# GENDER STREAMING AND PRIOR ACHIEVEMENT IN HIGH SCHOOL SCIENCE AND MATHEMATICS

Naomi Friedman-Sokuler and
Moshe Justman

Discussion Paper No. 15-13

November 2015

Monaster Center for
Economic Research
Ben-Gurion University of the Negev
P.O. Box 653
Beer Sheva, Israel

Fax: 972-8-6472941
Tel: 972-8-6472286

# Gender Streaming and Prior Achievement in High School Science and Mathematics*

Naomi Friedman-Sokuler† and Moshe Justman‡

July 27, 2015

**Abstract**

Women's underrepresentation in mathematically intensive fields is often attributed to gender differences in mathematical ability. We test this hypothesis using administrative data on a cohort of Israeli eighth-grade students. These students exhibit recognized gendered patterns in their subsequent choice of advanced matriculation electives: girls favor biology and chemistry while boys favor physics and computer science. Linking these choices to eighth-grade standardized test scores, we find that these gendered patterns remain largely intact after controlling for prior achievement, indicating that they are not driven by gender differences in mathematical ability, nor are they explained by boys' comparative advantage in mathematics.

**Keywords:** gender streaming, comparative advantage, gender gap in mathematics, Israel, secondary school

**JEL Classification Numbers:** I2, J24, J16.

*We gratefully acknowledge the financial support of the Rothschild Caesarea Fund, and the technical support of the Central Bureau of Statistics, especially Yaffa Shif, Edna Shimoni and David Gordon, in preparing the data and making it available to us. None are responsible for any of our findings or conclusions.

†Department of Economics, Ben Gurion University, Israel; corresponding author, *naomif@bgu.ac.il*

‡Department of Economics, Ben Gurion University, Israel, and Melbourne Institute of Applied Economic and Social Research, Melbourne University; *justman@bgu.ac.il*

# 1 Introduction

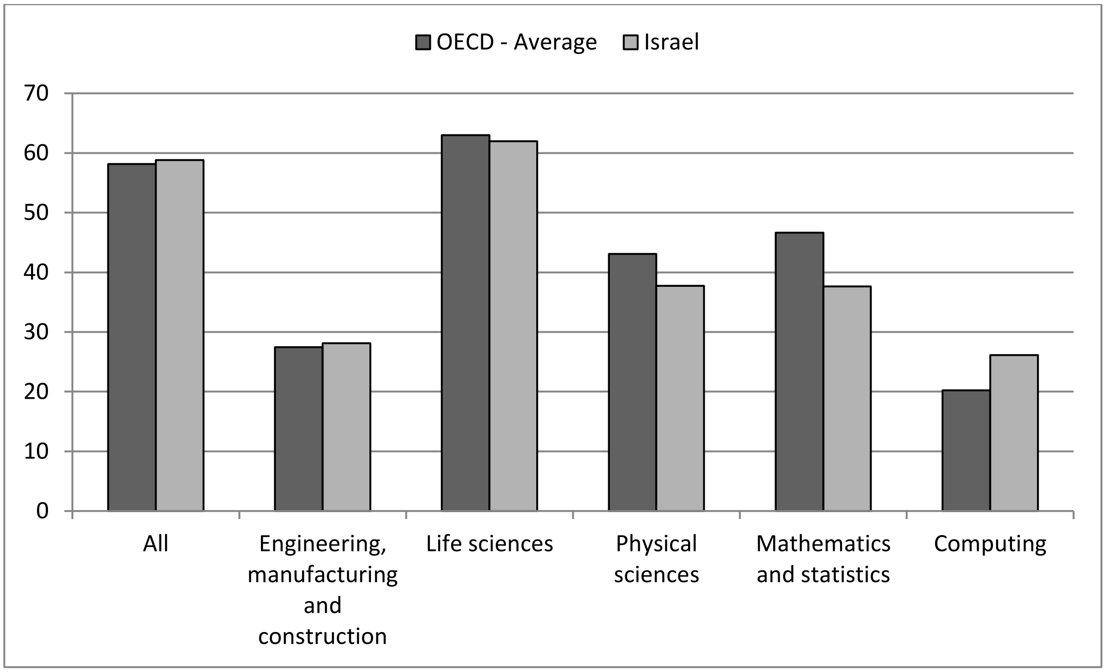
Under-representation of women in high-paying jobs in engineering and information technology occupations contributes substantially to the gender wage gap in advanced industrialized economies (OECD, 2007). In Israel, women constitute 46.5% of the general labor force and account for only 24% of employment in high-technology occupations (Fichtelberg-Barmatz, 2009).[1] Excluding women from high-paying professions has clear equity implications, and may also undermine efficiency, if it leads to less-able men displacing more-able women in key professions that drive economic growth, or if it contributes to a shortage of qualified graduates in these professions. Similar patterns are observed in higher education where women account for a minority of engineering and computer science degrees and a majority of degrees in life sciences and health professions (OECD, 2011). In Israel, women receive fewer than 30% of degrees in computer science and engineering while comprising over half of the total student population (Figure 1). Women have made huge strides in tertiary education (Goldin et al., 2006), overtaking men in overall participation and in some scientific fields, but engineering, physical science and IT remain predominantly male preserves.

Career choices in general, and specifically the choice to specialize in Science, Technology, Engineering, and Mathematics (STEM) fields in secondary and tertiary education are dynamic processes of successive decision making under uncertainty (Altonji, 1993; Arcidiacono, 2004; Altonji et al., 2012; Zafar, 2013). The mathematical intensity of fields in which women are under-represented has led many to assume that it is mathematics acting as a "critical filter", and males' absolute or comparative advantage in mathematics, that drives these patterns (Sells, 1973).[2] This has generated extensive research on whether and to what extent there is indeed a male advantage in mathematics. Findings indicate that males generally have a slight average advantage, which varies

[1] Included among "high-technology occupations" are: system analysts; academics in computer science; electric and electronic engineers, practical engineers and technicians; computer engineers, practical engineers and programmers; chemists; physicists; mathematicians; other engineers and architects.

[2] As Ceci et al. (2014, p. 75) summarize the extensive literature on women in academic science, "women are underrepresented ... in those fields that are the most mathematically intensive."

Figure 1: Share of tertiary qualifications awarded to women in Israel and OECD countries within field of education, %




Source: Indicators of Gender Equality in Education, OECD

with age, cultural context, type of test and other factors, and in some cases disappears.[3] There is clearer evidence of a male advantage at the high end of the distribution of mathematics outcomes, as a result of the greater variability in male outcomes (Hedges and Nowell, 1995; Xie and Shauman, 2003; Hyde et al., 2008; Ellison and Swanson, 2010; Pope and Sydnor, 2010). Evidence of a male comparative advantage in mathematics is similarly robust and persistent, as the female advantage in language skills is everywhere greater than any male advantage in mathematics (Goldin

[3]On the United States, see, e.g., Fryer and Levitt (2010), on the emergence of a gap favoring boys in the early years of elementary school; and Pope and Sydnor (2010) on a gap favoring boys in middle and high school, with substantial variation across states. Among international studies, Trends in International Mathematics and Science Study (TIMSS) 2003 indicates a gap favoring boys in OECD countries (Bedard and Cho, 2010), which does not extend to all participating countries (Else-Quest et al., 2010; Kane and Mertz, 2012). The OECD Program for International Student Assessment (PISA) shows a general advantage for boys (Guiso et al., 2008; Else-Quest et al., 2010). Meta-analyses covering a wide range of ages, test types and nationalities (e.g., Hyde et al., 1990, 2008; Lindberg et al., 2010) find a large dispersion of findings with a small average advantage for boys, of the order of 0.05 of a standard deviation, and some showing a female advantage. Boys show a larger advantage in complex problem solving and in high school, though this latter finding generally does not take into account the greater male attrition in high school. Over time, average gaps favoring boys have decreased (Goldin et al., 2006; Neuschmidt et al., 2008; Ceci et al., 2014). In Israel, boys show a slight advantage in PISA and TIMSS 2003 mathematics while girls slightly outperform boys in TIMSS 2007 and on curriculum-based national eighth-grade mathematics tests.

et al., 2006; Fryer and Levitt, 2010; Wang et al., 2013).

Several studies have tested the "critical filter" hypothesis directly with regard to the choice of college major in the United States, and found that significant gender gaps in choice remain after controlling for high school and SAT achievement.[4] We use longitudinal data to test the "critical filter" hypothesis directly with regard to an earlier stage of education, the choice of advanced science and mathematics electives by high-school students in Israel. To this end, we follow a large population of eighth-grade students, approximating a full cohort of students in Hebrew language schools, for whom we have standardized (eighth-grade) test scores in mathematics, Hebrew, science and English, to the twelfth-grade, when they are tested in matriculation electives chosen during high school.[5] We find that their choice of advanced electives in science and mathematics anticipates the gendered patterns subsequently observed in university and in the workforce: male students strongly prefer physics and computer science and have a smaller advantage in advanced mathematics; female students are much more likely to choose biology and chemistry.[6] Conditioning these choices on students' eighth-grade standardized test scores, we find that these patterns remain intact: girls and boys with similar eighth-grade scores exhibit the same gendered patterns described above. Mathematics regulates entry to science and mathematics electives but gender differences in prior mathematical achievement do not explain any of the gender gap in these electives. Moreover, we find no support for the comparative advantage hypothesis: students who do well in both mathematics and language arts are more likely to choose mathematics and science electives than students who do well only in mathematics.[7]

This bears directly on the earlier work of Paglin and Rufolo (1990), Turner and Bowen (1999),

[4]These include Turner and Bowen (1999), Xie and Shauman (2003), Riegle-Crumb and King (2010) and Riegle-Crumb et al. (2012).

[5]We look at two halves of the full national cohort of eighth-grade students in two successive years, excluding students in ultra-orthodox schools that do not participate in these tests. Matriculation electives are chosen in tenth-grade and most tests are administered at the end of grades eleven and twelve.

[6]Ayalon (1995), using earlier Israeli data aggregated at the school level, found similar patterns: boys are overrepresented in physics and girls in biology, but to a lesser extent than in college; and these patterns are more pronounced in schools with high average mathematical ability. Goldin et al. (2006, Table 4) find smaller gender gaps, in the same direction, in the choice of high-school courses in physics and biology in the United States.

[7]This departs from Riegle-Crumb et al. (2012) who find a significant positive effect for comparative advantage. We elaborate on this below.

