Causal Effects of Single-Sex Schools on Students' STEM
(Science, Technology, Engineering, and Math) Outcomes by Gender and Parental SES

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ABSTRACT

Despite women's significant improvement of educational attainment, underrepresentation of women in Science, Technology, Engineering, and Math (STEM) college majors persists in many countries. We address whether one particular institution – single-sex schools – may enhance female – or male -- students' STEM careers. Exploiting the unique setting in Korea where assignment to all-girls, all-boys or coeducational high schools is random, we move beyond associations to assess causal effects of single-sex schools. Besides *average* effects, we examine whether students differentially benefit from single-sex schools, depending on parental SES. With a longitudinal survey that followed up high school seniors over two years after high school, we find significant causal effects of all-boys schools, but not all-girls schools, consistently across different STEM outcomes – seniors' interest and self-efficacy in math and science, expectations of four-year college attendance and STEM college majors, and their actual transitions to four-year colleges and choices of STEM majors.

In recent decades, American women have significantly improved their educational attainment and since the mid 1980s females have surpassed males in acquiring college degrees (Buchmann and DiPrete 2006). The significant progress of women is, however, accompanied by persistent underrepresentation of women in Science, Technology, Engineering, and Math (STEM) college majors. In 2005-6, females accounted for 18 percent of engineering B.A.s, not much different from a decade earlier. In that year, females accounted for 21 percent of bachelor's degrees in computer and information sciences, lower than the 30 percent in 1979-80 (Freeman 2004; NCES 2007).

Underrepresentation of women in STEM majors, especially engineering, is not peculiar to the United States but general in most contemporary societies. In a comparative study of gender and field of college degrees in 44 countries, for instance, Charles and Bradley (2009) show that women are significantly underrepresented in the field of engineering in all 44 countries. More strikingly, male overrepresentation in engineering is quite considerable in several affluent societies like Switzerland, Germany, Finland, and the United Kingdom, highlighting the pervasive sex segregation regardless of countries' development levels.

Considering that a STEM degree is an important prerequisite for STEM occupations, the lower likelihood for women than for men to choose STEM majors in college naturally leads to lower representation of women than of men in STEM occupations (Xie and Shauman 2003; Frehill 1997). Given the growing importance of the science and engineering workforce in globalized economies as well as concerns about gender equity, a variety of educational programs and research activities to attract women to STEM fields are being enacted (NSF 2006a, 2006b). To broaden women's participation in STEM fields most efficiently, systematic evidence is

required regarding what factors constrain or enhance women's pursuit of STEM majors and occupations.

The major purpose of the current study is to assess the impact of one particular institution that is claimed by many to enhance female students' STEM careers – single-sex high schools. In this study we examine causal effects of single-sex schools across several STEM outcomes using a longitudinal dataset from South Korea (hereafter, Korea). We compare the levels of interest and self-efficacy in math and science subjects between high school seniors in single-sex schools and their counterparts in coeducational schools. We also assess the extent to which students in single-sex and coeducational students differ in their expectations of four-year college attendance and STEM college majors (if they enter college) during their final year of high school. Finally, utilizing longitudinal information gathered by following up those high school seniors over two years after they graduate from high school, we examine whether single-sex school experiences in high school affect students' actual attendance at a four-year college and their actual choice of a STEM college major.

There are many claims that all-girls high schools enhance female education, particularly in STEM, because of the absence of social interactions with boys that divert attention from academic activities and because of the absence of competition from boys for teachers' attention (Mael et al. 2004; LePore and Warren 1997). However, some studies find no significant differences between single-sex and coeducational schools, questioning any benefits of single-sex education (Marsh 1989; LePore and Warren 1997). Despite the voluminous literature on single-sex schools, there is far from a consensus on the effects of single-sex schools on educational outcomes including STEM career choices.

A fundamental issue underlying the disagreement on single-sex school effects is that it is difficult to discern what such differences in educational outcomes mean for students in single-sex and coeducational schools (Mael et al. 2005; Sax 2009). These differences may reflect selection mechanisms rather than the effects of the schools per se. Most studies that have examined differences in educational outcomes between students *choosing* to attend single-sex and those *choosing* to attend coeducational schools, on the basis of observational data, provide only associations. There has not been persuasive, systematic examination of single-sex school effects that controls for the selection of students into single-sex schools. In an educational system like that in the United States, in which some students are able to choose single-sex schools over coeducational schools, the two bodies of students attending single-sex and coeducational schools are likely to differ in observed and unobserved characteristics of both the students and their families.

