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HIGH SCHOOL CHOICES AND THE GENDER GAP IN STEM

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Women are less likely than men to graduate with a degree in science, technology, engineering, or math (STEM). We use detailed administrative data for a recent cohort of Ontario high school students, combined with data from the province's university admission system, to analyze the sources of this gap. We show that entry to STEM programs is mediated through an index of STEM readiness that depends on end-of-high school courses in math and science. Most of the gender gap in STEM entry can be traced to differences in the share of college entrants who are STEM-ready; only a small share is attributable to differences in the choice of major conditional on readiness. We then use high school course data to decompose the gender gap in STEM readiness into two channels: one reflecting the gap in the fraction of high school students with the necessary prerequisites to enter STEM, the other arising from differences in the overall fractions of females and males who enter university. The gender gap in the fraction of males and females with STEM prerequisites is small. The primary driver of the gap in STEM readiness is the low rate of university entry by nonscience-oriented males. (*JEL* I21, 28, I20)

I. INTRODUCTION

A lower fraction of women than men graduate with a degree in science, technology, engineering, or math (STEM). Figure 1, for example, shows the female share of baccalaureate graduates in eight OECD countries in 2011–2012. Depicted are the shares for all bachelor programs, sciences, and engineering. In all eight countries women make up the majority of college graduates. Except in Italy, however, they comprise less than half of the graduates in science or engineering.[1] This under-representation has implications both for the gender composition of the science professions and for the average gap in economic status between men and women. Recent data for the United States and Canada suggest that in both countries the gender gap in the likelihood of graduating with a STEM-related degree explains

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1. A large existing literature documents and analyzes the gender gap in STEM fields—see e.g., Ceci, Williams, and Barnett (2009), Hill, Corbett, and St. Rose (2010), Ceci et al. (2014), Perez-Felkner, McDonald, and Schneider (2014), Dasgupta and Stout (2014), Wiswall et al. (2014), Ellis, Fosdick, and Rasmussen (2016), Fischer (2017), Sax et al. (2016), Sassler et al. (2017), and Brenoe and Zolitz (2018). Kahn and Ginther (2017) provide a review of this literature. Dionne-Simard, Galarneau, and LaRochelle-Cote (2016) provide an overview of trends in the representation of women in scientific occupations in Canada.

ABBREVIATIONS

FSA: Forward Sortation Area
OUAC: Ontario University Application Centre
STEM: Science, Technology, Engineering, or Math
UP: University Preparation

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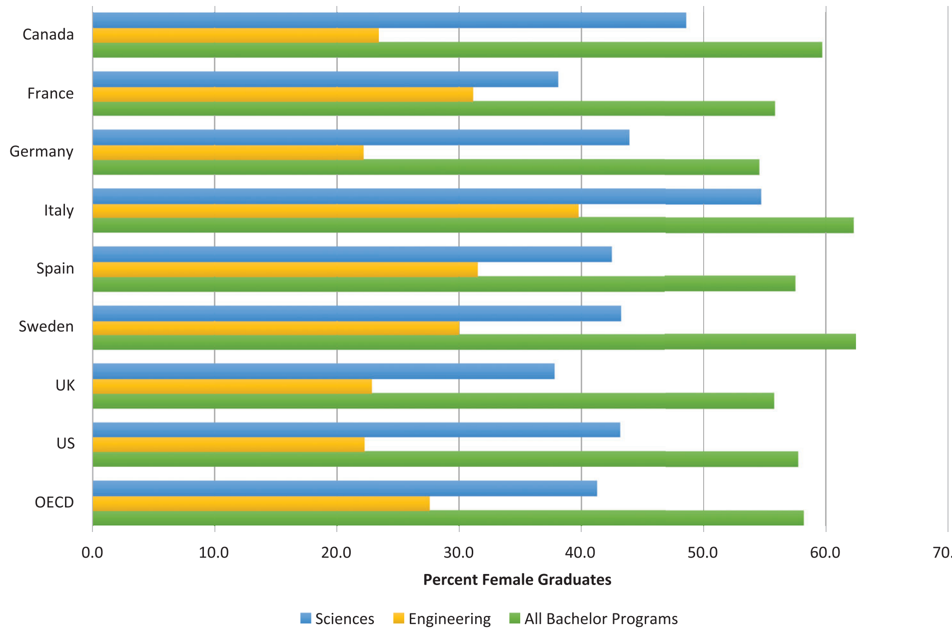
FIGURE 1

Percent Females among All University Graduates and in Engineering and Science (2011 or 2012).



Source: OECD (2016). Sciences include life sciences, physical sciences, computer science, and math

up to a fifth of the wage gap between younger college-educated men and women.[2]

In this paper, we use rich administrative data on high school courses and grades for a cohort of students from the province of Ontario to study the choices that lead to a *13 percentage point* gender gap in the probability of enrolling in a STEM program at university.[3] Although not all the students who enter a STEM program will graduate with a STEM degree, attrition rates from STEM programs appear to be similar for males and females (Dooley, Payne, and Robb 2012; Dooley, Abigail Payne, Steffler, and Wagner 2017). Moreover, most science and math programs have multiyear curriculums. Students who do not initially enroll in a STEM program have little chance of graduating with a STEM degree given the hurdles they face to transfer into the STEM program. Thus, we take entry to university in a STEM program as a proximate endpoint for understanding the gender gap in STEM.

Our analysis builds on three features of the Ontario university system that are shared with many other systems that use course-level achievement scores (rather than standardized tests) as the basis for admission (e.g., other Canadian provinces, the United Kingdom, and many Nordic countries). First, high school graduates apply to specific programs (e.g., computer science at the University of Toronto), allowing us to identify those who are likely to graduate with a STEM degree. Second, applicants are ranked on the basis of their grades in *standardized* courses offered in the final years of high school, with each program specifying a set of prerequisite courses. No other factors are considered for admission to the vast majority of programs.[4]

2. See Appendix Table A1, where we present regression models for wages of females and males with a bachelor degree or more in the 2006 Canadian Census and the 2009 U.S. American Community Survey. For Canada we estimate that field of study explains about 20% of the gender wage gap. Francesconi and Parey (2018) find that the gender wage gap for recent university graduates in Germany is reduced by about 50% by the addition of controls for field of study. Altonji, Blom, and Meghir (2012) present a broad overview of the literature on college major choice, occupational choice, and earnings.

3. As explained below, we define STEM programs to include engineering, physical and natural sciences, math, computer science, health sciences, environmental science, architecture, and agriculture.

4. A few specialized arts and music programs require students to submit a portfolio or similar material.

Consequently, end-of-high school courses and grades determine a student's opportunities at the university level. Third, the key end-of-high school courses needed for STEM are targeted to students who have been in an academically oriented track since ninth grade.[5]

We use two complementary data sets to analyze the gender gap in STEM entry. The first is a data base of university entrants from 2005 to 2012. We show that STEM entry for both genders is mediated through a simple measure of STEM readiness based on completion of at least three STEM-related classes in the last year of high school (including core math). Matriculants who fail to meet this minimal standard have only a 5%–7% chance of entering *any* STEM program in the province, while those who are STEM-ready have a 75%–80% chance of enrolling in STEM, with similar rates for men and women. Most of the gender gap in STEM entry is therefore attributable to the gap in STEM readiness, rather than to differences in program choices *conditional* on readiness. While the setting is different because most American students choose a major midway through college, Speer (2017) similarly finds that test scores on various components of the Armed Services Vocational Aptitude Battery test (measured prior to college) can account for a large share of differences in male and female college major choices.

In the second stage of our analysis, we use detailed transcript data for a province-wide cohort of public high school students to study the determinants of STEM readiness. At the end of high school, females have nearly the same overall rate of STEM readiness as males, and slightly *higher* average grades in the prerequisite math and science courses. The mix of STEM-related courses taken by men and women is different, with more women in biology and chemistry and more men in physics and calculus. And crucially, a much higher fraction of females who are **not** STEM-ready have completed enough other courses that they are qualified to enter a non-STEM program at university.

We perform a simple counterfactual exercise to decompose the gender gap in the fraction of university entrants who are STEM-ready into two channels: one representing the difference in the fractions of females and males who enter university with the prerequisites for STEM readiness; the other representing the overall gap in university entrance rates between females and males.[6] The contribution of the first channel is small: 14.5% of females enter university with the necessary courses to qualify as STEM-ready, compared to 15.3% of males. The main driver of the gender gap is the much higher rate of university entry by *non-STEM-ready* females. Simply assuming they have the same university entry rate as non-STEM-ready males would narrow the gender gap in STEM-readiness among entrants to less than 2 percentage points.

