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Understanding the STEM Path through High School and into University Programs

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Executive Summary

Jobs in the fields of science, technology, engineering and mathematics (STEM) are often predicted to account for a large share of job creation, and policy makers often encourage student enrolment in the STEM fields. Preparation for a STEM career requires students both to take the appropriate courses in high school and to apply to and register in a postsecondary STEM program. We use two unique administrative datasets to examine the correlates of ‘staying on the STEM path’ in high school, i.e., taking the math and science courses needed for university STEM programs and then applying to and registering in such programs.

We have two key empirical findings. First, the most important reason for failure to prepare for a university STEM program is the rate at which students stop taking university and mixed courses in science at Levels 3 and 4. These are the levels when courses in these subjects are no longer required for the Ontario Secondary School Diploma. Extensive multivariate analysis indicates that the key determinants of the decision to stay on the ‘STEM preparation path’ are the students’ previous grades in science and math, especially at the point when the subject becomes optional. Non-academic factors, such as gender, place of birth, average income and other neighbourhood characteristics, play predictable but quantitatively smaller roles.

Second, the most important correlate of the likelihood of applying to or registering in a university STEM program is the number of Level 4 university or mixed science courses passed. The second most important determinant is the GPA earned in such science courses. The number of math courses taken and the math GPA both have the expected positive effects, but the magnitudes of the effects are much smaller than in science, especially with regard to number of courses. Non-academic factors, such as gender, place of birth, average income and other neighbourhood characteristics have significant but smaller quantitative effects.

A very positive policy conclusion can be drawn from our findings regarding the educational system in Ontario. The most important determinant of whether or not students stay on the STEM path throughout high school and proceed to university STEM programs is individual academic performance, specifically the grades earned in STEM courses at each level and the types of course taken at Level 4. This is true of males and females, immigrants and the native born, and those from advantaged and disadvantaged neighbourhoods. This positive conclusion also leaves a big question unanswered. What lies behind the variation in math and science grades at all levels of high school? Much better data are needed to understand the mix of individual, home and school inputs that ultimately account for success in both high school and university.

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1. Introduction

Jobs in the fields of science, technology, engineering and mathematics (STEM) are often predicted to account for a large share of job creation, and policy makers often encourage student enrollment in the STEM fields.[1]

Preparation for a STEM career requires students both to take the appropriate courses in high school and to apply to and register in a postsecondary STEM program. This paper examines a series of questions concerning persistence on the STEM path in Ontario high schools. What differentiates those students who earn credits in the more rigorous math and science courses at each level of high school and who ultimately apply to and register in university STEM programs? These questions have received little attention in the Canadian literature. We use two rich administrative data sets that provide information on the high school performance of individual students in Ontario and the university programs to which they apply and in which they register. Both administrative data sets have been linked to Census data on the neighbourhoods in which the students live.

We find that the key factor associated with continuation in the high school math and science courses needed for university STEM programs at each level is the grade in that subject received in the previous level. This relationship is especially strong at the level at which the subject becomes optional. Other factors such as gender, immigrant status, the high school attended and neighbourhood average income play a much smaller role. We find that the most important determinant of applying to or registering in a university STEM program is the number of Level 4 university or mixed science courses passed, followed by the grade average earned in such science courses. Both grades in math courses and the non-academic factors mentioned above play predictable but quantitatively smaller roles. These findings indicate that staying on the STEM path is depends most importantly on academic achievement in relevant math and science courses. These results provide important insights but also raise the challenging question of what lies behind the variation in high school grades and courses taken in science, and what mix of individual, home and school inputs ultimately account for preparation for and entry to university STEM programs.

2. Literature Review

We have found little Canadian research on our topic. Cross-country comparisons of STEM graduates and jobs often omit Canada (e.g., Marginson et al., 2013). One exception is Conference Board of Canada (2013), which reports that Canada produces proportionately more STEM graduates than the United States but fewer than Finland, Germany and Austria.

Studies of high school preparation for university STEM programs are most commonly based on U.S. data. The actual level of achievement in math and science, and the student's perception of their ability in these disciplines, play important roles (Wang, 2012; Adelman, 1998). Maple and Stage (1991) also document an

1 For recent examples, see the Canadian Economic Action Plan (Government of Canada, 2013) and U.S. Department of Commerce (2011).

important role for parental education and influence regarding persistence in high school STEM courses. Wisall (2014) reports that students in STEM-focused high schools outperform their non-STEM counterparts in science and mathematics, but LeBeau et al. (2012) find that the high school curriculum is not a determining factor in postsecondary STEM performance and the selection of occupations.

Tyson et al. (2007) and You (2013) report that female students were almost as likely as their male counterparts to have advanced high school math courses, but pursued STEM programs and careers at a much lower rate. Mann and DiPrete (2013) suggest that more career-focused undergraduate STEM programs might lead more women to graduate-level STEM training as has been the case with law, business and medicine. There is also a literature on persistence in university STEM programs (e.g., Ehrenberg, 2010), but our data do not address this issue.