The changing context of single-sex education in the United States also merits revisiting the possible impacts of single-sex schools. In the past, access to single-sex education was offered basically only in the private sector. At the end of 2006, however, the United States Department of Education established new regulations to make it easier for school districts to create single-sex *public* schools and single-sex classrooms within coeducational public schools (Schemo 2006). As a result, the number of *public* schools that are single-sex or offer single-sex classrooms within coeducational schools has soared from 3 in 1995 to more than 545 in September 2009 (National Association for Single-Sex Public Education 2009). The recent interest in single-sex schooling is also distinguished by its increased interest in the potential of single-sex schooling for boys as well as girls, while the previous literature focused mostly on girls.

In this study, we utilize unique data from a context, Korea, in which assignment to all-girls, all-boys and coeducational high schools is random, to draw causal inferences on the effectiveness of single-sex schools with regard to STEM outcomes. The 'High School Equalization Policy' (*P'yŏongjunhwa Chŏngch'aek*) in Korea randomly sorts entering high school students into either single-sex or coeducation schools within school districts (Kim 2003). Exploiting this unique random assignment in Korea, we can move beyond associations that dominate in the existing literature to assess causal effects of single-sex schools.

Beside *average* effects of single-sex schools, we also examine whether students differentially benefit from single-sex schools, depending on their parental SES. An important question in educational research, besides identifying a single programmatic effect, is to identify for which type of students an educational intervention works and for which types of students the intervention effect is larger, non-existent or negative. Indeed, policy efforts in many countries have been devoted to increase participation in STEM fields of not only women but also of racial/ethnic minorities and lower SES students (NSF 2003; Royal Society 2008). Therefore, it is important to examine whether single-sex schools can promote, for example, advancement of low SES students into STEM as well as women. Moreover, moving beyond the focus on girls, in this study the effects of all-boys schools are also systematically assessed.

Why Might Single-Sex Schools More Beneficial?

In contrast to the common assumption that coeducational schools should promote gender equity in learning experiences, numerous studies of primary and secondary schools in the United States have suggested (through associational descriptions) pervasive, subtle gender discrimination and bias in teacher-student interactions and peer-group interactions in

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coeducational settings (LePore and Warren 1997; AAUW 1992). Therefore, some researchers and educational practitioners have proposed several reasons that single-sex schools may provide better environments for female students with regard to both teacher-student and peer-group interactions, which may encourage them to pursue their educational careers in STEM as well as improve female students' overall educational outcomes (Mael et al. 2004; Thompson 2003). First, single-sex schools may reduce influences of adolescent subcultures that tend to distract students' attention from academic learning and instead place emphasis on physical characteristics, social status and interpersonal relationships (Coleman 1961; Riordan 1990). More than four decades ago, Coleman (1961) showed that students in coeducational schools were more concerned about appearance and popularity, leading him to conclude on the basis of these associations that coeducational schools restrained academic achievement. Another related archetypical idea is that girls do not want to seem "too smart" because they do not want to lose their appeal to boys. Concerns for dating and interpersonal relationships may particularly discourage female students' interest in traditionally male-dominant subjects such as math and science: "…in a mixed-sex environment, girls may find it more difficult to compete academically, learning that their success might be threatening to boys, who might then reject them as potential sexual partners" (Riordan 1990: 57). By reducing the influences of adolescent culture, therefore, single-sex schools may help students concentrate on academic learning.

Another potential source of single-sex school effects, especially for girls, is related to classroom dynamics that affect students' self-concept, self-efficacy and confidence in academic learning (UNESCO 2007; Streimatter 1997; Lee and Bryk 1986). Interviewing and observing students in single-sex math classrooms in United States secondary schools, Streitmatter (2002) found that the girls in a single-sex classroom had the sense of ownership of their class, while the

same girls did not feel the sense of ownership in coeducational classrooms. Girls perceived the dominance of boys in coeducational schools: "Guys yell out the answer and want to give the answers. They take up a lot of attention. It's kind of like the whole class is spinning around that guy and not math" (Streitmatter 2002: 217, interview with a girl in a girls-only classroom). However, girls in a single-sex classroom reported that they were not afraid of asking and answering questions because they were no longer concerned about reactions from boys as in usual coeducational classrooms: "Being in this [girls-only] class, I've been able to ask questions and get help from the teacher without being afraid of being made fun of" (Streitmatter 2002: 221). Along with the sense of ownership of class, female students reported enhanced confidence in their abilities in math as a consequence of attending the single-sex math classroom: "…I am not sure what it will be like in math next year, but at least I know I can do math and I'm not stupid in it" (Streitmatter 2002: 221).