While higher university entry by non-STEM-oriented females accounts for most of the gender gap in STEM readiness, it is still surprising that women end up with a slightly ***lower*** rate of STEM readiness than men, since females are more likely to be on track to achieve STEM readiness in earlier years of high school.[7] We therefore study the choices of females and males to take STEM prerequisite courses in the last year of high school, conditional on their courses and grades in 11th grade. We find significant gender gaps in the probability of taking physics and calculus that are largely offset by a gap in the opposite direction for biology. A simple counterfactual analysis suggests that if females achieved the same rate of STEM readiness as males, conditional on their status at the end of 11th grade, they would complete high school and enter university with a slightly *higher* STEM readiness rate, instead of the modest shortfall we observe.

Finally, we examine the characteristics of non-STEM-ready students. We find that 47% of female students who lack the math and science preparation to be STEM-ready have completed enough **other** advanced courses to be ready to enter in non-STEM university programs. In contrast, only 27% of non-STEM-ready male students are qualified to enter university. This

5. As explained below, courses in Ontario high schools are highly standardized and tracked into two main streams. The critical courses required for entry to university STEM programs are in the so-called university preparation track. Students can and do often take a fifth year of high school to take or retake these courses.

6. By Bayes' law, P(SR = 1|Reg) = P(SR = 1&Reg)/P(Reg) where SR = 1 indicates STEM readiness and Reg indicates "registration" (i.e., formally matriculating) at university. Thus the gap in STEM readiness among registrants depends on the differences between males and females in both the numerator and denominator of this expression.

7. A common stereotype is that females have lower math ability than males. However, in most countries including the United States and Canada, the gender gap in math performance at high school is small—see Hyde et al. (2008) for an analysis using NAEP scores, and Else-Quest, Hyde, and Linn (2010) for comparisons across countries using PISA and TIMMS scores. See also Ferguson (2016).

gap in preparation—which begins with course selections and outcomes in ninth grade—fully explains the higher rate of university registration by women, and thus most of the gap in the fraction of women entering STEM programs at university.

Our findings contribute to three main areas. First, we contribute to the broad literature on the gender gap in STEM at the postsecondary level (Kahn and Ginther 2017). We show that in a setting with tracking of high school math courses and university admissions based on courses and grades, entry to STEM programs is closely linked to high school preparation. The gap in the fraction of university students in STEM, however, depends on gender gaps in both STEM and non-STEM preparation, and in our case the latter gap is far more important.

Second, we contribute to the growing economics literature on college major choice (see Altonji, Blom, and Meghir 2012 and Altonji, Arcidiacono, and Maurel 2016 for recent reviews). Much of this literature focuses on the United States, where high school tracks are less well defined (Betts 2011; Dieterle et al. 2015). Given the lack of data on standardized high school courses, many studies (Arcidiacono 2004) use Scholastic Assessment Test (SAT) scores and rank in high school class as summary measures of student preparation, without addressing the issue of course or track selection in high school. A recent study by Kirkeboen, Leuven, and Mogstad (2016) similarly uses average high school grades as a summary measure of student background in analyzing college major choice in Norway. Our work shows the importance of high school course selections in settings where student specialization begins in high school.

Finally, we contribute to the literature on gender gaps in educational achievement (Fortin, Oreopoulos, and Phipps 2015; Goldin, Katz, and Kuziemko 2006; Jacob 2002) by showing that the under-representation of men in college can be traced back to the (relatively large) group of nonscience-oriented men who fail to accumulate courses and grades in high school that could allow entry to non-STEM programs in university.

II. INSTITUTIONAL BACKGROUND AND CLASSIFICATION OF STEM PROGRAMS

A. Background

Ontario students enter their first year of high school (ninth grade) at age 14 or 15 and are expected to graduate in 4 years, though many spend a fifth year.[8] All publicly funded high schools offer a range of standardized courses that follow tightly prescribed province-wide curricula.[9] At each grade (or “level” in the terminology of the province) most courses are offered in two parallel tracks: academic and applied. Students who choose a given track in Level 1 (ninth grade) typically follow the same track in later years, although many who start in the academic track eventually switch to the applied track. (It is also possible, though rare, to switch in the opposite direction). Level 4 (12th grade) courses in languages, math, and science are divided into “university preparation” (UP) and “college preparation” tracks, with UP math and science classes targeted to students who have completed academic track math at Level 3. There are also “mixed” courses in areas such as history and geography that fulfill the requirements for university entry, and other courses for students who do not intend to pursue tertiary education (see Ontario Ministry of Education 2011, for an overview).

As might be expected in this tracked system, course selections in early grades have a substantial effect on the probability of entering university. Card and Payne (2015), for example, show that the university entry rate is about 70% for males and females who complete ninth grade academic track courses in math and language arts with grades of 70/100 or better, but less than 10% for those who fail to successfully complete these two gateway courses.

In their final year of high school students can apply to one of the 20 universities in the province—all of which are public—through a centralized system known as the Ontario University Application Centre (OUAC). Applications are made to specific programs—for example, Life and Physical Sciences at Queen’s University—or even specific subprograms (e.g., Biochemistry). Each program or subprogram lists a set of required UP course prerequisites on the OUAC web site.[10] No other criteria are required

8. The province had a 5-year high school system until 2003 (see Morin 2015 for more details).

9. There are two systems of publically funded schools: so-called “public” high schools, which are nonreligious and open to all students, and Catholic schools, which have some religious classes and are open to Catholics. Both use the same curriculum and we include students from both systems in our analysis.

10. For example, applicants to the BA Honors Program at Carleton University wishing to enter Economics must have UP courses in English and Advanced Functions (pre-Calculus); Calculus is strongly advised.

or used for admission: in particular, there are no standardized tests such as the SAT. Applicants to a program/subprogram are ranked on the basis of their grades in the prerequisite courses and their Top 6 qualifying Level 4 courses and admitted until the program is full. Students who accept an offer of admission normally "register" in that program (i.e., matriculate) at the start of the fall semester.

Importantly, while high school courses are standardized, teachers are free to set their own grades. As at the college level in the United States (Sabot and Wakeman-Linn 1991) this has led to concern over grade inflation (Cote and Allahar 2007) and some university programs adjust grades to account for differences in grading standards across high schools (University of Waterloo undated) though our understanding is that most programs take the grades as given. In some of our analyses below, we therefore include high school effects to account for potential differences in grading standards across high schools.

B. *Classification of STEM Programs*

A preliminary question in any analysis of STEM participation is which university programs to classify as STEM. Our classification includes the following programs under STEM: engineering, physical sciences, natural sciences, math, computer science, nursing, environmental science, architecture, and agriculture.[11] This list is similar to the one adopted by Beede et al. (2011) for U.S. programs, apart from the fact that we include nursing in STEM, whereas they do not.[12] Our decision to include nursing is based on the fact that these programs in Ontario require UP courses in math, chemistry, and biology—the same prerequisites as many other STEM programs—and typically award a Bachelor of Nursing Science degree. Holders of degrees in health sciences (including nursing) account for 12% of all younger women with a final bachelor degree in Canada, and nearly half of those with a STEM-related degree.[13] Moreover, health sciences graduates are among the most highly paid of all degree holders—second only to engineering graduates—so we believe it is important to include nursing in STEM.

11. See Appendix Table A2 for examples of STEM programs at Ontario Universities.

12. A recent classification by the US Bureau of Labor Statistics includes nursing in STEM—see Jones (2014). See also Carnevale et al. (2011).

13. See Appendix Table A3 for documentation of this fact.

III. PATHWAYS FOR STEM ENTRY

In this section, we use data on multiple cohorts of university entrants to develop a measure of STEM readiness which summarizes the high school preparation of different students. We then use this measure in Section IV to classify students in our high school cohort data set as STEM-ready or not, and study the determinants of STEM readiness.

We follow this two-step approach because our high school data set lacks information on the program choices of university entrants: we know only whether a student registered at an Ontario university. Given the sequential nature of the choice problem faced by students, however, we believe there is little loss in using a two-step approach. Students have to choose their Level 4 courses *before* they apply to university, and only know their admission offers after they have finished high school. If STEM entry were *fully mediated* by STEM readiness (i.e., STEM readiness is both necessary and sufficient to enter a STEM program) then a student's choice problem in the last year of high school could be reduced to a decision about whether to take the needed classes to become STEM-ready.[14] While our measure of STEM readiness does not *fully* mediate STEM entry, it is close to a necessary requirement. Moreover, we construct the measure to match the stated entry requirements for most STEM programs in the province, so it is clearly sufficient. We also believe that it closely approximates any rule of thumb that guidance counselors would use for helping students choose their end-of-high school courses.

