School Gender Composition and Academic Performance: Evidence from Transition from Single-Sex to Coeducational Schools

Jungmin Lee and Hye Yeon Park

We examine how the gender composition of students within schools affects their academic performance. For causal identification, we exploit within-school variation in the gender composition because of policy-driven transitions from single-sex to coeducational schools. In Seoul, South Korea, several high schools were converted from single-sex to coeducational schools between 1998 and 2003, by the city superintendent's Coeducational School Expansion Policy. We find that boys' test score dropped when their schools began to admit girls based on administrative test score data on standardized college entrance examination. However, the negative effect disappeared when the school transition was complete. We find no effect on girls who were admitted to previously boys-only schools.

Keywords: Gender composition of students; Single-sex schools, Coeducational schools; High school academic performance; College entrance examination score

JEL Classification: I2, J1, H5

Jungmin Lee, Professor, Department of Economics, Seoul National University & IZA, Seoul, South Korea. (E-mail): jmlee90@snu.ac.kr; Hye Yeon Park, Sogang University, Seoul, South Korea, respectively. We would like to thank discussants and seminar participants at the CSWEP session of the ASSA meetings, the Asian Conference on Applied Micro and Econometrics, Chinese University of Hong Kong, the Korean Society of Labor Economists for their valuable comments. This paper is based on the Master's thesis of Hye Yeon Park. This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2016S1A5A2A01025292).

[**Seoul Journal of Economics** 2017, Vol. 30, No. 4]

I. Introduction

Whether single-sex schooling can deliver better student outcomes than coeducational schooling is a public concern.[1] Parents are concerned with their children's academic performance. Education policy makers are keen on finding ways to improve student outcomes, and changing the gender composition of schools might be a cost-effective option.[2] To understand students' academic performance in coeducational schools, we should understand the gender peer effect, which is the manner in which students are affected by their opposite-sex peers. An ideal setting for identifying the effect would be an experiment, in which we randomly assign students to either single-sex or coeducational schools. However, this opportunity is rarely available. For example, in the United States, where single-sex schools are mostly private or Catholic, students self-select into these schools (Halpern *et al.* 2011; Billger 2009; Lee, and Marks 1992). Thus, previous studies exploited some marginal changes of gender composition that naturally occur across adjacent cohorts because of population changes in the neighborhood (Hoxby 2000; Lavy, and Schlosser 2011; Schneeweis, and Zweimüller 2012) or accidental variations created by policy experiments (Whitmore 2005).[3]

In this study, we exploit two unique institutional features of the high school system in Seoul, South Korea to estimate the causal effect of school gender composition. First, considering Seoul's "School Equalization Policy" (SEP), which commenced in 1974, middle-school graduates are assigned randomly to high schools within a school district (Park *et al.* 2012; Kang 2007). The formula used for assigning students is not known to the public, and a degree of uncertainty on the process exists among students and parents. If the random assignment of students to schools was implemented perfectly under

[1] Refer to Mael (1998) for a review of earlier research in the education literature and Myer (2008) for a more recent debate on single-sex schooling in the United States.

[2] In the United States, the 2006 reform to Title IX of the Educational Amendments of 1972 provided permission for public single-sex education, albeit to a limited degree.

[3] Most studies in the education literature use the standard estimation method of controlling for observable characteristics. See Harker (2000).

the SEP, then the simple comparison of test scores between single-sex and coeducational schools would suffice to estimate the causal effect. However, this is perhaps not the case here. For example, parents could obtain pretty accurate information from neighbors, realtors, and the Internet regarding which school their children would be assigned to when they move into a certain area. The probability that children will be assigned to their preferred school might increase by moving closer to the school in advance.

Second, to remove potential selection bias, we exploit a quasi-natural experiment in Seoul where several single-sex high schools were changed to coeducational schools during the late 1990s and early 2000s.[4] The transitions were led by the Seoul superintendent (Mr. In Jong Yoo, 1996–2004) under the Coeducational School Expansion Policy, beginning in 1998. The influx of opposite-sex students should be exogenous to incumbent students who entered their school shortly before the transition was commenced. Further, limited selection after the transition should be observed under the SEP, because students are not allowed to transfer to another school within the same school district, making school transfer extremely costly.[5] Indeed, the data show that significant transfer-outs did not occur during the transition period. Even if non-random selection occurred, our estimates would be biased toward zero because students who are expected to perform worse in coeducational schools should transfer out.

To summarize our main findings using administrative test score data on standardized college entrance examination (corresponding to the SAT in the U.S.), we find that boys' test score decreased when their schools began admitting girls. However, this negative effect disappeared when the school transition was complete. Our findings suggest that boys are vulnerable to *changes* in school environments regarding their peers' gender composition. This finding implies the existence of

[4] A concurrent paper is provided by Dustmann *et al.* (2017), which also exploits school transitions from single-sex to coeducational schools in Korea to identify the effects of single-sex schooling on academic outcomes. Overall, their paper is similar to ours. However, they are more interested in estimating the effect of single-sex schooling *per se*, whereas we are more limited to examining the effect of exposure to mixed-gender schools during the transition period.