3. The Ontario High School System and the Ministry of Education Data

The Ontario curriculum is designed for students to take Level 1 courses in grade 9, Level 2 in grade 10, Level 3 in grade 11 and Level 4 in grade 12. We observe in our data, however, many different paths to completing the high school diploma. Hence, our analysis focuses on the completion of courses by level and not by grade. Most high school courses at Levels 1 and 2 – including the core courses in math, science and English (or French) – are offered in two versions, academic and applied.[2] Students who choose the applied track in Level 1 math and science typically take the same track in Level 2. Beyond Level 2, most courses have prerequisites that are tied to either the academic or applied streams and are classified as ‘university’ or ‘college.’ There are also a few ‘mixed’ courses in math at Level 3 and in science at Levels 3 and 4 that offer some flexibility.

Students are expected to graduate in four years, but it is common for students to take or retake more challenging courses in a fifth year.[3] Ontario confers both an Ontario Secondary School Diploma (OSSD) and an Ontario Secondary School Certificate. The OSSD has more rigorous requirements and is obtained by the majority of students, especially those who intend to pursue postsecondary education. The OSSD requires a total of 30 credits, where a typical full-semester course counts as one credit.[4] Most students take a course load of seven or eight credits per year. Of the 30 required credits, 18 are compulsory courses, including four credits in English or French,[5] with one course per level at each level; three credits in mathematics, at least one of which is at Level 3 or 4; and two credits in science, at least one of which is at Level 2. There are also requirements in history, geography and second languages.

2 There are three other types of courses for which we have no information in our data. ‘Workplace’ courses prepare the student for entering the full-time labour force directly out of high school. ‘Open’ courses are for general interest and have no prerequisites. ‘Locally developed’ courses are designed to meet the needs of special and typically small groups of students.
3 Ontario formerly had a five-year system, but grade 13 was eliminated in 2003. As we explain later, this fact motivates us to limit our data period to post-2003.
4 Students are also required to pass a literacy test and complete 40 hours of community service.
5 Students in Francophone high school years are required to take four years of French rather than English.

Our Ministry of Education data are for the cohort that enrolled in grade 9 in the fall of 2005 in all publicly funded schools in the province.[6] The data follow these students for five years. Our data follow students who move among publicly funded Ontario high schools in Ontario, but not those who leave this system for any reason.

The school records include information on each student's gender, birth year, home postal code (the first 3 characters only), and place of birth (Canada or not).[7] We use the home postal code to link the high school record with neighbourhood characteristics from the 2006 Census, such as average family income. The high school record also indicates if a student applied to or registered at any university or college in Ontario within our five-year data window, but does not identify the names of programs or institutions.

The standardized curriculum allows us to identify the subject, grade level and track (academic or applied) of each course. We have information on academic and applied courses in Levels 1 and 2, and university, mixed and college courses at Levels 3 and 4. We observe the course taken, the credits earned and the grade for the course (reported at 5-point intervals from 0 to 100).

Table A-1 lists the exclusions that were made to arrive at the sample used for our analysis. First, we exclude the 3% of students who were not born within one year of the standard entry age (14) for grade 9, i.e., birth year before 1990 or after 1992.

Second, 11% of students were excluded for having less than three academic or applied track courses in the first year in which they are observed. Such students may have been enrolled part-time or may have followed a non-standard track in their first year. Given the lack of the information, we have dropped such students from our sample.

Third, we exclude the 0.5% of students who are enrolled in 'special condition' schools (e.g., special needs or prison schools) and small rural schools (less than 25 grade 9 students). Course offerings and typical academic paths in such schools may be quite different from other schools.

Fourth, 4% are excluded because they did not enroll in all of the following: one Level 1 Language (English or French) class, one Level 1 science class and one Level 1 math class. These omissions are due to the centrality of these courses in this paper.

Fifth, 2% are excluded because they enrolled in an average of less than three courses per year in 2006/2007, 2007/2008 and 2008/2009, and did not obtain a high school diploma. We checked for an early high school diploma (obtained less than four years following the start of high school) to ensure that this was not the explanation for the light course load. As explained above, we do not observe the courses and performance of a student after a switch to a private or out-of-province high school. Without a complete transcript or an explanation for same, it is difficult to study student choice and performance.

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6 The province provides equal funding for Catholic high schools and 'public' (non-religious) high schools in both English and French. Ninety-eight per cent of high school students attend one of these four types of publicly funded institutions. Our data include all four types of high schools.
7 There is some indication of special status (gifted, needs, and second language learners) but it is too limited to use for defining the sample.

The penultimate bottom row of Table A-1 indicates that these exclusions total 21% of our initial sample. This leaves us with a total sample of 135,307 students who follow the “normal path” through high school and are most likely to end up with a secondary school diploma or certificate. The share of these students residing in low-income neighbourhoods in our final sample is 28%, down from 30% in the full sample.