As mentioned above, however, scholars who pay attention to the way in which students (and their families) select into single-sex schools, argue that observed differences in educational outcomes, if any, between students attending single-sex and coeducational schools may be spurious due to unobserved students' (and families') characteristics (LePore and Warren 1997; Marsh 1989). Indeed, these studies showed that better outcomes of single-sex schools than coeducational schools often disappear when an extensive list of controls such as prior achievement are included in the model. Moreover, even though extensive controls of observable characteristics of students and their families in observational data are helpful in assessing effects of single-sex schools, potential biases due to students' selection can not be ignored as long as observational data are used because there are likely to be important unobserved factors that determine both the choice of type of school and success in school.

The Random Assignment in Korea

Although a randomized experiment may be the best option for drawing causal inferences about the effectiveness of single-sex schooling, it is extremely difficult to conduct such an experiment in the real world. Interestingly, the current educational system of Korea has a unique feature of random assignment of students into high schools. Before 1974, Korean high schools could choose their students on the basis of students' scores on entrance examinations administered by individual high schools, resulting in apparent clustering by family background and substantial between-school differences in students' academic performance. The rising concern about between-school inequality and academic pressure on students to do well on high-school entrance examinations led to a national educational reform called the 'Equalization Policy'(*P'yŏongjunhwa Chŏngch'aek*) (Kim 2003; Lee et al. 1996). This policy has created a de facto experiment, in which students after middle school graduation are *randomly* assigned to high schools within their school districts. Note that after middle schools students can proceed into two different types of high schools: academic high schools and vocational high schools. The high school equalization policy is applied only to academic high schools. In recent years, about three out of four high school students in Korea have attended academic high schools (from now on we simply call academic high schools as "high schools" unless specified otherwise).

The random assignment is applied regardless of whether schools are coeducational or single-sex schools. In other words, students cannot choose between single-sex or coeducational schools. The equalization policy even does not allow private schools to choose their students. Private schools are also subject to the random assignment of students. Therefore, there is no significant difference in students' socioeconomic background between students attending private

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and public schools (Park 2010).[1] Students have to accept the random assignment unless they

move to a different school district where they are subjected to another lottery. This procedure

guarantees genuine randomness in student assignment into schools. Overall, the assignment of

students to high schools in Korea is very close to a randomized experiment, which creates an

exceptional opportunity to see if single-sex schools have direct educational benefits not

attributable to the pre-existing characteristics of students (or their families) who choose to attend

single-sex schools.

There are two things to note regard the equalization policy. First, in recent years some

school districts have loosened the equalization policy to some extent. They allow students to list

a number of schools they prefer and then randomly select 30 – 40% of enrollments in a school

among those students who showed preference. Then, the remaining enrollments are randomly

selected among those who were not assigned to schools they listed. In other words, the

modification allows some choices of schools by students as compared to the restrictive random

assignment. When respondents in our data entered high schools, students in Seoul, capital of

Korea could not list preferred schools but were randomly assigned to schools, while in other

metropolitan areas students could list their preferred schools to some extent. However, given

that students are still randomly assigned to one of their preferred schools and even only a portion

of students are assigned in this way, the assignment still restricts considerably choices of

students. Unfortunately, in our data we are not able to identify which students were assigned to

their preferred schools in those areas where modified equalization policy was practiced.

Moreover, due to the small size of original sample in our data, it is practically difficult to

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[1] The Korean government also imposes uniform curriculum and tuition for public and private schools. However, private schools are owned by individuals and they do have rights to select teachers, although not students. Teachers in public schools have to move to a different school within the province every 4-5 years, while teachers in private schools can stay in the same school more than 4-5 years.

distinguish students in "intact" equalization policy areas and students in "modified" equalization policy areas. Therefore in this study we treat modified equalization policy areas the same as intact equalization policy areas. Although the sample size became too small to conduct meaningful statistical tests between the two equalization areas, our crude comparisons indicated that the overall pattern of the effect of single-sex schools was similar between the two areas. Moreover, our previous study, which compared effects of single-sex schools on overall college attendance using school-level data covering all high schools in both intact and modified equalization policy areas, showed very similar patterns of the effects of single-sex schools (Park and Behrman 2010).