[5] Particularly for high-school students, school transfers are very limited because most school districts and individual schools have minimum residential length requirements.

a potential risk for boys when they interact with girls. However, no single-sex school advantage is found *per se*. After the completion of the transition to coeducational schools, we find no differences between students previously in boys-only and currently in coeducational schools and those in non-transition schools.

The remainder of this paper proceeds as follows. Section II introduces the data and explains our empirical strategy, which exploits school transitions from single-sex to coeducational schools. Section III presents the empirical findings. Section IV discusses the implications of our findings for the current debate over single-sex school advantages and includes the conclusion.

II. Data and Empirical Strategy

We use administrative data on Korean college entrance examination scores for all students who graduated from high schools in Seoul. We focus on the Coeducational School Expansion Policy period, particularly in 1998–2003, because test scores during this period are standardized and comparable. We examine three high-stake subjects, namely, Math, English, and Korean. Test scores are standardized each year at the national level with mean and standard deviation of 50 and 10, respectively. We exclude vocational/special-purpose high school graduates and repeated test takers.[6] The sample consists of approximately 90,000–100,000 students per year from approximately 180 schools in Seoul. During the sample period, seven schools were changed from all-boys (BOYS) to coeducational schools (COED), whereas only one all-girls school was changed. Therefore, we focus on boys and identify the gender peer effect of within-school variation in gender composition arising out of the school transition from BOYS to COED.

School transition cannot occur in a year. Table 1 shows that different school cohorts (by entrance year over grades) undergo their school's transition process. Suppose a school that admits girls commenced at

[6] The college entrance examination in Korea is extremely important because all colleges require the test score and applicants can take the test only once a year. If they fail to gain admission, they have to wait another year to retake the test.

Table 1
Transition from All-Boys to Coeducational Schools

				Beginning to admit girls					
Cohort (entrance year)	$\tau - 3$	$\tau - 2$	$\tau - 1$	τ	$\tau + 1$	$\tau + 2$	$\tau + 3$	$\tau + 4$	$\tau + 5$
Before transition ($\tau - 4$)	B2	B3							
Before transition ($\tau - 3$)	B1	B2	B3						
Exited during transition ($\tau - 2$)		B1	B2	B3					
Exited during transition ($\tau - 1$)			B1	B2	B3				
Entered during transition (τ)				C1	C2	C3			
Entered during transition ($\tau + 1$)					C1	C2	C3		
After transition ($\tau + 2$)						C1	C2	C3	
After transition ($\tau + 3$)							C1	C2	C3

Notes: The vertical years represent high school entrance years. The horizontal years represent years around the transition from all-boys to coeducational schooling. At year τ, a high school begins to admit girls. B represents boys who entered the school before year τ. C represents boys who entered the school at τ or later. The numbers next to B and C represent grades. For example, B3 indicates boys that are currently in the third grade who entered the school before τ. Students appear for college entrance examinations when they are in their third grade of high school.

year τ.[7] We can define three distinct cohort groups. The first group comprises students who entered the school before the transition, that is, at ($\tau - 3$) or earlier and spent all of their three years of high school at BOYS. The second group comprises students who entered the school during the transition, that is, between ($\tau - 2$) and ($\tau + 1$). This group can be separated further into two different subgroups. The first subgroup comprises boys who entered the school at ($\tau - 2$) and ($\tau - 1$), that is, they entered BOYS, but when they were in the second and third years,

[7] Throughout the paper, a year indicates the year the test was held. In Korea, an academic year is from March to February and the second semester ends in December. The national college entrance examination is held once a year in November, and all students should appear for it on the same day.

the school began admitting girls to the first year. The second subgroup comprises boys who entered the school at τ and $(\tau + 1)$, that is, they entered COED, but the transition was not complete. The last group comprises students who entered the school at $(\tau + 2)$ or later, after the transition was complete.

Our main question is how different exposures to school transition would affect students' academic performance. In Table 2, we present the average test scores of transition school students (boys) by school entrance cohort, corresponding to Table 1. During the period from 1998 to 2003, seven schools changed from all-boys to coeducational schools, that is, one changed in 1999, one in 2001, four in 2002, and one in 2003. In the last column, we calculate the average share of girls at the school level for each cohort. For example, for students in the $(\tau - 2)$ cohort, if the cohort size is constant and exactly half of the first year students are girls, then the share of girls is zero in the first and second years and one-sixth in the third year. Thus, the average share of girls is approximately 0.055. The sample average is slightly lower at 0.048. The results in Table 1 suggest the gender peer effect could be nonlinear. We find that boys perform worse when girls begin entering their school. However, as more girls enter, the boys' test scores began to improve. When the gender composition at the school is almost balanced, the average scores recover to almost the pre-transition level.