4. The Ontario University Application System and Data

Ontario high school students usually submit applications to Ontario universities in the winter of their fourth or fifth year (or both) of high school and admissions are offered in early spring. Applications are made directly to specific programs within schools, though some institutions admit students to a broad first-year program in which students specialize later.[8] The Ontario Universities’ Application Center (OUAC) application permits students to apply to three programs for a set fee and to additional programs for a marginal fee per program. The student is limited, however, to three programs per university and individual universities may impose a lower limit. Students are required to rank all application choices, but universities are not permitted to use these rankings in their admission decisions. All universities require that students successfully complete their OSSD.

Almost all applications to Ontario universities are submitted through OUAC, which processes the following two types of applications: ‘101’ applications are submitted by students currently enrolled in an Ontario high school, and ‘105’ applications are submitted by a much smaller and very diverse group that includes Ontarians not currently enrolled in high school and all applicants from outside Ontario regardless of school enrollment status. We use only the data on 101 applicants, as they most closely resemble the students in our Ministry of Education data set.[9] In addition, the academic information in the high school records of the 105 applicants is often very limited and non-uniform. Our basic OUAC data set contains all 101 applications to Ontario universities over the period 2004 to 2012. OUAC applications include the subject taken and grades awarded in Level 4 courses, the gender and home postal code of the student, the programs and universities to which the student applied, and the program and university at which the student registered (if at all).

A program was deemed to be STEM if a similar program description existed in the United States Department of Homeland Security’s (DHS) STEM classifications list (US Department of Homeland Security, 2012). If the program was in a STEM-related field according to the DHS but led to a degree other than a Bachelor of Science, Bachelor of Mathematics, Bachelor of Computer Science, Bachelor of Applied Sciences or Bachelor of Engineering, it was given a classification of “STEM-lite.” In Section VI below, we report on two sets of probit functions. STEM-lite programs are included with STEM programs in one set and with non-STEM programs in the second set.

Most programs use the average grade in the best six university or mixed Level 4 courses as the basis for an offer of admission into a program. STEM programs commonly require specific Level 4 university math and science courses, but these vary widely by program and university. Universities are not required to provide

8 At McMaster University, for example, students apply for entry to life sciences and then choose to major in, for example, biology or chemistry after their first year of studies. At Wilfrid Laurier University, students may apply for direct entry to biology and chemistry programs through OUAC.
9 Some students in our Ministry data will end up filing 105 applications, but we are unable to identify such students.

OUAC with information concerning actual offers to individual students. In lieu of this information, we constructed a measure of the likelihood that a student received an offer of admission. We identify a student as likely having received an offer of admission if the average of her best six Level 4 university or mixed courses is at or above the 15th percentile of grade averages observed for students that register in that program – or, of course, if the student registered in the program. We use the 15th percentile due to the possibility of outlier cases. Finally, we use the postal code of the student's residence to link the student record with the socioeconomic characteristics of the Dissemination Area (neighbourhood) in the 2006 Census.

Table A-2 in the Appendix lists the OUAC exclusions that were made to arrive at the sample used for analysis in this paper. We began with 750,823 observations for the years 2004 through 2012.[10] We excluded observations that had one or more of the following characteristics: fewer than four Level 4 university or mixed high school courses (six such courses are usually required for university admission) (1%); no university choices recorded (less than 1%); invalid or missing postal code (less than 1%); high school courses from pre-double cohort curriculum (1%); a high school likely to have an unusual curriculum, e.g., special education or prison schools (1%); applied beyond age 20 (should be a 105 application) (1%); and high school cohort was less than 20 students (8%). The penultimate bottom row of Table A-2 indicates that these exclusions total 14% of our initial sample. This leaves us with a total sample of 648,033 students. Twenty percent of applicants resided in low-income neighbourhoods in both the original sample and the final estimation sample.

5. Analysis of High School Progression and Curriculum Choices

We begin with an analysis of the decisions that students make in high school concerning the math and science courses that lead towards university STEM programs. All data used in this section are from our Ministry of Education data set. Table 1 provides summary information. Column 1 contains the number of students passing an academic, university and mixed (AUM) course in math and science at each level. Column 2 shows the "progression rates," that is, the proportion of students who passed an AUM course at Level X from among those who passed an AUM course in the same subject at Level X-1. Column 3 shows the proportion of students who passed an AUM course at Level X from among the entire entering cohort. Column 4 shows the proportion of students who passed an AUM course at Level X from among those who passed an AUM course in the same subject at Level 1.

Row 1, column 3 indicates that two-thirds of entering grade 9 students in our cohort passed (earned at least one credit in) Level 1 in both AUM math and science. However, row 4, column 3 shows that only one-quarter of entering grade 9 students passed Level 4 in both AUM math and science. At which level was dropping out of the 'STEM path' most likely to occur? Column 2 demonstrates that the progression rates decreased across levels, the only exception being the increase from level 2 (85%) to Level 3 (91%) in math courses. The largest decline in the progression rate in both subjects occurs at the level at which the subject becomes optional for the OSSD (Level 4 for math and Level 3 for science). Note that the failure to complete Level 4 in both STEM

10 Earlier data were available but were not used due to major changes that occurred in 2003 when grade 13 was eliminated and the curriculum was revamped.

subjects is due more to science than to math. Thirty-nine per cent of entering grade 9 students complete Level 4 math, but only 29% of such students complete Level 4 science. We will return to this finding in the next section when we analyze the role of math and science courses in influencing the likelihood of applying to and registering in university STEM programs.