The second caveat is that the randomization is executed on a large scale across most of the nation, using a public lottery. Note, however, that this equalization is not applied to all areas. There are some school districts in Korea that have not yet implemented the equalization policy at all. In those areas, students apply to a specific school on their choice and are admitted on the basis of middle school GPA, test scores, and other criteria. In 2003, 72 percent of high school students in Korea resided in areas in which the equalization policy was applied, including all the students in metropolitan areas. In the current study, we conduct analysis separately for equalization policy areas (combining both intact and modified equalization policy areas) and non-equalization policy areas to see if the effects of single-sex schools might differ depending on the extent to which students can choose their schools.

Data

For this study, we use data from the Korean Education and Employment Panel (KEEP), which is a nationally representative, longitudinal survey that began in 2004 by interviewing

2,000 academic high school seniors (i.e., 3rd-year high school students) across 100 schools (Chae et al. 2006). In the 2004 baseline survey, KEEP collected a variety of information on high school seniors' attitudes toward study and specific subjects, their educational and occupational plans, their demographic characteristics, and other information. In each year since the baseline, KEEP reinterviewed respondents to collect information on educational transitions. In this study, we utilize the data from the baseline to the second follow-up conducted in 2006. Using the three-year data, we can determine who expected to major in STEM in college during their final year of high school, and who actually chose a STEM college major by two years after high school. As will be explained in more detail below, in Korean college application system students apply to a specific major (department) (or a group of majors) and are accepted or rejected by the department. Therefore, with only two years of data after high school graduation, we can still identify students' college majors. School administrators were also surveyed to provide information on the schools, including an indicator of single-sex or coeducational school. A parent of each respondent filled in the questionnaire to provide information on the respondent's family environment.

Among the total of 2,000 academic high school seniors, 180 seniors attended "specialized" high schools such as science and foreign language high schools that are not subject to the equalization policy. After excluding those 180 seniors, our final sample consists of 1,820 academic high school seniors in the baseline. Note that although we exclude those attending "specialized" high schools, we retain students attending other general academic high schools in non-equalization policy areas to compare the effects of single-sex schools in the areas to those in equalization policy areas.

Checking Randomness of Student Assignment: Differences in Students' Socioeconomic Backgrounds between Single-Sex and Coeducational Schools

Given the importance of random assignment into single-sex or coeducational schools for our analysis, it is critical to confirm the randomness from the survey data by checking for balance on observed characteristics of parents between students in single-sex and coeducational schools. Therefore, before discussing the effects of school type on STEM outcomes, we examine the extent to which students attending single-sex and coeducational schools are similar in their socioeconomic backgrounds. Among potentially many aspects of socioeconomic background, we select father's education, mother's education, household income, and number of books at home. Each of these four variables has been widely used to measure a specific aspect of family environments in the literature on social stratification (Buchmann 2002). Specially, we run a logistic regression for predicting single-sex attendance by these four background measures for boys and girls, separately. Our expectation is that when students are randomly sorted into single-sex and coeducational schools, background measures should not have significant association with students' enrolment in single-sex schools (as compared to enrolment in coeducational schools). For comparison, we also present the results of logistic regressions for non-equalization policy areas as well as equalization policy areas. As mentioned above, there are some areas in Korea where the high school equalization policy, which randomly distributes students into single-sex and coeducational schools, is not applied. Therefore, we can compare the degree of association between family background and students' attendance at single-sex schools between equalization policy areas and non-equalization policy areas.

TABLE 1 ABOUT HERE

Panel A in Table 1 shows the results of logistic regressions separately for boys and girls in the equalization policy areas. None of the four background measures is significantly associated with attendance at single-sex schools for either girls or boys. In other words, in equalization policy areas where students are randomly assigned into single-sex and coeducational schools, we find that students attending each type of school do *not* significantly differ at least in our four background measures. Interestingly, however, the results for non-equalization policy areas in Panel B, indicate somewhat, although weak, significant associations of family background, especially number of books at home for both boys and girls and father's college education for boys, with attendance at single-sex schools. Those who have more books at home are more likely to attend single-sex schools than coeducational schools for both girls and boys and boys who have fathers with college education also are more likely to attend single-sex schools than coeducational schools. Note that these results mean that if students in the non-equalization policy areas perform better in single-sex than in coeducational schools, it is not possible to identify confidently whether it is the effects of the single-sex schools or their better family background – the basic problem noted above in the literature to date using observational data.

