression analyses of longitudinal data. Section 5 discusses the possible channels and mechanisms through which school gender composition affects major choice. Section 6 concludes.

II. Institutional background

To alleviate the potential endogeneity issues found in earlier related studies, this study uses the Korean educational setting for two reasons: homogeneous application behavior under the Boston mechanism-type assignment, which effectively assign students, in random fashion, into general high schools in equalized education districts; the college-major-specific admissions policies.

A. Homogeneous application behavior under the Boston mechanism

The Education Statute (now the Framework Act of Education) was established in 1949 to enforce the constitutional right to an equal opportunity for education in South Korea. The statute included the compulsory education scheme at the elementary level (grades 1–6) and was revised in 1984 to extend it to the lower secondary level (grades 7-9).[5] Accordingly, all children aged six on the day before the first day of school are mandated to attend elementary schools.[6] The compulsory elementary education scheme led to a dramatic increase in the number of middle school applicants and intense competition for admission to prestigious schools. To increase the acceptance rate for top-tier schools, the elementary school curriculum was changed to focus more on preparing students for the middle school entrance exam,[7] and parents spent more money on after-school private tutoring for their children. As a result, educational inequality was further exacerbated.

Two policies were newly introduced to address educational inequality in secondary education in the late 1960s and early 1970s. In 1968, the Ministry of Culture and Education (now the Ministry of Education)[8] proposed the replacement of middle school entrance exam with a lottery system, which randomly assigned students into middle schools within their school districts. The rationale of the lottery system was to guarantee equal access to lower secondary education for all students regardless of their academic and socioeconomic backgrounds.

[5] South Korea has a homogeneous K-12 education system, consisting of 1-3 years of kindergarten education, six years of elementary education, three years of lower secondary education, and three years of upper secondary education. Nursery, pre-K, and kindergarten education are not compulsory, but the fees can be partially supported by the government. There are no other forms of schools spanning grades K-5, 6-8, 7-8, 7-9, and 9-12.

[6] The first day of school is homogeneous nationwide, occurring on September 1 from 1946 to 1949, June 1 in 1950, April 1 from 1951 to 1961, and March 1 since 1962 to the present. In 2007, the Education Statute was revised in parliament to change the compulsory school entrance age to six on the last day of the year before the first year of school and became effective in the academic year 2009/2010.

[7] The middle school entrance exam was standardized at different levels, including the school level (1945-1950, 1954-1957, 1966), the province level (1958-1961, 1963-1965, 1967), and the national level (1951-1953, 1962).

[8] The Ministry of Culture and Education was established in 1948 and restructured as the Ministry of Education in 1990. The Ministry of Education was further reorganized as the Ministry of Education and Human Resources Development in 2001. In 2008, the Ministry of Education, Science and Technology was created through the merger of the Ministry of Education and Human Resources Development and the Ministry of Science and Technology, but it was later split into the Ministry of Education and the Ministry of Science, ICT, and Future Planning in 2013.

This lottery system was adopted first in Seoul (1969), later in nine cities[9] (1970), and finally in the whole country (1971). Similar to the consequence of the prior compulsory elementary education scheme, increased access to middle schools, due to the lottery system, resulted in a surge of middle school graduates. It also triggered fierce competition for admission to prestigious high schools, further exacerbating school stratification in upper secondary education.

To mitigate those adverse effects, the Ministry of Culture and Education legislated the high school equalization policy in 1973. As a parallel to the lottery system in middle school admissions, it proposed the random assignment of students into general high schools within their school districts, unless they were admitted to special-purpose or vocational high schools.[10] The initial plan of the Ministry of Culture and Education was to execute the high school equalization policy nationwide until 1985. However, its nationwide implementation was deferred in 1980 due to concerns raised by the uneven distribution of school quality between and within districts in suburban and rural areas. In 1982, the high school equalization policy was revised to address these concerns by rearranging school districts and mandating all general high schools to provide different levels of classes for students of different abilities and after-school supplementary classes. At the same time, science magnet high schools[11] were introduced to minimize the potential disadvantages of gifted students in the equalized high school system.

[9] Busan, Daegu, Gwangju, Incheon, Jeonju, Daejeon, Chuncheon, Cheongju, and Jeju.

[10] Two types of special-purpose high schools, namely physical education and arts high schools, were established in 1974 with the aim of educating talented students in athletics and the arts. On the other hand, vocational high schools, such as commercial, technical, and agricultural high schools, focus more on career and professional training. The admissions process for special-purpose and vocational high schools is completed before the general high school admissions process begins, allowing unsuccessful applicants to apply to general high schools.

[11] Science high schools were established to educate gifted students in mathematics and science. In 1990, foreign language high schools were established to educate linguistically gifted students. While all science high schools are public schools, most foreign language high schools are private schools. The admissions process for science and foreign language high schools is completed before the general high school admissions process begins, allowing unsuccessful applicants to apply to general high schools.

In spite of these efforts, the high school equalization policy could not be implemented nationwide due to different institutional features of school system in each area municipality. The Regional Offices of Education were hereby delegated the entire authority to grant, modify, and deny (or delay) enforcement of the high school equalization policy in their school districts. The policy was enforced or disregarded based on the infrastructure and other facilities of schools as well as residents' opinions and perceptions of it. As of 2008, 13 Regional Offices of Education fully or partially implemented the high school equalization policy.[12] For convenience,, we define such areas as "equalized education districts" in the rest of this paper.

In equalized education districts, three steps were included in the general high school application process. First, middle school seniors submitted an application to their middle schools for general high school admissions in the subsequent academic year. Second, each middle school sent all collected applications to the Regional Office of Education, which was responsible for the administration and supervision of its school districts. Third, the Regional Office of Education assigned applicants to a general high school within their school district.

[12] As of 2008, the high school equalization policy was implemented by the Seoul, Busan, Daegu, Incheon, Gwangju (partial), Daejeon, and Ulsan (partial) Metropolitan Offices of Education, as well as the Gyeonggi (partial), Chungcheongbuk (partial), Jeollabuk (partial), Jeollanam (partial), Gyeongsangnam (partial), and Jeju (partial) Provincial Offices of Education. By contrast, the Gangwon, Chungcheongnam, and Gyeongsangbuk Provincial Offices of Education did not adopt the high school equalization policy while maintaining an admissions system that required all high school applicants to send the application package to each school they want to attend after taking a district-wide entrance exam. Therefore, the high school equalization policy was enforced and implemented in 7 metropolitan cities and 21 cities of six provinces: Seoul and Busan (except Gijang-gun) (1974); Daegu (except Dalseong-gun), Gwangju, and Incheon (except Ganghwa-gun, Yeongjong-do, and Ongjin-gun) (1975); Cheongju, Daejeon, Jeju, Jeonju, Masan (now Changwon Masanhoewon-gu and Masanhappo-gu), and Suwon (1979); Changwon (now Changwon Seongsan-gu and Uichang-gu), Jinju, and Seongnam (except Bundang-gu) (1980); Ulsan (except Ulju-gun, 2000); Anyang, Gwacheon, Gunpo, Uiwang (Anyang-kwon), Bucheon, Goyang, and Seongnam (Bundang-gu) (2002); Suncheon and Yeosu (2005); Gimhae (2006); Pohang (2008); Ansan, Gangneung, Gwangmyeong, and Uijeongbu (2013); Yongin (2015); Chuncheon (1979–1991/2013); Gunsan (1980–1990/2000); Iksan (1980–1991/2000); Mokpo (1980–1990/2005); Wonju (1980–1981/2013); Cheonan (1980–1995/2016); and Andong (1980–1990).

