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Gender streaming and prior achievement in high school science and mathematics[☆]

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ABSTRACT

Girls choose advanced matriculation electives in science and mathematics almost as frequently as boys, in Israel, but are very much under-represented in physics and computer science, and over-represented in biology and chemistry. We test the hypothesis that these patterns stem from differences in mathematical ability. Administrative data on two half-cohorts of Israeli eighth-grade students in Hebrew-language schools links standardized test scores in mathematics, science, Hebrew and English to their subsequent choice of matriculation electives. It shows that the gendered choices they make remain largely intact after conditioning on prior test scores, indicating that these choices are not driven by differences in perceived mathematical ability, or by boys' comparative advantage in mathematics. Moreover, girls who choose matriculation electives in physics and computer science score higher than boys, on average. Girls and boys react differently to early signals of mathematical and verbal ability; and girls are less adversely affected by socioeconomic disadvantage.

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1. Introduction

Under-representation of women in high-paying jobs in engineering and information technology (IT) contributes substantially to the gender wage gap in advanced industrialized economies (OECD, 2007). 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 (Fig. 1). In Israel, women constitute 46.5% of the labor force but account for only 24% of employment in high-technology occupations (Fichtelberg-Barmatz, 2009); and while comprising over half of all degree recipients, receive fewer than 30% of degrees in computer science and engineering. Women have made huge strides in tertiary education, overtaking men in overall participation and in many fields of study (Goldin, Katz, & Kuziemko, 2006), but

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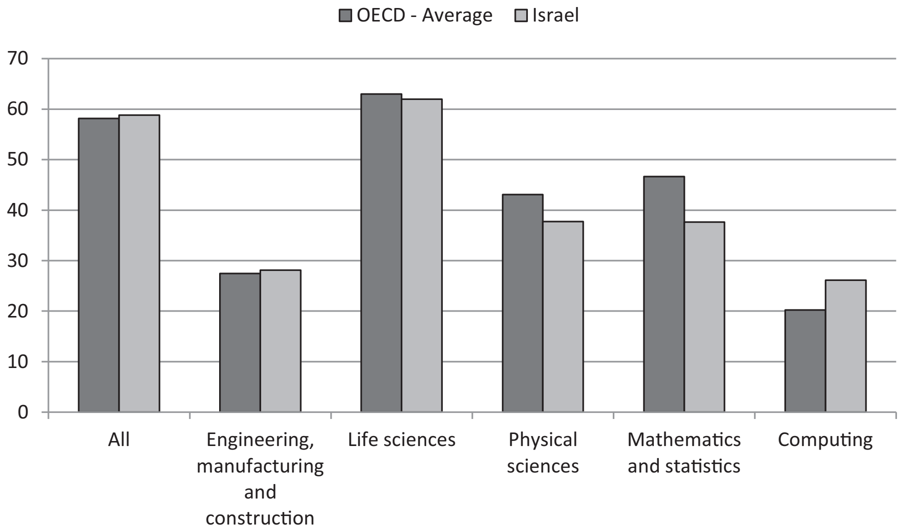

Fig. 1. Share of tertiary qualifications awarded to women in Israel and OECD countries within field of education, % Source: OECD (2011).

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 can be viewed as part of a dynamic process of successive decision making under uncertainty (Altonji, 1993; Altonji, Blom, & Meghir, 2012; Arcidiacono, 2004; 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).[1] 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 with age, cultural context, type of test and other factors, and in some cases disappears.[2] 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 (Ellison & Swanson, 2010; Hedges & Nowell, 1995; Hyde et al., 2008; Pope & Sydnor, 2010; Xie & Shauman, 2003). 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 (Fryer & Levitt, 2010; Goldin et al., 2006; Wang, Eccles, & Kenny, 2013).

Several studies have tested the "critical filter" hypothesis directly with regard to the choice of college major in the United States, among them Turner and Bowen (1999), Xie and Shauman (2003), Riegle-Crumb and King (2010) and Riegle-Crumb, King, Grodsky, and Muller (2012) found that significant gender gaps in choice remain after controlling for high school and SAT achievement. In this paper, we use longitudinal data to test this hypothesis directly at an earlier stage of education: the choice of advanced science and mathematics electives by high-school students in Israel, a country with patterns of gender streaming in the choice of tertiary degree fields that closely follow the OECD averages (Fig. 1). To this end, we follow two half-cohorts of eighth-grade students in Israeli 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 the three years of high school.[3]

[1] As Ceci, Ginther, Kahn, and Williams (2014, p. 75) summarize the extensive literature on women in academic science, "women are underrepresented ... in those fields that are the most mathematically intensive."

[2] On the United States, see, e.g., Fryer and Levitt (2010), on the emergence of a gap in the early years of elementary school; and Pope and Sydnor (2010) on middle and high school. Among international studies, TIMSS 2003 indicates a gap favoring boys in OECD countries (Bedard & Cho, 2010), which does not extend to all participating countries (Else-Quest, Hyde, & Linn, 2010; Kane & Mertz, 2012) while PISA shows a general advantage for boys (Else-Quest et al., 2010; Guiso, Monte, Sapienza, & Zingales, 2008). Meta-analyses covering a wide range of ages, test types and nationalities (Hyde, Fennema, & Lamon, 1990; Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Lindberg, Hyde, Petersen, & Linn, 2010) find a large dispersion of findings with a small average advantage for boys. Over time, average gaps favoring boys have decreased (Ceci et al., 2014; Goldin et al., 2006; Neuschmidt, Barth, & Hastedt, 2008). 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.

[3] We follow two halves of full national cohorts of eighth-grade students in Hebrew-language schools in two successive years, excluding students in ultra-orthodox schools that do not participate in these tests. We focus on Hebrew-language schools because of the the large cultural difference between the Jewish and Arab populations, not least in repect to gender roles. We investigate these differences as they affect choice of science subjects in high school in a separate paper (Friedman-Sokuler & Justman, 2016). Matriculation electives are chosen in tenth grade, and most tests are administered at the end of grades eleven and twelve.

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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.[4] 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 in the eighth grade are more likely to choose mathematics and science matriculation electives than students who do well only in mathematics.[5]

This extends previous work on the choice of college majors in the United States to an earlier stage of education and a different national context, and offers 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, when school attendance in Israel is virtually universal,[6] 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), college-level studies are likely to produce upward biased estimates of the gender gap in male-dominated fields, and downward biased estimates in female-dominated fields.[7] In addition, survey-based studies generally suffer from substantial 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.[8]

These differences lead us to slightly different conclusions from those reached in these previous, college-level, studies. Thus Turner and Bowen (1999) consider a subsample 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 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 stronger prior achievement in language arts increases the probability of specializing in each STEM subject.[9] Some of these differences may be due to the different stages of education we study, to variation over time, or to cultural differences. In a separate study (Friedman-Sokuler & Justman, 2016) we find substantial differences in gender streaming within Israel between Jewish and Arab students that highlight the importance of cultural differences. However, we note the close affinity between our findings here and parallel findings by Justman and Mendez (2015) on choice of grade-12 science and mathematics electives in Australian secondary schools and with a study of high school students in France by Rapoport and Thibout (2016). This suggests that it is the difference in the stage of education we study and the methodological differences noted above– rather than cultural differences–that are driving these differences in findings.

Our findings indicate that gendered patterns of specialization in science and mathematics in high school 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.[10] Consistent with this hypothesis, we find that

[4] 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.

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

[6] Compulsory schooling in Israel extended to tenth grade at the time, and compliance rates were very high. The benefit of using administrative data is that we see all students enrolled in school at the beginning of the eighth grade, irrespective of attendance. This means that we have some information also on students who are enrolled but attend infrequently or are on the verge of dropping out, and include them in our measures of attrition.

[7] We see this pattern of attrition from eighth to twelfth grade in our present data (Table 4, below). We avoid the bias by taking the eight-grade cohort as our frame of reference.

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

[9] 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%.

[10] 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.

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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.[11] We also find differences in the size of the gender gap between non-religious co-educational schools and single-sex religious schools. Among non-religious schools, the gendered patterns of streaming we observe are unaffected by the inclusion of school fixed-effects; all these effects are fully present within schools.

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 describes differences in boys' and girls' responses to eighth-grade test scores and the differential impact of social and economic factors on boys and girls, and examines the effect of schools on gender streaming. Section 5 concludes.

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

Our full population comprises two cohorts of eighth-grade students in Israeli Hebrew-language schools, in the school years 2001/2 and 2002/3 (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; we refer to the students in these schools as the GEMS sample.[12] It is a composite of two half-cohorts of eighth grade students representative of the full population, as evident from in Table 1 which compares it to the full population in terms of socio-economic indicators and twelfth-grade outcomes.