A. *Course Taking Patterns for Registrants*

We obtained data from OUAC on high school graduates who registered in an Ontario University between 2005 and 2012. The data set includes information on the Level 4 courses taken by each applicant and their grades in these courses. In addition it includes demographic information and the university program into which the student initially registered, which we classify as STEM or not using the categories listed above.[15]

14. Formally, consider a dynamic choice problem with two periods: a first period in which students choose high school courses, and a second period in which students register in university or not, and choose a STEM program or not. If STEM readiness is necessary and sufficient for entering STEM programs, the first period problem can be reduced to one that assigns payoffs to STEM readiness and nonreadiness.

15. Appendix Table A4 summarizes the characteristics of the university entrants in the OUAC data.

TABLE 1

Gender Differences in Course Taking Patterns and Registration in STEM Programs

	Female Registrants:			Male Registrants:		
	Percent of All Registrants with Course (1)	Percent Register in STEM If Completed Course (2)	Percent of STEM Registrants with Course (3)	Percent of All Registrants with Course (4)	Percent Register in STEM If Completed Course (5)	Percent of STEM Registrants with Course (6)
Successfully complete individual courses						
Functions (Precalculus)	54.1	51.5	91.9	73.1	57.7	97.0
Calculus	28.4	63.4	59.3	49.0	70.4	79.4
Biology	43.9	62.3	90.2	35.1	70.8	57.2
Chemistry	39.3	72.2	93.5	49.3	79.6	90.3
Physics	18.8	80.0	49.4	42.0	80.8	78.0
	Percent of All Registrants based on STEM-Readiness (1)	**Percent Register in STEM based on Stem-Readiness (2)**	**Percent of STEM Registrants based on STEM Readiness (3)**	**Percent of All Registrants based on STEM-Readiness (4)**	**Percent Register in STEM based on Stem-Readiness (5)**	**Percent of STEM Registrants based on STEM Readiness (6)**
Achieve STEM-readiness or not[a]						
STEM-ready	35.3	76.3	88.8	49.1	81.3	91.8
Not STEM-ready	64.7	5.3	11.2	50.9	7.0	8.2

Notes: Based on 2005–2012 university applicants in OUAC database who register in university in fall after their application, with valid student and course information. Sample is restricted to students age 17–20 at the time of application from publicly funded Ontario high schools. Sample has 237,743 females (30.3% of whom register in STEM programs) and 175,913 males (43.5% of whom register in STEM programs).

[a]STEM-readiness designation is based on having successfully completed Level 4 functions course plus at least one of calculus and biology and at least one of chemistry or physics.

We limit attention to registrants who were attending a public high school in Ontario and were between 17 and 20 years of age at the time of their application.[16] We also require that students have complete information on their Level 4 courses and grades. The resulting sample includes over 400,000 new university entrants, 57.5% of whom are female. Overall, 30.3% of females (about 72,000 women) and 43.5% of males (about 76,000 men) enrolled in a STEM program. Note that the gender gap in the *proportion* of students who register in STEM is large (13 percentage points) despite the fact that close to half (48.5%) of STEM registrants are female. The disparity reflects the much higher university entrance rate for females than males.[17]

16. Our analysis focuses on the applications by students who are enrolled in high school at the time of application, the vast majority of university applications. Applicants from high school can defer their offer of admission at many universities, allowing a gap year before resuming study. We exclude from our analysis nonenrolled (older) applications because OUAC uses a separate application form for these students.

17. These statistics can be found in Table 2.

The upper panel of Table 1 shows the fractions of all registrants and of STEM registrants who took each of the five core STEM-related UP courses in their last year(s) of high school. These classes include two key math classes (advanced functions [precalculus] and calculus) and three key science courses (biology, chemistry, and physics). Comparisons of columns 1 and 4 show that male registrants as a whole have higher rates of participation in all but one of these courses (biology). Among the subset of registrants who enter STEM programs (columns 3 and 6), however, over 90% of both females and males have taken functions and chemistry. There are much wider gaps for the other three courses. For example, only about one-half of female STEM registrants took physics (vs. 78% of males) whereas only about 60% of male STEM registrants took biology (vs. 90% for females). These patterns are consistent with well-known gender differences in entry to different types of STEM programs. Female students in Ontario, like those in the United States, are more likely to enter life sciences (which generally require functions, chemistry, and biology as prerequisites), whereas males are more likely to enter engineering and physical sciences (which generally require functions, calculus, and physics).[18]

To derive a simple indicator for STEM readiness we examined the stated prerequisites for many STEM programs and the course-taking patterns of STEM registrants, looking for a minimal standard that would have to be achieved to qualify for entry to STEM. After considerable experimentation, we settled on the following three-course standard:

1. Advanced functions (pre-calculus math).
2. At least one of chemistry or physics.
3. At least one of biology or calculus.

This criterion incorporates the typical requirements for life sciences programs (functions, biology, chemistry) as well as for many science and math programs (functions, calculus, physics), and is clearly sufficient to allow entry into many—though not all—STEM programs in the province.[19]

The lower panel of Table 1 presents information on STEM-ready and non-STEM-ready registrants based on this standard. Note first that 89% of female STEM registrants and 92% of male STEM registrants meet this threshold.[20] Even more importantly, only 5% of females and 7% of males that we classify as non-STEM-ready actually register in a STEM program, implying that our readiness measure is close to a minimum standard. Given the large share of non-STEM-ready registrants, however, these students make up about 11% of all female STEM registrants (column 3) and 8% of male STEM registrants (column 6).

We compared our measure of STEM readiness to several alternatives, including one based on completing any three of the five main science and math courses, and others based on various four-course combinations (e.g., functions, calculus, chemistry and one of biology or physics). None of these alternatives was as successful in representing a minimum standard for STEM eligibility, or in achieving (rough) equality between males and females in the fractions of STEM registrants who failed to meet the criterion (i.e., in the false negative rate in STEM-readiness).[21]

B. Gender Differences in STEM Readiness and STEM-Entry

Next, we develop a simple decomposition of the gender gap in STEM entry for our registrant sample. Although non-STEM-ready students are very unlikely to enter a STEM program, not all students who are STEM-ready actually enter one. We therefore ask: how much of the gender gap in the probability of registering in a STEM program can be attributed to the difference in STEM readiness, versus the choice to pursue a STEM program, conditional on STEM readiness?

The probability of choosing a STEM program (denoted by "STEM") conditional on registering (denoted by "Reg") can be decomposed as:

$$(1)\quad P(\text{STEM}|\text{Reg}) = P(\text{STEM}|\text{SR}=1,\text{Reg}) \times P(\text{SR}=1|\text{Reg}) + P(\text{STEM}|\text{SR}=0,\text{Reg}) \times P(\text{SR}=0|\text{Reg})$$

where SR is an indicator for STEM readiness. The average values of the terms in this expression for females and males are presented in Table 2. As shown in the second row of the table, 30.3% of female students register in STEM compared to 43.5% of males—a 13.2 percentage point gap. STEM readiness rates differ substantially between male and female registrants (with an overall gap of 13.8 percentage points) while rates of entering STEM conditional on SR = 1 or SR = 0 are fairly similar for females and males, suggesting that most of the difference in STEM entry is attributable to STEM readiness.

The low rates of STEM entry for non-STEM-ready students imply that the second term in Equation (1) is small for both genders. In particular, for females

$$P(\text{STEM}|\text{SR}=0,\text{Reg}) \times P(\text{SR}=0|\text{Reg}) = 0.053 \times (1-0.353) \approx 0.034,$$

18. Hill et al. (2010, Figure 5) show that female students in the United States are more likely to indicate an intended major in biological sciences than men, and less likely to indicate an intended major in engineering.

19. In particular, many engineering programs require functions, calculus, chemistry and physics, though most math and computer science programs only require functions, calculus, and physics.

20. Many of the STEM registrants who do not meet our readiness standard are in programs such as environmental science and kinesiology that do not require at least three STEM-related UP courses.

21. For example, using a four course threshold of functions, calculus, chemistry and one of biology or physics led to having 11.2% of all STEM registrants classified as non-STEM ready (nearly double the false negative rate for our preferred measure) and 73% of STEM registrants classified as STEM-ready (vs. 90% for our preferred measure).