Although students were asked to list three or four schools in order of their preference on the application form, the assignment rule relied heavily on the strict random selection and/or the distance between residence and school to obtain educational equality throughout school districts. Transferring to a neighborhood school was not legally allowed even when students did not like their assigned school.[13] Despite its contribution to an increase in educational equality, this strict random assignment procedure raised a constitutional challenge to Article 31 Section 4 which allows individuals' autonomy with regard to their decisions about educational choice.[14]

In response to those challenges, a new assignment rule, "multiple applications-then-lottery assignment," was limitedly implemented to allow students applying for high school admissions to their preferred schools regardless of residential location since the academic year 1996/1997.[15] The multiple applications-then-lottery assignment rule, close to the well-known Boston mechanism, enables schools to fill 30-100 percent of the freshman class through a computerized lottery based on student preferences and the rest of seats through the strict random assignment of students into high schools within their school district subject to residential area.[16] Specifically, a student can be assigned to the school listed as their first choice if the sum of students who chose

[13] Transferring to another school was allowed only if their household address was changed to a location in a different school district. In 2008, Seoul amended its transfer rule to allow students to transfer to a neighborhood school if the president of the transfer-out school approves a student's transfer and a vacancy in the transfer-in school occurs.

[14] Information was retrieved from the National Archives of Korea website: http://www.archives.go.kr.

[15] The multiple applications-then-lottery assignment was initially implemented as a pilot policy in 1996 (*e.g.*, 23 schools in Seoul) and later was officially enforced in restricted areas of the equalized educational districts (*e.g.*, the fifth school district of Seoul).

[16] The maximum percentage allowable for school seats in a manner that reflects student preferences was determined by each Regional Office of Education, taking into account the achievement gap within and between schools throughout its districts. For example, in 2002, Gyeonggi Provincial Office of Education implemented a different multiple applications-then-lottery assignment rule in Anyang, Gwacheon, Gunpo, Uiwang (Anyang-kwon) (for 40% of each school's freshmen enrollment capacity), Bucheon (for 100%), Seongnam, Goyang (for 50%), and Suwon (for 70%).

the same school as their first choice does not exceed the maximum number allowable for preference-based admissions. If the first-choice school is full, then students are assigned to their second choice In the final lottery, a student who unluckily fails to be offered a place at one of the schools listed on their application is randomly assigned to any school that still has open seats in the freshman class, regardless of their preference. If all the seats in high schools located near the residential area are filled, then students are assigned to high schools located far from their homes.

Likewise, the high school assignment system is no longer strictly random in equalized education districts but still provides a unique opportunity to study the effects of single-sex schooling due to a similar school choice among high school applicants. Most applicants list schools located near their residential area in order of the prestigious rankings of high schools determined by the school-wide average score of the College Scholastic Ability Test (CSAT) and the total number of alumni admitted to top-tier colleges. This information can be easily derived from a handful of newspapers and school placards.[17] If all students list the same schools in the same order based on same information, high school admissions outcomes under the multiple applications-then-lottery assignment are not significantly different from those under the strictly random assignment.[18] Hence, the high school admissions system in equalized education districts can alleviate the potential endogeneity of student characteristics to some extent.

A new form of high school called autonomous private high school was introduced in 2009 to meet demands for more diverse school choice options. Extensive autonomy in terms of administrative and financial

[17] To demonstrate the prestige of a school, most schools voluntarily create and display a large placard outside their building. These placards typically list the total number of graduates admitted to institutions such as Seoul National University, Yonsei University, Korea University, Pohang University of Science and Technology, and the Korea Advanced Institute of Science and Technology.

[18] The list of preferred high schools was often chosen based on the historical school rankings and the commuting distance to the school. To minimize the risk of being assigned to a school far from their residential area, students tend to adopt risk-averse application strategies. This risk-averse behavior leads to a homogeneity in students' choices of preferred high schools (Lee 2016). Consequently, both popular and less popular high schools utilize a lottery system to select their applicants.

management is provided to autonomous private high schools through the "Core Schools" project by the Ministry of Education. For example, the autonomous private high schools can admit applicants based on eligibility requirements specific to their own admissions criteria and application procedures, determine tuition rates, and design curriculum and instruction. The introduction of autonomous private high school can affect students' school choice which is associated with the potential endogeneity bias between student and school characteristics. Therefore, this study will use the sample of the cohort who entered high schools before 2009 to examine the effect of single-sex schools on the gender gap in the choice of college major.

B. A college-major pair admissions rule

South Korea has adopted college-major-specific admissions policies, requiring students to make application decisions for a college-major pair. In contrast to college-then-major admissions policies widely used in Western countries like Canada and the U.S., in South Korea, students cannot be admitted without declaring their majors.[19] This means that students must specify both their desired college and major when applying for admission. South Korean students have the option to apply to either two-year vocational or technical colleges or four-year research colleges. During an application season, students can submit up to three applications to four-year colleges.[20] In the case of two-year colleges, such restriction does not apply. The Korean government designates three separate periods for the four-year college admissions process, and each college can choose one day within each period for their admissions. For each period, only one application of a college-major pair is allowed[21] (for detailed information, see Avery *et al.* 2014).

[19] Only a limited number of colleges admit students without requiring them to declare their majors. For more comprehensive details on college-major-specific and college-then-major admissions policies, refer to Bordon and Fu (2015).

[20] Note that these restrictions do not apply to certain four-year colleges, which include vocational universities known as "University of Science and Technology," distance universities referred to as "Open University" or "Cyber University," and the Korea Advanced Institute of Science and Technology.

[21] Under this admissions regime, students are not required to apply for the same major across the three colleges they choose. For instance, a student can apply to "A" university with a major in "Engineering," "B" university with a major

Changing a major is allowed only in limited cases when the enrollment capacity for a particular major program is not met due to students dropping out or taking leave of absence for purposes such as study abroad, internships, or compulsory military service.[22] This small quota to the transfer-in program intensifies competition for transfer approval, which is primarily based on the grade point average of the student. As a result, the majority of students stick with their initially chosen major during the application period. Therefore, college major choice in South Korea is not significantly affected by college-related variables due to these college-major-specific admission policies. This unique admissions system allows for the estimation of the effect of single-sex schooling on the gender gap in the choice of college major, using longitudinal data that tracks students from high school to college.

III. Data and empirical framework

Two restricted-use datasets are combined to understand the effect of high school characteristics on students' choice of college major over time: (1) the Korean Education Longitudinal Survey (KELS) and (2) the Pre-primary, Primary, and Secondary Education Statistics (hereafter called Education Statistics). Using the merged data, this study empirically examines the effect of single-sex schooling on college major choice through multiple regression analyses.

A. Data source

For baseline analyses, we use data from the KELS, an ongoing longitudinal study of a nationally representative sample of 6,908 adolescents who were in the first grade at middle school in South Korea during the 2005-06 school year. Administered by the Korean Educational Development Institute (KEDI), the KELS was launched

in "Science," and "C" university with a major in "Nursing." This system enables students to develop their own application strategy to maximize their chances of being admitted (For more details, refer to Cho *et al.* 2018).