We construct our study sample from the GEMS sample by dropping all students with fewer than two of the four GEMS scores, or with missing data on both father's and mother's education.[13] This leaves us with a study sample of 61,633 students, 81.1% of the GEMS sample, of whom 49.8% are male. For students with only two or three GEMS scores we impute the missing scores from the scores we have, and from student background variables.[14] For all students we construct a new variable called "parents' maximal years of education", equal to the larger value when we have data on both parents' education, and to the value we have when we have education for only one parent. Income quintiles were collected only from students in the GEMS sample. They 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. Therefore, the upper income quintiles are over-represented in our GEMS sample.

Table 2 shows the patterns of change from the GEMS sample to our study sample, by gender. Over 11,000 students, about 14% of the GEMS sample, were dropped because they have fewer than two GEMS scores, and among these, boys outnumber girls by about 1250. In the other rows in Table 2, where observations are dropped due to missing data on parents' education, retention rates are roughly similar, 93.8% for girls and 93.9% for boys. As the relevant columns from Table 1 show, the differences between the study sample and the GEMS sample are small and similar in direction and magnitude for boys and girls: students from low socio-economic status are slightly underrepresented, and there are fewer immigrants in the study sample than in the population at large because recent immigrants are exempt from GEMS.

[11] On the role of psychological differences, Buser, Niederle, and Oosterbeek (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: girls have slightly higher expectations to attend college, but are substantially less likely to expect they will major in science or engineering. 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 background. Melzer (2014) highlights differences in returns to education in Israel across gender and socio-economic background.

[12] 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.

[13] These are the only background variables for which there are missing values.

[14] We regress each GEMS score on the other scores and on all available background characteristics for students with all scores, and use these regressions to predict missing scores, which we use in estimating student choices on prior scores. Adding school fixed effects made little difference to the imputed values. Summary statistics of the actual scores, in Table 3, below, are very similar to those of the scores used in the regression, which include also the imputed values. In Table A1 in the Appendix we replicate the choice regressions for students with all four GEMS scores. The results are substantively unchanged, with slight increases in the male advantage in physics or computer science and advanced mathematics and a slight fall in the female advantage in biology or chemistry, of up to 10% compared to our main results in Table 7.

Table 1
Descriptive statistics: family SES and school type.

	Female			Male		
	Full population	GEMS sample	Study sample	Full population	GEMS sample	Study sample
Father's years of education	12.97	12.96	13.03	13.02	13.04	13.18
	(3.21)	(3.19)	(3.11)	(3.14)	(3.13)	(3.12)
Mother's years of education	13.06	13.06	13.14	13.13	13.15	13.28
	(2.95)	(2.94)	(2.86)	(2.85)	(2.83)	(2.80)
Parents' maximal	13.66	13.64	13.73	13.72	13.75	13.91
years of education*	(3.21)	(3.19)	(2.86)	(3.14)	(3.13)	(2.80)
% immigrants	21%	21%	19%	21%	21%	18%
*Family income quintiles***						
1st	–	13%	12%	–	12%	11%
2nd	–	18%	17%	–	17%	17%
3rd	–	21%	21%	–	21%	21%
4th	–	23%	24%	–	24%	25%
5th	–	25%	26%	–	26%	27%
In 12th grade	93%	93%	95%	86%	87%	90%
Full matriculation	65%	65%	68%	50%	51%	56%
Total	72,037	37,500	30,915	74,217	38,478	30,718
Gender share	49.3%	49.4%	50.2%	50.7%	50.6%	49.8%
Retention rate	100%	52.1%	42.9%	100%	51.8%	41.4%

"Full population" is the full population of eighth-grade students in Hebrew-language schools in Israel, excepting ultra-orthodox schools, in the school years 2001/2 and 2002/3; "GEMS sample" includes students in schools in the half cohort sampled from the full population to participate in GEMS in each of these years; "study sample" are the students in the GEMS sample with at least two of the four GEMS scores and data on the education of at least one parent.

* Where we have both parents' education we take the larger value; where we have education for only one parent we use that.

** Income quintiles were collected only from students in the GEMS sample. 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
Retention rates from the GEMS sample to the study sample, by gender.

Number of GEMS scores	Female			Male		
	GEMS sample	Study sample	% retained	GEMS sample	Study sample	% retained
None	3642		0.0	4451		0.0
1	895		0.0	1330		0.0
None or 1	4537		0.0	5781		0.0
2	2692	2512	93.3	3106	2880	92.7
3	8554	8012	93.7	8938	8293	92.8
4	21,717	20,391	93.9	20,653	19,545	94.6
2 or 3 or 4	32,963	30,915	93.8	32,697	30,718	93.9
Total	37,500	30,915	82.4	38,478	30,718	79.8

2.1. Student background characteristics and GEMS scores

The student background characteristics we use include: gender, parents' years of education, family income quintile, 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. Comparing boys and girls in the study sample in Table 1 shows girls are slightly worse off than boys in terms of family income and parental education, with a difference in parents' years of schooling of about .02 of a standard deviation in the general population and .05 in the study sample. The larger difference in the study sample reflects higher attrition among boys from lower SES background in meeting the criterion of having at least two GEMS scores, which introduces a slight upward bias in measures of male achievement. This is evident in the difference between the full population and the study sample in the proportion of boys and girls reaching twelfth grade and fully matriculating: a difference of 2–3 percentage points for girls, and 4–6 percentage points for boys.

Table 3
Descriptive statistics: GEMS outcomes in GEMS and study samples.

	GEMS sample			Study sample		
	Female	Male	Gender gap*	Female	Male	Gender gap
Mathematics GEMS	52.93	51.78	0.05	53.44	52.40	0.04
	(23.41)	(24.85)		(23.41)	(24.85)	
Science GEMS	64.34	64.15	0.01	64.70	64.59	0.01
	(18.06)	(20.04)		(18.06)	(20.04)	
Reading GEMS	67.61	59.39	0.41	68.18	60.07	0.42
	(18.30)	(20.61)		(18.30)	(20.61)	
English GEMS	80.60	75.96	0.22	81.14	76.55	0.22
	(19.58)	(22.72)		(19.58)	(22.72)	

These are averages of actual scores, not including imputed scores
* Gender gap is the female–male difference divided by the sample standard deviation.

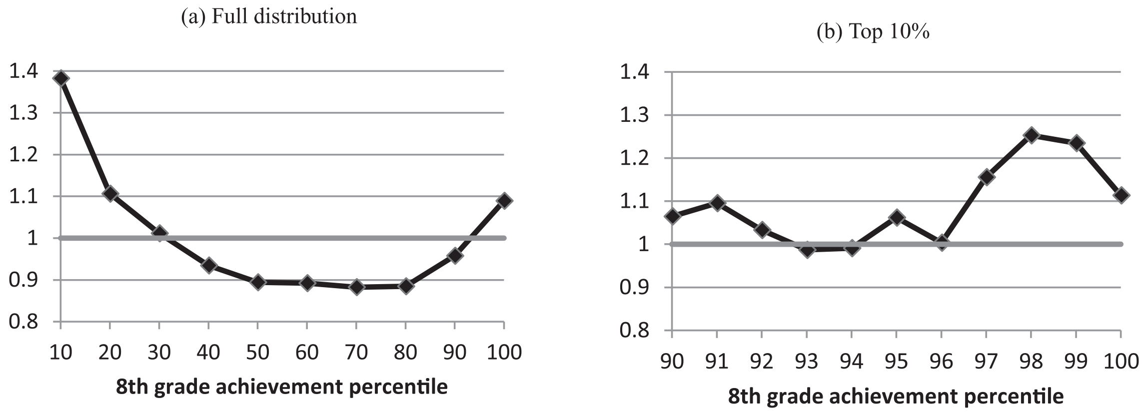

Fig. 2. Male/female ratio by eighth-grade mathematics achievement rank.

Table 3 compares eighth-grade GEMS scores between boys and girls for the GEMS and study samples.[15] Average scores in the study sample are slightly higher but there is little effect on the gender gap in scores. Girls score higher in all four subjects, with a greater advantage in language arts than in mathematics and science, implying that boys have a comparative advantage in mathematics and science. We also observe that standard deviations in GEMS scores are slightly higher for boys. This difference in the variability of mathematics achievement leads to the over-representation of boys among top scorers, illustrated in Fig. 2.

Panel A of Fig. 2 presents the ratio of male to female students in the study sample 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 presents 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 the National Assessment of Educational Progress (NAEP) scores in New England, the most gender-equal region in the United States. Fig. 2 confirms the greater male variability hypothesis while indicating its limited scope in the present context.