Table 2 contains the average marginal effects obtained from probit estimates for the likelihood of passing at least one AUM course at Levels 2, 3 and 4 in math and science. For both Level 2 probits, we use the sample of students who passed AUM math and science in Level 1. For the Level 3 and 4 probits, we use the sample of individuals who passed an AUM course in that subject at the previous level. Samples differ slightly from those in Table 1 due to missing data for other independent variables. The omitted category in the math (science) probits is a male immigrant from a middle-income neighbourhood who (1) received a math (science) grade of from 50% to 60% at the previous level and (2) either received a science (math) grade of less than 60% at the previous level or did not take science (math) at the previous level.

The most important determinant of the likelihood of continuing in AUM math and science is the prior grade in that subject. We plot the math coefficients from rows 1 through 4 and columns 1 through 3 in Figure 1, and the science coefficients from rows 5 through 8 and columns 4 through 6 in Figure 2. Figure 1 shows that the effect of doing very well in the prior level is especially important at Level 4, when math becomes optional for the OSSD. A student with a Level 3 U/M math grade of 90% or better is 42 percentage points more likely to pass Level 4 university math than is a student with a Level 3 U/M math grade of 50% to 60%. The differences are even more dramatic in Figure 2. Most students who took Level 1 Academic science continue on in Level 2 Academic science regardless of their Level 1 grade. However, once science becomes optional for the OSSD at Levels 3 and 4, the importance of prior science grades increases dramatically. The likelihood of staying in the U/M stream at Level 3 (4) is 50% (66%) greater for those with a prior grade of 90% or better than for those with a prior grade of 50% to 60%.

Math grades have a much smaller effect on the likelihood of taking the next level of science (rows 5 through 8 and columns 1 through 3) than on the likelihood of taking the next level of math. The same is true of the effect of science grades on the likelihood of taking math (rows 1 through 4 and columns 4 through 6), but these cross-disciplinary grade effects are usually significant and of the expected sign. One exception is the insignificant effects of math grades on the likelihood of taking Level 4 science. A second and surprising set of exceptions is the effect of a prior math (science) grade of 90% or higher on the likelihood of taking Level 3 and 4 science (math). These four coefficients are all negative and, in three cases, significant. We have no ready interpretation for these last findings.

The marginal effect of being female (row 9) or Canadian-born (row 10) is usually negative and significant, but only reaches a magnitude of 5 to 7 percentage points at Level 4. As expected, the coefficient for living in a low-income neighbourhood (row 11) is always negative, but these are invariably small in magnitude and non-significant in a majority of cases. The effect of living in a neighbourhood with a greater proportion of adults with a bachelor’s degree (row 13) is positive and significant in five out of six cases, but the size of the effect is quite small. An increase of 10 percentage points in this variable is associated with an increase of only 0.1 to 0.2 percentage points in the likelihood of taking math or science. A similar pattern is true for the effects of living in a neighbourhood with a greater proportion of unemployed adults (row 14), but we have no ready explanation for the positive sign of the coefficients in this case.

We estimated the following alternative specifications and always reached the same basic conclusions: high school fixed effects models; separate probits by gender, immigrant status and neighbourhood income; and adding math and science grades and the overall GPA from all previous levels to the probits. The key determinant of continuation in AUM math and science courses is the grade in that subject in the previous level, especially at the point when the subject becomes optional. Non-academic factors play a smaller role.

6. Analysis of Application to and Registration in University STEM Programs

Figure 3a below depicts the total number of 101 applicants and the number of such students who applied to one or more STEM programs. There was steady growth in both total and STEM applications over our sample period. Figure 3b indicates that the proportion of applicants applying to one or more STEM programs was also increasing after 2005. This last trend is not being driven by students applying to more programs. The mean and median number of programs to which students apply was quite stable at a value of four over time. Figures 3c and 3d show that both the probability of likely receiving an offer of STEM program admission among applicants and the probability of registering in a STEM program among those likely receiving an offer were basically flat over our sample period. These data imply that the growing number and proportion of students applying to STEM programs were being accommodated with offers of admission and registration spaces.

Table 3 shows the number and proportions of applicants to university STEM programs by the number of Level 4 university or mixed (UM) math and science courses passed. Row 1 shows that just over one-half (51%) of all university applicants passed at least one Level 4 UM course in both science and math. Twenty-nine percent passed at least one Level 4 UM course in just one of science and math and 20% passed neither type of course. Row 2 shows that 82% of all STEM program applicants passed at least one Level 4 UM course in both science and math, and only 6% passed neither type of course.

Row 3 shows that 79% of students who passed at least one Level 4 UM course in both math and science applied to one or more STEM programs. This was true of only 22% of students who passed a Level 4 UM course in just one of science or math and only 14% of students who passed neither. Row 4 shows that almost all (85%) STEM applicants who likely received an offer of admission also passed at least one Level 4 UM course in both science and math. Only 6% of likely offerees passed neither type of course. Row 5 indicates that a substantial majority of each type of STEM applicant, even those with no Level 4 UM math or science, likely received an offer.

