Foreign Peer Effects and STEM Major Choice

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Abstract

This paper examines whether foreign-born peers affect the likelihood U.S. college students graduate with a STEM major. Using administrative student records from a large public university in California, we exploit idiosyncratic variation in the share of foreign peers across introductory math courses taught by the same professor over time. Results indicate that a 1 standard deviation increase in foreign peers reduces the likelihood domestic students graduate with STEM majors by 3.3 percentage points – equivalent to 3.7 domestic students displaced for 9 additional foreign students in an average course. Importantly, earnings prospects are not affected because marginal students respond by switching into relatively high paying Social Science majors. We test several plausible mechanisms underlying these effects and demonstrate that STEM displacement can be attributed to changes in the communicative environment within classes.

Key Words: immigration, peer effects, higher education, college major, STEM.
JEL Codes: I21, I23, I28, J21, J24.

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1 Introduction

Encouraging skill acquisition in Science, Technology, Engineering and Mathematics (STEM) fields has been an important policy goal in the United States. However, global assessments show Americans continually lagging the rest of the world in Math and Science.[1] Higher education has been an area of particular concern. Between 1985 and 2010 the share of undergraduates completing STEM degrees declined by 5 percentage points (Figure 1) and nearly 50% of intended STEM majors end up either switching to non-STEM fields or dropping out (Chen, 2013). Because STEM college degrees often impose a barrier to STEM jobs, growing disinterest and attrition in college may eventually manifest in a shrinking STEM labor force.

At the same time, US higher education has sustained large increases in foreign-born students. From 1980 to 2010, universities saw foreign-born representation increase from 7.5% of total enrollment to 13% (Figure 1). While in the 80's and 90's, this increase was mostly driven by foreign-born permanent resident students, recent years have seen surges in the total number of "international students" on temporary visas (Bound et al., 2016). This paper explores whether the growing presence of foreign-born peers in higher education affects the decision to major in STEM fields.

Understanding the factors affecting STEM degree attainment is important for long run economic growth. The supply of STEM workers depends on the educational acquisition of STEM knowledge and skills, particularly at the post-secondary level. Failure to obtain a STEM degree presents a large obstacle to working in STEM occupations–among individuals with a college degree in a non-STEM field, fewer than 9% report working in a STEM occupation.[2] Because scientists and engineers are the primary contributors to technological innovation, and aggregate productivity growth (Griliches, 1992; Jones, 1995; Kerr and Lincoln, 2010; Peri, Shih and Sparber, 2015), declining interest in STEM majors is likely to reduce the STEM labor force and ultimately dampen economic growth.

From an individual perspective, those with STEM skills tend to earn higher wages than those without such skills. The difference in earnings across low and high paying majors rivals the high school-college wage gap (Altonji, Blom and Meghir, 2012) and the earnings inequality across many high paying STEM and low paying non-STEM majors has been widening over time (Altonji, Kahn and Speer, 2014).[3] Recent evidence indicates that the returns to high paying majors

[1]See PISA (2015), for example.

[2]Authors' tabulations from individuals age 30 and under, reporting both college major and occupation in the 2009-2016 ACS. STEM occupations categorized according to the Bureau of Labor Statistics' classification: `https://www.bls.gov/soc/Attachment_C_STEM.pdf`.

[3]Altonji, Blom and Meghir (2012) show that even after conditioning on basic demographics and potential experience, the log wage gap between Mathematics/Computer Science majors relative to General Education majors (0.638

may be even larger than the returns to attending selective institutions (Kirkeboen, Leuven and Mogstad, 2016; Arcidiacono, Aucejo and Hotz, 2016). Therefore, factors impacting major choice may explain observed patterns in earnings inequality among skilled workers.

Concerns over STEM graduation rates have stimulated inquiry into the factors affecting STEM major choice. At the individual level, poor preparation (Stinebrickner and Stinebrickner, 2011) or underestimation of the true labor market returns (Wiswall and Zafar, 2015) have been associated with disinterest in STEM majors. Other studies have identified a lack of female professors and improper matching of students to universities as contributing factors to gender and racial differences in STEM attainment (e.g. Carrell, Page and West, 2010; Arcidiacono, Aucejo and Hotz, 2016). Recent studies using geographic variation in immigrants find pronounced negative impacts on the likelihood of majoring in STEM (Orrenius and Zavodny, 2015; Ransom and Winters, 2016).