Xie and Shauman (2003), Riegle-Crumb and King (2010) and Riegle-Crumb et al. (2012) on the choice of college majors in the United States, extending it to an earlier stage of education and a different national context, and offering two significant methodological advantages that shed further light on the issue at large. The first is that our study population approximates a full cohort of eighth-grade students, whereas survey-based, college level analyses restrict their attention to students attending college immediately or soon after high school. As boys experience greater attrition in high school and beyond (Goldin et al., 2006), this is likely to produce upward biased estimates of the gender gap in male-dominated fields, and downward biased estimates in female-dominated fields.[8] In addition, survey-based studies generally suffer from sample attrition, which may introduce further bias. Our second advantage is that the eighth-grade measures of prior achievement on which we condition students' subsequent choice of matriculation electives predate specialization in Israeli schools. Turner and Bowen (1999), Xie and Shauman (2003) and Riegle-Crumb et al. (2012) condition students' choice of college majors on measures of prior high school achievement resulting from investment decisions that anticipate college choices, and are therefore likely themselves to exhibit gender streaming.[9]

These differences lead us to slightly different conclusions from those reached in these previous, college-level, studies. Thus Turner and Bowen (1999) consider a sub-sample drawn from twelve selective colleges and universities, and find that prior differences in SAT scores account for almost half the gap in mathematics and physical sciences, and a third of the gap in engineering, where we find that conditioning on eighth-grade scores does not reduce the gap at all. Xie and Shauman (2003) similarly find that the raw gender gap favoring boys in choosing a science or engineering major declines slightly when conditioning on high school standardized test scores, courses and family background. Riegle-Crumb et al. (2012) find that male and female students have similar propensities to major in biological sciences, where we find that female students have a significantly greater propensity to choose advanced biology; and where they find that the conditional advantage

[8] We see this pattern of attrition in our present data (Table 4, below), and it also appears in longitudal data on secondary school students in Victoria, Australia (Justman and Mendez, 2015).

[9] Paglin and Rufolo (1990), lacking better data, conditioned choice of major on (concurrent) GRE quantitative scores, which are directly affected by field of study.

of male students in choosing physical sciences or engineering, controlling for prior scores in mathematics, is smaller than the raw advantage, we find that it is as large or slightly larger. Moreover, where they find that a comparative advantage in mathematics has a positive effect on selection of physical sciences or engineering, we find that the opposite generally holds.[10] Some of these differences may be due to the different stages of education we study, to variation over time, or to cultural differences between the two countries. However, we note a close affinity between our findings here and a study by Justman and Mendez (2015) of grade-12 science and mathematics electives in Australian secondary schools, which similarly control for standardized test scores in grades 7 and 9, suggesting that the methodological differences noted above, rather than cultural differences, drive these different findings.

Analyses such as these indicate that gendered patterns of specialization in science and mathematics cannot be attributed to differences in prior achievement, except possibly in small measure, but rather predominantly reflect gendered differences in students' responses to prior indicators of ability due to psychological factors, social and economic incentives and the influence of the education system.[11] Consistent with this hypothesis, we find that part of the gender difference in the choice of science and mathematics electives can be attributed to differences in their responses to the signals of individual ability inherent in their eighth-grade test scores. We also find gendered differences in the effect of socio-economic deprivation on these choices. These channels of influence are consistent with a wide range of empirical research.[12]

[10] They include the difference between quantitative and verbal GPAs in their regression, as a measure of comparative advantage, and find that it reduces the gender gap in physics and engineering by a further 13%.

[11] Models of choice of college major under uncertainty (Altonji, 1993; Arcidiacono, 2004; Zafar, 2013) formalize the uncertainty students experience regarding their abilities and preferences, as they relate to particular fields of study and career trajectories and the different returns to education they offer.

[12] On the role of psychological differences in a similar context, Buser et al. (2014), show that despite similar average ability, high-school boys in the Netherlands select the prestigious science track more often than girls, and these choices are positively correlated with a measure of competitiveness derived from experiments they conduct. Catsambis (1994) finds that female high school students with similar test scores and class grades to those of male students tend to have less interest in mathematics and less confidence in their mathematical abilities; and these differences are largest among Latinos and smallest among African-Americans. Xie and Shauman (2003, ch. 3) find large gender differences in high school seniors' expectations of choosing a science or engineering major in college: girls have slightly higher expectations to attend college, but are substantially less likely to expect a science and engineering major. Goldin et al. (2006) show that variation in gender differences in school-leaving across socio-economic strata may be the result of socially disadvantaged parents having greater difficulty addressing the more prevalent behavioral problems of boys at school. Altonji (1993) finds that gender differences in the returns to the choice of college major differ by family

The remainder of this paper proceeds as follows. Section 2 describes our student population, their achievement on eighth-grade standardized tests, and their choice of matriculation electives in science and mathematics. Section 3 tests various hypotheses that relate gender streaming in science and mathematics electives to differences in mathematics achievement. Section 4 identifies differences in boys' and girls' responses to eighth-grade test scores, and the impact of social and economic factors on gender streaming. Section 5 concludes.

# 2 Population characteristics, eighth-grade achievement and gender streaming in science and mathematics matriculation electives

Our population comprises two half cohorts of eighth-grade students in Israeli Hebrew-language schools, in the school years 2002/3 and 2003/4 (we refer to them in what follows as 2002 and 2003), 146,254 students in all, of whom 50.7% were male (Table 1). Our measure of individual eighth-grade achievement is taken from Israel's Growth and Effectiveness Measures for Schools (GEMS; "meitzav" in Hebrew), a set of four standardized tests in Hebrew language arts, mathematics, science and technology, and English. In these two years all schools in Israel with an eighth grade, except most ultra-orthodox schools, were split into two balanced samples of equal size, with half the schools participating in GEMS in 2002 and the other half in 2003.[13] Dropping all students for whom we have no test scores leaves us with 46.4% of the population, and we drop another 1.5% of students for whom we have only one GEMS score. We drop observations with missing background variables, which reduces each cell with 2, 3 or 4 test results by between 5.2% and 7.3%.[14] This leaves us with 61,633 students, 42.1% of the full population; we refer to these as our

background. Melzer (2014) highlights differences in returns to education in Israel across gender and socio-economic background.

[13] Ultra-orthodox schools place less emphasis on secular subjects (English, mathematics, science), and on preparing their students for matriculation, and almost all do not participate in GEMS. Virtually all Israeli Hebrew-language schools not serving the ultra-orthodox population are publicly funded.

[14] The only background variables for which there are missing values are "father's years of education" and "mother's years of education." Where we have both observations we use the larger value as our explanatory variable; where we have education for only one parent we use that. We drop observations for which both are missing.

"GEMS sample". Over a third of the GEMS sample, 35.2%, have only two or three GEMS scores, and for these we impute the missing scores from the scores we have, and from student background variables.[15]

Table 1: Descriptive statistics: full population and GEMS sample

| *Number of GEMS scores* | Full population | | GEMS sample | | GEMS sample / Full population | |
|---|---|---|---|---|---|---|
| | Female | Male | Female | Male | Female | Male |
| *None* | 38,215 | 40,190 | 0 | 0 | | |
| 1 | 865 | 1,335 | 0 | 0 | | |
| 2 | 2,668 | 3,114 | 2,504 | 2,887 | 93.9% | 92.7% |
| 3 | 8,580 | 8,898 | 8,007 | 8,294 | 93.3% | 93.2% |
| 4 | 21,703 | 20,614 | 20,404 | 19,537 | 94.0% | 94.8% |
| *2+3+4* | 32,951 | 32,626 | 30,915 | 30,718 | 42.9% | 41.4% |
| *Total* | 146,254 | | 61,633 | | 42.1% | |

## 2.1 Student background characteristics and GEMS scores

The student background characteristics we use include: gender; parents' years of education; family income quintile;[16] and for individuals reaching the twelfth grade four years later (in 2006 for the 2002 cohort, in 2007 for the 2003 cohort), an identifier of the school attended in that grade. Table 2 compares these variables across gender. While they are generally very similar, note that girls are slightly worse off than boys in term of parental education and income, the result of higher attrition among boys from lower SES background in meeting the criterion of having at least two GEMS scores. It shows greater attrition among low-income families, with students in the lowest income quintile accounting for 12.5% of the full population and only 11.2% of the GEMS sample. There are also fewer immigrants in the GEMS sample than in the population at large, because recent

[15]We impute missing GEMS scores by regressing each GEMS score on the other scores and on all available background characteristics for students with all scores, and use the regression to predict missing scores. Adding school fixed effects made very little difference to the imputed values. Qualitatively, our results are robust to limiting the sample to students with all four GEMS score.

[16] Income quintiles are defined in reference to the population as a whole, including families of students attending Arabic-language and ultra-orthodox schools, who are poorer on average and not included in our population, hence the over-representation of our full population in the upper income quintiles.

Table 2: Descriptive statistics: Family SES and school type

| | Female | Male | Total |
|---|---|---|---|
| Father's years of education | 13.03 | 13.18 | 13.11 |
| (standard deviation) | (3.11) | (3.12) | (3.12) |
| | | | |
| Less than 12 years | 22.9% | 21.2% | 22.0% |
| 12 years | 37.1% | 37.6% | 37.4% |
| 12-15 years | 19.6% | 19.5% | 19.5% |
| 16+ years | 20.5% | 21.7% | 21.1% |
| | | | |
| Mother's years of education | 13.14 | 13.28 | 13.21 |
| (standard deviation) | (2.86) | (2.80) | (2.83) |
| | | | |
| Less than 12 years | 17.5% | 15.9% | 16.7% |
| 12 years | 40.3% | 40.1% | 40.2% |
| 12-15 years | 22.2% | 22.8% | 22.5% |
| 16+ years | 20.0% | 21.1% | 20.6% |
| | | | |
| Parents' maximal years of education* | 13.73 | 13.91 | 13.82 |
| (standard deviation) | (3.11) | (3.10) | (3.11) |
| | | | |
| Less than 12 years | 13.6% | 12.0% | 12.8% |
| 12 years | 36.8% | 36.4% | 36.6% |
| 12-15 years | 22.4% | 22.7% | 22.6% |
| 16+ years | 27.2% | 28.8% | 28.0% |
| | | | |
| Immigrant | 18.6% | 18.1% | 18.4% |
| | | | |
| Family income quintile** | | | |
| Lowest income quintile | 11.8% | 10.6% | 11.2% |
| 2nd income quintile | 17.5% | 16.8% | 17.1% |
| 3rd income quintile | 21.0% | 21.2% | 21.1% |
| 4th income quintile | 24.1% | 24.7% | 24.4% |
| Highest income quintile | 25.6% | 26.7% | 26.2% |

* Where we have both parents' education we take the larger value; where we have education for only one parent we use that. ** Income quintiles are defined in reference to the population as a whole, including families of students attending Arabic-language and ultra-orthodox schools, who are poorer on average and not included in our population, hence the over-representation of our full population in the upper income quintiles.

immigrants are exempt from GEMS.