2.2. Gender streaming in advanced mathematics and science electives

Our outcome measures are the students' choices 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 represented as numbers of units studied in a subject, generally between one and five. 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.[16] 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

[15] These are averages of actual scores, not including imputed scores.

[16] 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; the most popular are: natural and exact sciences, social sciences, languages (mainly Arabic and French), geography and art.

Table 4
Gender streaming and achievement gaps in matriculation outcomes.

	Choice of advanced STEM electives (proportion of 8th grade cohort)			
	Female		Male	
	Study sample	Full population	Study sample	Full population
Physics	5%	4%	13%	12%
Computer science	4%	4%	11%	9%
Physics or computer science	8%	7%	18%	16%
Advanced mathematics	14%	13%	17%	15%
Biology	15%	14%	9%	8%
Chemistry	7%	7%	5%	5%
Biology or chemistry	20%	18%	13%	12%
Matriculating with any advanced science or mathematics elective	28%	26%	31%	27%
Matriculating with no advanced science or mathematics electives	40%	38%	26%	23%
	Average scores			
	Female	Male	Gender gap* (standardized)	*p*-Value**
Physics	84.32 (10.65)	84.03 (11.05)	0.03	0.046
Advanced mathematics	85.03 (10.99)	85.33 (11.71)	−0.03	0.001
Computer science	89.45 (7.40)	89.01 (7.81)	0.06	0.010
Biology	84.87 (9.29)	81.98 (10.29)	0.30	0.001
Chemistry	85.88 (9.95)	85.51 (10.90)	0.04	0.032

* Gender gap is the female–male difference divided by the sample standard deviation.
** Statistical significance of the difference in means in a two-tailed comparison.

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. In the top panel, we find a strong pattern of gender streaming in the choice of electives in science and mathematics, common to both the full population and the study sample. The share of boys choosing advanced physics or computer science is more than twice that of girls; the share of boys choosing advanced mathematics is about 20% higher; while the share of girls choosing advanced biology is about 60% higher than boys and their share in advanced chemistry is 40% higher. We also present frequencies for combined categories, considering physics and computer science as one category, and biology and chemistry as another category, anticipating our statistical analysis in the following sections.

We combine categories to simplify the presentation of our results and increase statistical power, as each pair exhibits similar gender patterns.[17] The combined categories behave similarly to the single subjects: 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. 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. Boys have a slight advantage in the choice of at least one advanced elective (five units) among mathematics, physics, computer science, biology or chemistry. The bottom panel of Table 4 presents average test scores in the individual subjects by gender. Girls score slightly higher than boys in all four science subjects, on average, including the male dominated subjects, but boys score higher in advanced mathematics. The differences are small, except for biology where girls outperform boys by 0.30 of a standard

[17] These are also the two most common combinations of electives. Table A2 in Appendix reveals that 5% of girls in the cohort and 10% of boys take more than one advanced science elective, with 2.1% of girls and 2.9% of boys taking combinations of subjects that cross our categories. These students are counted in both science regressions. We also estimated our regressions for each subject separately. The results presented in Table A3 in Appendix are similar, though the absolute gender effects are smaller for each subjects, similar in size to the raw gender differences for individual subjects in Table 4. Note that selection within categories may also reflect restricted choice as fewer schools offer chemistry or computer science than offer biology or physics.

deviation, but the sample sizes are large and all five differences are statistically significant at the 5% level or better.

3. The effect of prior 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 prior 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. In addition, 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 from the specific propensity to choose an advanced elective

We begin by presenting the data graphically in the three panels of Fig. 3, which show the different propensities, by gender and percentile of achievement in mathematics, of choosing physics or computer science, advanced mathematics, and biology or chemistry. All six curves in Fig. 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 a small difference by gender in the propensity to choose advanced mathematics, and much larger differences for the science subjects: *at each level of ability*, boys are much more likely to choose physics or computer science and girls are much more likely to choose biology or chemistry.

The following decomposition quantifies the relative contribution of gender differences in achievement and in specific propensities to choose an advanced science or mathematics elective. We divide the population into 20 equal sub-groups, i, by GEMS mathematics rank, and apply equation (1) to decompose the raw difference in choice probabilities p for subject s between boys (B) and girls (G):

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

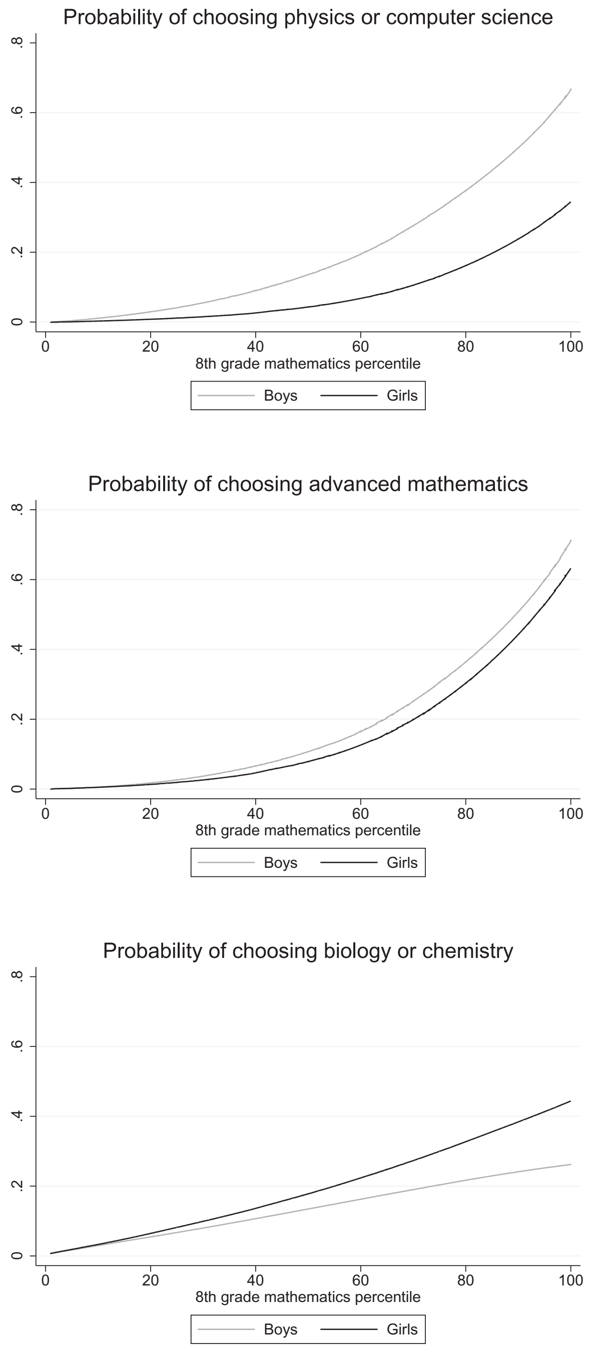

Fig. 3. Share choosing science and mathematics electives by gender and eighth-grade math scores (smoothed using Stata's Lowess procedure for kernel-weighted local polynomial smoothing).

The results are presented in Table 5. They show that for physics or computer science and for advanced mathematics, accounting for the observed gender difference in

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Table 5
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

Table 6
Female gender coefficients from subject choice regressions.

	(1)	(2)	(3)	(4)
Physics or computer science	−0.108***	−0.110***	−0.117***	−0.114***
	(0.005)	(0.005)	(0.005)	(0.005)
Advanced mathematics	−0.027***	−0.027***	−0.038***	−0.033***
	(0.005)	(0.004)	(0.004)	(0.004)
Biology or chemistry	0.063***	0.057***	0.049***	0.052***
	(0.006)	(0.005)	(0.005)	(0.005)
GEMS Mathematics	No	Yes	Yes	Yes
All GEMS scores	No	No	Yes	Yes
Family background	No	No	No	Yes

Notes: $N = 61{,}633$. Each entry is the female gender coefficient from a linear probability model, for each of three subject categories, and four specifications, with school-level clustered standard errors in parentheses. All include a cohort dummy. "GEMS mathematics" includes a linear and quadratic term. "All GEMS scores" include also linear and quadratic terms for GEMS scores in Science, Hebrew and English, and an interaction term for mathematics and Hebrew. "Family background" includes indicators for family income quintiles, four categories of parents' maximal years of schooling and immigrant status. GEMS scores are normalized to have a mean of 0 and standard deviation of 1. * $p < 0.05$ ** $p < 0.01$
*** $p < 0.001$

Table 7
Choice of matriculation electives, gender and GEMS score coefficients.