We conduct the following regression analyses to check whether the results in the unconditional mean comparison in Table 2 hold with control variables:

$$Y_{ijzt} = \sum_{k=-2}^{2} \beta_k D_{ijzt}^{k} + \alpha_j + \mu_{zt} + \epsilon_{ijzt}, \qquad (1)$$

where Y_{ijzt} is the standardized test score of student i from high school j in school district z, who sat for the test in year t. Let τ_j denote the year when school j commenced the admission of girls. The dummy variable, D_{ijzt}^{k}, is the indicator of whether the student attends a transition school and belongs to a $(\tau_j + k)$ cohort, except for D_{ijzt}^{2}, which includes cohorts $(\tau_j + 2)$ or later.[8] The omitted comparison group includes students who

[8] One might think that cohorts that enter after the transition began are endogenous because they preferred to enter COED. Although this choice is unlikely because of the SEP and other restrictions on school choice, we re-estimate our equation without these cohorts and find qualitatively similar results.

TABLE 2
AVERAGE TEST SCORES AND SCHOOL GENDER COMPOSITION BY COHORT

	(1) Math	(2) English	(3) Korean	(4) Girls' Ratio
[1] Boys at BS	50.99	51.24	51.01	
	(9.46)	(8.88)	(8.56)	
	250,537	250,347	250,698	
[2] Boys at CS	50.72	50.90	50.70	
	(9.44)	(8.98)	(8.58)	
	81,536	81,475	81,576	
[3] Boys before transition ($\tau - 3$) or earlier	52.09	52.23	52.59	0.00
	(9.10)	(7.87)	(7.36)	
	5,346	5,341	5,348	
[4] Boys during transition, ($\tau - 2$)	51.01	50.84	50.83	0.05
	(8.82)	(8.15)	(7.91)	
	2,671	2,671	2,675	
[5] Boys during transition, ($\tau - 1$)	49.30	48.82	48.98	0.14
	(9.28)	(8.84)	(9.16)	
	3,608	3,607	3,609	
[6] Boys during transition, (τ)	49.67	49.27	49.48	0.27
	(9.19)	(8.98)	(8.91)	
	2,336	2,335	2,337	
[7] Boys during transition, ($\tau + 1$)	49.95	49.19	49.19	0.37
	(9.31)	(9.33)	(8.88)	
	2,186	2,185	2,189	
[8] Boys after transition, ($\tau + 2$) or later	50.90	50.78	50.63	0.44
	(9.53)	(9.09)	(9.12)	
	2,298	2,297	2,299	
[9] Girls who entered CS but were mixed with BS seniors	49.68	51.07	51.63	
	(8.43)	(8.54)	(8.19)	
	2,584	2,582	2,585	
[10] Girls who entered CS with no BS seniors	51.62	53.69	53.51	
	(8.79)	(7.90)	(8.20)	
	755	755	757	

Notes: Average scores of boys who graduated from transition schools by high school entrance cohort. The average girls' ratio is the high school three-year average of the share of girls in the school for each cohort. Standard deviations are presented in parentheses.

entered at (τ_j – 3) or earlier, prior to the transition. We control for the school fixed effects (α_j) and school district-specific nonlinear time trends in Seoul students' average scores using school district-year fixed effects (μ_{zt}).[9] The last term would subsume any unobservable factors that may exist in a particular district in a particular year.

III. Empirical Results

A. Main Findings

Table 3 separately presents the regression results in the three subjects. The results are consistent across subjects. Boys' test scores decrease early in the transition. In particular, the influx of girls significantly lowers the test scores of cohort (τ – 1) by approximately two points (equivalent to 0.2 standard deviation). This value is substantial; around the national average, a one-point decrease in the standardized score indicates approximately a four percentile drop in the student's ranking. However, we find that the boys' academic performance improves as the school transition proceeds. In fact, once the transition is completed, the average test scores of cohorts (τ + 2) or later are only slightly lower than the pre-transition average test scores. The differences are not statistically different from zero.

The results in Table 3 show that the gender composition effect is nonlinear. For visualization, we plot the relationships between gender peer effect, as shown in Table 3, and the average share of girls as, shown in Table 2, and find a U-shaped relationship as shown in Figure 1. Boys seem to perform worst when girls comprise 10–20% of the total student population. When the proportion of girls is close to 50%, *i.e.*, the school becomes a coeducational school, boys perform as well as when only boys are in their school.

Our findings of nonlinear gender peer effects are consistent with those of Hoxby (2000), who exploits random variation in the gender composition of school cohorts, measured by unexpected deviations from

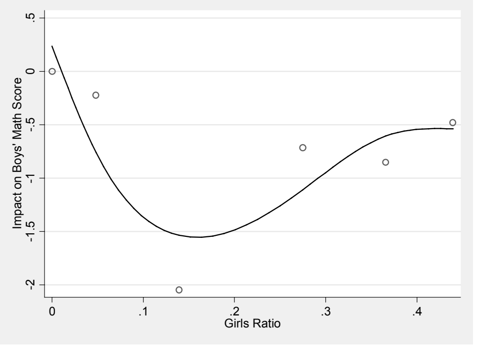
[9] We also control for major fixed effects. Students can select from only one of three majors; liberal arts and social sciences (including business), natural sciences and engineering, and arts. They take different subject tests, but the three high-stake subjects we considered in this paper are common. For the sake of notational simplicity, we omit the major fixed effects from the equation.