Causal Effects of Single-Sex Schools on Math and Science Interest and Self-Efficacy

The results in Table 1 showing no significant relationships between socioeconomic background and students' enrolment at single-sex schools in equalization policy areas increase our confidence regarding the random assignment in Korean high schools in these areas. We now estimate causal effects of single-sex schools on STEM outcomes. The first set of outcomes that we examine is the degree of students' interest and self-efficacy in math and science subjects.

The baseline survey of KEEP asked high school seniors to indicate the extent to which they agree upon the following two statements: 1) I am interested in this subject; and 2) I am good at this subject. Although the questions were asked for other subjects such as Korean language and English, in this study we focus on students' answers for math and science subjects. The first question item is related to student's interest in math and science, while the second question item measures the level of self-efficacy. Students indicated the degree of agreement on a five-point scale from "strongly disagree (1)" to "strongly agree (5)."

TABLE 2 ABOUT HERE

Table 2 presents mean differences between high school seniors attending single-sex and coeducational schools in four items for math and science interest and self-efficacy for girls and boys, separately. Note that if the assignment of students into schools is random, simple mean comparisons such as those in Table 2 should produce unbiased estimates of effects of single-sex schools. Controlling for students' socioeconomic backgrounds and other individual characteristics should not affect the coefficients of single-sex school effects but only increase precision. In the final version of this paper, we will run the regression analysis to control for those familial and individual characteristics to improve precision of our estimates.

The results in Panel A for equalization policy areas show that there is no significant difference between girls attending all-girls schools and their counterparts attending coeducational schools in any item. However, we do see significant differences by school type among boys. In both math and science, boys attending all-boys show significantly higher levels of interest and self-efficacy than boys attending coeducational schools.

However, the pattern in equalization policy areas is different from the pattern in non-equalization policy areas shown in Panel B. In non-equalization areas where students can select

single-sex versus coeducational schools, girls in all-girls schools show higher levels than girls in coeducational schools. Combined with the finding that there is no significant difference between girls attending the two different types of school in equalization policy areas, this finding of significant difference in non-equalization policy areas seems to suggest that better educational outcomes of all-girls schools than coeducational schools consistently found in previous literature may reflect selection effects to some extent. It is interesting, however, to see no significant difference by school type among boys in non-equalization policy areas.

Causal Effects of Single-Sex Schools on Expectations of a Four-Year College and a STEM Major

TABLE 3 ABOUT HERE

The second set of outcomes we examine is whether students in each type of school are different in their expectations of attending a four-year college and of selecting a STEM college major if they expect attending a four-year college. In the 2004 baseline survey, KEEP asked high school seniors to indicate whether they expected to go to college, and which majors they expected to choose if they entered college. Table 3 shows percentage differences in students' expectations by school type for girls and boys, separately. In Panel A for equalization policy areas, girls attending all-girls and coeducational schools do not significantly differ in their expectations of a four-year college and a STEM college major (among those who expect a four-year college). However, the effect of all-boys schools is evident. Boys attending all-boys schools have a significantly higher level of expecting a four-year college than boys attending coeducational schools (92% vs. 85%). Boys attending all-boys schools and expecting to attend a four-year college are also more likely to expect a STEM college major than their counterparts in

coeducational schools (32% vs. 23%). Overall, the pattern revealed in Table 3 is close to the pattern for math and science interest and self-efficacy shown in Table 2: no significant effect of all-girls schools but a significant effect of all-boys schools.

For the non-equalization policy areas in Panel B, there is evidence that girls attending all-girls schools are more likely to expect to attend a four-year college than their counterparts in coeducational schools (85% vs. 70%). Conditional on expectation of attending a four-year college, furthermore, girls in all-girls schools are more likely to expect a STEM college major than girls in coeducational schools. This significant effect of all-girls schools is also consistent with the pattern for math and science interest and self-efficacy in Table 2. In other words, in both outcomes in Table 2 and 3, girls in all-girls schools show higher levels than girls in coeducational schools only in non-equalization policy areas, not in equalization policy areas. In non-equalization policy areas, a larger share of boys in all-boys schools than their counterparts in coeducational schools expects a four-year college, while there is no significant difference in students' expectation of a STEM college conditional on expectation of a four-year college.