	Physics or computer science	Advanced mathematics	Biology or chemistry
Female	−0.114***	−0.033***	0.052***
	(0.005)	(0.004)	(0.005)
GEMS			
Mathematics	0.079***	0.108***	0.044***
	(0.003)	(0.004)	(0.003)
Science	0.027***	0.026***	0.023***
	(0.002)	(0.003)	(0.003)
Hebrew	0.021***	0.028***	0.040***
	(0.003)	(0.002)	(0.003)
English	0.014***	0.017***	0.013***
	(0.002)	(0.002)	(0.002)
Mathematics^2	0.054***	0.075***	−0.000
	(0.003)	(0.003)	(0.003)
Science^2	0.000	0.022***	0.016***
	(0.002)	(0.002)	(0.002)
Hebrew^2	0.021***	0.007***	0.005*
	(0.002)	(0.002)	(0.002)
English^2	0.007***	0.008***	0.008***
	(0.001)	(0.002)	(0.002)
Mathematics*Hebrew	0.008**	0.018***	0.016***
	(0.002)	(0.003)	(0.002)
R^2	0.234	0.309	0.106

Notes: $N = 61{,}633$. Coefficients from a linear probability model, for each of three subject categories, with school-level clustered standard errors. All regressions include indicators for cohort, family income quintiles, four categories of parents' maximal years of schooling and immigrant status. GEMS scores are normalized to have a mean of 0 and standard deviation of 1.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

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 Fig. 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 5 highlights our finding that gender gaps in specialization overwhelmingly reflect differences in specific propensities rather than differences in prior achievement.

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: physics or computer science, advanced mathematics, and biology or chemistry.[18] Table 6 presents the coefficients on an indicator for female from choice regressions for each of our three subject categories, estimating four specifications for each subject;

[18] We obtain very similar results from a non-linear logistic model. We also estimated a multinomial logit specification with the same right-hand variables as in column (4) of Table 6 and four categories: no matriculation, matriculation with no STEM electives, matriculation with biology or chemistry, and matriculation with physics or computer science. The marginal effect of (female) gender we obtain for physics or computer science is −0.103 and for biology or chemistry it is 0.070, compared to −0.114 and 0.052 in column (4) of Table 6 below. We prefer the linear probability model because it allows a more straightforward interpretation of coefficients as marginal effects and a simpler comparison across alternative specifications. Moreover, while the assumption of a single choice of subject underlying the multinomial model approximately fits the choice between science subjects it does not fit the choice of advanced mathematics.

Table 8
Specific choice propensities for students in the top 20% GEMS rank only in mathematics, and in the top 20% in mathematics and Hebrew, by gender.

	Female		Male	
	Mathematics only	Mathematics and Hebrew	Mathematics only	Mathematics and Hebrew
Physics or computer science	0.17	0.28	0.44	0.59
Advanced mathematics	0.33	0.52	0.43	0.63
Biology or chemistry	0.33	0.43	0.23	0.26

Table 7 presents the coefficients of the GEMS scores from the last, full specification for each subject group.[19]

The first column of Table 6 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, and given the non-linear relationship between prior mathematical achievement and choice evident from Fig. 3, we include also the GEMS score squared. As girls do slightly better than boys in eighth-grade mathematics, controlling for prior achievement in mathematics increases the gender gap favoring boys in physics or computer science and in advanced mathematics, 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 we add the eighth-grade GEMS scores in science, Hebrew and English, as well as quadratic terms for each, and an interactive term in mathematics and Hebrew. This slightly increases the male advantage in physics or computer science and in advanced mathematics by a further 0.7–1.1 percentage points, and similarly reduces the female advantage in biology or chemistry. Finally, in the fourth column we add controls for immigrant status, family income quintile and parents' maximal education, which enter in the regression as four categories: less than 12 years, 12 years, 13–15 years, more than 15 years.[20] Adding these variables slightly reduces the male advantage in male dominated subjects and increases the female advantage in female-dominated subjects, by 0.3–0.5 percentage points.

Table 7 presents the coefficients for the different GEMS scores from the full regression for each subject group (column (4) in Table 6). As expected, in all cases, eighth-grade mathematical ability has a substantial, significant positive effect on choice, and as indicated by Fig. 3, the function is convex. The largest effect is in advanced mathematics and the smallest in biology or chemistry, in line with the relevance of mathematical ability for each subject. Science scores also have the expected positive effect on choosing science and mathematics electives, especially biology or chemistry. 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 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 the humanities and social sciences. We see that all prior scores exhibit a statistically significant, positive (and in most cases convex) relationship with the probability of choosing a science or mathematics elective. Whereas the magnitude of the coefficient on mathematics varies substantially between electives, the coefficients on language arts are similar, indicating a general ability rather than a subject-specific component. An interaction term, the product of the mathematics and Hebrew scores, also has a significant positive effect. Taken together, these positive effects of prior achievement in language arts on all electives do not support the comparative advantage hypothesis.

To further illustrate the lack of support in our data for the comparative advantage hypothesis, we distinguish between two groups of high-achieving students: those in the top 20% in both mathematics and Hebrew; and those in the top 20% in mathematics but not in Hebrew. As Table 8 shows, 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. The propensity to choose science and mathematics electives

In the preceding section, we 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, slightly exceed the raw gender effect. In this section we quantify gender differences in the response to signals of mathematical ability implicit in prior scores; consider how gender differences in specific propensities vary with prior ability and parents' socio-economic status (SES); and examine to what extent do school characteristics contribute to the gendered choice patterns we observe.

[19] Full regression outputs for all specifications are presented in Table A4 in Appendix

[20] This allows parental education to have a non-linear effect. See Table A5 in Appendix for descriptive statistics.

Table 9
Effect of prior scores, interacted with female gender, on the probability to choose science and mathematics electives.

	Physics or computer science	Advanced mathematics	Biology or chemistry
Female	−0.089***	−0.042***	0.029**
	(0.008)	(0.007)	(0.010)
Interacted with female			
GEMS Mathematics	−0.054***	−0.018***	0.032***
	(0.004)	(0.004)	(0.005)
GEMS Science	−0.022***	0.001	0.019***
	(0.004)	(0.003)	(0.005)
GEMS Hebrew	−0.016**	−0.009	0.007
	(0.005)	(0.005)	(0.005)
GEMS English	−0.018***	−0.009**	0.002
	(0.003)	(0.003)	(0.004)
GEMS Mathematics^2	−0.013***	0.001	0.010*
	(0.004)	(0.004)	(0.004)
GEMS Science^2	−0.010***	0.001	0.007*
	(0.003)	(0.003)	(0.003)
GEMS Hebrew^2	−0.002	−0.005	0.001
	(0.003)	(0.003)	(0.004)
GEMS English^2	−0.010***	−0.005*	0.003
	(0.002)	(0.002)	(0.003)
Mathematics∗Hebrew	−0.010*	0.004	0.013**
	(0.004)	(0.004)	(0.004)
R^2	0.259	0.311	0.112

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. All regressions include GEMS scores and scores squared without interactions, and controls for family incomes; parents' maximal education; and immigrant status, with and without interaction with a dummy for female. Standard errors in parentheses. GEMS scores are normalized to have a mean of 0 and standard deviation of 1.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

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 previous research on gender differences in risk aversion and competitiveness suggests that boys are less deterred by adverse signals in choosing mathematically intensive subjects. To quantify this effect we estimate a linear probability model that allows different responses to GEMS scores by gender. The model includes all the controls in Table 6, column (4), interacted with a dummy variable for female. Table 9 presents the gender coefficient, which is reduced by the introduction of these interaction terms; and the coefficients of the interaction of female gender with all GEMS scores. 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.

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

	Less than 12	12 years	13–15 years	More than 15
Physics or computer science				
Female	−0.044	−0.074	−0.130	−0.186
	(0.005)	(0.004)	(0.007)	(0.009)
R^2	0.168	0.168	0.224	0.229
Advanced mathematics				
Female	−0.016	−0.017	−0.036	−0.061
	(0.004)	(0.004)	(0.006)	(0.009)
R^2	0.201	0.237	0.285	0.292
Biology or chemistry				
Female	0.030	0.044	0.057	0.068
	(0.007)	(0.005)	(0.008)	(0.011)
R^2	0.131	0.104	0.083	0.068
Observations	7899	22,567	13,908	17,259

Notes: N = 61,633. Dependent variables vary by row, and columns vary by sample. Coefficients are obtained from a linear probability model with school-level clustered standard errors. All regressions include controls for cohort, GEMS scores as in Table 7, family income, parents' education 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.