Row 6 shows that the consequence of the above rows is that virtually all (93%) of the students who register in a STEM program passed at least one Level 4 UM course in both science and math. Row 7 shows that, among those who likely received an offer of admission from a STEM program, 74% of students who passed at least one Level 4 UM course in both science and math registered in one or more STEM programs. This was true of only about one-third of students in the other two categories who likely received an offer of admission to a STEM program.

Row 8 indicates that just over one-half (52%) of university applicants with Level 4 UM math and science register in a STEM program, but this is true of only 5% of applicants with just one of math or science and only 3% of applicants with neither. The key message is that students who do not take Level 4 UM courses in both math and science are very unlikely to end up in STEM programs in university. Row (9) shows that the same is true even if we limit the sample to those who applied to a STEM program.

Table 4 contains the average marginal effects (evaluated at the mean) obtained from probit estimates for the likelihood of applying to and registering in university STEM programs. These probits use our OUAC data and, hence, contain only the subset of high school students who applied to university. We begin with a discussion of the results for the likelihood of application in Column 1. Note that “course” refers only to Level 4 university or mixed courses. The sample is limited to applicants with at least six such courses because this is an admission requirement for all university programs. The omitted category is a male who is not a Canadian citizen, finished high school in four years and had the following academic record: six best course GPA of less than 70%; either no science courses passed or a science GPA of less than 70%; and either no math courses passed or a math GPA of less than 70%. For the probit functions in Table 4, we have classified STEM-lite programs at STEM programs. Very similar estimates were obtained when we classified STEM-lite programs as non-STEM programs.

The first set of estimates in Rows 1 through 3 is for the GPA earned in the best six courses taken. Interestingly, the effects for these binary variables are all significantly negative in the applications probit. Not only are they negative, but they imply that a higher GPA is associated with a lower likelihood of applying to a STEM program. Note, however, that we are controlling for the GPAs and the number of courses taken in both science and math. The negative effects for “6 Best GPA” may reflect the fact that students who get high grades in humanities and social science courses, controlling for math and science grades and courses taken, tend to apply to humanities and social science programs. Presumably, most students willing to apply to one or more STEM programs despite a very low overall Level 4 GPA are those whose best grades are in math and science.

Rows 4 through 6 contain estimated marginal effects for the GPA earned in all Level 4 university or mixed science courses passed if any. Rows 7 through 9 contain estimated marginal effects for the number of Level 4 university or mixed science courses passed. These six rows indicate that higher science grades are indeed associated with a higher likelihood of applying to a STEM program, but that the number of science courses taken has a much bigger effect. The coefficients for both variables are shown in the bar graph Figure 4. A science GPA of 90% or better increases the likelihood of an application by only 11 percentage points compared to the omitted category, whereas taking two or three Level 4 U/M science courses increases the likelihood of a STEM application by 36 and 54 percentage points, respectively.

Rows 10 through 12 contain estimated marginal effects for the GPA earned in all Level 4 university math courses passed if any. Rows 13 and 14 contain estimated marginal effects for the number of Level 4 university math courses passed. A math GPA of 90% or higher increases the likelihood of STEM application by ten percentage points compared to the omitted category, which is similar to the effect of science grades. However, taking two or three Level 4 U math courses increases the likelihood of an application by only 12 percentage points. We believe that the smaller math effects reflect the fact that most business, economics, and a number of other programs require Level 4 math but not science.

Rows 15 through 21 show that females, Canadian citizens, late finishers (taking a fifth year) and applicants from low-income neighbourhoods are one to four percentage points less likely to apply to a STEM program. The final two rows show that the proportions of adults in one’s neighbourhood who have a university education or are unemployed has significant but small positive effects. A ten percentage point increase in these proportions leads to increases in the likelihood of a STEM application of 0.5 to 0.8 percentage points

Column 2 of Table 4 contains the average marginal effects for the likelihood that a high school student has registered in a university STEM program. Unlike Column 1, the effects in Rows 1 through 3 of Column 2 are all positive, implying that a GPA of 70% or higher is associated with a higher likelihood of registering in a STEM program. (The differences among these three coefficients are not significant.) We believe that this makes intuitive sense. Students with a low overall Level 4 GPA whose best grades are in math and science may still be willing to apply to one or more STEM programs just to see if an offer of admission and/or financial aid is forthcoming. Such students, however, will likely be denied an offer of admission and kept from registering due to their low overall GPA.

The remainder of the estimates in Column 2 are generally quite similar to those in Column 1. The basic message is that the most important determinant of the likelihood of applying to or registering in a STEM program is the number of Level 4 U/M science courses passed. The second most important determinant is the GPA earned in science courses. The coefficients for both variables are shown in the bar graph Figure 5. The number of math courses taken and math GPA both have the expected positive effects, but the magnitudes of the effects are not nearly as large as those for science, especially with regard to numbers of courses. As indicated above, these small math effects may reflect the fact that many planning on a business program take and do well in math but not necessarily in science. Both individual and neighbourhood characteristics frequently have statistically significant effects of the expected sign, but these coefficients are smaller in magnitude than those relating to academic achievement, especially in science.