Causal Effects of Single-Sex Schools on Actual College Attendance and Choice of a STEM Major in College

So far, we examined two sets of outcomes – 1) math and science interest and self-efficacy; and 2) expectations of a four-year college and a STEM college major – when respondents were high school seniors. Because the KEEP survey followed high school seniors over two years after high school graduation, using longitudinal information we can identify who actually enrolled in a four-year college by two years after high school graduation. Because Korean

students apply to specific majors (departments) for college admission, we can identify their majors (departments) even with the data of sophomore college students.

TABLE 4 ABOUT HERE

Among a total of 1,820 high school seniors, 63 % (1,140) made transitions to four-year colleges by two years after high school graduation, while 29 % either went to 2-year junior colleges or were not in post-secondary educational institutions, perhaps because they entered labor markets. KEEP was not able to resurvey 8% of original high school seniors, which are excluded from the analysis below.[2] Table 4 presents the results of making transitions to four-year colleges by two years after high school graduation. In equalization policy areas (Panel A), 68 % of female seniors who attended all-girls schools made transitions to four-year colleges by two years after high school, which is not significantly different from 65 % among their counterparts who attended coeducational schools. The tenuous relationship between school type and actual college attendance among girls seen in Table 4 is consistent with the results for math and science interest and self-efficacy (Table 2) and expectations of a four-year college (Table 3).

In contrast to no significant effect of all-girls schools, the effect of all-boys schools is positive and significant, which is also consistent with the pattern for the previous analyses in Table 2 and 3. Male seniors who attended all-boys schools are more likely to attend a four-year college by two years after high school than their counterparts who attended coeducational schools. The higher level of four-year college attendance among boys who attended all-boys high schools than boys who attended coeducational schools is also found in non-equalization policy areas. In those areas where students select into schools, girls who attended all-girls high

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[2] In the final paper we will examine how these 8% compare with the others. But because this is a fairly small group, we do not anticipate that this attrition affects importantly our results.

schools also show a higher percentage of four-year college attendance than girls who attended coeducational schools.

With regard to selecting a STEM major conditional on attending a four-year college, Panel A indicates that in the equalization policy areas 24.9% of girls who attended single-sex high schools select STEM majors as compared with 20.1% of girls who attended coeducational high schools, but this difference is not statistically significant. In contrast, 53.2% of boys who attended all-boys high schools selected STEM majors if they went to four-year colleges, significantly more than the 40.5% who attended coeducational high schools. In the non-equalization policy areas (Panel B), conditional on attending four-year colleges the percentages selecting STEM majors are slightly higher for those who attended single-sex versus coeducational high schools, but the differences are not statistically significant.

Variation in the Effect of Single-Sex School by Parental SES

The analyses done so far in Tables 2 – 4 assume uniform effects of single-sex schools regardless of students' socioeconomic backgrounds. As noted above, however, an interesting question is whether single-sex schools might be particularly beneficial to a certain population, for instance, students from economically disadvantaged families. Therefore, in this section we examine how the effects of single-sex schools may vary across students by parental SES. For the variables in Table 2, we estimate linear regressions for math and science interest and self-efficacy by school type (single-sex vs. coeducational schools), parental SES, and interaction between school type and parental SES. The interaction coefficients tell whether the effect of single-sex school varies by parental SES. For dichotomous outcome variables in Table 3 and Table 4, we conduct logistic regressions by school type, parental SES, and interaction between

school type and parental SES. [The results of the analysis will be included in the paper to be presented at the meeting but has not been completed yet.]

Conclusion

There has been long-standing interest in the possible positive effects of all-girls schools for improving girls' education in general and in STEM specializations in general. But the positive associations presented in the previous literature do not permit identifying the effects of selection into all-girls schools versus the effects of those schools. Using the unique Korean experience of random assignment in most, but not all areas, we find the all-girls schools do not significantly affect a range of indicators related to STEM education and careers. However, based on the areas in which the policy has not been applied, we do find evidence of selection effects of the sort that also may be present in previous studies that attempt to make causal inferences on the basis of associations in observational data – consistent with the possibility that it is selection, not the effects of all-girl schools per se, that underlies their results.

Recently there has been increasing interest in educational issues concerning adolescent boys and, relatedly, whether single-sex schools might improve their education. In contrast to girls, we find that single-sex schools enhance boys' interest in, confidence about, and expected and actual enrollments in STEM majors in college. Thus, strikingly, we do not find evidence of causal effects of all-girls schools on girls STEM concentrations – but do find significant evidence for boys, to whom the previous literature has paid very little attention until recently.