[22] Students have the option to take a voluntary leave of absence for purposes such as study abroad, internships, or compulsory military service. In South Korea, it is mandatory for every man over the age of 18 to serve in the military for approximately two years, unless they are disabled or under special conditions (For more information, see Kam 2016).

to investigate the academic and social progress of young adults throughout their education and career development. The current released data provides rich information on student and school characteristics from 2005 through 2011. To link the characteristics of high school from which a student graduated to their major chosen when first enrolled in a college, we use KELS data collected from 2008 to 2011.[23] The fourth to the sixth waves of the KELS cover student and school characteristics throughout high school while the seventh wave documents the postgraduate outcomes of each student. These four waves of the KELS are analyzed to understand the impact of single-sex schooling on college major choice.

In the next step, we narrow the sample down to students who entered in March 2008 and graduated in February 2011 from high schools located in equalized education districts and enrolled in two or four-year colleges in March 2011. The random assignment of students to high schools in equalized education districts can help alleviate the endogeneity concerns. This identification strategy is further refined by excluding students who transfer to other schools[24]. To determine whether a school is located in an equalized education district and to control for district-level characteristics, school district information is needed. Although the KELS does not provide a school's district code, it provides sufficient information to identify a district for each school by matching 10 variables including an identifier for school location type (capital, metropolitan, urban, and rural), school type (coed, all boy's, and all-girls; national/public and private), school gross floor area, principal's gender, and the number of classes by grade, as well as the number of students by grades and gender, with equivalent information in the Education Statistics.

The reliability of variables on school characteristics can be enhanced by matching them across two datasets. Administrated by the KEDI, the Education Statistics is a nationwide census of all schools It annually collects comprehensive information about school characteristics, ranging from school gender composition to financing and administration. Basic information for all schools, such as the

[23] The sample attrition rate from 2008 to 2011 is 4.60 percent.

[24] Only five students in the sample have transferred to another school during their high school years.

number of teachers and students by gender, is provided through the Korean Educational Statistics Service by the KEDI. Additionally, more detailed information, such as teacher information by subject or title, is available through the Korea Education and Research Information Service via the EduData Service System. This step allows for the acquisition of information about the gender composition of teachers by subject for each school. The baseline sample is ultimately constructed by combining the KELS and the Education Statistics, including only schools that are consistently coded as either single-sex or coeducational schools throughout every year of the sample.

The key outcome variable of this study is college major m_i of individual *i*. The KELS dataset offers comprehensive information on students' majors. To facilitate analysis and interpretation, we group detailed majors into seven categories: Engineering, Science, Medicine/Public Health, Humanities/Social Science, Economics/Business, Education, and Arts/Athletics (see Table 1). The differences in college major distribution across gender are statistically significant at the 1 percent level, as indicated by the Kolmogorov-Smirnov test. To provide policy-relevant insights into the gender gap in specific fields between upper secondary and higher education, college majors are further classified into three categories based on t-statistics of gender composition: predominantly male (*e.g.*, Engineering, t = 20.96), predominantly female (*e.g.*, Medicine/Public Health, t = -10.17; Humanities/Social Science, t = -4.97; Education, t = -7.27; and Arts/Athletics, t = -6.22), and gender-balanced majors (*e.g.*, Science, t = 1.65; and Business/Economics, t = -1.42). Using the differences between the proportion of males and females in a specific major group, we conduct t-tests by college type (two-year and four-year colleges) to test the null hypothesis that the gender proportions are the same. The results of t-test show the different gender composition of students by field of study across college types. For example, Humanities/Social Science majors are categorized into gender-balanced majors among two-year colleges (t = -0.89) and into predominantly female majors (t = -6.04) among four-year colleges. Therefore, to minimize potential conflicting effects, the baseline sample is further restricted to students who enrolled in four-year colleges. Tables 2 and 3 describe the summary statistics for the baseline sample. As reported in Table 4, the distribution of college majors in the baseline sample is comparable to that of the population.

B. Empirical framework

To estimate the impact of single-sex schooling on the gender gap in college major choice, we use a regression model with the following form:

$$Y_i^m = \alpha^{SS} SS_{s(i)}^f + \alpha^{coed} Coed_{s(i)}^f + \beta SS_{s(i)} + X_i'\lambda + Z_{s(i)}'\eta + \Pi'_{c(i)}\tau + \rho_{d(i)} + \varepsilon_i \quad (1)$$

where i represents a student who graduated from a high school $s(i)$ located in district $d(i)$ and proceeds to college $c(i)$, Y_i^m is 1 if a student i selects a major m at college, $SS_{s(i)}^f$ is 1 if the student is a female graduate from a single-sex high school $s(i)$, $Coed_{s(i)}^f$ is 1 if the student is a female graduate from coeducational high school $s(i)$, $SS_{s(i)}^f$ is 1 if the student i graduated from a single-sex high school $s(i)$, X_i is a vector of student characteristics, $Z_{s(i)}$ is a vector of high school characteristics, $\Pi_{c(i)}$ is a vector of college-specific characteristics, $\rho_{d(i)}$ includes a full set of school district dummies, and ε_i is the error term. The parameters of interest are α^{SS} and α^{coed}, which estimate the gender gap in college major choice among students in single-sex and coeducational schools, respectively. College majors are classified into three categories: predominantly male, predominantly female, and gender balanced majors. If $\alpha^{SS} < 0$, female students at single-sex schools are less likely to select a major m than their male counterparts at single-sex schools. Similarly, if $\beta + \alpha^{SS} - \alpha^{coed} < 0$, female students at single-sex schools are less likely to select a major m than their female counterparts at coeducational schools. If $\beta < 0$, male students at single-sex schools are less likely to select a major m than their male counterparts at coeducational schools. Therefore, $\alpha^{SS} - \alpha^{coed}$ $(= \beta + \alpha^{SS} - \alpha^{coed} - \beta)$ measures the effect of single-sex schooling on the gender gap in the choice of a major m. A positive value $(\alpha^{SS} - \alpha^{coed} > 0)$ indicates that single-sex schooling encourages relatively more females to select major m.

Although estimates from Equation (1) show whether and to what extent single-sex schooling affects students' decisions in selecting a college major, results cannot be interpreted as the sole effect of school gender composition on the student body. Referring back to Table 2, by school type, another significant difference is observed in the proportion of female teachers within a school. This difference is more pronounced when broken down by private and public schools.[25] The proportion of

[25] Note that the baseline sample only includes general high schools located

female teachers in public single-sex schools is higher than that in their private counterparts, where more autonomy is offered —for example, he proportion of female teachers in public all-girls schools is 0.64, whereas that in their private counterparts is 0.47. Similarly, the proportion of female teachers in public all-boys schools is 0.52, and that in their private counterparts is 0.16. These statistics support a strong preference of private single-sex schools in hiring teachers with same gender as the student body. Motivated by these statistics, we attempt to gauge the indirect effects of single-sex schooling possibly associated with the proportion of female teachers within a school.