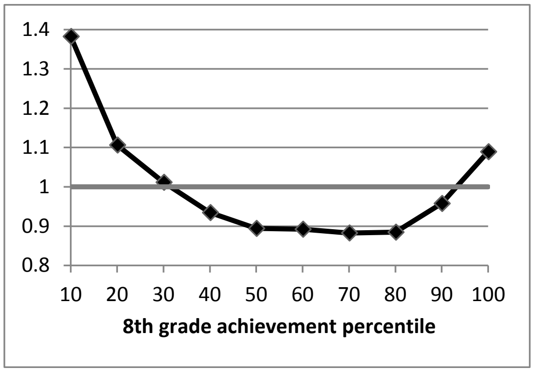
Table 3: Descriptive statistics: GEMS outcomes

| *Average GEMS scores* | Female | Male | Gender gap (standardized) |
|---|---|---|---|
| Mathematics | 53.44 | 52.40 | 0.04 |
| | (23.21) | (24.72) | |
| Science | 64.70 | 64.59 | 0.01 |
| | (17.79) | (19.81) | |
| Hebrew | 68.18 | 60.07 | 0.42 |
| | (17.87) | (20.28) | |
| English | 81.14 | 76.55 | 0.22 |
| | (19.12) | (22.32) | |

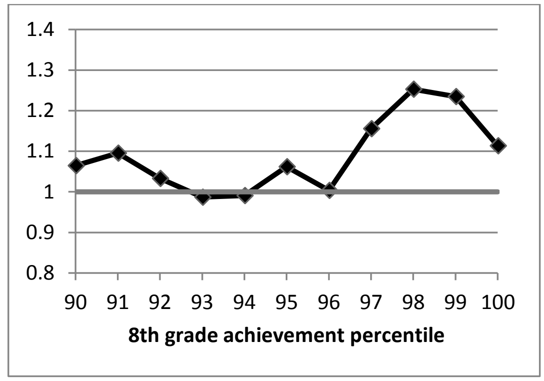
Table 3 compares eighth-grade GEMS scores between boys and girls. Girls score higher in all four subjects, with a greater advantage in language arts than in mathematics and science, which implies that boys have a comparative advantage in mathematics and science. We also observe that standard deviations in GEMS mathematics scores are higher for boys, though the difference is not large, about 6%, with similar gender differences in the other three GEMS subjects. This difference in the variability of mathematics achievement and the consequent over-representation of boys among top scorers is illustrated in Figure 2. Panel A of Figure 2 presents the ratio of male to female students by achievement decile in eight-grade (GEMS) mathematics outcomes. Boys are the majority in the lower four deciles and again a small majority (5.5% boys to 4.5% girls) in the top decile. Panel B follows the male/female ratio by percentiles in the top decile, where we see a greater representation of boys above the 96th percentile. Ellison and Swanson (2010) similarly found an advantage for boys at the high end of the distribution but the differences we find are substantially smaller, closer to those found by Pope and Sydnor (2010) for NAEP scores in New England, the most gender-equal region in the United States. Figure 2 confirms the greater male variability hypothesis while indicating its limited scope, in the present context.

Figure 2: Male/female ratio by eighth-grade mathematics achievement rank

(a) Full distribution




(b) Top 10%




## 2.2 Gender streaming in advanced mathematics and science electives

Our outcome measures are the choice of advanced electives in twelfth-grade matriculation. Matriculation outcomes are important determinants of access to higher education in Israel. Full matriculation, a prerequisite for university admissions, entails achieving a passing score in seven basic-level mandatory subjects as well as a passing score in at least one advanced-level elective. Levels of difficulty are expressed as numbers of units studied in a subject, generally between one and five.[17] Our data includes scores in all seven mandatory subjects, a selection of scores in principal electives, and the level of difficulty chosen by the student in each subject. An average score or better in four or five units of mathematics is required for admission to most quantitative degree programs. Many of these programs also require an advanced elective in at least one other science subject—physics, chemistry, biology or computer science.

Table 4 highlights the extent of gender streaming observed in students' choice to matriculate in each advanced science and mathematics elective, along with average scores and standard deviations in each subject. The top panel shows that boys have higher attrition rates than girls in reaching twelfth grade, and lower success rates in matriculating. Among students with a full matriculation,

[17]Basic-level mandatory subjects are: 3 units mathematics, 3 units English, 2 units language arts (Hebrew), 2 units history, 2 units bible studies, 2 units literature and 2 units civics. Any of these subjects can be taken as an advanced elective at the 5 unit level. There are over 50 potential elective subjects available to students, but the central electives are: natural and exact sciences, social sciences, languages (mainly Arabic and French), geography and art.

Table 4: Gender streaming in matriculation outcomes (%)

| | Female | | Male | | Standardized |
|---|---|---|---|---|---|
| | % of girls | Score (std dev) | % of boys | Score (std dev) | gender gap (female-male) |
| *Matriculation* | | | | | |
| Twelfth-grade enrollment | 95.2% | | 90.5% | | |
| Full matriculation | 64.8% | 84.49 | 55.4% | 82.40 | 0.22 |
| | | (9.53) | | (9.70) | |
| *Mathematics* | | | | | |
| Not tested | 11.5% | | 18.6% | | |
| 1 unit | 11.3% | 79.36 | 13.1% | 79.49 | -0.01 |
| | | (17.02) | | (16.78) | |
| 3 units | 38.0% | 81.79 | 32.1% | 78.48 | 0.26 |
| | | (12.43) | | (12.37) | |
| 4 units | 25.0% | 81.53 | 19.3% | 79.46 | 0.17 |
| | | (11.91) | | (12.06) | |
| 5 units | 14.2% | 85.00 | 16.9% | 85.30 | -0.03 |
| | | (10.99) | | (11.71) | |
| Total | 100% | | 100% | | |
| *Science electives* | | | | | |
| Advanced physics | 4.9% | 84.32 | 12.9% | 84.03 | 0.03 |
| | | (10.65) | | (11.05) | |
| Advanced computer science | 3.9% | 89.45 | 11.0% | 89.01 | 0.06 |
| | | (7.40) | | (7.81) | |
| Advanced chemistry | 7.1% | 85.88 | 5.1% | 85.51 | 0.04 |
| | | (9.96) | | (10.90) | |
| Advanced biology | 14.9% | 84.87 | 9.4% | 81.98 | 0.30 |
| | | (9.29) | | (10.29) | |
| *Pooled electives* | | | | | |
| Physics or computer science | 7.7% | | 18.5% | | |
| Biology or chemistry | 19.7% | | 13.4% | | |
| Any science or mathematics elective | 28.3% | | 30.5% | | |

Shares refer to the GEMS sample, N=61,633. Scores are on a scale of 0-100.

girls' average matriculation scores are 0.22 of a standard deviation higher on average than boys'.[18] In the second panel, we find that the share of boys not meeting the minimal matriculation requirement in mathematics (three units) is 31.7%, much larger than the corresponding share of girls, 22.8%. Girls choose three or four units more frequently than boys while boys choose five units more frequently. In addition, girls score slightly lower, on average, in five units but considerably higher in three and four units.

Turning to the third panel, we find a strong pattern of gender streaming in the choice of electives among science subjects. The share of boys choosing advanced physics or computer science is more than twice that of girls, while the share of girls choosing advanced biology is 45% higher than boys and their share in advanced chemistry is 33% higher. This generally accords with Turner and Bowen (1999) and Riegle-Crumb et al. (2012) who identify a corresponding disparity in engineering and physics, but not in other science fields, among college-bound student in the United States. Note that girls score slightly higher than boys in all of these subjects, on average. The differences are small, except for biology where girls outperform boys by 0.30 of a standard deviation.

In the bottom panel, we consider physics and computer science as one category, and biology and chemistry as another category, anticipating our statistical analysis in the following sections. We consider these combined categories to simplify the presentation of our results and increase statistical power, as each pair exhibits similar gender patterns.[19] Choice frequencies for the two groups mirror the four groups from which they are derived: the frequency of boys choosing physics or computer science is more than twice that of girls, while the frequency of girls choosing biology or chemistry is almost half as large again as the frequency of boys choosing either of these subjects. Boys have a slight advantage in the choice of at least one advanced elective (five units) in mathematics, physics, computer science, biology or chemistry. This difference is much less pronounced

[18] These averages are the scores used by universities in determining admissions and include bonuses for advanced level electives (four and five units). This understates the advantage that girls have in matriculation outcomes, as 64.8% of all girls in the cohort achieve full matriculation compared to 55.4% of boys.

[19] These are also the two most common combinations of electives. Of 16,497 students choosing science electives, 1,864 combined physics and computer science (17% of them girls); and 991 combined biology and chemistry (68% of them girls). Our results hold also for each elective separately but with weaker significance for computer science and chemistry due to the smaller sample sizes. Note that selection within categories may also reflect restricted choice as fewer schools offer chemistry or computer science than offer biology or physics.

than the gendered pattern of choice among advanced science and mathematics electives.

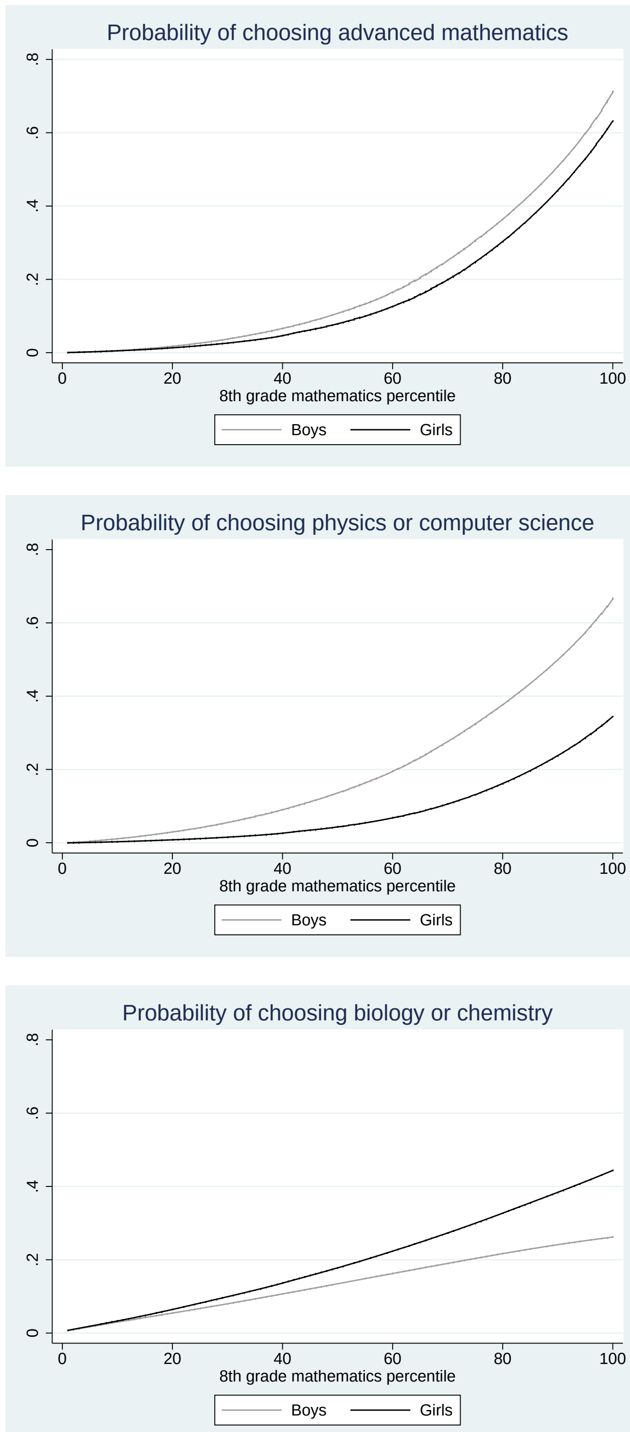
# 3 The effect of prior mathematics achievement on the choice of science and mathematics matriculation electives

In this section, we estimate the effect of gender differences in eighth-grade GEMS scores, as indicators of differences in ability, on the choice of science and mathematics matriculation electives. We use two methods to quantify this effect. The first is a non-parametric decomposition of the overall gendered choice patterns to weights and propensities: the share that can be attributed to differences in the distribution of mathematics achievement and the share attributed to differences in propensities to choose a science and mathematics elective conditioned on the level of achievement. The second method is a binary regression analysis. We regress subject choice on eighth-grade GEMS scores and see by how much the gender effect is reduced. Finally, we implement both non-parametric and parametric analysis to estimate the impact of comparative advantage in mathematics on the choice of mathematics and science electives.