TABLE 2
Decomposition of Gender Differences in STEM Registration

	All (1)	Females (2)	Males (3)	Gender Gap (4)
Number of university registrants	413,656	237,743	175,913	—
Percent register in STEM program	35.9	30.3	43.5	−13.2
STEM-readiness and STEM registration[a]				
Percent of all registrants who are STEM-Ready	41.2	35.3	49.1	−13.8
Percent register in STEM if STEM-ready	78.9	76.3	81.3	−5.0
Percent register in STEM if not STEM-ready	5.8	5.3	7.0	−1.7
Part of STEM registration gap attributable to STEM-readiness gap:				
a. Using male rate of STEM registration if STEM-ready				−11.2
(standard error)				(0.1)
b. Using Female Rate of STEM Registration if STEM-ready				−10.5
(standard error)				(0.1)
Part of STEM registration gap attributable to registration gap conditional on readiness:				
a. Using Female Rate of STEM-readiness				−1.8
(standard error)				(0.1)
b. Using Male Rate of STEM-readiness				−2.5
(standard error)				(0.2)

Notes: See note to Table 1. Standard errors for counterfactual calculations of shares of registration gap due to different components calculated by delta method.
[a]STEM-readiness designation is based on having successfully completed at least three Level 4 math and science classes—see Table 1.

while for males

$$P(\text{STEM}|\text{SR}=0,\text{Reg})\times P(\text{SR}=0|\text{Reg})$$
$$=0.070\times(1-0.491)\approx 0.036.$$

Thus, most of the gap in STEM registration is driven by differences attributable to the first term in (1).

The lower rows of Table 2 provide a set of "Oaxaca-style" counterfactuals for evaluating the sources of the gender gap in this term.[22] Assuming that STEM-ready females had the same probability of registering in STEM as STEM-ready males, the gap would be 11.2 percentage points (85% of its actual value); whereas assuming males had the same rate as females, the gap would be 10.5 percentage points (81%). These calculations imply that less than one-fifth of the registration gap can be attributed to differences in choices made by female and male registrants, conditional on STEM readiness. The majority (81–85%) is due to the gender gap in the rate of STEM readiness.

C. A Closer Look at STEM-Entry by STEM-Ready Students

A potential concern with the counterfactual analysis in Table 2 is that our measure of STEM readiness does not take account of student grades. In particular, if females and males have different average grades in their math and science classes they may be admitted to STEM programs at different rates, contributing to the gender gap in STEM entry rates between STEM-ready women and men. Table 3 summarizes the grades in UP courses for the registrants in our OUAC sample. To simplify comparisons between students who took different combinations of courses, we first convert a student's grade in a given course into a percentile rank within the distribution of grades for registrants who took that course in a given cohort.[23] We then construct the average rank of each student's six best grades, and the average rank of their Top 3 STEM-related classes.[24] Since female students have different average grades than males, we also constructed a "within-gender and cohort" rank for each student's grade in each

22. Specifically, let π^g = P(SR = 1|Reg, gender = g) and θ^g = P(STEM|SR = 1,Reg, gender = g). Then the gender gap in the first term in Equation (1) can be written as $\pi^F\theta^F - \pi^M\theta^M = (\pi^F - \pi^M)\theta^M + \pi^F(\theta^F - \theta^M)$, which is the difference in STEM readiness rates times the male rate of STEM registration if STEM-ready plus the female rate of STEM readiness times the difference in rates of STEM registration if STEM-ready. The alternative decomposition is $(\pi^F - \pi^M)\theta^F + \pi^M(\theta^F - \theta^M)$. In either case we can estimate the sampling errors of the two terms using the delta method.

23. A value of 1 means the student is ranked highest; a value of 0 means the student is ranked lowest.

24. For STEM-related classes (advanced functions, calculus, biology, chemistry, and physics) we compute ranks within the distribution of scores for *all* students who took the class (in a given cohort or gender/cohort) but we only report average ranks in top three STEM-related courses for students who are STEM-ready, and therefore took at least three STEM-related courses.

TABLE 3
Average Rank of Course Grades of Female and Male Students

	Female Students			Male Students		
	All (1)	**STEM Ready (2)**	**STEM Ready and Register in STEM (3)**	**All (4)**	**STEM Ready (5)**	**STEM Ready and Register in STEM (6)**
A. Average ranking (0 to 1) of Top 6 Level 4 classes						
Within-cohort	0.52	0.61	0.62	0.47	0.55	0.56
Within-cohort/gender	0.50	0.59	0.60	0.50	0.59	0.59
Number of students	237,743	83,939	64,044	175,913	86,369	70,241
B. Average ranking (0 to 1) of Top 3 STEM-related classes						
Within-cohort	0.49	0.50	0.53	0.50	0.51	0.54
Within-cohort/gender	0.50	0.50	0.53	0.50	0.51	0.53
Number of students	87,200	83,939	64,044	90,205	86,369	70,241

Notes: See Table 1 for sample information and definition of STEM-readiness. Table entries represent mean rank of Top 6 Level 4 classes (panel A) or Top 3 STEM-related courses (panel B) for student group in column heading. Samples in columns 1 and 4 exclude students with fewer than six Level 4 classes (panel A) or fewer than three STEM-related courses (panel B).

course. Averages of these ranks are only comparable within a gender group.

The upper panel of Table 3 compares the average ranks of female and male students in their Top 6 classes. The tendency for female students to earn higher course grades in high school is reflected in their higher within-cohort rank: 0.52 versus 0.47 for males. For both gender groups STEM-ready students have higher average grades than the overall population of registrants, with a 9 percentile gap among females and an 8 percentile gap among males. STEM-ready students who actually enter STEM programs (columns 3 and 6) have even higher mean ranks, though the differences relative to the STEM-ready subpopulation are small (+1 percentile points).

The lower panel of Table 3 compares the average ranks of the Top 3 STEM-related courses for STEM-ready students. Females have a slightly lower average rank in their Top 3 math and science classes (1 percentile point lower than males). Thus, their higher average rank for their Top 6 classes is driven by higher grades in *non-STEM-related* courses. Students who register in STEM have about 3 percentiles higher average scores in their STEM-related courses than the overall STEM-ready subpopulation, with a similar degree of selectivity for females and males.

The pattern of positive selection in math/science achievement for STEM entrants evident in Table 3 is similar to the pattern noted by Hango (2013) in a study of standardized math scores for a national sample of Canadian university entrants in the YITS-PISA (Youth in Transition Survey—Program for International Student Assessment) survey. In particular, Hango (2013), Table 2) finds that both male and female students who enter STEM programs at university have higher math scores at age 15 than those who enter non-STEM programs, though in his sample the selectivity gap associated with STEM entry is larger for women (0.2 standard deviation units) than for men (0.1 standard deviation units).

Having constructed each student's average course grade rank, we turn to the question of how differences in grades affect the gender gap in the probability of registering in a STEM program. Table 4 presents a set of linear probability models for the event of registering in STEM, fit to the combined population of STEM-ready male and female registrants. We begin in column 1 with a benchmark model that includes only a dummy for female gender. As noted in Table 2, among STEM-ready students the gender gap in STEM registration is 5.0 percentage points. The model in column 2 introduces cohort effects, a complete set of dummies for each high school in the province (which will adjust for differing grade standards across high schools in the subsequent models), and student demographics, including age dummies and controls for foreign born status, main language spoken at home, and gifted/special needs status. These controls widen the gender gap slightly to 5.8 percentage points.

In column 3, we introduce controls for each student's average rank based on his or her Top 6 Level 4 classes, and the average rank based on his or her Top 3 math/science classes. The estimated

TABLE 4
Models for Probability of Registering in STEM-Related Program, Conditional on STEM-Readiness

	Dependent Variable = 1 if Register in STEM-Related Program			
	(1)	**(2)**	**(3)**	**(4)**
Female indicator (×100)	−5.0	−5.8	−1.7	−0.1
	(0.2)	(0.2)	(0.2)	(0.2)
Within-cohort rank of Top 3 STEM courses	—	—	0.73	0.42
			(0.01)	(0.01)
Within-cohort rank of Top 6 Level 4 courses	—	—	−0.52	−0.34
			(0.01)	(0.01)
Indicator: 4 STEM courses	—	—	—	0.20
				(0.01)
Indicator: 5 STEM courses	—	—	—	0.28
				(0.01)
Age, year, and high school effects?	No	Yes	Yes	Yes
Other controls (Language, foreign born, gifted or special needs)	No	Yes	Yes	Yes

Notes: Standard errors in parentheses, clustered by school. Table reports linear probability model coefficients for event of registering in STEM-related program. Sample is 170,288 STEM-ready students. Models in columns 2–4 include dummies for age, graduating cohort, student's main language, foreign-born status, and high school. See Table 1 for STEM-ready definition.