To examine the indirect single-sex schooling effects interacting with the share of female teachers within a school, a regression model of the following form is estimated.

$$\begin{aligned} Y_i^m &= \alpha^{SS} SS_{s(i)}^f + \alpha^{coed} Coed_{s(i)}^f + \beta SS_{s(i)} + \alpha_1^{SS} SS_{s(i)}^f \times FF_{s(i)} \\ &+ \alpha_2^{coed} Coed_{s(i)}^f \times FF_{s(i)} + \beta_1 SS_{s(i)} \times FF_{s(i)} + X_i'\lambda + Z_{s(i)}'\eta \\ &+ \Pi_{c(i)}'\tau + \rho_{d(i)} + \varepsilon_i \end{aligned} \tag{2}$$

where Y_i^m is 1 if a student selects a major m at college, $SS_{s(i)}^f$ is 1 if the student is female, graduating from a single-sex high school, $Coed_{s(i)}^f$ is 1 if the student is female, graduating from a coeducational high school, $SS_{s(i)}$ is 1 if the student graduated from a single-sex high school, $FF_{s(i)}$ is the proportion of female teachers within a school, $SS_{s(i)}^f \times FF_{s(i)}$, $Coed_{s(i)}^f \times FF_{s(i)}$, and $SS_{s(i)} \times FF_{s(i)}$ are a full set of interaction terms between school type and the proportion of female teachers within a school, X_i is a vector of the student's characteristics, $Z_{s(i)}$ is a vector of high school-specific characteristics, $\Pi_{c(i)}$ is a vector of college-specific characteristics, $\rho_{d(i)}$ is a full set of school district dummies, and ε_i is the error term. The parameters of interest are α^{SS}, α^{coed}, α_1^{SS}, and α_2^{coed}. With the same logic of the baseline analyses, $\alpha^{SS} - \alpha^{coed} + (\alpha_1^{SS} - \alpha_2^{coed}) \times FF_{s(i)}$ measures the effect of single-sex schooling on the gender gap in the choice of a major m. If single-sex schooling encourages females to select a major m, $\alpha^{SS} - \alpha^{coed} + (\alpha_1^{SS} - \alpha_2^{coed}) \times FF_{s(i)}$ will be positive.

in equalized education districts. Accordingly, there is no systematic difference between private and public schools in terms of curriculum, instruction, teacher quality, tuition and fees, and building and other physical infrastructure.

IV. Results

A. Main findings

The results do not fully support the popular hypothesis that single-sex schooling can reduce gender stereotypes. Single-sex schooling is not associated with more female students choosing predominantly male majors towards which more male students are directed under single-sex schooling. Table 5 displays estimates from Equation (1). Column (1) of Table 5 shows that among students who enroll in four-year colleges after their high school graduation, female students are 34.7 percentage points less likely to select a predominantly male major (*i.e.*, Engineering) than their male counterparts in single-sex schools, and 19.3 percentage points less likely than their male counterparts in coeducational schools, both at the 0.01 significance level. On average, single-sex schooling is found to widen the gender gap in the choice of predominantly male majors by 15.4 percentage points compared to coeducational schooling, at the 0.05 significance level.

In contrast, female students are more likely to choose a predominantly female major (*i.e.*, Medicine/Public Health, Humanities/Social Science, Education, and Arts/Athletics) by 24.9 percentage points compared to their male counterparts in single-sex schools and by 32.6 percentage points compared to their male counterparts in coeducational schools, both at the 0.01 significance level. Despite these significant relationships, the gap in the choice of predominantly female majors among female students and male students between all-girls' or all-boys' schools and coeducational schools is not statistically significant at the 0.10 level. Accordingly, no statistical difference is found in women's likelihood of choosing a predominantly female major between single-sex and coeducational schools (column (2) of Table 5).

There is no statistically significant gender gap in the selection of gender-balanced majors (*i.e.*, Science and Business/Economics) between all-girls' and all-boys' schools. In contrast, female students in coeducational schools are 13.4 percentage points less likely to choose a gender-balanced major compared to their male counterparts. Similarly, male students in single-sex schools are 15.9 percentage points less likely to opt for a gender-balanced major compared to their male counterparts in coeducational schools. Although female students in single-sex schools are 7.3 percentage points more likely to choose gender-balanced majors, this result is not statistically significant at the 0.10 level. Consequently, the gender gap in the choice of gender-balanced majors is reduced by 23.2 percentage points due to single-sex schooling, as demonstrated in column (3) of Table 5.

Similar to Billger (2009), we can define two Duncan indices (Duncan, O. D. & Duncan, B. 1955) as below:

$$D^{SS} = \frac{1}{2}\sum_j \left| \frac{n^f_{SS,j}}{n^f_{SS}} - \frac{n^m_{SS,j}}{n^m_{SS}} \right|$$

$$D^{coed} = \frac{1}{2}\sum_j \left| \frac{n^f_{coed,j}}{n^f_{coed}} - \frac{n^m_{coed,j}}{n^m_{coed}} \right|$$

where $n^f_{SS,j}$ and $n^m_{SS,j}$ represent the number of female and male students in major j from single-sex school, while $n^f_{coed,j}$ and $n^m_{coed,j}$ represent the number of female and male students in major j from coeducational school. n^f_{SS}, n^f_{coed} (n^m_{SS}, n^m_{coed}) represent the number of female (male) students from single-sex school and from coeducational school, respectively. The Duncan index aggregates the absolute difference in major composition between male and female students. Given that the observed gender gap is positive in predominantly female majors but negative in predominantly male majors and gender-balanced majors, in our setting, decreasing the Duncan index would involve reallocating female students away from predominantly female majors, while male students should be reallocated toward predominantly female majors. Thus, the observed reallocation pattern due to single-sex schooling does not make notable differences in terms of the Duncan index.

To investigate how students change their intention to major in a specific discipline during high school years, Equation (1) is estimated with intended majors. In this analysis, the sample is narrowed to students who report their intention to attend four-year college after graduating high school in every year of the sample regardless of their actual college placement. Table 6 presents the estimates of the single-sex schooling effect on the gender gap in the intended choice of college majors by grade. As reported in column (1) of Table 6, the extent of the single-sex schooling effect on the gender gap in the intended choice of predominantly male majors increases as students progress through grades 1-3. For example, on average, single-sex schooling widens the gender gap in the intended choice of predominantly male majors by 1.7 percentage points in the freshman year, by 3.7 percentage points in the sophomore year, and by 14.1 percentage points in the senior year. The results also show the contribution of single-sex schooling to the reallocation of female students from predominantly male majors to gender-balanced majors (columns (1) and (3) in Table 6). Changes in the significance levels of the single-sex schooling effect can indicate no notable gender difference in students' intended major choice by school type in the freshman year. That is, influenced by schooling effects specific to school type, students may change their intended college major. The mechanism underlying the single-sex schooling effect will be discussed in the following section.

These findings support that school type matters in recognizing students' own abilities and preferences in learning. In particular, single-sex schooling is associated with the reallocation of female students from predominantly male majors to gender-balanced majors, while the net change in the gender gap is not statistically significant for predominantly female majors at a conventional level. In other words, all else being equal, female students at single-sex schools are more likely to select a predominantly female major or a gender-balanced major than their female counterparts in coeducational schools.

B. Evidence on mechanisms

Table 7 displays estimates from Equation (2). The results are generally consistent with the findings from Section 4.1, supporting significant single-sex schooling effects on the gender gap in the choice of a college major. The substantial coefficients of the interaction terms provide evidence of the indirect single-sex schooling effects associated with the proportion of female teachers within a school. These findings imply that the gender composition of teachers may serve as the underlying mechanism through which single-sex schooling affects students' choice of a college major. Using this mechanism, a school can either offset or enhance the single-sex schooling effects. For example, the negative effect of single-sex schooling on the gender gap in the choice of predominantly male majors can be nullified if a school increases its share of female teachers to 57.8 percent or higher.

Similarly, to diminish the single-sex schooling effect on the gender gap in the choice of predominantly female majors and gender-balanced majors, a school needs to maintain its share of female teachers at 41.7 percent and 23.7 percent, respectively.