This study is the first to link exposure to foreign-born peers in college classrooms to eventual completion of particular fields of study. Existing studies on foreign peer impacts have solely focused on primary and secondary education, often in settings outside the United States. While informative, the literature remains far from conclusive. Using cross-country variation, Brunello and Rocco (2013) find that increases in immigrant students in secondary schooling are associated with small reductions in the test scores of native-born students. Gould, Lavy and Daniele Paserman (2009) find that exposure to immigrant peers in Israel in the 5th grade results in lower test scores during high school. Ballatore, Fort and Ichino (2015) find sizable negative and persistent impacts of immigrant students on native students' performance in Italian primary schools.

In contrast, several papers find positive or no impacts from foreign peers. Using variation in foreign students across classes in Dutch primary schools, Ohinata and Van Ours (2013, 2016) find no evidence of negative impacts on test scores of native students. Geay, McNally and Telhaj (2013) similarly find no effects of immigrant primary students in England. Diette and Oyelere (2012, 2014) examine immigrant peers in North Carolina public schools. Interestingly, their results indicate positive impacts at the middle to lower end of the ability distribution, and negative impacts towards the top. Finally, very recent studies by Conger (2015) and Figlio and Özek (2017), use administrative data from Florida and find no effect of immigrant peers or refugees on the academic performance of native-born students. There have also been a small number of inquiries into whether international students crowd-out native students in postsecondary education (Hoxby, 1998; Borjas, 2004; Shih, 2017), and a broader literature about the relationship between immigration and education (Betts, 1998; Cascio and Lewis, 2012; Jackson, 2015; Hunt, 2017). We are not aware of any studies that have examined impacts on intensive-margin outcomes in college. Dis-

log points for males, 0.722 log points for females) is even larger than the college vs. high school wage gap (0.577 log points).

tinct from prior literature, this paper examines undergraduate education and estimates the impact of foreign peers on STEM major attainment.

Several stylized facts motivate the link between foreign peers and STEM major. First, unconditionally, foreign students exhibit a high predilection for STEM fields.[4] Therefore, students in STEM fields are likely to be exposed to more foreign peers in their classes than those in non-STEM fields.

Second, foreign-born college students on average exhibit lower levels of preparedness and face many barriers to education (Erisman and Looney, 2007). In particular, weaker English proficiency contributes to decreased communicative engagement in class.[5] Recent evidence has linked disruptions to the communicative environment within classrooms to lasting negative impacts on students' schooling outcomes and future labor market success (Carrell and Hoekstra, 2010; Carrell, Hoekstra and Kuka, 2016). Therefore, foreign students who communicate less, may reduce the scope for positive externalities that arise from peer-to-peer or peer-to-instructor interactions. Alternatively, instructors alter their lecture style or divert attention away from American students to accommodate foreign students.

Lastly, our student level data indicates that foreign students on average possess a comparative advantage in STEM-related disciplines. Exposure to foreign peers may lead students to update their prior beliefs on their own relative ranking in terms of comparative advantage in STEM, and accordingly switch to non-STEM fields. Recent work has shown that exogenous changes to an individual's relative ranking within classrooms, due to different peer composition, even conditional on her absolute ability and her ability relative to overall means, can impact confidence and educational performance (Murphy, Weinhardt et al., 2014; Elsner and Isphording, 2017; Cicala, Fryer and Spenkuch, 2017). Outside of education, Peri and Sparber (2009, 2011) show that inflows of immigrants with strong comparative advantage in tasks requiring particular skills (e.g. manual strength, quantitative ability) lead native-born workers to switch towards occupations requiring different skills (e.g. communication).

This paper utilizes administrative student-level data from a large, selective public university in California, which covers the academic years 2000-01 through 2011-12. Our empirical design relates foreign peer exposure during one's first-term introductory math course to the eventual likelihood of graduating with a STEM degree. Student Peers are identified as foreign if they are

[4]Recent statistics show that nearly 40% of foreign bachelor's recipients major in STEM, while the comparable figure for natives is only 31%. See NSF Science and Engineering Indicators 2012: https://www.nsf.gov/statistics/seind12/c2/c2s2.htm

[5]Much qualitative evidence has examined contributing factors to the lower vocal engagement of foreign students (e.g. Horwitz, Horwitz and Cope, 1986; Rodriguez and Cruz, 2009; Stebleton, Huesman Jr and Kuzhabekova, 2010; Stebleton, 2011; Yamamoto and Li, 2011). Borjas (2000) finds that foreign graduate student Teaching Assistants lead to lower performance of students, possibly due to poorer communication.

non-citizens and indicate a foreign nationality: Legal Permanent Residents, Non-Resident Aliens, Non-documented Residents. Inferring changes in STEM degree attainment from these introductory calculus-based courses is appropriate as they have long been considered a gateway class for STEM majors (Steen, 1988). Over 70% of all students in our data take an introductory math course as it is a prerequisite to virtually every STEM major, and also satisfies a university-wide quantitative course requirement.