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). We analyze these patterns by splitting students into four categories by parents' maximal years of schooling, as above. As Table 10 shows, selection of science and mathematics electives increases in parents'

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

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

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

	Co-educational non-religious		Co-educational religious		Single-sex religious	
	Female	Male	Female	Male	Female	Male
Eighth-grade students	24,903	24,827	2068	2529	3944	3362
Twelfth-grade students	24,052	23,146	1569	1583	3750	3006
Lowest	11%	10%	20%	15%	10%	7%
2nd	17%	16%	23%	19%	16%	13%
3rd	21%	21%	24%	23%	21%	19%
4th	25%	25%	21%	25%	26%	27%
Highest	27%	29%	12%	18%	28%	35%
GEMS mathematics	0.09	0.04	−0.17	−0.12	0.06	0.11
GEMS science	0.07	0.07	−0.24	−0.11	0.02	0.16
GEMS Hebrew	0.23	−0.13	0.02	−0.22	0.37	0.04
GEMS English	0.18	0.00	−0.29	−0.41	0.07	−0.14
% matriculating	71%	62%	64%	57%	80%	67%
Physics or computer science	8%	20%	9%	17%	10%	25%
Advanced mathematics	15%	18%	12%	16%	14%	23%
Biology or chemistry	21%	15%	25%	14%	20%	17%

Notes: The student sample by school type is reduced between the eighth and the twelfth grade by 4402 students who do not attend state schools with their cohort and 682 students who attend schools for which we have less than 10 observations. GEMS scores are standardized with a mean of 0 and standard deviation of 1.

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 three panels of Fig. 4 demonstrate graphically how the effect of parental education on choice of electives, conditioned on eighth-grade mathematical achievement, varies by gender. It shows, for each elective, separately for girls and boys, the difference in choice frequencies between children in families where at least one parent has more than 15 years of education (the highest category) and children of families in which both parents have less than 12 years (the lowest category), by the level of prior mathematical achievement. Parental education has a persistent effect throughout the ability distribution for both boys and girls, but the gaps are larger for boys; and they are largest in advanced mathematics, and smallest in biology or chemistry. This is consistent with the patterns described in Table 10, where the share of girls among students choosing an elective, declines with parental education.[21]

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 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, and more steeply in the male-dominated subjects, mathematics and physics or computer science, 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 (DiPrete & Jennings, 2012; Goldin et al., 2006). 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, Hodson, & McCloud, 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. To analyze the effect of schools we need to distinguish between three types of secondary Hebrew-language schools in Israel (excluding ultra-orthodox schools): non-religious coeducational schools, religious single-sex schools, and religious

[21] Fig. A1 in Appendix presents a full set of graphs for each of the three subject groups, for each of the four categories of parental education, by gender. The same findings hold also for family income, as shown in Table A6 and A7 and Figs. A2 and A3 in Appendix, which recalculates Table 10 and 11 and redraws Figs. A1 and 4 by income quintiles instead of parental education.

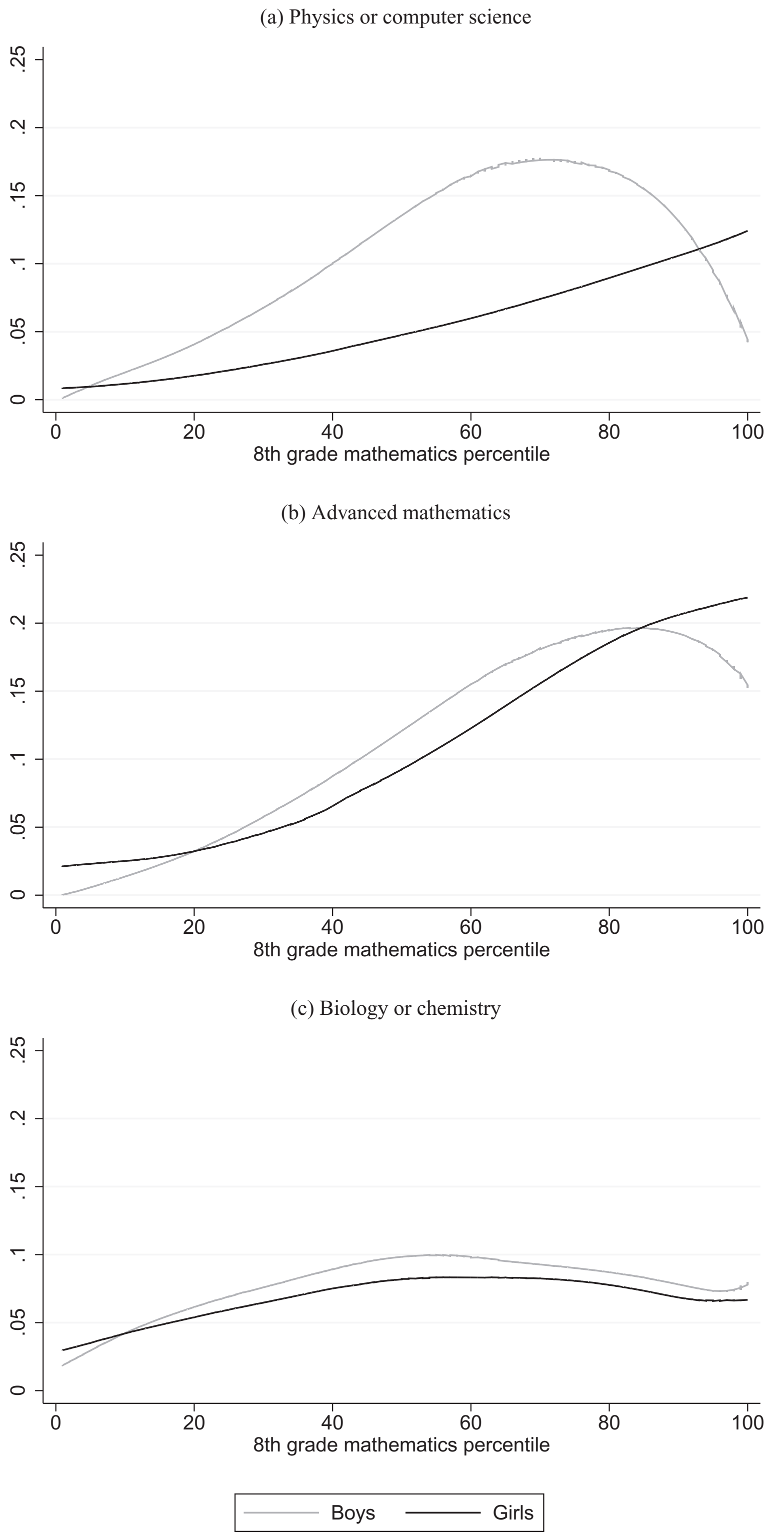

Fig. 4. Differences in share of students selecting advanced science or mathematics electives between the highest category of parents' schooling (at least one parent with more than 15 years of schooling) and the lowest category (both parents with less than 12 years of schooling) by gender and eighth-grade mathematical achievement.

Table 13
Gender coefficients from estimates of choice of advanced matriculation electives, non-religious schools, with fixed effects and school characteristics.

	Female	School characteristics			
		School size (standardized)	Share of girls	Six-year school	Average parent education
Physics or computer science					
LPM	−0.128***				
	(0.005)				
LPM with school fixed-effects	−0.128***				
	(0.003)				
LPM with school characteristics	−0.128***	0.004	−0.056	0.024**	−0.000
	(0.005)	(0.004)	(0.061)	(0.008)	(0.004)
Advanced mathematics					
LPM	−0.036***				
	(0.004)				
LPM with school fixed-effects	−0.035***				
	(0.003)				
LPM with school characteristics	−0.035***	−0.001	−0.080	0.039***	0.007
	(0.004)	(0.004)	(0.062)	(0.009)	(0.004)
Biology or chemistry					
LPM	0.051***				
	(0.005)				
LPM with school fixed-effects	0.046***				
	(0.003)				
LPM with school characteristics	0.045***	0.005	0.299***	0.016	0.000
	(0.005)	(0.006)	(0.065)	(0.012)	(0.005)

Notes: $N = 47{,}198$, only schools with a minimum of 10 students in a cohort are included in the analysis. Coefficients are obtained from a linear probability model with a dummy for cohort, GEMS scores, quadratic GEMS scores, interaction between mathematics and Hebrew scores, family income quintile, parents' maximal years of schooling and immigrant status; row 2 adds school fixed effects; and row 3 adds school characteristics to the equation estimated in row 1. GEMS score are normalized to have a mean of 0 and standard deviation of 1. Standard errors, in parenthesis clustered at the school level. * $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

coeducational schools.[22] There are curricular differences between non-religious and religious schools, especially in the allocation of teaching hours between subjects and added teaching hours for religious studies. The top two rows of Table 12 show the distribution of students by gender across the different school types in the eighth and twelfth grade. To analyze school effects during high school we drop from the sample students not enrolled in school in the twelfth grade, as well as schools with fewer than 10 students in the full population. This reduces the sample by 7.3%, leaving us with 57,106 students.