## 3.1 Separating the impact of gender differences in mathematical achievement and in the specific propensity to choose an advanced elective

We begin by presenting the data graphically in the three panels of Figure 3, which show the different propensities, by gender and percentile of achievement in mathematics, of choosing advanced mathematics (5 units); physics or computer science; and biology or chemistry. All six curves in Figure 3 are upward sloping; the probability of selecting a science and mathematics elective is positively correlated with achievement rank in mathematics in the eighth-grade. This is most pronounced for advanced mathematics, where the graphs are most concave; and least pronounced for biology or chemistry, where the graphs are more or less linear. There is little difference by gender in the propensity to choose advanced mathematics, but for the science subjects the differences are marked: *at each level of ability*, boys are much more likely to choose physics or computer science

Figure 3: Share choosing science and mathematics electives by gender and eighth-grade math scores (smoothed using Stata's Lowess procedure for kernel-weighted local polynomial smoothing)



and girls are much more likely to choose biology or chemistry.

Table 5: Share of students choosing science and mathematics electives by category of eighth-grade mathematics achievement and gender

| | Girls ($p^B_{i,s}$) | Boys ($p^G_{i,s}$) |
|---|---|---|
| *Physics or computer science* | | |
| Top 5% | 0.37 | 0.69 |
| 5-10% | 0.25 | 0.53 |
| 10-15% | 0.17 | 0.41 |
| All | 0.08 | 0.19 |
| *Advanced mathematics* | | |
| Top 5% | 0.66 | 0.74 |
| 5-10% | 0.47 | 0.54 |
| 10-15% | 0.37 | 0.40 |
| All | 0.14 | 0.17 |
| *Biology or chemistry* | | |
| Top 5% | 0.43 | 0.26 |
| 5-10% | 0.41 | 0.24 |
| 10-15% | 0.37 | 0.24 |
| All | 0.20 | 0.13 |

This is highlighted in Table 5 for the top 15% of students (by mathematics GEMS score), where $p^B_{i,s}$ and $p^G_{i,s}$ are respectively the share of boys and girls in row $i$ who choose subject $s$; these are the specific propensities by gender and subject. Here again we see that the probability of selecting a science and mathematics elective is positively correlated with prior mathematics achievement. The gendered patterns evident in Figure 3 are again apparent in Table 5: boys have a greater propensity to choose physics or computer science; girls have a greater propensity to choose biology or chemistry; and boys have a slightly greater propensity to choose advanced mathematics.

Next, we divide the population into 20 equal sub-groups by GEMS mathematics rank, and apply the following decomposition to calculate the relative contribution of gender differences in achievement and of differences in specific propensities to choose an advanced science or mathematics elective. Equation 3.1 decomposes the raw difference in choice probabilities for subject $s$ between boys ($B$) and girls ($G$):

$$P_s^B - P_s^G = \sum_{i=1}^{20} w_i^B p_{i,s}^B - \sum_{i=1}^{20} w_i^G p_{i,s}^G = \underbrace{\sum_{i=1}^{20} \frac{p_{i,s}^B + p_{i,s}^G}{2}(w_i^B - w_i^G)}_{\text{Prior achievement}} + \underbrace{\sum_{i=1}^{20} \frac{w_i^B + w_i^G}{2}(p_{i,s}^B - p_{i,s}^G)}_{\text{Propensity}} \quad (1)$$

The results are presented in Table 6. They show that for advanced mathematics, and for physics or computer science, accounting for the observed gender difference in the distribution of prior mathematics achievement *widens* the gender gap very slightly, by 0.2 and 0.1 percentage points respectively. This reflects the fact that girls are in the majority between the fifth and ninth deciles of the mathematical ability distribution, as we saw in Figure 2, which more than offsets the male majority in the top decile. Applying the same decomposition to explaining the choice of biology or chemistry, where girls are in the majority, we find that accounting for differences in prior achievement reduces the gap favoring girls by 0.6 percentage points. Table 6 highlights our finding that gender gaps in specialization overwhelmingly reflect differences in specific propensities rather than differences in prior achievement.

Table 6: Decomposition of the gender gap by eighth-grade mathematics ranks

| | Total gender gap | Contribution of achievement distribution | Contribution of propensities |
|---|---|---|---|
| Physics or computer science | 0.108 | −0.002 | 0.110 |
| Advanced mathematics | 0.027 | −0.001 | 0.028 |
| Biology or chemistry | −0.063 | −0.006 | −0.057 |

## 3.2 Regression analysis

The preceding analysis focused on the relationship between prior mathematical achievement and the choice of science and mathematics electives. To gain insight on the relationship between the full vector of prior achievement and gendered choice patterns we estimate a linear probability model of the average gender effect for each of our three choice variables: advanced mathematics, physics or computer science, and biology or chemistry.[20] The first column of table 7 shows choice conditioned only on a gender indicator (female), which yields the average raw gender gap.

In the second column we add eighth-grade GEMS mathematics scores. As expected, in all cases, eighth-grade mathematical ability has a significant positive effect on choice. An increase of one standard deviation in the eighth-grade mathematics GEMS score is associated on average with an increase of 13 percentage points in the probability of choosing physics or computer science; 16.5 percentage points for advanced mathematics; and 10.1 for biology or chemistry. As girls do better than boys in eighth-grade mathematics, by 0.04 of a standard deviation on average, controlling for prior achievement in mathematics increases the gender gap favoring boys in advanced mathematics and physics or computer science, by 1.0 and 1.2 percentage points respectively while reducing the gender gap favoring girls in biology or chemistry by 0.8 of a percentage point. The direction and relatively small magnitude of these effects is consistent with our findings in the previous section.

In the third column, the eighth-grade GEMS scores in science, Hebrew and English are added. This increases the size of the gender coefficient for physics or computer science and for advanced mathematics by a further 0.7-0.8 percentage points, and similarly reduces the gender coefficient for biology or chemistry. As expected science scores have a positive effect on choosing science and mathematics electives. The impact of English and Hebrew language arts is less clear, a priori. On the one hand, they are additional indications of general ability, which may correlate positively with mathematical ability or may be valuable for science and mathematics in their own right; this

[20] Our main results remain qualitatively similar when using a non-linear logistic model. We present the results of the linear probability model because the interpretation of coefficients as marginal effects is straightforward, and comparison across estimations of alternative specifications for the same dependent variable requires fewer assumptions regarding the underlying distributions.

Table 7: Choice of matriculation electives, conditioned on gender and eighth-grade scores.

| ***A. Physics or computer science*** | | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Female | -0.108 | -0.118 | -0.125 | -0.124 | −0.120 |
| | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) |
| *GEMS* | | | | | |
| Mathematics | | 0.130 | 0.098 | 0.090 | 0.086 |
| | | (0.003) | (0.003) | (0.003) | (0.003) |
| Science | | | 0.024 | 0.027 | 0.026 |
| | | | (0.002) | (0.002) | (0.002) |
| Hebrew | | | 0.019 | 0.033 | 0.032 |
| | | | (0.003) | (0.003) | (0.003) |
| English | | | 0.006 | 0.019 | 0.012 |
| | | | (0.002) | (0.002) | (0.002) |
| Mathematics#Hebrew | | | | 0.056 | 0.053 |
| | | | | (0.002) | (0.002) |
| Family background | | | | | √ |
| $R^2$ | 0.026 | 0.171 | 0.179 | 0.207 | 0.215 |

| ***B. Advanced mathematics*** | | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Female | -0.027 | -0.039 | -0.047 | -0.045 | −0.040 |
| | (0.005) | (0.004) | (0.004) | (0.004) | (0.004) |
| *GEMS* | | | | | |
| Mathematics | | 0.165 | 0.134 | 0.122 | 0.117 |
| | | (0.004) | (0.004) | (0.004) | (0.004) |
| Science | | | 0.023 | 0.028 | 0.027 |
| | | | (0.002) | (0.002) | (0.002) |
| Hebrew | | | 0.022 | 0.044 | 0.042 |
| | | | (0.003) | (0.003) | (0.003) |
| English | | | 0.003 | 0.023 | 0.014 |
| | | | (0.002) | (0.002) | (0.002) |
| Mathematics#Hebrew | | | | 0.085 | 0.082 |
| | | | | (0.002) | (0.002) |
| Family background | | | | | √ |
| $R^2$ | 0.001 | 0.205 | 0.212 | 0.269 | 0.280 |

Continued on next page

**Table 7 – continued from previous page**

| ***C. Biology or chemistry*** | | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Female | 0.063 | 0.055 | 0.047 | 0.047 | 0.050 |
| | (0.006) | (0.005) | (0.005) | (0.005) | (0.005) |
| *GEMS* | | | | | |
| Mathematics | | 0.101 | 0.056 | 0.052 | 0.048 |
| | | (0.004) | (0.004) | (0.003) | (0.003) |
| Science | | | 0.038 | 0.040 | 0.039 |
| | | | (0.003) | (0.003) | (0.003) |
| Hebrew | | | 0.020 | 0.028 | 0.027 |
| | | | (0.003) | (0.003) | (0.003) |
| English | | | 0.011 | 0.018 | 0.012 |
| | | | (0.002) | (0.002) | (0.002) |
| Mathematics#Hebrew | | | | 0.030 | 0.028 |
| | | | | (0.002) | (0.002) |
| Family background | | | | | √ |
| $R^2$ | 0.007 | 0.080 | 0.092 | 0.099 | 0.103 |

*Notes*: N = 61,633. Dependent variables vary by column. Coefficients are obtained from a linear probability model with school-level clustered standard errors and a dummy for cohort. Family background variables include family income quintiles, parents' maximal years of schooling and immigrant status. Standard errors in parentheses. GEMS score are normalized to have a mean of 0 and standard deviation of 1. All coefficient are significant at the $p < 0.001$ level or better.

indicates a positive effect on choice. On the other hand, the comparative advantage hypothesis suggests that strong performance in language arts might have a negative effect on the choice of science and mathematics electives, as it opens up further possibilities for achievement in humanities and social sciences. We see that all prior scores are positively related to the probability of choosing a science or mathematics elective, and with the exception of the impact of English on choosing mathematics, all are statistically significant. This positive effect of prior achievement in language arts on all electives does not support the comparative advantage hypothesis. In the fourth column we add an interaction term, the product of the mathematics and Hebrew scores, which also has a significant positive effect, substantially increasing the $R^2$ value but with little change in the gender coefficient. This further undermines the comparative advantage hypothesis. Finally, in the fifth column we add controls for family income quintile, parents' maximal education, and immigrant status. This has little effect on our coefficient estimates.