In a hypothetical scenario where the proportion of female teachers at private all-girls schools (0.47) is the same as that of public all-girls schools (0.64), the effect of single-sex schooling on the gender gap in the choice of predominantly male majors could become positive. In this scenario, all else being equal, a portion of the female group, which previously tended to choose gender-balanced majors, may opt for predominantly male majors. Consequently, the gender composition of teachers is revealed to be a significant factor in determining the gender gap in the choice of college major at high schools. This finding contrasts with the results of Lee *et al.* (2015), who found little evidence supporting the influence of teacher gender on the gender gap in academic achievement across school types.

To further investigate whether the subjects taught by female teachers have an impact on alleviating single-sex schooling effects on the gender gap in college major choice, additional analyses were conducted. Table 8 presents the estimates of Equation (2) with the proportion of female teachers by subject: mathematics and science versus non-mathematics and science. In a hypothetical scenario where the proportion of female teachers increases from the mean level of all-girls schools (0.53) to 0.58, the estimated proportion at which the single-sex schooling effect on the choice of predominantly male majors is nullified, but with only new hires of female mathematics and science teachers, the effect intensifies. On average, the proportion of female teachers at all-girls schools (0.53) consists of 23.3 percent mathematics and science teachers (0.12) and 76.7 percent non-mathematics and science teachers (0.41). Under this female teacher composition, single-sex schooling widens the gender gap in the choice of predominantly male majors by 17.1 percentage points compared to coeducational schooling, at the 0.05 significance level. However, if all increases in the share of female teachers are due to a rise in the proportion of female teachers instructing mathematics or science, while maintaining the proportion of female teachers instructing non-mathematics or science at 0.41, the single-sex schooling effect can be intensified, resulting in a gap of 35.9 percentage points. On the other hand, if all increases in the share of female teachers are induced by raising the proportion of female teachers instructing non-mathematics or science, while maintaining the proportion of female teachers instructing mathematics or science at 0.12, the single-sex schooling effect can be nullified.

These results suggest that the overall proportion of female teachers is linked to the shifting of female students from predominantly female majors to gender balanced majors. Additionally, the proportion of male teachers who instruct mathematics and science is associated with the movement of female students from gender balanced majors to predominantly male majors. Based on these findings, we recommend a policy measure aimed at encouraging more female students in all-girls schools to choose predominantly male majors. This can be achieved by recruiting more male mathematics and science teachers while maintaining the overall share of female teachers at a certain level.[26]

V. Concluding remarks

There has been a growing promotion of single-sex schools as a response to the gender gap in academic outcomes. The significant benefits of single-sex schooling in test scores, as found in extensive literature, provide evidence that schools matter in the short run, but they raise questions about whether schools matter in the long run.[27] The related literature also underscores the difficulty in identifying the causal impact of potentially endogenously formed groups. The findings of this study contribute to the literature by addressing the impact of single-sex schooling on the gender gap in the choice of college major, which is closely related to postgraduate labor market outcomes. The potential endogeneity concerns are mitigated due to the Korean educational setting, where homogeneous application behavior under a

[26] To support the validity of the findings, we estimate Equations (1) and (2) using a Probit model. The results are consistent with ordinary least squares (OLS) regression coefficients.

[27] To estimate the short-run single-sex schooling effect using our baseline sample, we regress students' test scores on covariates as presented in Equation (1). Female students are shown to be more likely to attain higher scores in Korean and math subjects than their male counterparts in single-sex schools at the 0.01 significance level. However, there is no significant difference between female students in single-sex schools and both their female and male counterparts in coeducational schools. Supplementary estimation results are available upon request.

Boston mechanism-type assignment creates randomness in the choice between single-sex and coeducational schools. Additionally, students are required to make a joint decision for a college-major pair during the application stage.

The results indicate that single-sex schooling does not reduce the gender gap in predominantly male majors, but it does narrow the gender gap in gender-balanced majors. To understand the potential mechanisms behind this effect, this study investigates the overall impact of teacher gender as well as the impact of teacher gender by subject, which yield contrasting results. The findings suggest that the influence of single-sex schooling on the gender gap in students' college major choice can be addressed by altering the proportions of female teachers, particularly among mathematics and science instructors.

This is in line with earlier research findings emphasizing the role of teachers as role models (Bettinger & Long 2005; Carrington *et al.* 2007; Dee 2005, 2007; Holmlund & Sund 2008). However, this study goes beyond the existing literature on teacher effects on student outcomes by shedding light on the influence of teachers on students' college major choices, an area that has received limited attention. Most previous studies have primarily focused on the impact of a teacher's gender or race/ethnicity on student academic performance, typically measured through standardized achievement test scores. For instance, Winters *et al.* (2013) discovered a statistically significant relationship between being assigned to a female teacher and student achievement in secondary education, based on their analysis of administrative panel data from Florida public schools. Similarly, Lim and Meer (2017) demonstrated that female students achieve significantly better results on standardized tests when taught by female teachers, utilizing the random assignment of students to Korean middle school classrooms. Our findings contribute to this body of research, highlighting the importance of the gender composition of teachers within a school in influencing students' rational choices of college majors, free from stereotype threats.

Paradoxically, single-sex schools have been promoted to reduce stereotype threat in shaping rigid gender roles (Bigler & Signorella 2011; Park *et al.* 2013; Sullivan 2009). This conventional belief was cemented by the supporting results of relevant studies which showed the positive relationship between single-sex schooling and academic achievement, especially for female students. Contrary to popular belief, the results of this study suggest that single-sex schooling can increase the gender gap in the choice of college major unless a school has a balanced gender composition of teachers. The findings imply that same-gender peer effects might be sufficient to alleviate stereotype threat effects on specific subject test scores but are insufficient to address stereotype threat effects on major choice.[28]

Our results also indicate that increasing the overall proportion of female teachers could encourage more female students to pursue gender-balanced majors instead of predominantly female majors, although it may not be sufficient to attract them to predominantly male majors. In addition, to facilitate the choice of predominantly male majors, all-girls schools should consider hiring more male teachers who specialize in mathematics and science. This is because female mathematics and science teachers at all-girls schools are more likely to encourage female students, particularly those considering Engineering (*i.e.*, predominantly male majors) or Science (*i.e.*, gender-balanced majors) as their major, to select a Science major.[29] Since female mathematics and science teachers often hold degrees in Science or Education majors (*i.e.*, mathematics or science education), which are typically gender-balanced or predominantly female majors, Engineering majors may not be a familiar field for them. Therefore, they might be more inclined to motivate female students to choose a Science major, a field they are more familiar with. Consequently, alongside promoting gender diversity among the teaching staff, systematic teacher training in career counseling is necessary to encourage more female students to

[28] To simply compare the extent of the single-sex schooling effect on the gender gap in teacher, peer, and class attachment/interaction, supplementary analyses were conducted. However, no significant effect was found.

[29] Based on the KEDI's 2012 Analytical Study on the Qualitative Level and Actual Condition of School Education—the Case of High School in Korea, it was found that approximately 40% of male full-time, regular teachers who instruct mathematics and science in general high schools completed their bachelor's degree in non-Education majors, while around 30% of female teachers with the same responsibilities had a similar background. In addition, according to the Korea Employment Information Service's 2014 Graduates Occupational Mobility Survey, around 60% of female mathematics and science teachers earned their high school diploma from single-sex schools. The relatively limited knowledge and experiences related to engineering majors among female mathematics and science teachers might dissuade female students from choosing engineering over science as their college major.

select predominantly male majors.