coefficients on these two averages are highly significant and show strong comparative advantage effects in program selection. In particular, students with higher grades in STEM-related courses are more likely to enter STEM, holding constant their overall Top 6 grades, whereas students with higher overall grades are less likely to enter STEM, holding constant their Top 3 math/science grades.[25]

Controlling for both sets of average ranks, the gender gap in STEM entry falls to 1.7 percentage points. The narrowing of the gender gap relative to the specification in column 2 is explained by the higher average rank of females on their Top 6 classes (contributing −2.9 points), their lower average rank on their Top 3 math/science classes (contributing −0.9 points), and small changes in the coefficients of several of the control variables (contributing −0.3 points). Interestingly, the most important factor is therefore female's comparative advantage in non-STEM-related courses.[26]

Finally, in column 4, we report a model that includes controls for having completed four or five UP STEM courses. As might be expected, students with more than the minimum of three math and science courses to achieve STEM-readiness are substantially more likely to register in a STEM program. STEM-ready males are also somewhat more likely than STEM-ready females to have completed four or five math and science classes, so controlling for these variables lowers the gender gap in STEM registration by 1.6 percentage points. Their introduction also reduces the effects of the two rank variables by about 40%, though both remain highly significant. Thus females' comparative advantage in non-STEM courses still explains about 1.7 percentage points of the observed gender gap in STEM entry.

We believe that the results in Tables 2–4 point to two key conclusions. First, the gap in STEM readiness is a reasonable summary of the differences in end-of-high school qualifications of female versus male students. In particular, conditional on STEM readiness, females have only very slightly lower average grades in their Top 3 math and science courses, offset by higher grades on their non-STEM courses. Second, the relatively small (5 percentage point) gender gap in the probability of registering in STEM conditional on STEM readiness falls to under 2 percentage points when we account for the relatively higher grades that STEM-ready females have in non-STEM versus STEM courses, and to almost 0 when we control for having a fourth or fifth STEM course. Arguably, then, the simple

25. The average rank on a student's top 6 courses is roughly an average of their average rank on their top 3 STEM-related courses and their average rank on their top 3 non-STEM courses. Thus the coefficients in column 3 imply that the probability of registering in STEM varies with 0.47 × (Average Rank on Top 3 STEM-related classes) − 0.26 × (Average Rank on Top 3 non-STEM classes).

26. We also estimated the model in column 3 allowing an interaction between a female dummy and the coefficients on the two rank variables. In this specification, the effects of rank on the top 3 STEM-related courses and the top 6 courses are 0.79 and −0.57 for males, and 0.68 and −0.47 for females. Thus the relative effects of the ranks in STEM courses and all six courses are very similar for males and females.

TABLE 5
Characteristics of Students in High School Cohort

	All Students	Females	Males
Number of students	135,261	67,994	67,267
Gifted	7.9%	5.3%	10.5%
Special needs	2.1%	1.7%	2.5%
Born outside Canada	11.2%	11.1%	11.3%
Attended catholic high school in Level 1 (Grade 9)	34.1%	34.6%	33.7%
Participation in academic track math courses			
Took academic math in Level 3 (Grade 11)	40.9%	41.9%	39.9%
Took academic math in Level 1 (Grade 9) but not Level 3 (Grade 11)	30.0%	31.3%	28.6%
All other permutations	29.1%	26.8%	31.5%
Postsecondary schooling participation (within 6 years of entering Grade 9)			
Applied to Ontario University	48.0%	54.6%	41.3%
Applied to Ontario 2–3 year college	35.3%	35.1%	35.5%
Entered Ontario University	37.8%	43.5%	32.2%
Entered Ontario College	26.4%	25.9%	26.9%

Notes: Sample includes students who entered Grade 9 in Fall 2005 at age 14 or 15, took a full course load in 2005–2006 academic year, have complete information on their Level 1 (Grade 9) math and language course selections and grades, and are observed taking at least one Level 4 course within the next 5 years. Students at small rural schools are excluded.

decomposition in Table 2 that relies on our minimal standard for STEM entry, ignoring grades and extra course work, *overstates* the importance of gender-specific preferences for STEM versus non-STEM programs.

IV. PREPARING FOR STEM AT HIGH SCHOOL

A. High School Cohort Data

We now turn to our high school cohort data, focusing on course-taking in the last year of high school and the determinants of STEM readiness. Our analysis is based on administrative records for all students who enrolled in ninth grade in the 2005/2006 school year at any publicly funded Ontario high school. These records include information on courses and grades taken over the next 5 years (i.e., up to and including the 2009/2010 school year) as well as information on whether the student applied to an Ontario university or vocational college, and whether they registered in either type of institution. We also have access to some student-level information, including an indicator for being at a Catholic school

in Grade 9, the share of students in the ninth grade cohort who drop out or disappear from our sample, and the share of ninth grade students classified as non-English/French language learners. We also merge in information on the characteristics of the neighborhood around the school, including distance to the nearest university and vocational college, mean household income, fraction of single parent families, and the share of visible minorities.[27]

Since our focus is on university entry, we limit attention to students who are observed taking Level 4 courses within 5 years of entering high school. Summary statistics for our resulting analysis sample are reported in Table 5. Overall, we have 135,261 students, 50.3% of whom are female. A total of 69.4% of females in the sample entered an Ontario vocational college or university within 6 years of entering high school, compared to 59.1% of males. Interestingly, the gender gap in entry to tertiary education is entirely driven by the higher fraction of females who enter university. Rates of entry to vocational college are similar for females and males.

B. Course Taking Patterns at Level 4 and the Gap in STEM Readiness

Table 6 shows the fractions of female and male students in our high school sample who took each of the five main STEM-related UP courses, as well as their average grades in these courses and the average grades received by two subgroups: those who achieved STEM readiness, and those who achieved STEM readiness and registered in university. In the last rows of the

27. We use the Forward Sortation Area (FSA) which is based on the first three digits of the postal code of the high school to identify the neighborhood. Statistics Canada supplies tabulations of the 2006 census by FSA that we use to measure neighborhood characteristics.

TABLE 6
STEM-Related Course Taking and Grades in Last Year of High School

	Females (1)	**Males (2)**	**Gender Gap (3)**
STEM-related course taking in last year(s) of high school			
a. Functions (Precalculus)			
Percent of cohort taking course	28.1	30.2	−2.1
Mean grade (all takers)	80.6	80.6	0.0
Mean grade if STEM-ready	82.3	82.6	−0.3
Mean grade if STEM-ready and register in University	82.7	83.3	−0.6
b. Calculus			
Percent of cohort taking course	16.8	20.5	−3.7
Mean grade	80.9	80.4	0.5
Mean grade if STEM-ready	81.8	81.4	0.4
Mean grade if STEM-ready and register in University	82.1	82.1	0.0
c. Biology			
Percent of cohort taking course	25.7	15.3	10.4
Mean grade	82.4	82.1	0.3
Mean grade if STEM-ready	83.4	83.0	0.4
Mean grade if STEM-ready and register in University	83.8	83.5	0.3
d. Chemistry			
Percent of cohort taking course	21.5	19.4	2.1
Mean grade	80.9	80.2	0.7
Mean grade if STEM-ready	81.5	80.8	0.7
Mean grade if STEM-ready and Register in University	81.9	81.4	0.5
e. Physics			
Percent of cohort taking course	9.1	16.6	−7.5
Mean grade	81.1	80.6	0.5
Mean grade if STEM-ready	81.5	81.2	0.3
Mean grade if STEM-ready and Register in University	81.7	81.8	−0.1
STEM-readiness and university registration			
Percent of cohort STEM-ready	17.9	18.8	−0.9
Percent Register in University	43.5	32.2	11.3
Percent Register and STEM ready	14.5	15.3	−0.8
Percent STEM-ready if register in university	33.3	47.4	−14.1

Notes: Based on cohort of students entering Grade 9 in 2005 at Ontario public schools and observed taking Level 4 (Grade 12) classes within next 5 years. STEM-readiness defined as having a minimum of three STEM-related courses in Level 4, including functions, at least one of calculus or biology, and at least one of chemistry or physics. Sample contains 67,994 females and 67,267 males.

table, we also show the fractions of students that achieved STEM readiness, the fractions that registered in university, and the STEM readiness rate among registrants.