TABLE 3

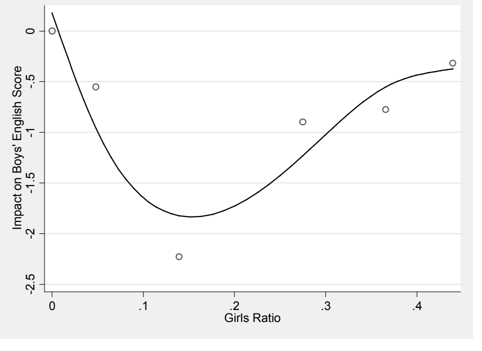
EFFECTS OF SCHOOL GENDER COMPOSITION ON BOYS' TEST SCORE

	(1) Math	(2) English	(3) Korean
Omitted group: Entered BS at (τ – 3) or earlier			
Entered BS and attended transition CS: (τ – 3) to (τ – 1)	−1.193*** (0.191)	−1.444*** (0.178)	−1.674*** (0.173)
Entered and attended transition CS: (τ) and (τ + 1)	−0.630*** (0.214)	−0.698*** (0.199)	−0.834*** (0.194)
Entered and attended complete CS: (τ + 2) or later	−0.121 (0.310)	0.010 (0.288)	0.158 (0.281)
Constant	48.888*** (0.133)	49.177*** (0.124)	48.838*** (0.120)
Observations	332,073	331,822	332,274
Adjusted R–squared	0.067	0.091	0.067
Omitted group: Cohorts (τ – 3) or earlier			
Cohort (τ – 2)	−0.222 (0.490)	−0.552 (0.376)	−0.814* (0.438)
Cohort (τ – 1)	−2.045*** (0.534)	−2.228*** (0.643)	−2.431*** (0.792)
Cohort (τ)	−0.714 (0.678)	−0.897 (0.736)	−1.085 (0.719)
Cohort (τ + 1)	−0.851*** (0.279)	−0.776* (0.412)	−0.848* (0.481)
Cohorts (τ + 2) or later	−0.477 (0.390)	−0.316 (0.506)	−0.157 (0.534)
Constant	49.481*** (0.380)	50.398*** (0.306)	47.122*** (0.359)
Observations	332,073	331,822	332,274
Adjusted R–squared	0.068	0.091	0.067
School FE	YES	YES	YES
School District*Year FE	YES	YES	YES

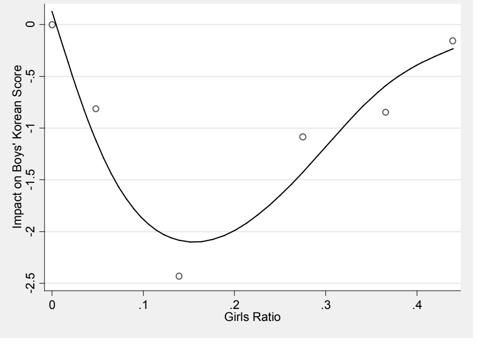
Notes: Robust standard errors clustered by school are presented in parentheses. *** Significant at 1% level. * Significant at 10% level. The dependent variable is the standardized national college entrance examination score with mean and standard deviation of 50 and 10, respectively.



A. Math



B. English



C. Korean

Notes: The horizontal axis represents the average share of girls, whereas the vertical axis represents the estimated peer effect presented in Table 3. The curve is the fitted cubic function.

FIGURE 1

NONLINEAR EFFECTS DURING TRANSITION

within-school cohort-to-cohort gender composition trends. Specifically, she finds that an increase in the share of girls decreases boys' test scores when the share is lower than 1/3, and significantly increases boys' scores when the share is higher than 2/3. She finds that a change in the share of girls has small positive or no effect when the share is between 1/3 and 2/3 of the total students.[10] These patterns are similar to our findings in Figure 1.

We find that the negative effect is the highest among the boys of cohort ($\tau - 1$). The effect is substantial, that is, their average test score is lower by more than two standard deviations than the average of those who have never had any girls in schools. Why is the negative effect particularly substantial for the cohort? One possible explanation is that the gender composition is too unbalanced for that cohort which creates some adverse effects. For them, the average girls' ratio is approximately 14%. Furthermore, the ratio is minimal (only 5%) for the previous cohort ($\tau - 2$), whereas the ratio is 27% for the next cohort τ.

Another notable characteristic of cohort ($\tau - 1$) is that the boys in the cohort have never been in the same classes with girls, although some girls are in their school. The boys in cohort ($\tau - 2$) have also never been in gender-mixed classes, but have experienced the unbalanced gender composition for only one year, the last year of high school when their test performance should be determined to an extent. The boys in cohort τ or later have always been with girls in the same grade or even in the same classes for three years in high school. The differences in the duration of exposure to gender-mixed environments or types (or intensity) of exposure might result in differences in gender peer effect across cohorts.

The insignificant difference in average scores before and after the transition is also consistent with recent papers that carefully control for selectivity bias. Lavy and Schlosser (2011), find a change in gender composition of cohort using the same identification strategy of Hoxby (2000) does not significantly change students' behavior at the individual level. Jackson (2012) exploits a quasi-natural experiment arising out of the institutional rule of assigning students to secondary schools

[10] Using within-school variation in girls' ratio among coeducational schools, which is variation at the intensive margin, heavily concentrated between 0.45 and 0.65, we find that the girls' ratio had no effect on boys' test scores. The results are available in Appendix Table 1.