Table 12 compares students in our reduced sample by twelfth-grade school type. 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. Coeducational non-religious schools and single-sex religious schools have more similar student populations. However, eight-grade achievement in mathematics differs between religious and non-religious schools. In non-religious schools, girls outperform boys, whereas boys outperform girls in religious schools. Single-sex religious schools have the highest matriculation rates, followed by coeducational non-religious schools. This patterns accords with the socio-economic rankings of the three groups.

The qualitative patterns observed in the population as a whole with regard to selecting advanced science or mathematics electives 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 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. The male advantage in physics or computer science and in advanced mathematics electives is substantially larger in single-sex religious schools while the female advantage in choosing biology or chemistry electives is smallest in these schools. These differences highlight the importance of cultural factors, broadly defined, in shaping these choices. 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

[22] About a third of students in religious schools attend coeducational schools, however few of these schools are fully coeducational; in most, boys and girls study in separate classes. We do not have class level data.

measure the specific preferences of students who choose to attend these schools, but also constrain their choices.

To gauge the effect of schools and school characteristics on gendered streaming patterns, we focus our attention on co-educational non-religious schools, estimating two specifications based on the linear probability model of Table 6. The first specification adds school fixed effects to the model; the second adds school characteristics. The first row of each panel in Table 13 estimates the raw gender gap for each elective for our limited sample. These gaps are slightly higher than those estimated for the full population in the first column of Table 6, mainly due to the greater attrition among male students. Including fixed effects in the second row of each panel of Table 13 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. We calculated correlations between the school fixed effects for the different choices and found, as might be expected, a strong positive correlation of 0.69 between the effect of a school on choosing physics or computer science and its effect on choosing advanced mathematics; many schools require students who choose advanced physics to also take advanced mathematics.

In the third row of each panel we replace the school fixed effects with specific school characteristics, constructed from student-level data by school in the full population. The characteristics we control for are: the number of students in the school, in the cohort studied (standardized); the share of girls in the cohort in the school; whether it is a six-year school (from grades 7 to 12); and the average years of education of parents in the school.[23] Controlling for observable school characteristics yields a gender gap identical to that of the specification with school fixed effects, and not far removed from the raw differences. Of our observable school characteristics, school size and parental education had no effect on subject choice. Attending a 6-year school significantly increases the probability of choosing advanced mathematics, and physics or computer science. Choosing biology or chemistry is positively correlated with the share of girls in the school, but the causal direction of this effect cannot be determined from our data.

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 60% 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 advanced matriculation electives in science and mathematics to their eighth-grade standardized test scores in mathematics, science, Hebrew and English for two half-cohorts of eighth-grade students in Hebrew-language schools in Israel 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 that socio-economic disadvantage adversely affects male students more than female students. We also find substantial differences in gendered choice patterns between single-sex religious schools and non-religious coeducational schools, further highlighting the importance of cultural factors in shaping these choices. Finally, we note that in non-religious coeducational schools, school effects have no impact on gender gaps: within-school gender differences are nearly identical to the overall gender effects.

There is extensive evidence that field of study in university contributes substantially to the gender wage gap, and university choices are constrained and shaped by the choice of matriculation electives in high school. Advanced electives in physics and computer science pave the way to careers in engineering and information technology, and girls choose to specialize in these subjects much less often than boys, even when comparing boys and girls with equally high prior scores in mathematics. Yet girls' average matriculation scores in physics and computer science are slightly higher than boys' average scores. These gendered patterns reflect the influence of social, cultural and economic factors. Addressing these issues at an early age, before the final years of high school, is important for reducing the gender wage gap; and it can increase efficiency by lowering the invisible barriers that keep talented young women from realizing their full potential in key fields that fuel economic growth.

[23] We use parents' education rather than GEMS scores as a proxy for peer effects because students often switch schools between the eighth grade and high school, so that for a given high school in a given year, we see eighth grade scores for only a subset of students. We have parental education for the full population.

Appendix

Table A1
Choice regressions, students with all four GEMS scores.

	Physics or computer science	Advanced mathematics	Biology or chemistry
Female	−0.125***	−0.036***	0.050***
	(0.006)	(0.005)	(0.006)
GEMS			
Mathematics	0.078***	0.108***	0.048***
	(0.003)	(0.004)	(0.004)
Science	0.026***	0.026***	0.039***
	(0.003)	(0.003)	(0.003)
Hebrew	0.022***	0.026***	0.025***
	(0.003)	(0.003)	(0.004)
English	0.014***	0.017***	0.014***
	(0.002)	(0.002)	(0.003)
Mathematics^2	0.056***	0.081***	−0.004
	(0.003)	(0.003)	(0.003)
Science^2	0.025***	0.026***	0.014***
	(0.002)	(0.002)	(0.003)
Hebrew^2	0.000	0.009***	0.006*
	(0.002)	(0.002)	(0.003)
English^2	0.008***	0.011***	0.008***
	(0.002)	(0.002)	(0.002)
Mathematics∗Hebrew	0.007*	0.018***	0.017***
	(0.003)	(0.003)	(0.003)
Family background	Yes	Yes	Yes
R^2	0.238	0.318	0.099

Notes: $N = 39{,}936$. 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. * $p < 0.05$ ** $p < 0.01$
*** $p < 0.001$

Table A2
Combinations of advanced science electives.

	Female (%)	Male (%)
Frequency of combination of two advanced science electives		
Computer science and physics	1.0	5.0
Chemistry and biology	2.2	1.0
Chemistry and physics	0.8	1.3
Biology and computer science	0.5	0.7
Biology and physics	0.3	0.4
Chemistry and computer science	0.4	0.5
Share of students combining across categories	2.1	2.9
Three or more sciences	0.2	0.4

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Table A3
Gender gap in choosing separate advanced science electives.

	Physics	Computer science	Biology	Chemistry
Female	−0.082***	−0.075***	0.047***	0.016***
	(0.004)	(0.005)	(0.005)	(0.003)
GEMS				
Mathematics	0.060***	0.044***	0.020***	0.031***
	(0.003)	(0.003)	(0.003)	(0.002)
Science	0.023***	0.013***	0.034***	0.011***
	(0.002)	(0.002)	(0.003)	(0.002)
Hebrew	0.013***	0.013***	0.017***	0.010***
	(0.002)	(0.003)	(0.003)	(0.002)
English	0.009***	0.010***	0.005*	0.010***
	(0.001)	(0.001)	(0.002)	(0.001)
$Mathematics^2$	0.049***	0.030***	−0.013***	0.013***
	(0.003)	(0.003)	(0.002)	(0.002)
$Science^2$	0.019***	0.010***	0.013***	0.006***
	(0.002)	(0.002)	(0.002)	(0.001)
$Hebrew^2$	−0.002	0.002	0.004*	0.001
	(0.001)	(0.002)	(0.002)	(0.001)
$English^2$	0.004***	0.005***	0.004*	0.006***
	(0.001)	(0.001)	(0.002)	(0.001)
Mathematics∗Hebrew	0.005*	0.003	0.010***	0.010***
	(0.002)	(0.002)	(0.002)	(0.002)
Family background	Yes	Yes	Yes	Yes
R^2	0.195	0.123	0.058	0.072

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

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Table A4
Choice of matriculation electives, conditioned on gender and eighth-grade scores.