To further illustrate the lack of support in our data for the comparative advantage hypothesis, we partition high-achieving students into three groups: those in the top 20% in both mathematics and Hebrew; those in the top 20% in mathematics but not in Hebrew; and those in the top 20% in Hebrew but not in mathematics. The top panel in Table 8 confirms that boys enjoy a comparative advantage in mathematics versus language arts (Hebrew) compared to girls. The second panel reveals that students in the top 20% in mathematics but not in Hebrew are less likely to choose each of the science and mathematics electives than students in the top 20% in both mathematics and Hebrew. This holds for both male and female students.

# 4 Propensity to choose science and mathematics electives

Section 3 established that the underrepresentation of girls in advanced matriculation electives in mathematics, physics and computer science cannot be attributed to gender differences in eighth-grade scores. Indeed, gender differences in the propensity to choose science and mathematics electives, controlling for eighth-grade mathematics scores, *exceed* the raw gender effect. In this section we consider how gender differences in specific propensities vary with prior ability and parents' socio-economic status (SES). Finally we examine to what extent do school characteristics contribute to the gendered choice patterns we observe.

## 4.1 Gender differences in the effect of ability on propensity

As the choice models of Altonji (1993) and Arcidiacono (2004) highlight, scores serve as a signal of ability for the student. Lower GEMS achievement levels are adverse signals, and the large differences between the girls' and boys' entries in Tables 5 and 8 indicate that they react differently

Table 8: Specific propensities by prior achievement in mathematics and Hebrew, and gender

| | *Shares* | |
|---|---|---|
| | Girls ($w_i^G$) | Boys ($w_i^B$) |
| Top 20% in both | 11.4% | 8.4% |
| Top 20% in mathematics only | 8.4% | 11.8% |
| Top 20% in Hebrew only | 14.0% | 6.1% |

| | *Specific propensities* | | |
|---|---|---|---|
| | Girls ($p_{i,s}^G$) | Boys ($p_{i,s}^B$) | Relative gap* |
| | *Physics or computer science* | | |
| Top 20% in both | 0.28 | 0.59 | -0.71 |
| Top 20% in mathematics only | 0.17 | 0.44 | -0.88 |
| Top 20% in Hebrew only | 0.09 | 0.29 | -1.04 |
| All | 0.08 | 0.19 | -0.83 |
| | *Advanced mathematics* | | |
| Top 20% in both | 0.52 | 0.63 | -0.20 |
| Top 20% in mathematics only | 0.33 | 0.43 | -0.26 |
| Top 20% in Hebrew only | 0.18 | 0.26 | -0.38 |
| All | 0.14 | 0.17 | -0.17 |
| | *Biology or chemistry* | | |
| Top 20% in both | 0.43 | 0.26 | 0.48 |
| Top 20% in mathematics only | 0.33 | 0.23 | 0.36 |
| Top 20% in Hebrew only | 0.28 | 0.23 | 0.20 |
| All | 0.20 | 0.13 | 0.38 |

*Relative gap is the ratio of the difference between girls' and boys' propensities to the average propensity. (Positive values indicate a greater propensity for girls).

to these signals. The relative gap in Table 8 favoring boys increases as prior achievement decreases, suggesting that boys are less deterred by adverse signals in choosing advanced mathematics and physics or computer science. Table 9 presents the results of a linear probability model, estimating the different responses by gender to GEMS scores as signals of ability. The model includes all measures of prior achievement as well as an interaction term for each prior score with female gender. The interactive term for mathematics is significant for all three subjects, with the same sign as the female gender coefficient. Boys' and girls' different propensities to choose science and mathematics electives are partly a reflection of their different responses to prior signals of ability. A signal of strong mathematical ability has a positive effect on both boys and girls for all three categories, but the effect is stronger for boys with regard to choosing advanced mathematics and physics or computer science, and stronger for girls with respect to choosing biology or chemistry; and a similar pattern applies to prior achievement in science.

## 4.2 The effect of socio-economic status

Gendered patterns of choice of advanced science and mathematics electives in high school vary also with socio-economic status (SES), which we proxy here by parents' education.[21] As table 10 shows, selection of science and mathematics electives increases in parents' education. The rate of increase is more moderate in biology or chemistry; and the share of girls declines with parents' education in all electives. These findings are a further indication that boys benefit from a strong family background more than girls. The six panels of figure 4 demonstrate graphically the effect of parental education on choice of electives, conditioned on eighth-grade mathematical achievement. For each elective, for girls and for boys, the differences by parental education are persistent throughout the ability distribution. Trends are similar, but again SES is seen to have a stronger effect on boys. Figure 5 highlights this point, depicting the difference between students in the highest category (at least one parent with graduate level education) and students in the lowest category (neither parent completing high school), by gender and elective. Overall, these gaps are larger for boys than for girls, largest in advanced mathematics, and smallest in biology or chemistry. This is consistent with our findings in table 10 that the share of girls choosing a particular elective declines with parental education.

To further quantify the average gender gap within socio-economic groups we estimate our linear probability model for each group separately. Estimates of the average gender gap within these

[21] Similar results are presented for income quintiles in the Appendix.

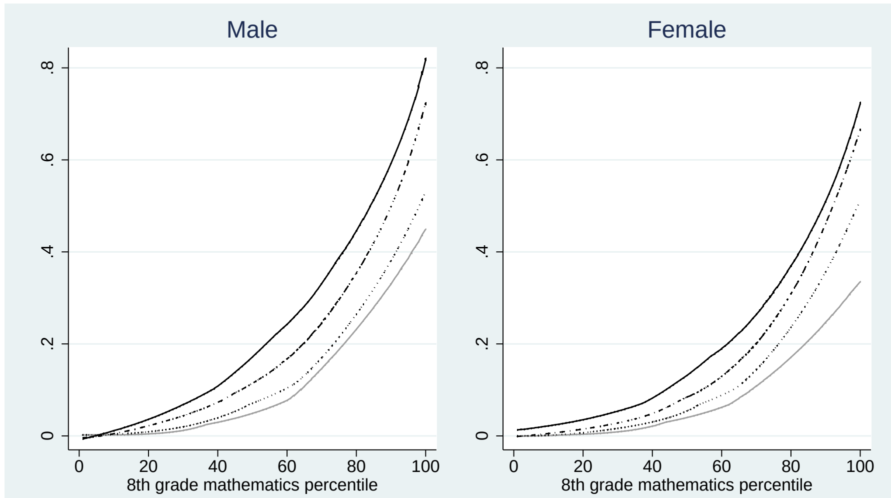
Table 9: Effect of prior scores on the probability to choose science and mathematics electives, by gender

| | Physics or computer science | Advanced mathematics | Biology or Chemistry |
|---|---|---|---|
| Female | -0.103*** | -0.043*** | 0.032*** |
| | (0.005) | (0.004) | (0.006) |
| GEMS | | | |
| | | | |
| Mathematics | 0.129*** | 0.141*** | 0.035*** |
| | (0.005) | (0.004) | (0.004) |
| Science | 0.038*** | 0.027*** | 0.030*** |
| | (0.003) | (0.003) | (0.003) |
| Hebrew | 0.042*** | 0.049*** | 0.026*** |
| | (0.005) | (0.004) | (0.004) |
| English | 0.026*** | 0.025*** | 0.015*** |
| | (0.002) | (0.002) | (0.003) |
| | | | |
| Mathematics#Hebrew | 0.078*** | 0.090*** | 0.016*** |
| | (0.003) | (0.002) | (0.003) |
| | | | |
| Female # Mathematics | -0.075*** | -0.041*** | 0.030*** |
| | (0.004) | (0.004) | (0.005) |
| Female # Science | -0.021*** | 0.003 | 0.020*** |
| | (0.004) | (0.003) | (0.005) |
| Female # Hebrew | -0.021*** | -0.009* | 0.005 |
| | (0.005) | (0.004) | (0.005) |
| Female # English | -0.017*** | -0.006* | 0.007 |
| | (0.003) | (0.003) | (0.004) |
| | | | |
| Female#Mathematics#Hebrew | -0.029*** | -0.001 | 0.023*** |
| | (0.003) | (0.003) | (0.003) |
| | | | |
| R-squared | 0.235 | 0.273 | 0.104 |

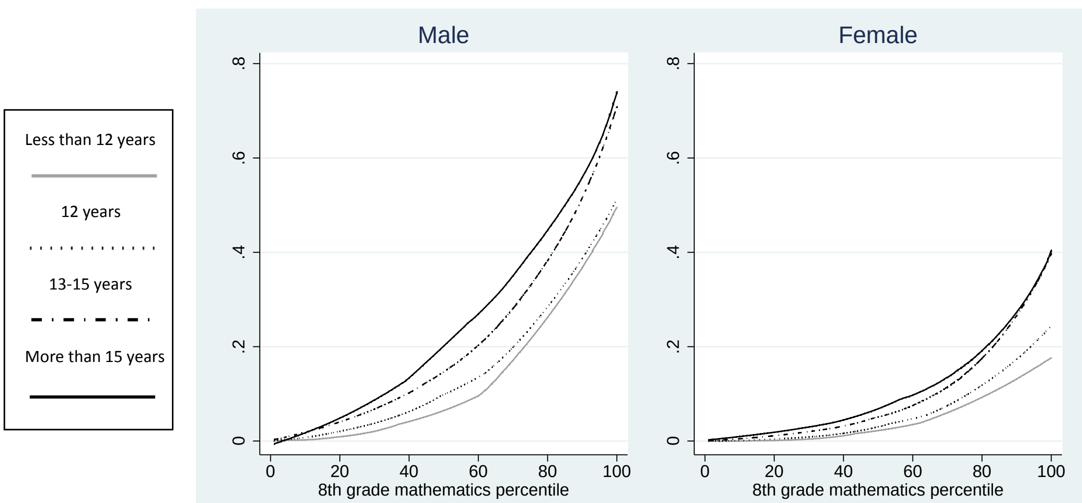
*Notes*: N = 61,633. Dependant variables vary by column. Coefficients are obtained from a linear probability model with school-level clustered standard errors and a dummy for cohort. Standard errors in parentheses. GEMS scores are normalized to have a mean of 0 and standard deviation of 1.
* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Figure 4: Share of students selecting advanced science or mathematics electives by eighth-grade mathematical achievement and parents' maximal years of schooling