We leverage variation in the share of a student's peers that are foreign within classes taught by the same instructor/professor over time.[6] Our motivation follows from the ideal experiment, which would hold fixed the instructor, course material, and all other classroom factors, and only vary the share of foreign peers. We focus our main analysis on domestic American students – students with U.S. citizenship – that take introductory math during their first college term, which has the benefit of reducing the scope for selection bias by minimizing confounding exposure in prior college courses. We also measure foreign peer composition of each class on the day prior to the first day of instruction to nullify the influence of later withdrawals or additions to the class after students observe their peers.

Balancing tests on various individual background characteristics, including race, gender, and ability measures, show no consistent evidence of selection and support the notion that the variation in the foreign share within courses taught by the same instructor is as good as random. Additionally, our estimates are not confounded by mechanical crowd-out whereby the entry of foreign students prevents some native domestic students from registering for the class. This is because introductory math classes have high enrollment caps that never bind in our setting. Further, our estimates remain robust when controlling for bias arising from contemporaneous shocks, such as increases in class size associated with more foreign peers.

We find evidence that foreign peers lower the likelihood that American students graduate with a STEM major. A 1 standard deviation increase in the foreign share in the introductory math class reduces the probability of graduating in STEM by 3.3 percentage points, or 6% of the mean. This implies that for an average-sized class, an additional 9 foreign students displaces 3.7 domestic freshmen from graduating with STEM majors. However, the earnings prospects of American students remain unchanged. Displacement from STEM is offset by increases in the likelihood of majoring in relatively high earning Social Science majors. Domestic student displacement is not offset by an increased likelihood of foreign students graduating in STEM, indicating that foreign peers ultimately reduce the aggregate number of STEM graduates.

We test several plausible channels for our findings (linguistic dissonance, signal on own com-

[6]Similar identifying strategies that rely on idiosyncratic variation include Carrell and Hoekstra (2010), Hoxby (2000) and Anelli and Peri (2017)

parative advantage in STEM and social preferences) and show evidence that low levels of communication skills are the most important underlying mechanism. STEM displacement is entirely driven by foreign peers with low measures of communication ability. This effect is exacerbated in courses in which the overall communicative environment is affected further by low levels of English proficiency of the instructor. To the contrary, foreign peers who have above average levels of English proficiency appear to have no impact.

Analyses of student heterogeneity further corroborate our findings. Domestic students with relatively weak comparative advantage in STEM fields are most affected. These students are naturally at the margin of the choice between STEM and non-STEM fields and are thus the most likely to be influenced by the learning experience in these introductory math classes. There are no detectable impacts on females suggesting that foreign peers do not exacerbate the existing gender gap in STEM attainment.

We proceed by describing the institutional setting and our data in the next section. Section 3 details our empirical framework and provides tests of selection on observables. Results and robustness checks are presented in section 4. Section 5 describes and tests various mechanisms underlying our main findings. Section 6 concludes.

2 Data

2.1 Institutional Setting

This paper uses administrative data from a selective public research university in California. Current enrollment exceeds 30,000, with undergraduate students comprising roughly 80%. The average SAT scores of incoming students are usually one standard deviation above the national average. The university consistently rank among the top 20 public universities in the United States.

Undergraduate degrees can be earned in more than 100 different majors. Applicants may declare a major or may remain undeclared. Students are required to formally declare a major before accumulating credits equal to two full-time years of course work. To switch majors students must obtain approval from an advisor in the major they wish to leave and from an advisor in the major they wish to join. Each year roughly 7,000 students earn bachelors degrees, with STEM majors (e.g. Biology, Chemistry, Mechanical Engineering) comprising half of the top 20 most popular majors. Within each entering cohort, approximately 50-60% of students graduate within 12 terms (4 years), 70-80% in 15 terms (5 years), and 80-85% in 18 terms (6 years).

The academic calendar follows a trimester schedule, with instruction occurring over three terms. Students register for courses online within an assigned 4-hour window. Registration dates and times are assigned by academic seniority. Students are divided into 4 bins demarcated by the normal accumulated credits for freshmen, sophomores, juniors, and seniors. Within each bin, however, the exact times and dates are assigned randomly. If a student misses their registration window, the online system is reopened to all students after all 4 hour registration windows have passed.