Females are less likely to apply to and register in STEM programs, as are those who finish late. Canadian citizens are less (more) likely to apply to (register in) STEM programs. Being from a low-income DA has significantly negative but very small effects. The proportion unemployed in the DA has significantly positive but small effects on both likelihoods.

We have run an extensive set of sensitivity tests, all of which yield estimates similar to those above. These tests include the following: high school fixed effects models; interactions between the number of courses taken and the GPA earned in each of science and math; separate probits for males and females; separate probits for the Canadian citizens and non-citizens; separate probits for applicants from low-, middle- and high-income DAs; re-classifying programs in STEM fields that lead to a BA degree (“STEM-Lite” programs) as non-STEM programs; omitting applicants with a best 6 GPA of less than 70% from the estimation sample; and limiting the sample to only those who register in a university program.

7. Policy Discussion and Conclusion

We have used two unique administrative datasets to examine the correlates of ‘staying on the STEM path’ in high school, i.e., taking the math and science courses needed for university STEM programs and then applying to and registering in such programs. Our data suffer less from reporting and recall error, and from response and selection bias than do survey data. We have students’ actual high school courses taken and grades earned for a complete cohort of Ontario students. We also have all university application and registration records for nine years for all Ontario universities.

We have two key empirical findings. First, the most important reason for failure to prepare for a university STEM program is the rate at which students stop taking university and mixed courses in science at Levels 3 and 4. These are the levels when courses in these subjects are no longer required for the Ontario Secondary School Diploma. Extensive multivariate analysis indicates that the key determinants of the decision to stay on the 'STEM preparation path' are the students' previous grades in science and math, especially at the point when the subject becomes optional. Non-academic factors, such as gender, place of birth, average income and other neighbourhood characteristics, play predictable but quantitatively smaller roles.

Second, the most important correlate of the likelihood of applying to or registering in a university STEM program is the number of Level 4 university or mixed science courses passed. The second most important determinant is the GPA earned in such science courses. The number of math courses taken and the math GPA both have the expected positive effects, but the magnitudes of the effects are much smaller than in science, especially with regard to number of courses. Non-academic factors, such as gender, place of birth, average income and other neighbourhood characteristics have significant but much smaller quantitative effects.

A very positive policy conclusion can be drawn from our findings regarding the educational system in Ontario. The overwhelming determinant of whether or not students stay on the STEM path throughout high school and proceed to university STEM programs is individual academic performance. Grades at each level of high school critically influence who stays on the STEM path at the next level. The number of Level 4 science courses taken and grades earned are the key factors associated with application to and registration in university STEM programs. This is true of males and females, immigrants and the native born, and those from advantaged and disadvantaged neighbourhoods. The importance of grades in science and math remained when we estimated models with fixed effects for both high school and neighbourhood.
The above findings echo those reported in a paper coauthored by two of the coauthors of this paper. In Dooley, Payne and Robb (2012), we used OUAC data linked to administrative data from four Ontario universities to examine the correlates of four measures of persistence and success in university: cumulative grade averages, credits completed, departures during the first two years, and degree completion within six years. Our key empirical findings were two. First, the grade point average in Level 4 university and mixed courses was strongly linked to all of our university outcomes in the sense of both the magnitude and the precision of the estimated regression coefficients. Second, the individual, neighbourhood and high school characteristics, which are similar to those used in the current study, have weak links with university outcomes. The explanatory power of the high school grades greatly dominates that of other variables considered individually or jointly.

The positive message from this earlier paper is similar to the message of our current findings. Our 2012 paper found that students with similar grades in Level 4 university and mixed courses had very similar chances of success in university regardless of the neighbourhoods or high schools from which they came. In the current paper, we push that analysis back further to Level 1 high school courses and reach a very similar conclusion. Staying on the STEM path through high school and into university programs is overwhelmingly a function of grades earned in STEM courses at each level and of the types of course taken at Level 4.

We concluded the 2012 paper by commenting that our findings left a very big question unanswered. What lies behind the variation in Level 4 high school grades? Our current findings leave unanswered an even bigger question: What lies behind the variation in math and science grades at all levels of high school? The 'black box' to which we then pointed appears to have grown in size. As we stated earlier, one possibility is that grades stand as a proxy, in part, for family level variation in economic resources, though the studies reviewed in that paper and in the current one do not indicate that income *per se* is a key factor in accounting for persistence in university. A second possibility we mentioned is that high school grades mainly reflect cognitive ability or intelligence quotient (IQ), but we noted that an accumulating body of research casts doubt on this interpretation (Bowen, Chingos & McPherson 2009). We pointed to a growing number of studies that look to traits other than cognitive ability, such as personality and motivation, for answers (Borghans et al., 2008).