[More to be added about SES interaction effects.]

REFERENCES

American Association of University Women (AAUW). 1992. *How schools shortchange girls*. Washington, DC: American Association of University Women Educational Foundation.

Buchmann, C. & DiPrete, T. A. (2006). The Growing female advantage in college completion. *American Sociological Review* 71: 515-541.

Chae, C. Choi, J. Jung, J. Min, J. Ryu, J. Shin, D. Choi, G. 2006. *The report of descriptive analysis of KEEP (Korean Education & Employment Panel) baseline data*. Seoul: Korea Research Institute for Vocational Education and Training (KRIVET) (in Korean).

Charles, M. & Bradley, K. (2009). Indulging our gendered selves? Sex segregation by field of study in 44 countries. *American Journal of Sociology* 114: 924-976.

Coleman, J. (1961). *The adolescent society*. New York: Free Press.

Freeman, C. E. (2004). *Trends in educational equity of girls & women: 2004* (NCES 2005–016). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

Frehill, L.M. (1997). Education and occupational sex segregation: The decision to major in engineering. *Sociological Quarterly* 38: 225-249.

Kim, K. 2003. Modifications of the equalization policy and suggested policy measures. *Korea Journal* 43: 200-214.

Lee, D-H. et al. (1996). Educational policy in Korea. Background Paper for OECD Review of Korean Educational Policy. Korean Educational Development Institute (in Korean).

Lee, V.E. & Bryk, A.S. 1986. Effects of single-sex secondary schools on student achievement and attitudes. *Journal of Educational Psychology* 78: 381-395.

LePore, P., & Warren, J. R. (1997). A comparison of single-sex and coeducational Catholic secondary schooling: Evidence from the National Educational Longitudinal Study of 1988. *American Educational Research Journal, 34,* 485-511.

Mael, F. Smith, M. Alonso, A. Rogers, K. & Gibson. D. (2004). *Theoretical arguments for and against single-sex schools: A critical analysis of the explanations*. Washington, DC: American Institutes for Research.

Mael, F. A. et al. (2005). *Single-sex versus coeducational schooling: A systematic review*. U.S. Department of Education, Office of Planning, Evaluation and Policy Department, Policy and Program Studies Service.

Marsh, H.W. (1989). Effects of attending single-sex and coeducational high schools on achievement, attitudes, behaviors, and sex differences. *Journal of Educational Psychology* 81: 70-85.

National Center for Educational Statistics (NCES). 2007. *2005-06 Integrated postsecondary education data system (IPEDS)*.

National Science Foundation. (2003). *Women, minorities, and persons with disabilities in science and engineering: 2002*. Arlington, VA: NSF.

National Science Foundation. 2006a. *New tools for America's workforce: Girls in science and engineering*. NSF 06-59. http://www.nsf.gov/pubs/2006/nsf0659/nsf0659.pdf

National Science Foundation. 2006b. *New formulas for America's workforce 2: Girls in science and engineering*. NSF 06-60. http://www.nsf.gov/pubs/2006/nsf0660/nsf0660.pdf

Riordan, C. 1990. *Girls and boys in school: Together or separate?* NY: Teachers College Press.

Royal Society. 2008. *Exploring the Relationship between Socioeconomic Status and Participation and Attainment in Science Education*. London: The Royal Society.

Sax, L. J. (2009). *Women graduates of single-sex and coeducational high schools: Differences in their characteristics and the transition to college*. The Sudikoff Family Institute for Education & New Media.

Schemo, D.J. (2006). Federal rules back single-sex public education. *New York Times*. October 25, 2006.

Streitmatter, J. (1997). An exploratory study of risk-taking and attitudes in a girls-only middle school math class. *Elementary School Journal* 98: 15-26.

Streitmatter, J. (2002). Perceptions of a single-sex class experience: Females and males see it differently. In A. Datnow & L. Hubbard (Eds.), *Gender in policy and practice: Perspectives on single-sex and coeducational schooling* (pp. 212-226). New York: Routledge.

Thompson, J. S. (2002). The effect of single-sex secondary schooling on women's choice of college major. *Sociological Perspectives* 46: 257-278.

United Nations Educational, Scientific, and Cultural Organization (UNESCO). 2007. *Single-sex schools for girls and gender equality in education*. Bangkok, Thailand: UNESCO.