TABLE 4
STUDENT MOBILITY BEFORE TRANSITION

	(1) Log	(2) Level
Omitted group: Cohort (τ – 4) or earlier		
Cohort (τ – 3)	−0.031	−16.764
	(0.078)	(35.080)
Cohort (τ – 2)	−0.035	−7.473
	(0.086)	(38.659)
Cohort (τ – 1)	−0.023	16.115
	(0.085)	(38.288)
Constant	6.280***	560.102***
	(0.032)	(14.497)
School District*Year FE	YES	YES
Observations	430	430
Adjusted R-squared	0.815	0.879

Notes: Robust standard errors are presented in parentheses. *** Significant at 1% level. * Significant at 10% level. The dependent variable is the natural logarithm of total number of students per school in column (1) and the number of students per school in column (2).

in Trinidad and Tobago. He finds no benefit in attending single-sex schools. We find significant benefits for all three subjects using the Korean dataset by controlling for school district-year fixed effects without school-specific fixed effects.[11] In this study, we control for both fixed effects that exploit transition schools and find no significant benefit. As long as transition schools are not peculiar, our findings suggest the observed benefits of single-sex schools are likely to be driven by students' selection into single-sex and coeducational schools.

B. Selection Problem

A potential econometric issue is that students in transition schools might transfer out. Upon anticipating school transition, a conceivable step is that students most likely to suffer in a mixed-gender environment would transfer out to another all-boys school.[12] However, this situation

[11] The results are presented in Appendix Table 2.

[12] Note that this would bias the estimates against our findings.

Table 5

Pre-Transition Comparison between Transition and Non-Transition Schools

	(1) Non-transition schools	(2) Transition schools	(3) Conditional difference
Math	52.32	52.02	−0.54
	[9.45]	[9.25]	(0.78)
	88,327	6,970	
English	52.65	51.93	−0.84
	[8.29]	[8.15]	(0.80)
	88,290	6,965	
Korean	52.45	52.11	−0.51
	[7.92]	[7.86]	(0.75)
	88,370	6,972	

Notes: Average test scores for three high-stake subjects. Standard deviations are presented in brackets. The number of observations is presented below standard deviations. Pre-transition period is 1998 and 1999. One transition school whose transition year is 1999 is excluded from the 1999 sample. The last column presents the average score difference between transition and non-transition schools after controlling for school district*year and major fixed effects. Robust standard errors clustered by individual school are presented in parentheses.

is unlikely in the Seoul high-school system. The first reason is because school transfer is restricted by a minimum residential requirement, and second, because even if students move to another district, they will still be subjected to the equalization policy. Thus, they could end up in a coeducational school. Table 4 shows that transferring out before the transition period is not significant.

Our identification strategy exploits school transition from all-boys to coeducational school. This strategy is similar to the difference-in-differences (DID) method, and we construct counterfactuals during the transition period from students in control schools, *i.e.*, in non-transition schools. Thus, one may wonder whether these transition schools are actually comparable to non-transition schools.

To address this valid concern, we conduct two robustness checks. First, we compare the average test scores between transition and non-transition schools during the pre-transition period. Considering that transition years vary school by school, we select the first two years of our sample, 1998 and 1999, as pre-transition period. However, the transition year of one school is 1999, hence this school is excluded

TABLE 6
MATCHING ESTIMATION RESULTS

		(1) Math	(2) English	(3) Korean
	Omitted group: Cohorts (τ – 3) or earlier			
Entered BS and attended transition CS	Cohort (τ – 2)	0.031	−0.041	−1.002***
		(0.407)	(0.356)	(0.283)
	Cohort (τ – 1)	−1.008**	−1.089**	−1.587**
		(0.461)	(0.409)	(0.609)
Entered and attended transition CS	Cohort (τ)	−1.468	−1.242	−2.186***
		(1.053)	(0.788)	(0.586)
	Cohort (τ + 1)	−1.175*	−1.028	−1.090**
		(0.629)	(0.847)	(0.516)
Entered and attended complete CS	Cohorts (τ + 2) or later	0.476	−0.265	−0.109
		(0.791)	(0.426)	(0.345)
	Constant	0.097	0.033	0.042
		(0.340)	(0.312)	(0.261)
	School FE	YES	YES	YES
	Observations	30	30	30
	Adjusted R-squared	0.450	0.362	0.507

Notes: Robust standard errors are presented in parentheses. *** Significant at 1% level. * Significant at 10% level. Only five transition schools whose data are available for at least two years prior to their transition are included in the sample. Each transition school is matched to a non-transition, all-boys school with the minimum distance in pre-transition average test score for each subject. The dependent variable is the difference in school-level average test score between transition and matched schools (transition– matched).

from the 1999 sample. In Table 5, we find that the average scores of transition schools are not different or only slightly lower for English from non-transition schools. The last column shows the score differences are not statistically significant after controlling for the school district-year and major fixed effects.