Two key patterns emerge from the table. First, as would be expected given the comparisons among *registrants* in Table 1, females are more likely to take biology in their last year of high school, whereas males are more likely to take physics. Males are also somewhat more likely to take advanced functions (precalculus) and calculus, while females are somewhat more likely to take chemistry. Despite these differences, at the end of high school, 17.9% of females are STEM-ready, compared to 18.8% of males—a gap of only 0.9 percentage points. The gender gap in the fraction that is STEM-ready ***and*** registers in university is comparable: 14.5% of females versus 15.3% of males. Since many more females than males register in university, however, the difference in the probability of being STEM-ready, conditional on registering, is 14.1 percentage points—very close to the 13.8 point gap we measured in our OUAC sample of registrants.

A second finding is that in all five STEM-related UP courses, females have either the same or slightly higher grades than males. As would be expected, STEM-ready students have higher grades than average course-takers, and STEM-ready registrants have even higher grades, with a higher selectivity differential for males than females in math and physics. Accounting for these selection effects, STEM-ready females have slightly lower average grades than STEM-ready males in functions and physics, slightly higher average grades in biology and

TABLE 7
Gender Differences in University Registration and STEM-Readiness

	Females (1)	Males (2)	Gender Gap (3)	Counterfactual: Give Females the Male Probability of Registration if non-STEM Ready[a] Females (4)	Gender Gap (5)
Registration rates by STEM-readiness status					
Percent STEM-ready	17.9	18.8	−0.9	17.9	−0.9
Percent register if STEM-ready	80.9	81.2	−0.3	80.9	−0.3
Percent register if Not STEM-ready	35.3	20.9	14.5	20.9	0.0
STEM-readiness among registrants (Equation 2)					
Percent register and STEM-ready (numerator of Equation 2)	14.5	15.3	−0.8	14.5	−0.8
Percent register and not STEM-ready	29.0	19.9	9.1	17.2	−2.8
Percent register in university (denominator of Equation 2)	43.5	32.2	11.3	31.6	−0.6
Percent STEM-ready if register	33.3	47.4	−14.1	45.8	−1.6

Notes: Entries derived from sample described in Table 5. See notes to Table 1 for definition of STEM-ready.
[a]Counterfactual under assumption that STEM-ready share of female students and probability of registration conditional on STEM-readiness do not change, but probability of registration for non-STEM-ready females is reset to male rate (i.e., from 35.3% to 20.9%).

chemistry, and about the same average grades in calculus.

We are now in a position to assess the role of STEM readiness at the end of high school in determining the gap in STEM readiness among registrants. Using the notation of Equation (1), the probability of being STEM-ready (SR = 1) conditional on registering in university (Reg) can be decomposed as:

(2)
$$P(\mathrm{SR}=1|\mathrm{Reg}) = P(\mathrm{Reg}\ \&\ \mathrm{SR}=1)/P(\mathrm{Reg}) = P(\mathrm{Reg}|\mathrm{SR}=1) * P(\mathrm{SR}=1)/ [P(\mathrm{Reg}|\mathrm{SR}=1) * P(\mathrm{SR}=1) + P(\mathrm{Reg}|\mathrm{SR}=0) * P(\mathrm{SR}=0)].$$

Table 7 presents the various terms underlying this equation for the two gender groups. In the upper panel, we show the STEM-readiness rate among all students, and the registration rates of STEM-ready and non-STEM-ready students. While the gender gaps in STEM-readiness and in the probability of registering conditional on STEM-readiness are small, the gap in registration conditional on non-STEM readiness is large. In the lower panel we show the numerators and denominators of Equation (2) for each gender: clearly, most of the gap in the probability of STEM readiness among registrants is due to the much higher rate of registration of non-STEM-ready females.

Columns 4 and 5 summarize a simple counterfactual where we assume that non-STEM-ready females have the same registration rate as non-STEM-ready males. Under this scenario, the university entry rate of females would fall to 31.6% and the gender gap in STEM readiness among entrants would fall from 14.1 percentage points to 1.6 percentage points. An alternative counterfactual (not shown in the table) is to assume that non-STEM-ready males have the same probability of entering university as non-STEM-ready females. This would raise the registration rate of males to 44% and narrow the gap in the STEM readiness of entrants to 1.5 percentage points. Under either counterfactual about 90% of the STEM readiness gap is due to the higher rate of university entry by non-STEM-ready females.

C. Level 3 Math Achievement and Course Taking Patterns at Level 4

Although the gender gap in STEM readiness at the end of high school is relatively small, the lower rate of participation in UP math and science courses by female students is potentially surprising given that in earlier years of high school females perform somewhat better than males in academic track math. Based on patterns of entry to Level 4 STEM courses we decided to categorize students as on track for STEM readiness if they achieved a grade of 70 or higher in Level 3 academic math, and "off track" if they scored less than 70 or failed to take the course. Using this classification, the total share of students who are STEM-ready and enter university after high school (i.e., the numerator of Equation 2) can be

TABLE 8
Decomposition of STEM-Readiness/Registration Gap at End of High School

	Females (1)	Males (2)	Gender Gap (3)	Counterfactual: Give Females same rates of STEM-Readiness as Males[a] Females (4)	Gender Gap (5)
A. For students on track for Level 4 STEM courses					
1. Prob. on track at end of Level 3	26.1	22.4	3.7	26.1	3.7
2. Prob. STEM-ready if on track	54.8	63.4	−8.6	63.4	0.0
3. Prob. register if STEM-ready and on-track	83.8	84.6	−0.8	83.8	−0.8
4. Contribution of on track students = Row 1 × Row 2 × Row 3	12.0	12.0	0.0	13.9	1.9
B. For students off track for Level 4 STEM courses					
5. Prob. off track at end of Level 3	73.9	77.6	−3.7	73.9	−3.7
6. Prob. STEM-ready if off track	4.8	5.9	−1.1	5.9	0.0
7. Prob. register if STEM-ready and off-track	69.8	70.6	−0.8	69.8	−0.8
8. Contribution of off track students = Row 5 × Row 6 × Row 7	2.5	3.2	−0.8	3.0	−0.2
C. All Students					
9. Percent of students STEM Ready and Registered in university (Row 4 + Row 8)	14.5	15.3	−0.8	16.9	1
10. Prob. STEM-ready if register	33.2	47.4	−14.1	37.3	−10.1

Notes: Entries derived from sample described in Table 5. Students are classified as on track at end of Level 3 (grade 11) if they have completed academic track Level 3 mathematics with a grade of 70 or higher.

[a]Probabilities of STEM-readiness at end of high school for females are recalculated assuming females have same probabilities as males of achieving STEM-readiness given either on track or off track at end of Level 3. Probabilities of being on/off track and probabilities of registration, conditional on STEM readiness and on/off track status are held constant, as are probabilities of registration for students who are not STEM ready.

decomposed as:

(3)
$$P(\mathrm{SR}=1\,\&\,\mathrm{Reg}=1) = P(\mathrm{Reg}|\mathrm{SR}=1,\mathrm{Ontrack})$$
$$\times P(\mathrm{SR}=1|\mathrm{Ontrack}) \times P(\mathrm{Ontrack})$$
$$+ P(\mathrm{Reg}|\mathrm{SR}=1,\mathrm{Offrack})$$
$$\times P(\mathrm{SR}=1|\mathrm{Offtrack}) \times P(\mathrm{Offtrack})$$

The first term on the right hand side represents the contribution of on-track students to the overall share of STEM-ready registrants. The second term represents the contribution of off-track students.

Panel A of Table 8 shows the mean values of the three components in the first term in Equation (3) for female and male students, while panel B shows the means for the three components of the second term. Comparisons of the terms for females and males lead to two key conclusions. First, since only 5%–6% of students who are off-track at the end of 11th grade become STEM-ready (row 6), the overall contribution of off-track students is small (2.5 percentage points for females and 3.2 percentage points for males—see row 8). Second, among students who are on track, the probability of becoming STEM-ready is substantially lower for females (54.8%) than males (63.4%), offsetting the higher fraction of females who are on-track.

Columns 4 and 5 illustrate a simple counterfactual exercise where we assume that females have the same probabilities of achieving STEM readiness as males, conditional on being on or off track at the end of 11th grade. This shift would raise the overall fraction of female students who are STEM-ready and register in university to 16.9% and convert the 0.8 percentage point shortfall of females relative to males into a 1.6 point advantage for females. Holding constant the other terms would then narrow the gender gap in the *fraction* of registrants who are STEM-ready from 14.1 percentage points to 10.1 percentage points. Most of the gain (75%) comes from students who are on track for taking STEM-related math and science classes.

This analysis suggests that a higher fraction of females than males who have been doing well in advanced math up to 11th grade decide to opt out of STEM-related courses. This difference can account for a modest share (around one-fifth) of the gap in STEM readiness between females and males, relative to the counterfactual in which well-prepared females pursued advanced track math and science courses at the same rate as well-qualified males.