(a) Advanced mathematics




(b) Physics or computer science




(c) Biology or chemistry

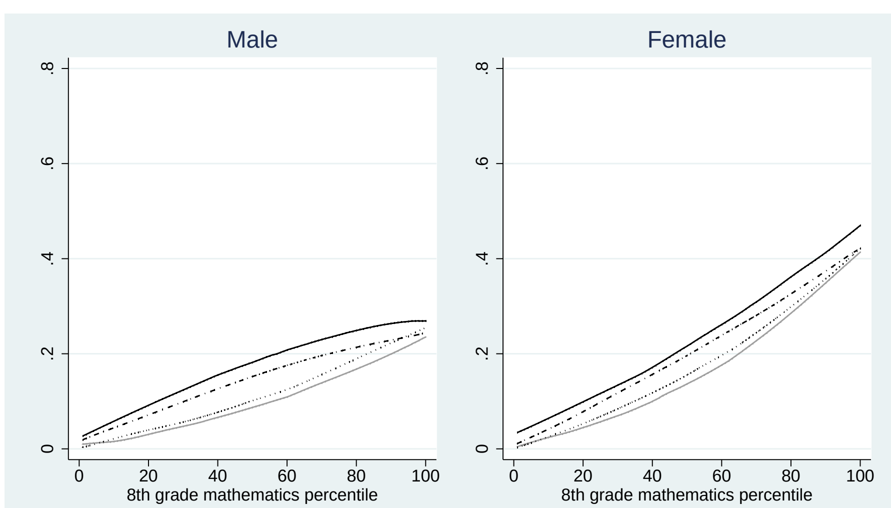
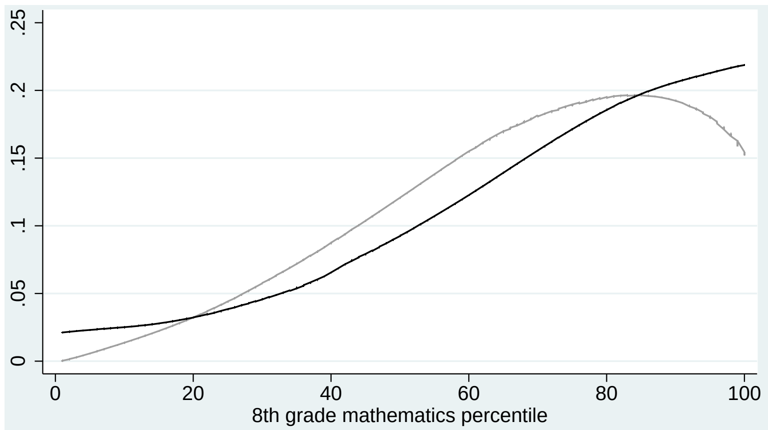
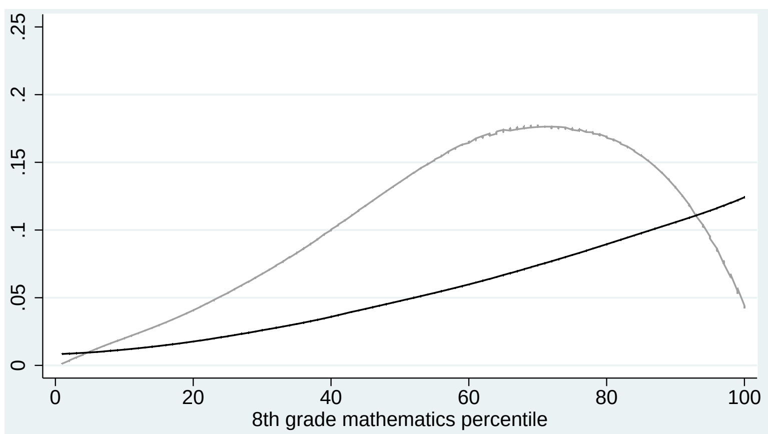


Figure 5: Differences in share of students selecting advanced science or mathematics electives between the highest category of parents' schooling (at least one parent with some graduate education) and the lowest category (neither parent completed high school) by gender and eighth-grade mathematical achievement

(a) Advanced mathematics




(b) Physics or computer science




(c) Biology or chemistry

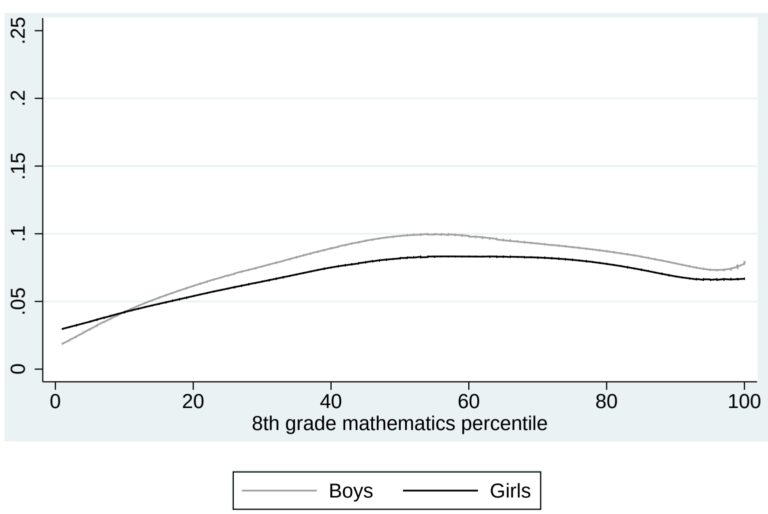


Table 10: Selection of science and mathematics electives by parents' years of education

| Parents' maximal years of education | Advanced mathematics | | Physics or computer science | | Biology or chemistry | |
|---|---|---|---|---|---|---|
| | Share | % girls | Share | % girls | Share | % girls |
| Less than 12 | 4.4% | 50.7% | 3.8% | 31.1% | 8.8% | 67.3% |
| 12 | 8.5% | 49.4% | 7.4% | 29.4% | 12.3% | 62.9% |
| 13-15 | 17.9% | 46.6% | 15.7% | 30.9% | 18.9% | 59.3% |
| 16 or more | 28.1% | 43.8% | 22.6% | 28.6% | 23.8% | 56.5% |
| All | 15.6% | 45.9% | 13.0% | 29.5% | 16.5% | 59.7% |

groups, after controlling for prior achievement and student background variables are presented in table 11. The size of the gender gap increases in parental education for all electives, showing again that boys benefit more from a strong family background. The literature suggests two potential explanations for this phenomenon. The first relates to gender differences in non-cognitive skills, resulting in males having higher rates of developmental problems, disruptive behavior, attention disorders, reading disabilities, and other related phenomena which may be amplified when combined with dimensions of social disadvantage correlated with fewer years of parental education (Goldin et al., 2006; DiPrete and Jennings, 2012). In addition, as occupational segregation and the gender pay gap for women are more pronounced in jobs that do not require post-secondary education, girls have stronger incentives to invest in education (Dwyer et al., 2013). In Israel, Melzer (2014) shows that women from low SES groups, characterized by relatively low levels of parental education, earn higher returns to education than men in these groups. Boys from a low SES background face a wider set of outside options in terms of employment and earnings than girls from the same background.

## 4.3 Supply-side effects on gender streaming

Israel's secondary schools differ in the choice of advanced electives they offer in science and mathematics, and we now ask, to what extent this contributes to the gendered patterns of subject choice we observe. We distinguish in this regard between religious single-sex schools, which ac-

Table 11: Gender gap by elective and parents' maximal years of schooling conditioned on prior achievement and family characteristics

| | <12 | 12 | 13-15 | 15< |
|---|---|---|---|---|
| ***Physics or computer science*** | | | | |
| Female | $-0.047$ | $-0.078$ | $-0.138$ | $-0.191$ |
| | $(0.005)$ | $(0.004)$ | $(0.007)$ | $(0.009)$ |
| $R^2$ | $0.146$ | $0.151$ | $0.204$ | $0.216$ |
| ***Advanced mathematics*** | | | | |
| Female | $-0.019$ | $-0.021$ | $-0.045$ | $-0.067$ |
| | $(0.004)$ | $(0.004)$ | $(0.007)$ | $(0.009)$ |
| $R^2$ | $0.173$ | $0.205$ | $0.257$ | $0.272$ |
| ***Biology or chemistry*** | | | | |
| Female | $0.028$ | $0.043$ | $0.055$ | $0.067$ |
| | $(0.007)$ | $(0.005)$ | $(0.007)$ | $(0.011)$ |
| $R^2$ | $0.125$ | $0.101$ | $0.080$ | $0.067$ |
| Observations | 7,899 | 22,567 | 13,908 | 17,259 |

*Notes*: N = 61,633. Dependent variables vary by row, and columns by sample. Coefficients are obtained from a linear probability model with school-level clustered standard errors, a dummy for cohort, GEMS scores, interaction between mathematics and Hebrew scores, family income and immigrant status. Standard errors in parentheses. GEMS scores are normalized to have a mean of 0 and standard deviation of 1. All coefficients are significant at $p < 0.001$ or better.

Table 12: Student characteristics, achievement and matriculation outcomes by type of school

| | Coeducational non-religious | | Coeducational religious | | Single-sex religious | |
|---|---|---|---|---|---|---|
| | Female | Male | Female | Male | Female | Male |
| Eighth-grade students | 24,903 | 24,827 | 2,068 | 2,529 | 3,944 | 3,362 |
| Twelfth-grade students | 23,556 | 22,355 | 1,935 | 2,242 | 3,644 | 2,817 |
| **Family background** | | | | | | |
| % immigrant | 19% | 18% | 16% | 12% | 8% | 7% |
| *% in income quintile* | | | | | | |
| Lowest | 11% | 9% | 19% | 15% | 10% | 7% |
| 2nd | 16% | 16% | 23% | 20% | 15% | 12% |
| 3rd | 21% | 21% | 24% | 23% | 21% | 19% |
| 4th | 25% | 25% | 22% | 26% | 26% | 27% |
| Highest | 28% | 29% | 12% | 17% | 28% | 35% |
| **GEMS scores** | | | | | | |
| Mathematics | 0.10 | 0.06 | -0.15 | -0.17 | 0.07 | 0.15 |
| Science | 0.08 | 0.08 | -0.21 | -0.12 | 0.04 | 0.21 |
| Hebrew | 0.24 | -0.12 | 0.04 | -0.26 | 0.39 | 0.08 |
| English | 0.19 | 0.02 | -0.23 | -0.39 | 0.07 | -0.10 |
| **Matriculation** | | | | | | |
| % matriculating | 0.72 | 0.63 | 0.61 | 0.53 | 0.80 | 0.69 |
| % eligible for university admission | 0.65 | 0.57 | 0.51 | 0.41 | 0.73 | 0.62 |
| *% choosing advanced electives* | | | | | | |
| Advanced mathematics | 15% | 19% | 11% | 13% | 14% | 24% |
| Physics or computer science | 8% | 21% | 8% | 14% | 10% | 26% |
| Biology or chemistry | 21% | 15% | 22% | 12% | 21% | 18% |
| Any advanced science or mathematics | 29% | 33% | 30% | 27% | 33% | 45% |