The choice of a college major reflects one's aptitude, preferences, and career goals, often influenced by knowledge and information. This study is based on the assumption that students make decisions about their college major based on the knowledge and information about the major itself or their own abilities and skills obtained from their peers and teachers at school. In the real world, the choice of a college major might be influenced by a more diverse set of factors, such as high school assessment practices, college admissions policies, and labor market conditions. For instance, if a school heavily weighs its assessment on the college enrollment rate for graduates, the school may encourage more students to apply for majors that have higher admission rates. Similarly, if the Ministry of Education requests colleges to expand their engineering departments, students are more likely to apply for engineering majors due to the higher likelihood of admissions.[30] Additionally, if there is limited demand for non-engineering majors in the labor market, more students may choose engineering majors to avoid potential unemployment after graduating from college. In further study, we will extend our model to discuss to what extent those exogenous factors account for the gender gap in the choice of college major and provide additional policy implications.

(Submitted Oct 24 2023; Revised Nov 10 2023; Accepted Nov 10 2023)

[30] Another example of admissions policies that can influence students' choice of college major is the distribution of early and regular admissions. If the number of admission seats available for early and regular admissions varies across academic programs, students may adjust their application strategies to improve their chances of admission. According to the Korea Employment Information Service's 2014 Graduates Occupational Mobility Survey, around 60% were regularly admitted, and 40% were early admitted to colleges. There is no significant difference in the percentages of female students in engineering majors between regular and early admissions, with approximately 16.18% among regularly admitted students and 16.91% among early-admitted students. The reasons for choosing their major also do not significantly differ between early and regularly admitted students, with over half of students choosing their major based on their aptitude and interests, regardless of their admission types.

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TABLE 1

CATEGORIZATION OF MAJOR DEPARTMENT INTO SEVEN MAJOR FIELDS

Major field of study	Major department
- Engineering	Architecture, Civil Construction/Urban Engineering, Transportation, Mechanical/Metallurgical Engineering, Electricity/Electronics, Precision/Energy, Materials, Computers/Communication, Industrial Engineering, Chemical Engineering, Mechatronics Engineering, Applied Engineering, General Engineering
- Science	Agriculture/Fisheries, Biology, Chemistry/Environmental Science, Food/Nutrition, Mathematics, Physics, Astronomy/Geology
- Medicine/Public Health	Medical Science, Nursing, Pharmacy, Therapeutics & Public Health
- Humanities/Social Science	Linguistics/Literature, Humanities, Law, Social Science
- Business/Economics	Business Administration, Economics
- Education	General Education, Early Childhood Education, Special Education, Elementary Education, Secondary Education
- Arts/Athletics	Design, Applied Arts, Dancing/Athletics, Fine/Formative Arts, Drama/Cinema, Music

Table 2
Descriptive Statistics: School Characteristics

	Single-sex school		Coed	Diff. (1)-(3)	Diff. (2)-(3)
	All-boys	All-girls	School	[t-statistics]	[t-statistics]
	(1)	(2)	(3)	(4)	(5)
No. of schools	18	18	12	-	-
School founded by private entity (%)	68.22	64.65	33.33	34.89***	31.31***
	(0.468)	(0.480)	(0.474)	[4.980]	[4.328]
College admitted students (%)	79.24	84.02	82.84	-3.61*	1.18
	(0.136)	(0.122)	(0.132)	[-1.806]	[0.614]
Class size	36.31	37.34	36.66	-0.35	0.68
	(3.887)	(3.078)	(3.321)	[-0.634]	[1.401]
Student-teacher ratio	17.24	17.53	17.40	-0.16	0.12
	(1.966)	(1.570)	(1.658)	[-0.600]	[0.503]
Average teacher age	43.33	42.38	41.34	1.99***	1.04**
	(2.637)	(2.862)	(3.568)	[4.373]	[2.156]
Average teacher years of schooling	16.79	16.74	16.87	-0.08**	-0.13***
	(0.255)	(0.256)	(0.270)	[-2.061]	[-3.279]
Tenured teachers (%)	89.53	90.34	91.64	-2.11**	-1.30
	(0.063)	(0.061)	(0.053)	[-2.403]	[-1.503]
Female teachers (%)	27.45	53.01	47.59	-20.14***	5.42**
	(0.189)	(0.138)	(0.186)	[-7.207]	[2.225]
- In public schools	51.67	64.15	58.51	-6.83***	5.64***
	(0.103)	(0.085)	(0.094)	[-3.172]	[2.854]
- In private schools	16.17	46.93	25.77	-9.60***	21.16***
	(0.085)	(0.124)	(0.118)	[-4.449]	[7.463]
Science and math female teachers (%)	7.23	12.47	12.34	-5.11***	0.13
	(0.059)	(0.055)	(0.067)	[-5.504]	[0.142]
- In public schools	13.51	15.97	15.21	-1.70	0.76
	(0.043)	(0.052)	(0.058)	[-1.463]	[0.626]
- In private schools	4.30	10.56	6.61	-2.30**	3.95***
	(0.040)	(0.046)	(0.040)	[-2.527]	[3.797]
Location (%)					
- Capital (Seoul)	25.23	28.28	19.23	6.00	9.05
	(0.436)	(0.453)	(0.397)	[0.960]	[1.394]
- Metropolitan city	53.27	45.45	48.72	4.55	-3.26
	(0.501)	(0.500)	(0.503)	[0.609]	[-0.430]
- Small/medium-size city	20.56	26.26	29.49	-8.93	-3.22
	(0.406)	(0.442)	(0.459)	[-1.397]	[-0.474]
- Municipal area	0.93	0.00	2.56	-1.63	-2.56
	(0.097)	(0.000)	(0.159)	[-0.864]	[-1.605]

Notes: Sample is limited to students graduating from high schools in equalized education districts. The asterisks *, **, and *** indicate statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

TABLE 3

DESCRIPTIVE STATISTICS: STUDENT CHARACTERISTICS

	Single-sex school		Coed school		Diff. (1)-(2)	Diff. (3)-(4)
	Male	Female	Male	Female	[t-statistics]	[t-statistics]
	(1)	(2)	(3)	(4)	(5)	(6)
No. of students	329	348	133	181	-	-
Household income	453.69	350.04	406.02	446.35	103.65**	-40.34
	(7.096)	(2.450)	(2.077)	(5.467)	[2.568]	[-0.809]
Educational expenditure	67.24	58.12	58.51	61.40	9.12*	-2.89
	(0.786)	(0.394)	(0.488)	(0.427)	[1.923]	[-0.558]
CSAT score						
- Korean	0.20	0.38	0.10	0.32	-0.18***	-0.22**
	(0.911)	(0.794)	(0.849)	(0.853)	[-2.591]	[-2.109]
- English	0.22	0.33	0.07	0.36	-0.11	-0.29***
	(0.947)	(0.844)	(0.865)	(0.895)	[-1.423]	[-2.700]
- Math	0.38	0.21	0.17	0.14	0.16**	0.03
	(0.983)	(0.979)	(0.913)	(0.959)	[1.985]	[0.239]
Four-year college (%)	78.42	72.41	79.70	72.38	6.01*	7.32
	(0.412)	(0.448)	(0.404)	(0.448)	[1.813]	[1.491]
Among four-year college (%)						
- Private college	68.99	77.78	74.53	74.81	-8.79**	-0.28
	(0.463)	(0.417)	(0.438)	(0.436)	[-2.250]	[-0.049]
- Located in metropolitan city	25.19	32.14	30.19	36.64	-6.95*	-6.45
	(0.435)	(0.468)	(0.461)	(0.484)	[-1.738]	[-1.042]
- College selectivity (%)						
- Top decile	16.67	12.30	11.32	12.98	4.37	-1.66
	(0.373)	(0.329)	(0.318)	(0.337)	[1.399]	[-0.385]
- Medium decile	32.56	31.75	31.13	41.22	0.81	-10.09
	(0.470)	(0.466)	(0.465)	(0.494)	[0.196]	[-1.604]
- Low decile	50.78	55.95	57.55	45.80	-5.18	11.75*
	(0.501)	(0.497)	(0.497)	(0.500)	[-1.171]	[1.803]
- College Major						
- Predominantly male majors	39.92	12.30	29.25	14.50	27.62***	14.74***
	(0.491)	(0.329)	(0.457)	(0.353)	[7.448]	[2.800]
- Predominantly female majors	32.17	58.33	31.13	59.54	-26.16***	-28.41***
	(0.468)	(0.494)	(0.465)	(0.493)	[-6.141]	[-4.525]
- Gender balanced majors	27.91	29.37	39.62	25.95	-1.46	13.67**
	(0.449)	(0.456)	(0.491)	(0.440)	[-0.364]	[2.256]