Second, we refine the comparison group by finding the "most comparable" school for each transition school. This method is similar to the synthetic control (SC) method with multiple treated units (Abadie *et al.* 2010).[13] Specifically, for one particular transition school, we calculate

[13] We cannot use the SC method because we have only a very short pre-

and compare the average scores during the pre-transition period with all the non-transition schools individually.[14] For each pair, we compute the average geometric distance and select the matched pair with the minimum distance. We then use the difference in the average test score between a transition school and its matched school as the dependent variable and estimate our basic equation with transition school-specific fixed effects.

The matching results are presented in Table 6. The results corroborate our previous findings. The gender peer effect is nonlinear, that is, the influx of girls is harmful for boys' test scores in the beginning, but as the gender composition becomes more balanced, the negative effect is dissipated. Once the transition is complete, we find no negative effect.

C. Distributional Effects

We have focused on average effects. In this section however, we examine heterogeneous effects, such as the effect for students who obtain high and low scores. Specifically, we estimate a linear probability model after replacing the dependent variable with the indicator of whether the student's score is higher than 60, which is one standard deviation above the national average. We also estimate the probability that a student's score is lower than 40 to examine the effect at a lower tail.

The results are presented in Table 7. We find at both tails, boys are negatively affected by the influx of girls. We also find that the effect is larger at a lower tail. For cohort ($\tau - 1$), where the effect is the greatest, the probability of a student scoring higher than 60 drops by 3–4 percentage points, whereas that of a student scoring lower than 40 increases by 5–8 percentage points.[15]

transition period.

[14] For five transition schools, we use two years (1998–1999) as the pre-transition period. The number of observations used in the regression analysis is 30 because five schools and six years, from 1998 to 2003, are used. Please refer to Appendix Figure 1, which shows the average score trends from 1998 to 2003 for these five transition schools and their matched schools.

[15] For transition schools before transition, the sample average share of students that score higher than 60 is 14–21%, and that of students that score lower than 40 is 6–8%. The number of students per school on average is 594.

TABLE 7
DISTRIBUTIONAL EFFECTS OF SCHOOL TRANSITION

	Math		English		Korean	
	(1)	(2)	(3)	(4)	(5)	(6)
	Higher	Lower	Higher	Lower	Higher	Lower
Sample mean	0.186	0.112	0.181	0.123	0.125	0.112
Omitted group: Cohorts (τ – 3) or earlier						
Cohort (τ – 2)	−0.008	−0.008	−0.010	0.017	−0.017***	0.020
	(0.015)	(0.016)	(0.011)	(0.021)	(0.006)	(0.018)
Cohort (τ – 1)	−0.041***	0.051***	−0.039***	0.072**	−0.031***	0.084***
	(0.013)	(0.017)	(0.011)	(0.027)	(0.010)	(0.031)
Cohort (τ)	−0.012	0.017	−0.008	0.038	−0.013	0.033
	(0.020)	(0.015)	(0.012)	(0.026)	(0.012)	(0.028)
Cohort (τ + 1)	−0.013	0.027**	−0.008	0.027	−0.013*	0.030
	(0.013)	(0.012)	(0.011)	(0.017)	(0.007)	(0.020)
Cohort (τ + 2) or later	−0.008	0.004	0.008	0.011	−0.003	0.004
	(0.013)	(0.011)	(0.014)	(0.024)	(0.009)	(0.022)
Constant	0.126***	0.147***	0.106***	0.197***	0.092***	0.214***
	(0.006)	(0.008)	(0.007)	(0.009)	(0.006)	(0.007)
School FE	YES	YES	YES	YES	YES	YES
School District* Year FE	YES	YES	YES	YES	YES	YES
Observations	332,274	332,274	332,274	332,274	332,274	332,274
Adjusted R-squared	0.037	0.022	0.057	0.032	0.031	0.031

Notes: Robust standard errors clustered by school are presented in parentheses. *** Significant at 1% level. * Significant at 10% level. The dependent variable is the indicator of whether the individual student's score is one standard deviation higher than the national average (Higher) or one standard deviation lower than the national average (Lower).

IV. Discussion and Conclusion

In this paper, we exploited the school-level variation in the proportion of girls in the total student population because of the transition from all-boys to coeducational schools and examine the effect of school gender composition on the academic performance of students. We find

TABLE 8

EFFECTS ON GIRLS' ACADEMIC PERFORMANCE

	(1) Math	(2) English	(3) Korean
Omitted Group: Entered CS at (τ + 2) or later			
Entered CS but mixed with BS seniors: τ and (τ + 1)	0.239	−0.234	0.305
	(0.431)	(0.407)	(0.383)
Constant	49.790***	51.730***	51.882***
	(0.111)	(0.105)	(0.099)
Observations	288,998	288,914	289,078
Adjusted R-squared	0.069	0.089	0.054
Omitted Group: Entered CS at (τ + 4) or later			
Entered CS at (τ)	−0.102	−0.335	0.500
	(0.725)	(0.684)	(0.644)
Entered CS at (τ + 1)	−0.714	0.007	0.570
	(0.730)	(0.690)	(0.649)
Entered CS at (τ + 2)	−0.686	0.301	0.508
	(0.782)	(0.738)	(0.695)
Entered CS at (τ + 3)	−1.069	−0.408	−0.167
	(0.849)	(0.802)	(0.755)
Constant	49.797***	51.729***	51.880***
	(0.111)	(0.105)	(0.099)
Observations	288,998	288,914	289,078
Adjusted R-squared	0.069	0.089	0.054
School FE	YES	YES	YES
School District*Year FE	YES	YES	YES