*Notes:* The student sample by schools type is reduced between the eighth- and the twelfth-grade by 4,402 students who do not attend state schools with their cohort and 682 students who attend schools for which we have less than 15 observations. GEMS scores are standardized with a mean of 0 and standard deviation of 1.

count for 11.4% of our sample of Israel's Hebrew-language, non-ultra-orthodox, secondary school students; coeducational religious schools, accounting for 7.3% of our students; and the remaining non-religious coeducational schools.[22] The top two panels of table 12 presents descriptive statistics for the three school populations.[23] Of the three groups, coeducational religious schools serve a population of students from markedly lower income groups, and achieve the lowest GEMS scores in all subjects for both male and female students in these schools. Comparing coeducational non-religious schools and single-sex religious schools, we see that their student populations have more similar backgrounds, though non-religious schools have a higher share of immigrants, and single-sex religious schools have a higher share of male students from the top income quintile. Eight-grade achievement in mathematics differs between coeducational and single-sex schools. In coeducational schools, girls slightly outperform boys, whereas boys substantially outperform girls in single-sex schools. Consequently girls in non-religious schools do better than girls in single sex religious schools while for boys the order is reversed. In all schools, girls substantially outperform boys in eighth-grade language arts, in Hebrew and English, with larger differences in Hebrew. In Hebrew, the highest level is achieved in single-sex religious schools; in English the highest level is achieved in coeducational non-religious schools. The bottom panel of Table 12 shows matriculation outcomes by school type and gender. The highest matriculation rates are for single-sex religious schools followed by coeducational non-religious schools. This patterns accords with the socio-economic rankings of the three groups.

Focusing now on how gender differences in selecting advanced science or mathematics electives vary across the different types of schools, we find that with one minor exception, the qualitative patterns observed in the population as a whole are also observed in each type of school: males are in the majority in advanced mathematics and in physics or computer science while females are in the majority in biology or chemistry; the exception is the small female majority in

[22] In most of the coeducational religious schools, boys and girls study in separate classes. We do not have class level data.

[23] In this part of the analysis we exclude students who are not enrolled in state schools in the twelfth grade, and students belonging to schools for which we have less than 15 observations, reducing our sample by 5,084 students, 8.3%.

choosing any advanced science or mathematics elective, in coeducational religious schools. The female share choosing each subject category is relatively stable while the male share varies more widely and is always greatest in single-sex religious schools. Consequently the size of the gender gap differs across school types, with the gender gap favoring males in advanced mathematics, in physics or computer science and in any advanced science or mathematics elective substantially larger in single sex religious schools; and the gap favoring females students in choosing biology or chemistry electives is smallest in these schools. Male and female single-sex religious secondary schools offer their students different possibilities for specializing in advanced science and mathematics electives. These differences reflect in some measure the specific preferences of students who choose to attend these schools, but also constrain their choices.

Finally we control for school effects on the gender gap in the choice of matriculation electives for students in non-religious coeducational schools by including school fixed-effects in the choice regressions reported in table 7, for each of our three subject groups. We focus here on the fullest specification, reported in column (5) of table 7, which controls for prior scores and student background variables, and present the estimated gender effects from these equations in table 13. The first row presents the estimates for the full population without school fixed effects, from table 7; the second row gives the gender effects for coeducational schools without school fixed effects; and the third row shows estimates of the gender effects for coeducational schools with fixed-effects. Overall, the gender effects are slightly larger for students in non-religious coeducational schools than for the whole population, consistent with the descriptive statistics presented in table 14. Including fixed effects has no effect on the gender coefficient for physics or computer science or for advanced mathematics, and a very small effect for biology or chemistry. In coeducational schools, almost all the gender effect on choice is present within schools.

Table 13: Gender coefficients from estimates of choice of advanced matriculation electives, non-religious schools, with and without fixed effects

| | Physics or computer science | Advanced mathematics | Biology or chemistry |
|---|---|---|---|
| All students no FE (table 7, col 5) | −0.120 | −0.040 | 0.050 |
| | (0.005) | (0.004) | (0.005) |
| Students in coeducational | −0.134 | −0.042 | 0.049 |
| non-religious schools, no FE | (0.005) | (0.004) | (0.005) |
| Students in coeducational | −0.134 | −0.042 | 0.044 |
| non-religious schools, with FE | (0.003) | (0.003) | (0.003) |

*Notes*: N=61,633 in the first row, and N=47,210 in rows 2 and 3. In rows 1 and 2, coefficients are obtained from a linear probability model with a dummy for cohort, GEMS scores, interaction between mathematics and Hebrew scores, family income and immigrant status; row 3 adds school fixed effects to the equation estimated in row 2. GEMS score are normalized to have a mean of 0 and standard deviation of 1. Standard errors, in parenthesis clustered at the school level. All coefficients are significant at p = 0.001 or better.

# 5 Concluding remarks

We show that female underrepresentation in high-paying jobs in engineering and information technology, and in corresponding fields in tertiary education, has its direct roots in students' choice of matriculation electives in science and mathematics at the end of high school; and that these gendered patterns of choice are not driven by differences in mathematical ability. In Israel, male students choose advanced electives in physics and computer science two and a half times as frequently as female students and are over-represented in the most advanced level of mathematics; female students are 50% more likely to take advanced biology and 40% more likely to take advanced chemistry. Similar patterns observed in other countries, together with the strong positive correlation between specialization in male-dominated fields and prior achievement in mathematics, have led many to assume that these gendered patterns are driven by differences in prior mathematical achievement. We show that this is not the case, reinforcing earlier findings on gendered patterns of choice of college majors in the United States conditioned on high school achievement.

Using longitudinal data that links students' choice of science and mathematics matriculation electives to their eighth-grade standardized test scores in mathematics, science, Hebrew and English for two halves of the full cohort of eighth-grade students in two successive years, we find that the significant gender gap in the choice of matriculation electives remains virtually intact after controlling for eighth-grade scores. Moreover, where earlier studies of choice of college major found that comparative advantage in mathematics has a positive effect on subject selection, we find to the contrary that students who do well in both mathematics and language arts are more likely to choose advanced science and mathematics electives than those who do well only in mathematics.

This suggests that social norms and economic factors play an important role in the choice of matriculation electives. In line with this, we find significant gender differences in how students respond to the signals inherent in eighth-grade test scores, mirroring previous findings on gender differences in responding to risk and competition; and we find differences in how socio-economic background affects the matriculation choices of male and female students. We also find substantial differences in gendered choice patterns between single-sex religious schools and non-religious coeducational schools indicating that male and female single-sex religious schools offer their students different sets of advanced electives to choose from. Among non-religious coeducational schools, school effects have no impact on gender gaps: within-school gender differences are nearly identical to the overall gender effects in these schools.

# References

Altonji, J. G. (1993). "The demand for and return to education when education outcomes are uncertain." *Journal of Labor Economics*, *11*(1), 48–83.

Altonji, J. G., Blom, E., and Meghir, C. (2012). "Heterogeneity in human capital investments: High school curriculum, college major, and careers." Working Paper 17985, National Bureau of Economic Research.

Arcidiacono, P. (2004). "Ability sorting and the returns to college major." *Journal of Econometrics*, *121*(1–2), 343 – 375.

Ayalon, H. (1995). "Math as a gatekeeper: Ethnic and gender inequality in course taking of the sciences in Israel." *American Journal of Education*, *104*(1), 34–56.

Bedard, K., and Cho, I. (2010). "Early gender test score gaps across OECD countries." *Economics of Education Review*, *29*(3), 348–363.

Buser, T., Niederle, M., and Oosterbeek, H. (2014). "Gender, competitiveness, and career choices." *The Quarterly Journal of Economics*, *129*(3), 1409–1447.

Catsambis, S. (1994). "The path to math: Gender and racial-ethnic differences in mathematics participation from middle school to high school." *Sociology of Education*, *67*(3), 199–215.

Ceci, S. J., Ginther, D. K., Kahn, S., and Williams, W. M. (2014). "Women in academic science: A changing landscape." *Psychological Science in the Public Interest*, *15*(3), 75–141.

DiPrete, T. A., and Jennings, J. L. (2012). "Social and behavioral skills and the gender gap in early educational achievement." *Social Science Research*, *41*(1), 1 – 15.

Dwyer, R. E., Hodson, R., and McCloud, L. (2013). "Gender, debt, and dropping out of college." *Gender & Society*, *27*(1), 30–55.

Ellison, G., and Swanson, A. (2010). "The gender gap in secondary school mathematics at high achievement levels: Evidence from the American Mathematics Competitions." *Journal of Economic Perspectives*, *24*(2), 109–28.

Else-Quest, N. M., Hyde, J. S., and Linn, M. C. (2010). "Cross-national patterns of gender differences in mathematics: A meta-analysis." *Psychological Bulletin*, *136*(1), 103–127.

Fichtelberg-Barmatz, O. (2009). "Women's employment in hi-tech." Working Paper X8982A, Research and Economics Administration. Ministry of Economy, State of Israel.

Fryer, R. G., and Levitt, S. D. (2010). "An empirical analysis of the gender gap in mathematics." *American Economic Journal: Applied Economics*, *2*(2), 210–240.

Goldin, C., Katz, L. F., and Kuziemko, I. (2006). "The homecoming of American college women: The reversal of the college gender gap." Working Paper 12139, National Bureau of Economic Research.

Guiso, L., Monte, F., Sapienza, P., and Zingales, L. (2008). "Culture, gender, and math." *Science*, *320*(5880), 1164–1165.

Hedges, L. V., and Nowell, A. (1995). "Sex differences in mental test scores, variability, and numbers of high-scoring individuals." *Science*, *269*(5220), 41.

Hyde, J. S., Fennema, E., and Lamon, S. J. (1990). "Gender differences in mathematics performance: A meta-analysis." *Psychological Bulletin*, *107*(2), 139–155.

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., and Williams, C. C. (2008). "Gender similarities characterize math performance." *Science*, *321*(5888), 494–495.

Justman, M., and Mendez, S. J. (2015). "Gendered selection of STEM electives in secondary school matriculation in Victoria." Working paper, Melbourne Institute of Applied Economic and Social Research, University of Melbourne.

Kane, J. M., and Mertz, J. E. (2012). "Debunking myths about gender and mathematics performance." *Notices of the American Mathematical Society*, *59*(1), 10–21.

Lindberg, S. M., Hyde, J. S., Petersen, J. L., and Linn, M. C. (2010). "New trends in gender and mathematics performance: A meta-analysis." *Psychological Bulletin*, *136*(6), 1123–1135.

Melzer, Y. (2014). "Education returns: Inequality between different populations in Israel (Hebrew)." Policy Studies 17, Van Leer Institute in Jerusalem.

Neuschmidt, O., Barth, J., and Hastedt, D. (2008). "Trends in gender differences in mathematics and science (TIMSS 1995–2003)." *Studies in Educational Evaluation*, *34*(2), 56 – 72.