A. Physics or computer science

	(1)	(2)	(3)	(4)
Female	−0.108***	−0.110***	−0.117***	−0.114***
	(0.005)	(0.005)	(0.005)	(0.005)
GEMS				
Mathematics		0.130***	0.083***	0.079***
		(0.003)	(0.003)	(0.003)
Science			0.028***	0.027***
			(0.002)	(0.002)
Hebrew			0.021***	0.021***
			(0.003)	(0.003)
English			0.022***	0.014***
			(0.002)	(0.002)
Mathematics^2		0.065***	0.054***	0.054***
		(0.003)	(0.003)	(0.003)
Science^2			0.022***	0.021***
			(0.002)	(0.002)
Hebrew^2			0.002	0.000
			(0.002)	(0.002)
English^2			0.010***	0.007***
			(0.002)	(0.001)
Mathematics∗Hebrew			0.008**	0.008**
			(0.002)	(0.002)
Family background	No	No	No	Yes
R^2	0.026	0.208	0.227	0.234

B. Advanced mathematics

	(1)	(2)	(3)	(4)
Female	−0.027***	−0.027***	−0.038***	−0.033***
	(0.005)	(0.004)	(0.004)	(0.004)
GEMS				
Mathematics		0.167***	0.112***	0.108***
		(0.003)	(0.004)	(0.004)
Science			0.029***	0.028***
			(0.002)	(0.002)
Hebrew			0.028***	0.026***
			(0.003)	(0.003)
English			0.026***	0.017***
			(0.002)	(0.002)
GEMS2				
Mathematics^2		0.096***	0.076***	0.075***
		(0.003)	(0.003)	(0.003)
Science^2			0.023***	0.022***
			(0.002)	(0.002)
Hebrew^2			0.009***	0.007***
			(0.002)	(0.002)
English^2			0.012***	0.008***
			(0.002)	(0.002)
Mathematics∗Hebrew			0.018***	0.018***
			(0.003)	(0.003)
Family background	No	No	No	Yes
R^2	0.001	0.274	0.298	0.309

(*continued on next page*)

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Table A4 (*continued*)

C. Biology or chemistry

	(1)	(2)	(3)	(4)
Female	0.063***	0.057***	0.049***	0.052***
	(0.006)	(0.005)	(0.005)	(0.005)
GEMS				
Mathematics		0.101***	0.047***	0.044***
		(0.004)	(0.003)	(0.003)
Science			0.040***	0.040***
			(0.003)	(0.003)
Hebrew			0.024***	0.023***
			(0.003)	(0.003)
English			0.019***	0.013***
			(0.003)	(0.002)
GEMS2				
Mathematics^2		0.016***	-0.000	-0.000
		(0.003)	(0.003)	(0.003)
Science^2			0.017***	0.016***
			(0.002)	(0.002)
Hebrew^2			0.006**	0.005*
			(0.002)	(0.002)
English^2			0.010***	0.008***
			(0.002)	(0.002)
Mathematics∗Hebrew			0.016***	0.016***
			(0.002)	(0.002)
Family background	No	No	No	Yes
R^2	0.007	0.081	0.102	0.106

Notes: N = 61,633. Dependent variables vary by panel. 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, four categories of 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.

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

Table A5

Parents' maximal years of education: descriptive statistics.

	Female			Male		
	Full cohorts	GEMS sample	Study sample	Full cohorts	GEMS sample	Study sample
Father's years of education	12.97	12.96	13.03	13.02	13.04	13.18
	(3.21)	(3.19)	(3.11)	(3.14)	(3.13)	(3.12)
By category						
> 12	24%	24%	23%	23%	23%	21%
12	37%	37%	37%	37%	37%	38%
13-15	19%	19%	20%	19%	19%	19%
15 <	21%	20%	20%	21%	21%	22%
Total	63,538	33,022	29,262	65,329	33,896	29,182
Mother's years of education	13.06	13.06	13.14	13.13	13.15	13.28
	(2.95)	(2.94)	(2.86)	(2.85)	(2.83)	(2.80)
By category						
> 12	19%	19%	18%	18%	18%	16%
12	39%	40%	40%	40%	40%	40%
13–15	22%	22%	22%	22%	22%	23%
15 <	20%	20%	20%	20%	20%	21%
Total	64,038	33,198	29,516	65,614	33,948	29,197
Parents' maximal years of education	13.66	13.64	13.73	13.72	13.75	13.91
	(3.21)	(3.19)	(2.86)	(3.14)	(3.13)	(2.80)
By category						
> 12	15%	15%	14%	14%	14%	12%
12	36%	37%	37%	37%	37%	36%
13–15	22%	22%	22%	22%	22%	23%
15 <	27%	27%	27%	28%	27%	29%
Total	67,415	34,999	30,915	69,167	35,851	30,718

Table A6
Selection of science and mathematics electives by family income quintiles

Family income	Physics or computer science		Advanced mathematics		Biology or chemistry	
	Share (%)	% girls	Share (%)	% girls	Share (%)	% girls
Lowest	7	31	8	50	10	64
2nd	7	31	9	50	13	62
3rd	10	29	11	46	14	61
4th	13	30	15	48	18	61
Highest	22	29	27	44	23	57

Table A7
Gender gaps in the choice of electives by family income quintiles conditioned on prior achievement and family characteristics.

	Income quintiles				
	(1)	(2)	(3)	(4)	(5)
Physics or computer science					
Female	−.070	−0.069	−0.091	−0.115	−0.182
	(0.006)	(0.006)	(0.006)	(0.007)	(0.009)
R^2	0.194	0.185	0.210	0.220	0.233
Advanced mathematics					
Female	−0.021	−0.015	−0.020	−0.030	−0.064
	(0.006)	(0.006)	(0.006)	(0.005)	(0.008)
R^2	0.265	0.246	0.276	0.284	0.306
Biology or chemistry					
Female	0.032	0.037	0.048	0.059	0.066
	(0.008)	(0.008)	(0.007)	(0.008)	(0.010)
R^2	0.101	0.121	0.103	0.103	0.068
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 $p < 0.01$ or better.

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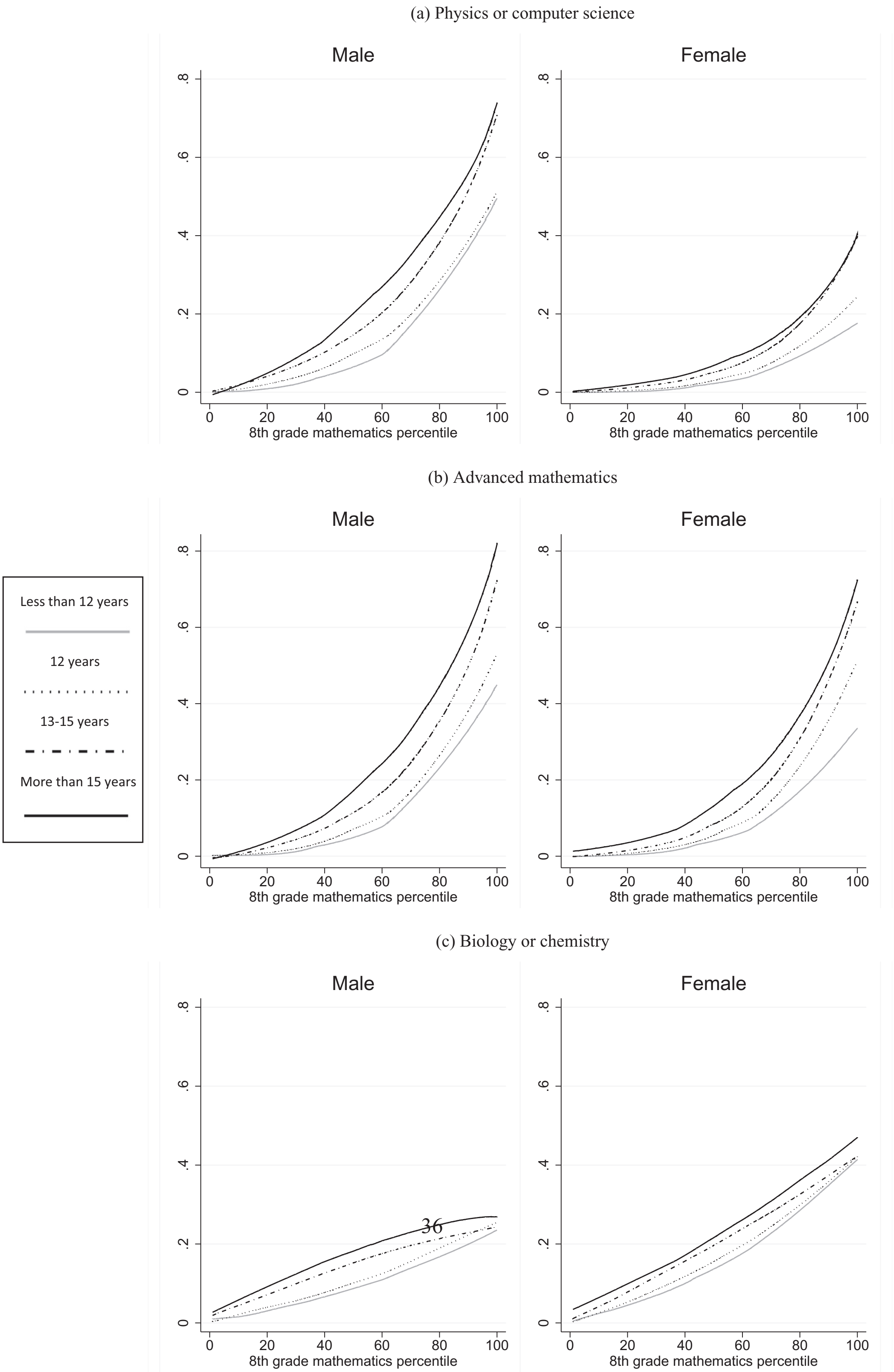

Fig. A1. Share of students selecting advanced science or mathematics electives by eighth-grade mathematical achievement and parents' maximal years of schooling.