Notes: Robust standard errors clustered by school in parentheses. Asterisks *** represent significance at 1% level, ** at 5% level, and * at 10% level. The dependent variable is the standardized national college entrance exam score with mean and standard deviation of 50 and 10, respectively.

that the influx of girls caused a decrease in the boys' scores on college entrance examination in all three high-stake subjects, namely, Math, English, and Korean. However, this gender peer effect was nonlinear. The results reveal that the presence of a relatively small proportion of girls causes a substantial decrease in boys' test scores, whereas these scores improve as the gender composition becomes more balanced.

The latter finding is consistent with the recent finding that the absence of single-sex schooling advantage for boys (Booth *et al.* 2013; Park *et al.* 2013). However, an unbalanced gender composition of students, particularly when boys outnumber girls, might cause boys, especially those at a lower tail, to indulge in disruptive behavior or lose focus on their studies.

The gender peer effect may arise through various channels. For example, an unbalanced gender composition might affect students' academic performance indirectly via its effects on teachers. In our case, the negative impact could be attributed to either the students' behavioral changes or increased teaching costs because of gender composition shocks. Supposing that teachers need to change their teaching style if they teach mixed-gender classes is reasonable because boys and girls are likely to have different learning patterns. However, limited evidence suggests that teaching costs are higher when the gender composition of students is unbalanced. Furthermore, in our setting, the gender composition within classrooms is not unbalanced because schools admit girls only for new incoming students after the transition to coeducational schools. Moreover, girls admitted to the transition schools did not experience a negative effect. This phenomenon suggests that teaching difficulty has no significant effect or, if any, the effect should be asymmetric between boys and girls.[16]

Our findings have some implications for the current debate over single-sex versus coeducational schooling. We find that boys are vulnerable to *changes* in school environments regarding their peers' gender composition. However, this finding does not mean boys are worse off in coeducational schools. Instead, it implies that a potential risk for boys may be observed when they are exposed to mixed-gender schools. However, considering that only one school was converted from girls-only to coeducation school, we cannot examine the effect on girls. However, no single-sex school seems to have any advantage *per se*. After the completion of the transition to coeducational schools, we find no differences between students in previously boys-only and now coeducational schools and those in non-transition schools.

[16] Unfortunately, because of data limitation, we cannot investigate the channels for negative gender peer effect to arise when the gender composition is unbalanced because we do not have any information on student or teacher behavior and school policies.

(Received 2 November 2017; Revised 7 November 2017; Accepted 16 November 2017)

Appendix

Appendix Table 1

Variation of Girls' Ratio at the Intensive Margin

	(1) Math	(2) English	(3) Korean
Girls' ratio	−0.988	−0.033	−0.301
	(1.089)	(1.020)	(0.986)
Constant	49.184***	48.905***	48.323***
	(0.523)	(0.488)	(0.473)
School FE	YES	YES	YES
School District*Year FE	YES	YES	YES
Observations	74,716	74,658	74,751
Adjusted R-squared	0.067	0.091	0.065

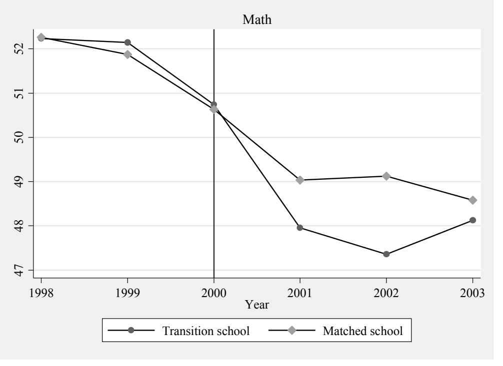
Notes: Robust standard errors clustered by school are presented in parentheses. *** Significant at 1% level. * Significant at 10% level. The sample includes male students in non-transitional coeducational schools. The dependent variable is the standardized national college entrance examination score with mean and standard deviation of 50 and 10, respectively.