OECD (2007). "Women in science, engineering and technology (SET): Strategies for a global workforce." `http://www.oecd.org/sti/inno/38819188.pdf`.

OECD (2011). "Indicators of Gender Equality in Education." `http://www.oecd.org/gender/data/indicatorsofgenderequalityineducation.htm`.

Paglin, M., and Rufolo, A. M. (1990). "Heterogeneous human capital, occupational choice, and male-female earnings differences." *Journal of Labor Economics*, *8*(1), 123–144.

Pope, D. G., and Sydnor, J. R. (2010). "Geographic variation in the gender differences in test scores." *The Journal of Economic Perspectives*, *24*(2), 95–108.

Riegle-Crumb, C., and King, B. (2010). "Questioning a white male advantage in STEM: Examining disparities in college major by gender and race/ethnicity." *Educational Researcher*, *39*(9), 656–664.

Riegle-Crumb, C., King, B., Grodsky, E., and Muller, C. (2012). "The more things change, the more they stay the same? Prior achievement fails to explain gender inequality in entry into STEM college majors over time." *American Educational Research Journal*, *49*(6), 1048–1073.

Sells, L. W. (1973). "High school mathematics as the critical filter in the job market." In R. T. Thomas (Ed.), *Developing opportunities for minorities in graduate education*, 37–39, Berkeley: University of California Press.

Turner, S. E., and Bowen, W. G. (1999). "Choice of major: The changing (unchanging) gender gap." *Industrial and Labor Relations Review*, *52*(2), 289 – 313.

Wang, M.-T., Eccles, J. S., and Kenny, S. (2013). "Not lack of ability but more choice: Individual and gender differences in choice of careers in science, technology, engineering, and mathematics." *Psychological Science*, *24*(5), 770–775.

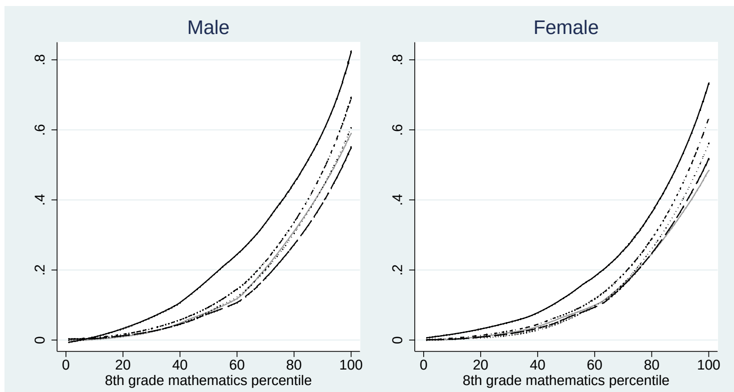
Xie, Y., and Shauman, K. A. (2003). *Women in science: Career processes and outcomes*. Cambridge, Massachusetts: Harvard University Press.

Zafar, B. (2013). "College major choice and the gender gap." *Journal of Human Resources*, *48*(3), 545–595.

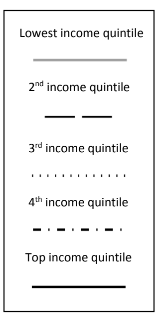
# Appendix:
# The effect of socio-economic status: Analysis by family income quintiles

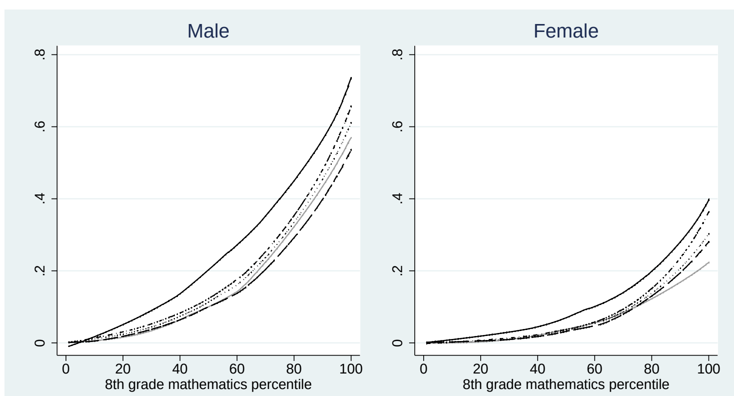
Figure A1: Share of students selecting advanced science or mathematics electives by eighth-grade mathematical achievement and family income

(a) Advanced mathematics




(b) Physics or computer science




(c) Biology or chemistry

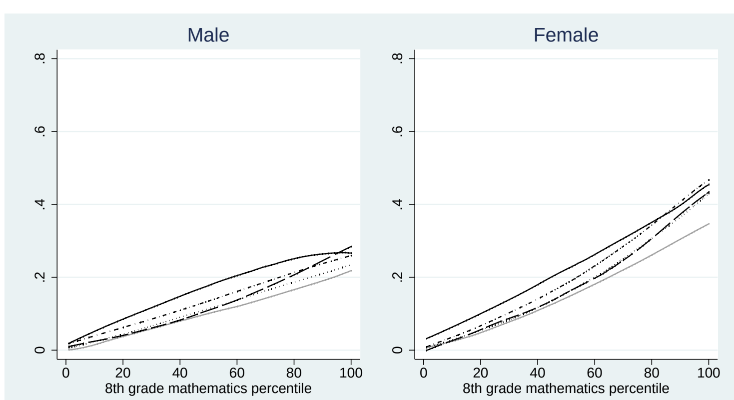


Figure A2: Differences in share of students selecting advanced science or mathematics electives between highest and lowest family income by gender and eighth-grade mathematical achievement

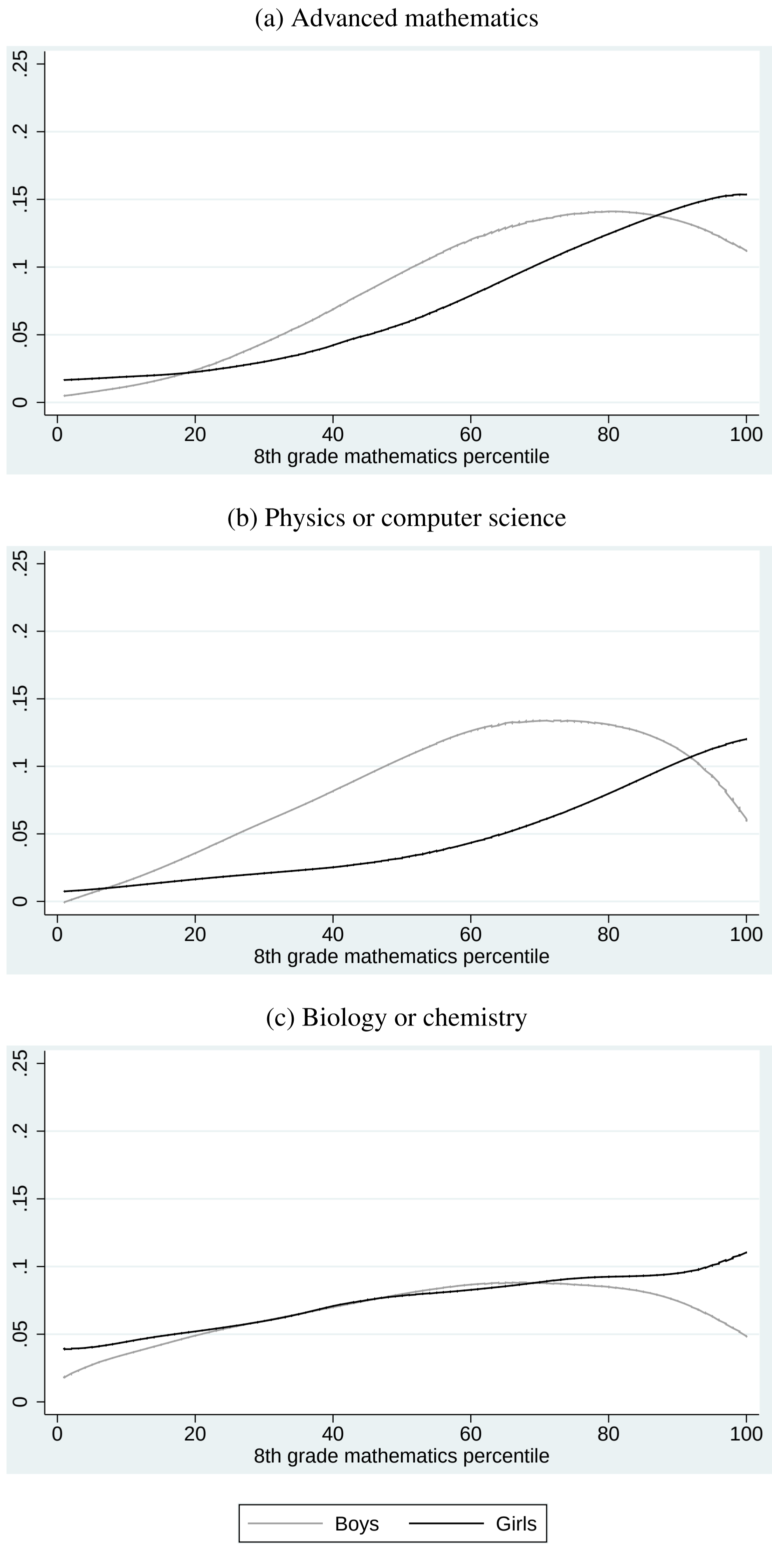


Table A1: Gender gap by elective and family income quintiles conditioned on prior achievement and family characteristics

| | Family income quintiles | | | | |
|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th |
| ***Physics or computer science*** | | | | | |
| Female | −0.074 | −0.073 | −0.097 | −0.120 | −0.188 |
| | (0.006) | (0.006) | (0.006) | (0.007) | (0.009) |
| $R^2$ | 0.173 | 0.162 | 0.190 | 0.200 | 0.220 |
| ***Advanced mathematics*** | | | | | |
| Female | −0.025 | −0.019 | −0.028 | −0.036 | −0.072 |
| | (0.006) | (0.005) | (0.006) | (0.006) | (0.008) |
| $R^2$ | 0.234 | 0.211 | 0.242 | 0.256 | 0.285 |
| ***Biology or chemistry*** | | | | | |
| Female | 0.031 | 0.034 | 0.046 | 0.058 | 0.065 |
| | (0.008) | (0.007) | (0.007) | (0.008) | (0.010) |
| $R^2$ | 0.098 | 0.115 | 0.101 | 0.100 | 0.067 |
| Observations | 6,913 | 10,548 | 13,019 | 15,033 | 16,120 |

*Notes*: N = 61,633. Dependent variables vary by row, and columns by sample. Coefficients are obtained from a linear probability model with school-level clustered standard errors, a dummy for cohort, GEMS scores, interaction between mathematics and Hebrew scores, parents' maximal years of schooling and immigrant status. Standard errors in parentheses. GEMS scores are normalized to have a mean of 0 and standard deviation of 1. All coefficients are significant at $p < 0.001$ or better.