Xie, Y. & Shauman. K. K. (2003). *Women in science: Career processes and outcomes*. Cambridge, MA: Harvard University Press.

Table 1. Predicting Single-Sex School Attendance by Students' Socioeconomic Backgrounds

	Girls All-Girls Schools (vs. Coed Schools)		Boys All-Boys Schools (vs. Coed Schools)	
Panel A. Equalization Policy Areas	**b**	**se**	**b**	**se**
Father's college education	0.116 (0.235)		0.216 (0.202)	
Mother's college education	-0.014 (0.298)		0.245 (0.275)	
Monthly household income	-0.032 (0.151)		-0.052 (0.119)	
Number of books at home	0.012 (0.062)		0.005 (0.054)	
Constant	0.456 (0.864)		0.605 (0.685)	
N	336		705	
Panel B. Non-Equalization Policy Areas				
Father's college education	0.588 (0.503)		0.579 (0.351)[^]	
Mother's college education	-1.012 (1.043)		0.792 (0.610)	
Monthly household income	-0.205 (0.172)		-0.006 (0.158)	
Number of books at home	0.240 (0.108)[*]		0.156 (0.088)[^]	
Constant	0.327 (0.925)		-0.470 (0.873)	
N	224		555	

Note: Values in the column of "b" indicate logistic regression coefficients. Values in the column of "se" indicate robust standard errors.

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

Table 2. Mean Differences in Students' Math and Science Interest and Efficacy by School Type

Variable	Girls				Boys			
	All-Girls	Coed	Difference	P value	All-Boys	Coed	Difference	P value
Panel A. Equalization Policy Areas								
Math Interest	2.99	2.91	0.08	0.45	3.09	2.82	0.26	**0.01**
Math Self-Efficacy	2.30	2.25	0.05	0.58	2.46	2.23	0.23	**0.01**
Science Interest	2.66	2.72	-0.06	0.58	3.31	2.87	0.43	**0.00**
Science Self-Efficacy	2.26	2.29	-0.03	0.72	2.71	2.38	0.34	**0.00**
Panel B. Non-Equalization Policy Areas								
Math Interest	2.97	2.63	0.34	**0.05**	2.71	2.74	-0.03	0.82
Math Self-Efficacy	2.23	2.19	0.04	0.74	2.24	2.18	0.06	0.60
Science Interest	2.88	2.56	0.32	0.37	2.86	2.98	-0.13	0.06
Science Self-Efficacy	2.42	2.12	0.30	**0.03**	2.38	2.54	-0.16	0.17

Note: Each variable is measured on the basis of a five-point scale. Higher values indicate higher levels of interest or self-efficacy.

Table 3. % Differences in Students' Expectations of a 4-Year College and a STEM College Major by School Type

Variable	Girls				Boys			
	All-Girls	Coed	Difference	P value	All-Boys	Coed	Difference	P value
Panel A. Equalization Policy Areas								
Expecting a Four-Year College	88.8	89.8	-1.0	0.70	92.4	85.3	7.1	**0.00**
Expecting a STEM College Major	8.8	10.4	-1.6	0.54	32.0	23.1	8.9	**0.02**
(among those who expect a four year college)								
Panel A. Non-Equalization Policy Areas								
Expecting a Four-Year College	85.0	70.2	14.8	**0.00**	85.6	70.5	15.2	**0.00**
Expecting a STEM College Major	16.5	6.9	9.6	**0.05**	25.6	25.0	0.6	0.92
(among those who expect a four year college)								

Table 4. % Differences in Actual Attendance at a Four-Year College and Choice of a STEM Major by Two Years after High School

Variable	Girls				Boys			
	All-Girls	Coed	Difference	P value	All-Boys	Coed	Difference	P value
Panel A. Equalization Policy Areas								
Attending a Four-Year College	67.7	65.0	2.7	0.52	79.5	58.5	21.0	**0.00**
Choosing a STEM College Major	24.9	20.1	4.7	0.31	53.2	40.5	12.7	**0.01**
(among those who attend a four year college)								
Panel A. Non-Equalization Policy Areas								
Attending a Four-Year College	65.6	52.1	13.5	**0.05**	78.6	67.5	11.1	**0.03**
Choosing a STEM College Major	27.0	18.0	9.0	0.23	51.2	48.2	3.0	0.64
(among those who attend a four year college)								