We concluded then and conclude now that much better data are needed to understand the mix of individual, home and school inputs that ultimately account for success in both high school and university. Administrative data clearly play a useful role, and this study has significantly expanded the administrative information available for analyzing these critical questions. However, detailed survey data also have a central role to play especially in uncovering the personal and environmental factors that lie behind individual levels of academic achievement and persistence.

8. Tables

Table 1: Students Passing an Academic, University or Mixed (AUM) Course(s)

		(1)	(2)	(3)	(3)
	Academic Level	Number Passing AUM Course(s)	Number Passing AUM Course(s)/Number Passed AUM Course(s) in Previous Level	Number Passing AUM Course(s)/Number Entering Cohort	Number Passing AUM Course(s)/Number Passing Level 1 AUM Course(s)
	Entering Cohort = 135,307				
		Math & Science			
(1)	1	90,009		67%	100%
(2)	2	76,311	85%	56%	85%
(3)	3	60,144	79%	44%	67%
(4)	4	33,558	56%	25%	37%
		Math			
(5)	1	95,172		70%	100%
(6)	2	80,443	85%	59%	85%
(7)	3	73,102	91%	54%	77%
(8)	4	52,507	72%	39%	55%
		Science			
(9)	1	98,408		73%	100%
(10)	2	88,186	90%	65%	90%
(11)	3	67,616	77%	50%	69%
(12)	4	39,372	58%	29%	40%
* Authors' calculations					

Table 2: Probit Average Marginal Effects for Likelihood of Completing Academic, University or Mixed (AUM) Levels 2, 3 and 4 of Math and Science

		(1)	(2)	(3)	(4)	(5)	(6)
		Math 2	**Math 3**	**Math 4**	**Science 2**	**Science 3**	**Science 4**
(1)	Prior Level AUM Math Grade 60%-70%	0.109***	0.064***	0.083***	0.034***	0.035***	0.002
		(0.003)	(0.003)	(0.005)	(0.002)	(0.004)	(0.006)
(2)	Prior Level AUM Math Grade 70%-80%	0.199***	0.112***	0.150***	0.055***	0.055***	0.000
		(0.004)	(0.005)	(0.005)	(0.003)	(0.004)	(0.006)
(3)	Prior Level AUM Math Grade 80%-90%	0.259***	0.164***	0.236***	0.072***	0.068***	0.003
		(0.005)	(0.006)	(0.006)	(0.004)	(0.005)	(0.007)
(4)	Prior Level AUM Math Grade 90%+	0.264***	0.220***	0.423***	0.067***	-0.073***	-0.069***
		(0.008)	(0.020)	(0.010)	(0.008)	(0.004)	(0.008)
(5)	Prior Level AUM Sci Grade 60%-70%	0.067***	0.040***	0.100***	0.070***	0.110***	0.189***
		(0.003)	(0.003)	(0.006)	(0.002)	(0.004)	(0.006)
(6)	Prior Level AUM Sci Grade 70%-80%	0.116***	0.076***	0.193***	0.121***	0.213***	0.348***
		(0.003)	(0.003)	(0.006)	(0.003)	(0.004)	(0.006)
(7)	Prior Level AUM Sci Grade 80%-90%	0.158***	0.095***	0.241***	0.148***	0.343***	0.507***
		(0.005)	(0.006)	(0.008)	(0.005)	(0.005)	(0.007)
(8)	Prior Level AUM Sci Grade 90%+	0.149***	-0.005	-0.053***	0.143***	0.502***	0.664***
		(0.008)	(0.006)	(0.006)	(0.008)	(0.009)	(0.010)
(9)	Female	-0.010***	-0.003	-0.046***	0.007***	-0.030***	-0.071***
		(0.002)	(0.002)	(0.004)	(0.002)	(0.003)	(0.004)
(10)	Canadian Born	-0.030***	-0.018***	-0.072***	-0.010***	-0.041***	-0.072***
		(0.004)	(0.004)	(0.006)	(0.003)	(0.005)	(0.006)
(11)	Low-Income Neighbourhood	-0.005	-0.012***	-0.004	-0.003	-0.014**	0.000
		(0.004)	(0.004)	(0.006)	(0.003)	(0.005)	(0.007)
(12)	Middle-Income Neighbourhood	0.003	0.009**	0.023***	0.007*	-0.005	0.004
		(0.004)	(0.004)	(0.007)	(0.004)	(0.006)	(0.007)
(13)	% Neighbourhood BA Degree	0.002***	0.001***	0.001***	0.001***	0.001***	-0.002***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
(14)	% Neighbourhood Unemployed Age 15+	0.003***	0.000	0.003	0.003***	0.008***	0.006***
		(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)
	Observations	90,009	77,949	71,201	90,009	83,840	65,786
	Sample Proportion	0.85	0.91	0.72	0.9	0.77	0.58
	Robust standard errors in parentheses						
	*** p<0.01, ** p<0.05, ** p<0.10						
	*Authors' calculations. For both Level 2 probits, we use the sample of students who completed academic math and science in Level 1. For the 3 and 4 probits, we use that sample of individuals who completed the AUM course in that subject in the previous level. Samples differ slightly from those in Table 1 due to missing data for other independent variables. In the math (science) probits, those students who did not take science (math) at the previous level are included in the omitted category for science (math) grades at the previous level. The units for the proportion of the neighbourhood with a BA degree and the proportion unemployed are percentage points, i.e., a seven per cent unemployment rate is 7.0.						