TABLE 9
Gender Gaps in University Readiness and University Registration

	All (1)	Female (2)	Male (3)	Gender Gap (4)
A. University readiness:				
STEM-ready *and* university-ready (%)	17.3	17.2	17.4	−0.2
Not STEM-ready but university-ready (%)	30.8	38.9	22.6	16.3
Share of non-STEM/University-ready that are University-ready (%)	37.2	47.0	27.3	19.7
University-ready (with or without STEM)	48.0	56.1	39.9	16.2
B. University registration:				
Percent register in university	37.9	43.5	32.2	11.3
Percent register if university-ready	75.8	75.3	76.5	−1.2
Percent register if university-ready and STEM-ready	84.1	83.1	85.1	−2.0
Percent register if university-ready and not STEM-ready	71.1	71.8	69.8	2.0
Percent register if not university-ready	1.5	1.3	1.6	−0.3
Decomposition				
Part of registration gap attributable to being university-ready and not STEM-ready:				
a. Using male registration rate if university-ready and not STEM-ready			11.4	
b. Using female registration rate if university-ready and not STEM-ready			11.7	

Notes: See notes to Table 5. University-readiness is defined as having completed at least five university preparation or mixed track Level 4 courses. STEM readiness is defined in Table 1.

D. University Entry by non-STEM-Ready Students

As a final step in our analysis, we examine the group of students who fail to take the minimum set of math and science courses to be STEM-ready. In view of the standards for university admission in Ontario, we classify students as *university ready* if they successfully complete at least five qualifying Level 4 classes (i.e., UP or mixed track courses). We then divide all high school students in our cohort sample into three groups: university-ready *and* STEM-ready; university-ready and *not* STEM-ready; and not university ready.[28]

The entries in panel A of Table 9 show that 56.1% of all female students are university ready by their last year of high school, versus 39.9% of males. Females and males have very similar rates of being university and STEM-ready (17.2% vs. 17.4%). But among the non-STEM-ready, female students have a much higher probability of being university-ready (47.0% vs. 27.3% for males), leading to the large disparity in overall university readiness rates.

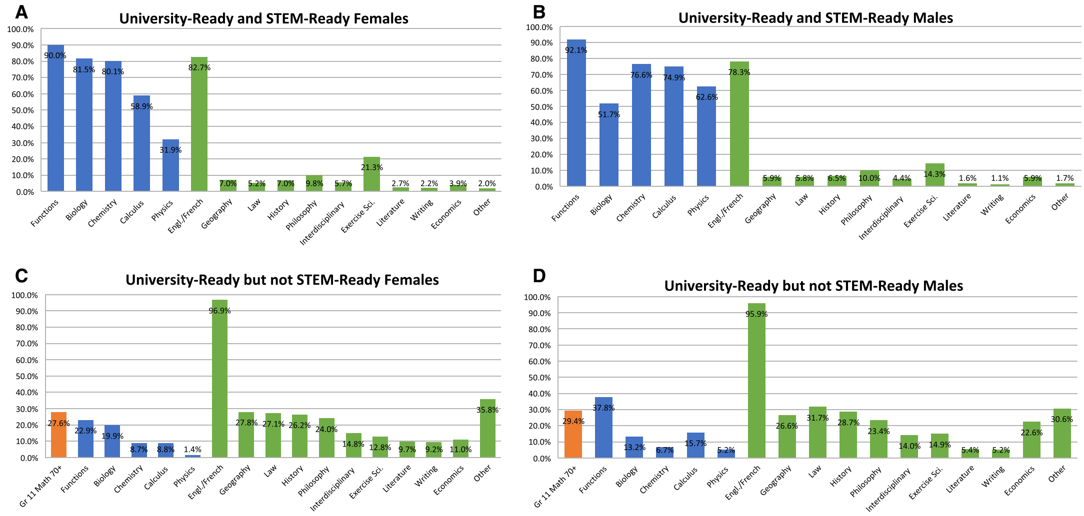
The entries in panel B of Table 9 give university registration rates for all students and those in each of the three subgroups. Conditional on readiness status, the gender gaps in registration rates are small. Registration rates for females and males who are university and STEM-ready are 83.1% and 85.1%, respectively, while the rates for those who are university ready but not STEM-ready are also quite similar (71.8% vs. 69.8%). Moreover, university entry rates for students who fail to meet the minimum threshold of at least 5 qualifying courses are very low for both groups—1.3% for females and 1.6% for males. These patterns mean that the shortfall in the overall university registration rate for males is driven by the lower fraction of men who are university ready but not STEM-ready. Indeed, the decompositions in the bottom two rows of Table 9 suggest that virtually all of the shortfall in male registration rates can be explained this way.

We have also examined the end-of-high school course taking choices of male and female students who are university-ready with out without being STEM-ready. Figure 2 shows the distribution of course titles among each student's Top 5 UP and mixed courses for students who are university-ready and STEM-ready (upper panels) and university ready but not STEM-ready (lower panels). Comparing males and females who are STEM-ready and university-ready, we see that STEM-ready females are more likely to have biology and chemistry in their Top 5 courses, while STEM-ready males are more likely to have physics and calculus in their Top 5. Around 80% of both gender groups have UP English or French in their Top 5 courses, but otherwise STEM-ready students take relatively few social science and humanities classes.

28. Our definition of STEM readiness requires that students have successfully completed at least three UP math and science classes. A small fraction of these students (4% of females and 7% of males) do not have enough other qualifying courses to meet our threshold for university-readiness.

FIGURE 2

Distributions of Top 5 Level 4 Courses for University-Ready Students, Classified by Gender and STEM-Readiness



In contrast, students who are university ready but *not* STEM-ready (in the lower panel) have few math or science courses in their Top 5, and focus instead on social science and humanities classes like geography, history, and law. Within this group the gender differences are relatively small, especially compared with the very wide gap in course taking patterns relative to the STEM-ready group.

We also show (in orange) the fractions of university-ready but not STEM-ready males and females who completed academic track Level 3 (11th grade) math with a grade of 70 or higher. This rate is just under 30% for both females and males, suggesting that most students of either gender who end up being university ready but not STEM-ready had "opted out" of UP math by 11th grade (or earlier).

The group of nonuniversity-ready students (who are excluded from Figure 2) includes those who fail to take enough Level 4 classes to obtain a high school graduation diploma (15% of all females in our high school sample and 20% of all males), as well as a larger group of students who obtain a diploma but concentrate on applied courses (30% of all females and 41% of all males).[29] Most of the students in this group take few if any UP courses and are very far from the threshold needed to achieve university readiness.

29. The minimum requirements for a high school diploma include 3 years of math and 4 years of either English or French.

Card and Payne (2015) show that much of the gender gap in university entry in our Ontario high school sample can be predicted by differences in course selections and grade outcomes in *ninth grade*. Specifically, they show that students of either gender who fail to achieve a grade of 70 or better in at least one of the two main academic track courses in ninth grade (math and languages) have only about a 10% chance of entering university within the next 5 years. Most of the students who fail to meet this threshold take nonacademic track courses in levels 2–4 and end up with relatively few UP or mixed courses in their last years of high school. The 15 percentage point higher fraction of males than females who fall below the threshold at the end of ninth grade (Card and Payne 2015, Table 4) is remarkably similar to the gender gap in university readiness that drives both the gender gap in overall university entry *and* the lower share of female students who are STEM-ready when they enter university.

V. SUMMARY AND CONCLUSIONS

To summarize our main findings, Table 10 combines the decomposition results in Tables 2, 7, and 9 to show the sources of the 13.2

TABLE 10

Components of the Gender Gap in STEM Registration at Entry to University

	Female−Male Gap	**Share of Overall Gap (%)**
1. Gap in probability of registering in STEM (conditional on registering)	−13.2	100
a. Component due to gap in choice of STEM major if STEM-ready	−2.1	16
b. Component due to gap in STEM-readiness rate	−11.1	84
2. Of **−11.1 point gap** due to STEM-readiness of registrants:		0
a. Component due to gap in choice of STEM-ready students to register (numerator effect of Equation 2)	−1.7	13
b. Component due to gap in registration choices of non-STEM-ready students to register (denominator effect of Equation 2)	−9.4	71
3. Of **−9.4 point gap** due to registration choices of non-STEM-ready students:		
a. Component due to gap in registration conditional on university-readiness	0.0	0
b. Component due to gap in university-readiness	−9.4	71

Notes: See notes to previous tables. Decompositions are formed using average of alterative counterfactuals.

percentage point gender gap in the fraction of newly entering university students who enroll in a STEM program. Overall, 2.1 percentage points are attributable to a lower rate of entering a STEM major by STEM-ready females than males (row 1a); 1.7 percentage points are attributable to the slightly lower fraction of females than males who are STEM-ready at the end of high school and the slightly lower fraction of STEM-ready females who enter university (row 2a); and 9.4 percentage points are attributable to the higher fraction of non-STEM-ready females who finish high school with enough qualifying classes to be university ready. Thus, the gap in the fraction of women who enter STEM programs at university is largely a reflection of the lower rate of university entry by men—a problem that is shared by many countries.