Notes: Sample is limited to students graduating from high schools in equalized education districts. Each CSAT subject score is standardized to have a mean equal to 0 and standard deviation equal to 1. Household income and educational expenditure 1,000,000 (one billion) KRW in 2010. The asterisks *, **, and *** indicate statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

TABLE 4
COLLEGE MAJOR DISTRIBUTION

Entrance year = 2011	Total (1)	Men (2)	Women (3)
A. Population			
All (%)			
- Engineering	25.06	40.16	8.97
- Science	7.62	7.55	7.69
- Medicine/Public Health	8.58	4.98	12.43
- Humanities/Social Science	22.32	17.26	27.71
- Business/Economics	14.76	14.67	14.85
- Education	5.29	2.64	8.11
- Arts/Athletics	16.37	12.74	20.24
No. of observations	635,350	327,927	307,470
Four-year college (%)			
- Engineering	24.32	36.43	10.63
- Science	11.64	11.01	12.35
- Medicine/Public Health	5.65	3.45	8.15
- Humanities/Social Science	25.41	20.38	31.10
- Business/Economics	15.20	15.74	14.59
- Education	5.64	3.79	7.72
- Arts/Athletics	12.13	9.19	15.46
No. of observations	381,735	202,751	179,031
B. KELS Sample			
All (%)			
- Engineering	22.81	37.01	10.4
- Science	12.11	15.15	9.45
- Medicine/Public Health	8.78	4.33	12.67
- Humanities/Social Science	25.03	19.91	29.49
- Business/Economics	16.25	15.58	16.82
- Education	5.25	2.38	7.75
- Arts/Athletics	9.79	5.63	13.42
No. of observations	991	462	529
Four-year college (%)			
- Engineering	24.53	37.02	12.63
- Science	13.48	16.57	10.53
- Medicine/Public Health	3.91	1.93	5.79
- Humanities/Social Science	28.03	22.1	33.68
- Business/Economics	16.44	14.92	17.89
- Education	5.93	3.04	8.68
- Arts/Athletics	7.68	4.42	10.79
No. of observations	742	362	380

Notes: Panel A includes all students who newly enrolled in colleges which consider CSAT scores in admissions decisions such as university, university of education, industrial university, junior college, technical college, and polytechnic college. Panel B is limited to students graduating from high schools in equalized education districts. The distribution difference in college major by a school type is statistically significant at the 1 percent level based on Kolmogorov-Smirnov test.

Source: Statistical yearbook of education, Korean Educational Development Institute and Ministry of Education.

TABLE 5

SINGLE-SEX SCHOOLING EFFECT ON STUDENT MAJOR CHOICE

	Predominantly male majors	Predominantly female majors	Gender balanced majors
	(1)	(2)	(3)
Panel A. All			
Gap in major choice: Boys-Girls			
- Students in single-sex schools (α_{all}^{ss})	-0.318***	0.176***	0.142**
	(0.054)	(0.062)	(0.056)
- Students in coeducational schools (α_{all}^{coed})	-0.237***	0.385***	-0.148***
	(0.055)	(0.053)	(0.056)
1 if attending a single-sex schools (β_{all})	0.109*	0.057	-0.167***
	(0.059)	(0.059)	(0.056)
R-square	0.177	0.211	0.087
No. of observations	991	991	991
Panel B. Four-year college			
Gap in major choice: Boys-Girls			
- Students in single-sex schools (α_{4yr}^{ss})	-0.347***	0.249***	0.098
	(0.064)	(0.074)	(0.061)
- Students in coeducational schools (α_{4yr}^{coed})	-0.193***	0.326***	-0.134**
	(0.058)	(0.059)	(0.064)
1 if attending a single-sex schools (β_{4yr})	0.174***	-0.015	-0.159***
	(0.056)	(0.064)	(0.061)
R-square	0.182	0.197	0.074
No. of observations	742	742	742
Gap in major choice: Girls between single-sex and coed schools			
- All ($\beta_{all}+\alpha_{all}^{ss}-\alpha_{all}^{coed}$)	0.029	-0.151***	0.122**
	(0.043)	(0.055)	(0.052)
- Four-year college ($\beta_{4yr}+\alpha_{4yr}^{ss}-\alpha_{4yr}^{coed}$)	0.020	-0.092	0.073
	(0.053)	(0.065)	(0.059)
Gap reduction due to single-sex schooling			
- All ($\alpha_{all}^{ss}-\alpha_{all}^{coed}$)	-0.080	-0.209**	0.289***
	(0.073)	(0.082)	(0.074)
- Four-year college ($\alpha_{4yr}^{ss}-\alpha_{4yr}^{coed}$)	-0.154*	-0.077	0.232***
	(0.079)	(0.093)	(0.082)

Notes: Sample is limited to students graduating from high schools in equalized education districts. School district, school region type, and college decile rank fixed effects are included. Other controls include the logarithm of household income and educational expenses and school characteristics such as a dummy for private school, class size, student-teacher ratio, proportion of female teachers, proportion of regular teachers, the average teacher age, teachers' average years of schooling, and proportion of students who went to a college. College characteristics such as dummies for private college and being located in metropolitan areas are also controlled. Robust standard errors, clustered at school level, are reported in parentheses. The asterisks *, **, and *** indicate statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

TABLE 6

SINGLE-SEX SCHOOLING EFFECT ON INTENDED MAJOR CHOICE

Sample: Intended to attend four-year colleges	Predominantly male majors (1)	Predominantly female majors (2)	Gender balanced majors (3)
No. of observations	622	622	622
Panel A. Freshman			
Gap in intended major choice: Boys-Girls			
- Students in single-sex schools (α_1^{ss})	-0.124***	0.111	-0.037
	(0.041)	(0.081)	(0.053)
- Students in coeducational schools (α_1^{coed})	-0.107*	0.146**	-0.129**
	(0.057)	(0.058)	(0.052)
1 if attending a single-sex schools (β_1)	0.040	0.063	-0.064
	(0.055)	(0.071)	(0.056)
R-square	0.160	0.133	0.091
Panel B. Sophomore			
Gap in intended major choice: Boys-Girls			
- Students in single-sex schools (α_2^{ss})	-0.135***	0.133	-0.022
	(0.047)	(0.080)	(0.057)
- Students in coeducational schools (α_2^{coed})	-0.098*	0.238***	-0.191***
	(0.052)	(0.079)	(0.059)
1 if attending a single-sex schools (β_2)	0.070	0.089	-0.173**
	(0.055)	(0.083)	(0.067)
R-square	0.159	0.151	0.102
Panel C. Senior			
Gap in intended major choice: Boys-Girls			
- Students in single-sex schools (α_2^{ss})	-0.277***	0.334***	0.102
	(0.061)	(0.083)	(0.070)
- Students in coeducational schools (α_2^{coed})	-0.136**	0.202**	-0.093
	(0.053)	(0.089)	(0.068)
1 if attending a single-sex schools (β_2)	0.175***	-0.115	-0.082
	(0.060)	(0.091)	(0.072)
R-square	0.174	0.132	0.092
Gap reduction due to single-sex schooling			
- 1st grade: ($\alpha_1^{ss} - \alpha_1^{coed}$)	-0.017	-0.036	0.092
	(0.065)	(0.101)	(0.069)
- 2nd grade: ($\alpha_2^{ss} - \alpha_2^{coed}$)	-0.037	-0.106	0.169**
	(0.069)	(0.107)	(0.081)
- 3rd grade: ($\alpha_2^{ss} - \alpha_2^{coed}$)	-0.141*	0.132	0.195**
	(0.075)	(0.123)	(0.094)