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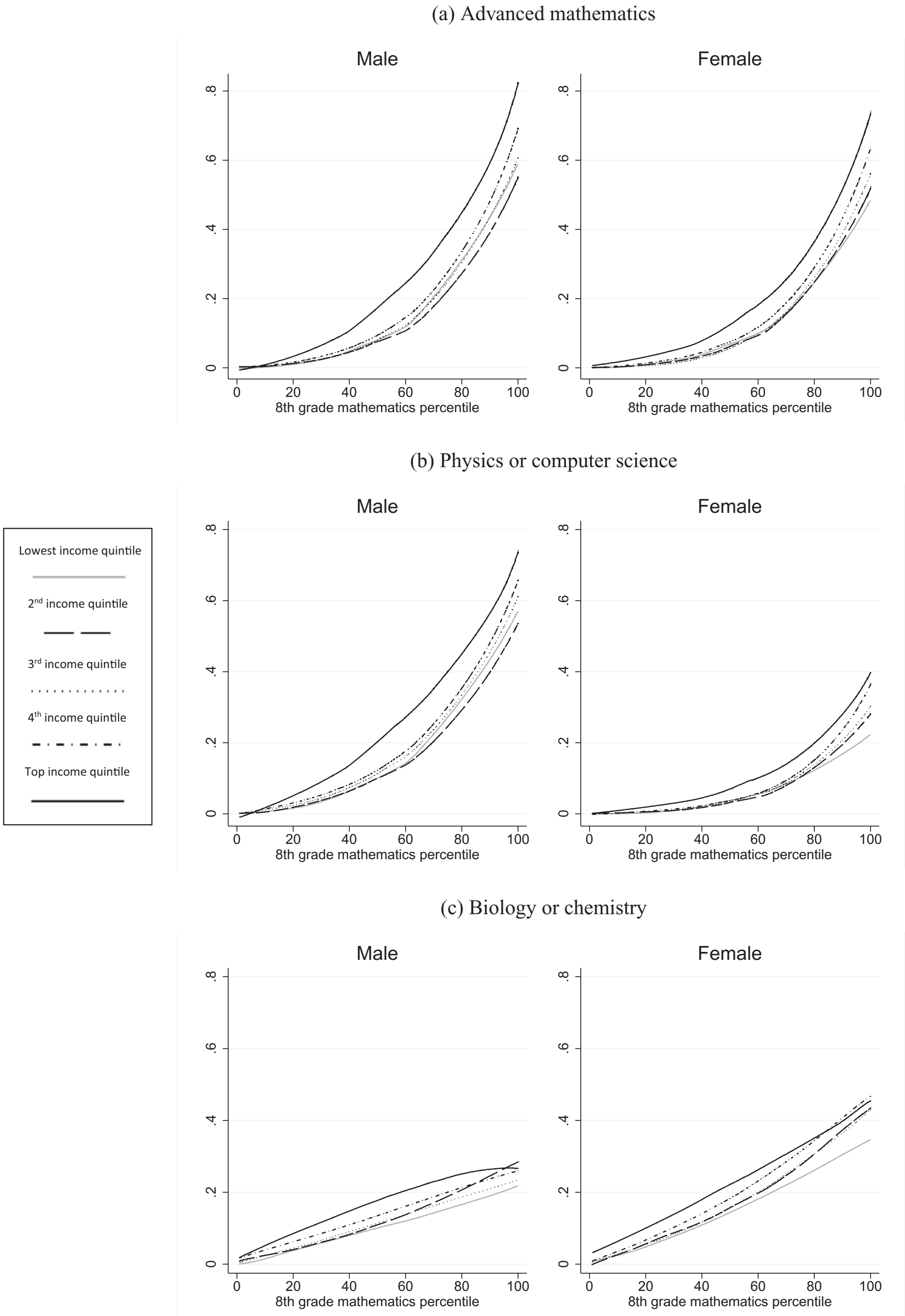

Fig. A2. Share of students selecting advanced science or mathematics electives by eighth-grade mathematical achievement and family income.

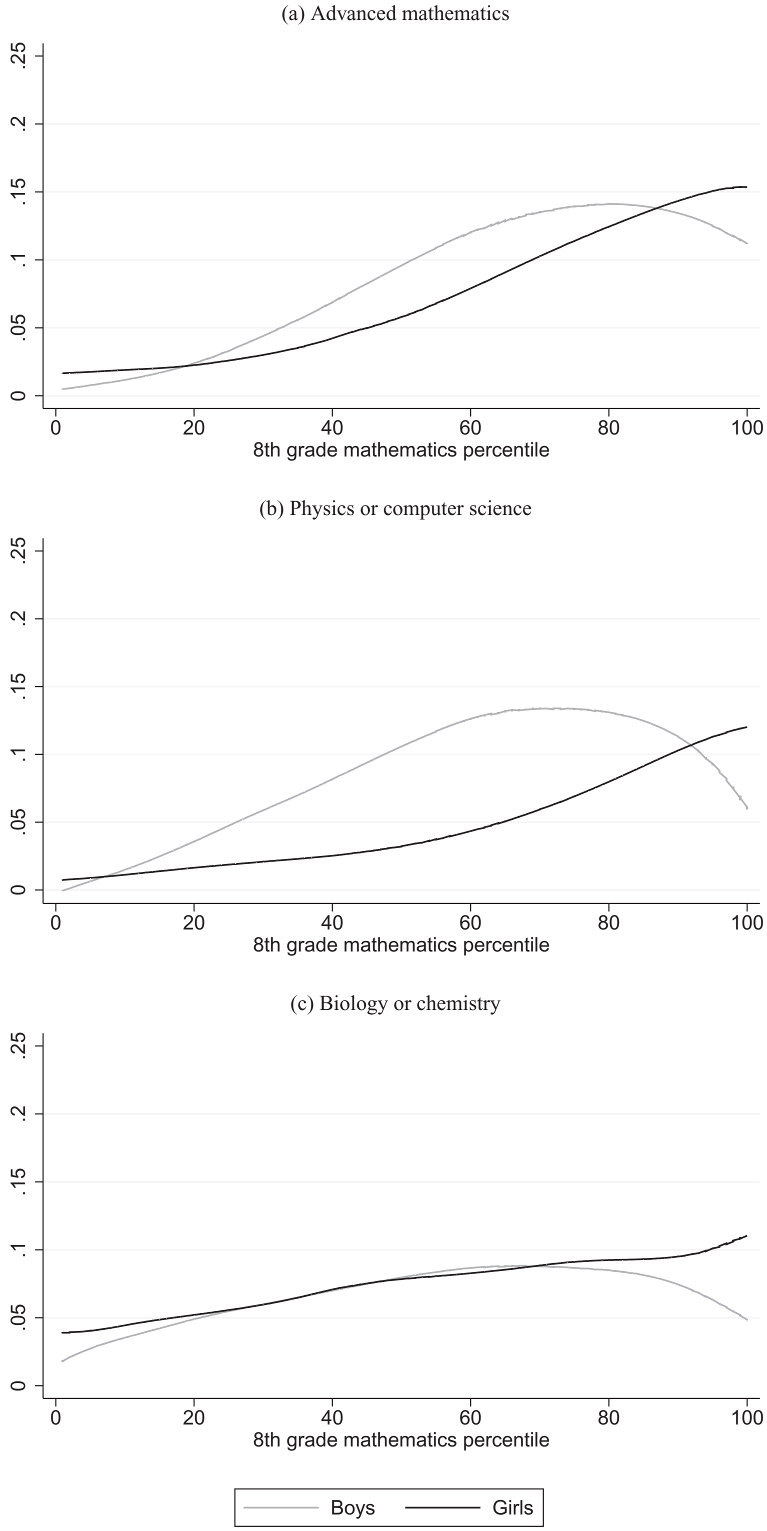

Fig. A3. Differences in share of students selecting advanced science or mathematics electives between highest and lowest family income by gender and eighth-grade mathematical achievement.

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