In addition to these key findings, our analysis points to several other important differences between female and male students. On average, females have about the same average grades in UP math and sciences courses as males, but higher grades in English/French and other qualifying courses that count toward the Top 6 scores that determine their university rankings. This *comparative advantage* explains a substantial share of the gender difference in the probability of pursing a STEM major, conditional on being STEM-ready at the end of high school. STEM-ready males are also more likely to have taken four or five math/science UP courses, a factor that accounts for a similar share of the gender gap in STEM entry. We also find that females are more likely than males to be on track to take STEM-related courses in their last year of high school, as measured by obtaining a grade of 70 or higher in Level 3 academic track math. But fewer of these females take enough STEM-related UP classes to achieve STEM readiness, so females end up slightly less STEM-ready at the end of high school. This slippage presents a potential opportunity for policies to raise the fraction of females who complete three or more math and science courses in Level 4, though we suspect that again the forces of comparative advantage may compel at least some of the on track female students to opt out of STEM courses. Loyalka et al. (2017) report that a similar comparative advantage effect drives some of the differences in high school track choices by young women in China.

A third pattern revealed by our analysis is the wide divergence in course-taking between students who are STEM-ready at the end of high school and those who are university ready but not STEM-ready. Very few of the latter group are on the margin of STEM readiness, and less than 30% were on track for STEM courses at the end of 11th grade. Relatedly, much of the gender gap in the probability of being university-ready by the end of high school can be traced back to ninth grade, where boys are much less likely to successfully complete the gateway language and math classes that lead to the university-qualifying courses at the end of high school. University-bound students in Ontario schools tend to specialize early, suggesting that any attempt to raise the fractions of university-ready or STEM-ready students will require significant changes in student course taking starting at the earliest years of high school.

APPENDIX A

TABLE A1
Effect of Field of Study on Gender Wage Gap for University-Educated Workers Age 25–34

	Bachelor Degree Holders			Bachelor Degree or Higher		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
A. Canada—2006 Census						
Female	−0.103	−0.076	−0.075	−0.107	−0.087	−0.073
	(0.011)	(0.011)	(0.011)	(0.010)	(0.010)	(0.014)
STEM major	—	0.188	—	—	0.154	—
		(0.012)			(0.011)	
Field of study Controls (10 fields)	No	No	Yes	No	No	Yes
B. United States—2009 American Community Survey						
Female	−0.160	−0.142	−0.118	−0.158	−0.139	−0.117
	(0.006)	(0.006)	(0.007)	(0.005)	(0.005)	(0.006)
STEM major (based on first major)	—	0.188	—	—	0.187	—
		(0.007)			(0.006)	
Field of study Controls (10 fields)	No	No	Yes	No	No	Yes

Notes: Standard errors in parentheses. Samples includes people age 25–34 in 2006 Census or 2009 ACS who were native born or immigrated before age 15 and were not attending school at the survey date. Sample in columns 1–3 includes people whose highest degree is a bachelor's degree. Sample in columns 4–6 includes people with a bachelor degree or more. Dependent variable in all models is log of average weekly wage, excluding observations with weekly wage less than \$15 or over \$4,000. Canadian sample size in columns 1–3 is 12,237; U.S. sample size is 534,419. Canadian sample size in columns 4–6 is 15,772; U.S. sample size is 750,035. All models control for age (grouped variable in Canadian data), part-time status, highest degree, and province/state.

TABLE A2
Examples of STEM Programs at Ontario Universities

Program Type	Examples
1. Engineering	Univ. of Waterloo, Chemical Engineering (co-op)
	Univ. of Ottawa, GeNie Informatique
	McMaster Univ., Engineering
	Univ. of Guelph, Biomedical Engineering
2. Physical/Natural Sciences	Ryerson Univ., Medical Physics
	Carleton Univ., Science: Honours
	Western Univ., Health Sciences
	Univ. of Toronto Scarborough, Co-op Neuroscience
	York Univ., Kinesiology and Health Science BSc
	Trent Univ., Biology
	Nipissing Univ., BSc Psychology
	Univ. of Windsor, BFS Forensic Science
3. Math	York Univ. Science: Computational Mathematics
	McMaster Univ., Mathematics and Statistics
	Ryerson Univ., Mathematics and Its Applications
	Wilfrid Laurier Univ., BSc Honours Financial Mathematics
4. Computer Science and Information Technology	Univ. of Ottawa, Computer Science Honours
	Univ. of Toronto St. George, Computer Science
5. Nursing/Midwifery	Queen's Univ., Nursing
	Univ. of Ottawa, BScN Nursing
	York Univ. (Collaborative BSc)
6. Environmental Science	Lakehead Univ. BSc Forestry Honours
	Univ. of Waterloo, Environmental Sciences
7. Architecture	Ryerson Univ., Architectural Science
	Carleton Univ., Industrial Design
8. Agriculture	Univ. of Guelph, BSc Agriculture
	Trent Univ., Sustainable Agriculture and Food Systems

Note: Authors' classification based on university programs students report in OUAC system.

TABLE A3
Field Distribution and Mean Wages for Degree-Holding Workers Age 25–34 in 2006 Census

	Females		Males		
	Percent in Field (1)	**Mean Weekly Wage[a] (2)**	**Percent in Field (3)**	**Mean Weekly Wage[a] (4)**	**Full-Time Gender Wage Gap (%) (5)**
All individuals	100.0	1,030	100.0	1,217	−16.6
A. Non-STEM fields					
All Non-STEM fields	75.0	996	62.7	1,161	−15.3
1. Education, recreation and counselling	23.0	956	10.1	1,009	−5.4
2. Fine and applied arts	3.2	817	2.6	933	−13.3
3. Humanities	12.1	892	10.2	1,032	−14.6
5. Commerce and business	15.0	1,158	22.1	1,318	−12.9
B. STEM fields					
All STEM fields	25.0	1,157	37.3	1,315	−12.8
1. Biological sciences and related	5.2	966	3.9	1,128	−15.5
2. Engineering and applied science	3.7	1,357	16.9	1,369	−0.9
3. Health professions	11.9	1,206	4.1	1,341	−10.6
4. Math, computer science, phy. sciences	4.1	1,079	12.1	1,292	−18.0

Notes: Sample includes employed individuals in 2006 Census age 25–34 with bachelor degree or higher education, not enrolled in school, who were Canadian-born or immigrated before age 16. Individuals are classified by their major field of study. Samples in columns 2, 4 and 5 include only full time workers. Entry in column 5 is difference between entries in columns 2 and 4, divided by average of columns 2 and 4.

[a]Mean weekly wage calculated for bachelor graduates, age 30–34, working full time.

TABLE A4
Characteristics of New University Entrants ("Registrants")

	All Students		STEM Registrants	
	Female	**Male**	**Female**	**Male**
Number of students	2,37,719	1,75,894	72,124	76,489
Canadian born	94.1%	92.7%	91.7%	90.2%
Permanent resident	5.2%	6.4%	7.6%	8.9%
Study visa or other	0.7%	0.9%	0.8%	0.9%
Home language = English	79.5%	77.3%	73.6%	72.1%
Home language = French	3.0%	2.3%	3.4%	2.5%
Home language = Other	17.5%	20.4%	23.1%	25.4%
Age = 17	1.2%	1.1%	1.8%	1.6%
Age = 18	82.0%	71.6%	83.7%	76.1%
Age = 19	15.6%	25.1%	13.2%	20.3%
Age = 20	1.3%	2.2%	1.3%	2.1%
Mean grade - Top 6 Courses[a]	83.27	82.24	85.14	84.05
(standard deviation)	(6.35)	(6.65)	(6.33)	(6.63)

Notes: Sample includes OUAC applicants from Ontario public high schools in years 2005–2017 who were between the ages of 17 and 20 and were recorded as registering in an Ontario university in the fall after the year of their application. A small number of applicants ($n = 1{,}038$) with missing high school course information are excluded.

[a]Mean grade (out of 100) for the Top 6 Level 4 courses taken by student.

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