Notes: Sample is limited to students graduating from high schools in equalized education districts. The sample is further narrowed to students intending to attend a four-year college. School district fixed effects are included. Other controls include the logarithm of household income and educational expenses and school characteristics such as a dummy for private school, class size, student-teacher ratio, proportion of female teachers, proportion of regular teachers, the average teacher age, teachers' average years of schooling, and proportion of students who went to a college. Robust standard errors, clustered at school level, are reported in parentheses. The asterisks *, **, and *** indicate statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

TABLE 7
TEACHER GENDER EFFECT ON COLLEGE MAJOR CHOICE

Sample: Four-year college	Predominantly male majors	Predominantly female majors	Gender balanced majors
	(1)	(2)	(3)
Gap in major choice: Boys-Girls			
- Students in single-sex schools (α^{ss})	-0.609***	0.714***	-0.104
	(0.100)	(0.134)	(0.128)
- Students in coeducational schools (α^{coed})	-0.063	-0.034	0.097
	(0.151)	(0.128)	(0.137)
1 if attending a single-sex schools (β)	0.529***	-0.382***	-0.147
	(0.097)	(0.118)	(0.105)
Teacher gender effect			
- Proportion of female teachers (η_1)	0.571**	-0.376	-0.195
	(0.221)	(0.288)	(0.241)
- × students in single-sex schools (α_1^{ss})	0.681***	-1.063***	0.382
	(0.211)	(0.259)	(0.235)
- × students in coeducational schools (α_1^{coed})	-0.264	0.729***	-0.465*
	(0.271)	(0.247)	(0.239)
- × 1 if attending a single-sex schools (β_1)	-0.953***	0.984***	-0.031
	(0.230)	(0.272)	(0.227)
R-square	0.199	0.219	0.081
No. of observations	742	742	742
Gap reduction due to single-sex schooling by school type, s_i			
s_i = (proportion of female teachers)			
- Private all boys' schools (0.16)	-0.396***	0.461***	-0.065
	(0.118)	(0.138)	(0.133)
- Private all girls' schools (0.47)	-0.103	-0.094	0.197**
	(0.081)	(0.092)	(0.083)
- Private coed schools (0.26)	-0.301***	0.282**	0.019
	(0.096)	(0.114)	(0.109)
- Public all boys' schools (0.52)	-0.056	-0.184*	0.240***
	(0.085)	(0.095)	(0.085)
- Public all girls' schools (0.64)	0.058	-0.399***	0.341***
	(0.105)	(0.114)	(0.100)
- Public coed schools (0.59)	0.011	-0.309***	0.299***
	(0.095)	(0.104)	(0.092)
Proportion of female teachers: Gap → 0	0.578	0.417	0.237

Notes: Sample is limited to students graduating from high schools in equalized education districts. School district, school region type, and college decile rank fixed effects are included. Other controls include the logarithm of household income and educational expenses and school characteristics such as a dummy for private school, class size, student-teacher ratio, proportion of regular teachers, the average teacher age, teachers' average years of schooling, and proportion of students who went to a college. College characteristics such as dummies for private college and being located in metropolitan areas are also controlled. Robust standard errors, clustered at school level, are reported in parentheses. The asterisks *, **, and *** indicate statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

TABLE 8
TEACHER GENDER EFFECT ON STUDENT MAJOR CHOICE BY SUBJECT

Sample: Four-year college	Predominantly male majors (1)	Predominantly female majors (2)	Gender balanced majors (3)
Gap in major choice: Boys-Girls			
- Students in single-sex schools (α^{ss})	-0.631***	0.729***	-0.097
	(0.088)	(0.130)	(0.132)
- Students in coeducational schools (α^{coed})	-0.062	-0.088	0.150
	(0.155)	(0.126)	(0.136)
1 if attending a single-sex schools (β)	0.497***	-0.350***	-0.147
	(0.097)	(0.125)	(0.111)
Teacher gender effect			
- Proportion of female math/science teachers (η_1)	0.784	-1.181	0.396
	(0.693)	(0.828)	(0.885)
- × students in single-sex schools (α_1^{ss})	-0.590	-0.217	0.806
	(1.106)	(1.034)	(0.959)
- × students in coeducational schools (α_1^{coed})	1.767	-1.569	-0.197
	(1.307)	(1.196)	(1.250)
- × 1 if attending a single-sex schools (β_1)	-0.412	0.920	-0.508
	(1.206)	(1.153)	(1.181)
- Proportion of female non-math/science teachers (η_2)	0.514	-0.108	-0.405
	(0.396)	(0.410)	(0.519)
- × students in single-sex schools (α_2^{ss})	1.157**	-1.391***	0.233
	(0.514)	(0.495)	(0.478)
- × students in coeducational schools (α_2^{coed})	-0.958	1.659***	-0.701
	(0.627)	(0.462)	(0.580)
- × 1 if attending a single-sex schools (β_2)	-1.080*	0.954*	0.126
	(0.558)	(0.496)	(0.571)
R-square	0.207	0.230	0.086
No. of observations	742	742	742
Gap reduction due to single-sex schooling by school type, s_{ij}			
s_{ij} = (proportion of female math/science teachers, proportion of female non-math/science teachers)			
- Private all boy's schools (0.04, 0.12)	-0.410***	0.505***	-0.095
	(0.117)	(0.136)	(0.134)
- Private all girl's schools (0.11, 0.36)	-0.067	-0.132	0.199**
	(0.087)	(0.096)	(0.088)
- Private coed schools (0.07, 0.20)	-0.312***	0.302***	0.010
	(0.095)	(0.110)	(0.108)
- Public all boy's schools (0.14, 0.39)	-0.075	-0.183*	0.258***
	(0.088)	(0.093)	(0.086)
- Public all girl's schools (0.16, 0.47)	0.047	-0.400***	0.352***
	(0.108)	(0.110)	(0.101)
- Public coed schools (0.15, 0.43)	-0.014	-0.291***	0.305***
	(0.096)	(0.100)	(0.092)

Notes: Sample is limited to students graduating from high schools in equalized education districts. School district, school region type, and college decile rank fixed effects are included. Other controls include the logarithm of household income and educational expenses and school characteristics such as a dummy for private school, class size, student-teacher ratio, proportion of regular teachers, the average teacher age, teachers' average years of schooling, and proportion of students who went to a college. College characteristics such as dummies for private college and being located in metropolitan areas are also controlled. Robust standard errors, clustered at school level, are reported in parentheses. The asterisks *, **, and *** indicate statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.