Appendix Table 2

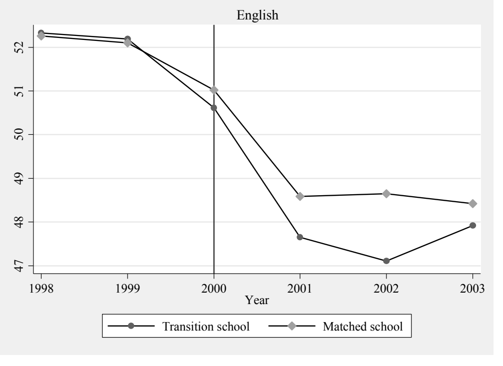
Results after Controlling for Year and School District

	(1) Math	(2) English	(3) Korean
All-boys school	0.417***	0.438***	0.260***
	(0.041)	(0.038)	(0.037)
Constant	51.192***	51.626***	51.329***
	(0.041)	(0.038)	(0.037)
School District*Year FE	YES	YES	YES
Observations	313,628	313,386	313,817
Adjusted R-squared	0.049	0.066	0.049

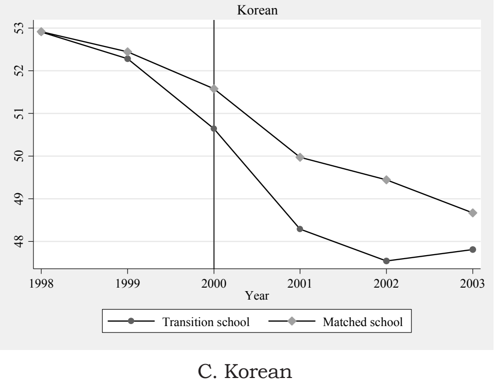
Notes: Robust standard errors clustered by school are presented in parentheses. *** Significant at 1% level. * Significant at 10% level. The sample includes male students that attend either an all-boys or coeducational schools. The dependent variable is the standardized national college entrance examination score with mean and standard deviation of 50 and 10, respectively.



A. Math



B. English



C. Korean

Notes: The trends of average test scores for five transition schools in 1998-1999 are used as the pre-transition period and their matched schools.

Appendix Figure 1

Average Test Scores of Transition and Matched Schools

References

Abadie, Alberto, Alexis Diamond, and Jens Hainmueller. "Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program." *Journal of the American Statistical Association* 105 (No. 490 2010): 493-505.

Billger, Sherrilyn M. "On Reconstructing School Segregation: The Efficacy and Equity of Single-Sex Schooling." *Economics of Education Review* 28 (No. 3 2009): 393-402.

Booth, Alison L., Lina Cardona-Sosa, and Patrick Nolen. Do Single-sex Classes Affect Exam Scores? An Experiment in a Coeducational University. IZA Discussion Paper No. 7207, 2013.

Dustmann, Christian, Hyejin Ku, and Do Won Kwak. Why Are Single-Sex School Successful? CESifo Working Paper No. 6535, 2017.

Halpern, Diane F., Lise Eliot, Rebecca S. Bigler, Richard A. Fabes, Laura D. Hanish, Janet Hyde, Lynn S. Liben, and Carol Lynn Martin. "The Pseudoscience of Single-Sex Schooling." *Science* 333 (No. 6050 2011): 1706-07.

Harker, Richard. "Achievement, Gender and the Single-Sex/Coed Debate." *British Journal of Sociology of Education* 21 (No. 2 2000): 203-18.

Hoxby, Caroline. Peer Effects in the Classroom: Learning from Gender and Race Variation. National Bureau of Economic Research Working Paper 7867, 2000.

Jackson, C. Kirabo. "Single-Sex Schools, Student Achievement, and Course Selection: Evidence from Rule-based Student Assignments in Trinidad and Tobago." *Journal of Public Economics* 96 (No. 1 2012): 173–87.

Kang, Changhui. "Classroom Peer Effects and Academic Achievement: Quasi-Randomization Evidence from South Korea." *Journal of Urban Economics* 61 (No. 3 2007): 458-95.

Lavy, Victor and Analía Schlosser. "Mechanisms and Impacts of Gender Peer Effects at School." *American Economic Journal: Applied Economics* 3 (No. 2 2011): 1-33.

Lee, Soohyung, Lesley J. Turner, Seokjin Woo, and Kyunghee Kim. All or Nothing? The Impact of School and Classroom Gender Composition on Effort and Academic Achievement. NBER Working Paper No. w20722, 2014.

Lee, Valerie E. and Helen M. Marks. "Who Goes Where? Choice of

Single-Sex and Coeducational Independent Secondary Schools." *Sociology of Education* 65 (No. 3 1992): 226-53.

Mael, Fred A. "Single-Sex and Coeducational Schooling: Relationships to Socioemotional and Academic Development." *Review of Educational Research* 68 (No. 2 1998): 101-29.

Myer, Peter. "Learning Separately: The Case for Single-Sex Schools." *Education Next* 8 (No. 1 2008) 10-21.

Park, Hyunjoon, Jere R. Behrman, and Jaesung Choi. "Single-Sex Education: Positive Effects." *Science* 335 (No. 6065 2012): 165-6.

______. "Causal Effects of Single-Sex Schools on College Entrance Exams and College Attendance: Random Assignment in Seoul High Schools." *Demography* 50 (No. 2 2013): 447-69.

Schneeweis, Nicole and Martina Zweimüller. "Girls, Girls, Girls: Gender Composition and Female School Choice." *Economics of Education Review* 31 (No. 4 2012): 482-500.

Whitmore, Diane. "Resource and Peer Impacts on Girls' Academic Achievement: Evidence from a Randomized Experiment." *American Economic Review Papers and Proceedings* 95 (No. 2 2005): 199-203.