	The omitted category in the math (science) probits is a male born outside Canada and from a high income neighbourhood who received an AUM math grade of less than 60% at the previous level and either received an AUM science (math) grade of less than 60% at the previous level or did not take AUM science (math) at the previous level.

Table 3: Applicants to University STEM Programs by Number of Level 4 University/Mixed (UM) Math and Science Courses Passed

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Both UM Math and Science		**One of UM Math or Science**		**Neither UM Math nor Science**		**Total**	
(1)	Total number of applicants	331953	51%	185180	29%	130,900	20%	648,033	100%
(2)	Number of applicants who applied to one or more STEM programs	263051	82%	41133	13%	17919	6%	322,103	100%
(3)	Share of applicants who applied to one or more STEM programs	79%		22%		14%		50%	
(4)	Number of STEM applicants who likely received an offer to a STEM program	235651	85%	28853	10%	11363	4%	275,867	100%
(5)	Share of STEM applicants who likely received an offer to a STEM program	90%		70%		63%		86%	
(6)	Number of likely recipients of STEM offers who registered in a STEM program	173284	93%	9889	5%	3448	2%	186,621	100%
(7)	Share of likely recipients of STEM offers who registered in a STEM program	74%		34%		30%		68%	
(8)	Number of registrants in a STEM program	173289	93%	9889	5%	3448	2%	186,626	100%
(9)	Share of university applicants who registered in a STEM program	52%		5%		3%		29%	
(10)	Share of university STEM applicants who registered in a STEM program	66%		24%		19%		58%	
	*Authors' calculations								

Table 4: Probit Average Marginal Effects of Application to and Registration in a University STEM Program (All courses measured are for Level 4 University and Mixed)

		(1)	(2)
		Likelihood of Applying to 1+ STEM Programs	**Likelihood of Registering in 1+ STEM Programs**
(1)	Six Best GPA 70% - 80%	-0.045***	0.207***
		(0.002)	(0.004)
(2)	Six Best GPA 80% - 90%	-0.097***	0.198***
		(0.002)	(0.004)
(3)	Six Best GPA 90%+	-0.162***	0.155***
		(0.004)	(0.005)
(4)	Science GPA 70% - 80%	0.040***	0.055***
		(0.002)	(0.002)
(5)	Science GPA 80% - 90%	0.074***	0.092***
		(0.003)	(0.002)
(6)	Science GPA 90% +	0.109***	0.112***
		(0.004)	(0.003)
(7)	One Science Completed	0.145***	0.088***
		(0.002)	(0.003)
(8)	Two Science Completed	0.363***	0.264***
		(0.002)	(0.002)
(9)	Three+ Science Completed	0.539***	0.365***
		(0.003)	(0.003)
(10)	Math GPA 70% - 80%	0.008***	0.019***
		(0.002)	(0.001)
(11)	Math GPA 80% - 90%	0.032***	0.040***
		(0.002)	(0.002)
(12)	Math GPA 90% +	0.094***	0.068***
		(0.003)	(0.003)
(13)	One Math Completed	0.049***	0.036***
		(0.002)	(0.002)
(14)	Two+ Math Completed	0.116***	0.098***
		(0.003)	(0.003)
(15)	Female	-0.030***	-0.027***
		(0.001)	(0.001)
(16)	Canadian Citizen	-0.037***	-0.006***

		(1)	(2)
		Likelihood of Applying to 1+ STEM Programs	**Likelihood of Registering in 1+ STEM Programs**
		(0.003)	(0.002)
(17)	Late Finish in High School	-0.025***	-0.021***
		(0.002)	(0.001)
(18)	Low-Income Neighbourhood	-0.006**	-0.011***
		(0.003)	(0.002)
(19)	Middle-Income Neighbourhood	-0.001	-0.003
		(0.002)	(0.002)
(20)	% Neighbourhood BA Degree	0.001***	0.0001
		(0.0002)	(0.0001)
(21)	% Neighbourhood Unemployed Age 15+	0.001***	0.001***
		(0.0002)	(0.0002)
	Observations	648,033	648,033
	Sample Proportion	0.5	0.29
	Robust standard errors in parentheses		
	*** p<0.01, ** p<0.05, * p<0.10		
	*Authors' calculations. The units for the proportion of the neighbourhood with a BA Degree and the proportion unemployed are percentage points, i.e., a seven per cent unemployment rate is 7.0. The omitted category is a male immigrant who finished high school in four years and had the following: six best GPA of less than 70%; either no science courses completed or a science GPA of less than 70%; either no math courses completed or a math GPA of less than 70%; and either no English/French courses completed or an English/French GPA of less than 70%. (All courses refer to Level 4 University or Mixed.)		

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