We utilize multiple administrative datasets. These contain all course registration activity of students by term as well as background information on each student, including SAT scores, race, gender, nationality, and visa status. We observe outcomes for each student (e.g. course grades, GPA, graduation, major, etc.) measured term by term. For each course, we observe the title, department and the identity of the instructor. These data span the academic years 2001-2002 to 2011-2012.

We measure exposure to foreign peers during a student's first-term at the university. This is the cleanest measure of exposure, as new freshmen have no prior educational experiences or interaction with foreign peers at the institution and still represents the large majority (on average 56%) of students enrolled in these courses. We hone in on exposure in introductory math courses (generally calculus-based). These have long been viewed as gateways to STEM degrees (Steen, 1988) as they provide necessary prerequisites for continued progression in STEM majors. Within U.S. higher education, such courses generally cover uniform subject material, thereby limiting the scope for potential issues arising from differences in subject matter breadth and depth, while also enhancing the generalizability of our findings.

Students are identified as foreign if they are non-citizens and indicate a foreign nationality. Domestic students are those that are U.S. citizens, which include native-born and immigrants that obtained citizenship, likely to be highly assimilated and face similar incentives as native-born individuals.

Foreign peer exposure is measured within classes, which are identified by a course, professor, and term. The class is a natural unit where peer interactions might occur as students attend lectures in the same physical location at the same time, and are evaluated jointly by the professor with the same exams and assignments.[7] We adopt a standard peer measure for each student by calculating the fraction of their peers in the introductory math class that are foreign. Foreign students need not be first-term freshman to be counted in our peer measure.

Introductory math courses are identified as follows. In the university we study, all students must satisfy at least one quantitative course requirement, and institutional rules prevent using Advanced

[7] In rare instances when a single professor teaches multiple sections of the same course in a given term, the students in different sections are treated as distinct peer groups. In the data, a professor teaches two sections of the same course in the same term 6 times out of 181 different course-professor offerings.

Placement credits as a substitute. The list of eligible courses include many mathematics courses and some non-mathematics courses. To better identify gateway courses for STEM majors, we compiled a list of mathematics courses that are required prerequisites for each STEM major. We then defined introductory math courses as those that satisfy both the quantitative and STEM major requirements. As a final refinement, we removed courses requiring college course prerequisites which cannot be taken by first-term freshmen.

The list of introductory math courses is shown in Table 1. These courses are all calculus-related. Due to the various STEM major and university quantitative requirements, these courses are large, with an average class size of 230 students. Note, our analysis includes high achieving freshmen who place out of more basic courses, as evidenced by the presence of more advanced courses like Calculus III.[8] Nonetheless, a majority of the domestic freshmen in our sample take one of the more basic courses (e.g. Precalculus, Calculus I) as their first math course. Figure 2 displays histograms of the overall variation in the foreign share across introductory math classes. While the foreign share ranges between 8-15%, some classes have less than 5%, and a few have greater than 20%.

Approximately 70% of all students in our data take an introductory math course at some point during their undergraduate studies, with over 40% of domestic students in each entering cohort enrolling during their first term. These courses have very high enrollment caps that never bind – in our sample, enrollment never exceeds 40% of the cap. This high cap implies that having an earlier registration time does not affect an individual's ability to enroll in a specific introductory math course. Furthermore, domestic students cannot be mechanically crowded-out of these classes when more foreign students enroll.

The administrative data contain all course registration activity for each student, which we use to construct rosters for each introductory math class, identified by the course number, instructor, and term offered. We reconstruct the rosters on the day prior to the first day of instruction. As such, they reflect the class composition *before* students have met the professor, examined the syllabus, or been physically present to meet their peers. Continued registration activity beyond the first day of instruction also identifies whether students add or drop the class. To the class rosters we link in each student's background characteristics (e.g. gender, ethnicity/race, nativity, high school GPA, etc.) and future outcomes (e.g. course grade, graduation in STEM major, etc.).

We focus our analysis on students' majors at graduation, which provides a more definitive measure of both choice and skill acquisition. Students that graduate are assigned one of three outcomes – STEM degree, Social Science degree, or Arts & Humanities degree. Because upwards

[8]Students enrolling in introductory math courses must take an exam to determine whether they can enroll in Calculus I, or whether they have sufficient knowledge to enroll in Calculus II or III.

of 80% of students complete the degree within 6 years (18 terms), we measure graduation outcomes within 6 years. Those that do not complete within 6 years are referred to as “dropouts”, however a small number may actually take 7+ years to graduate. Because the data on student outcomes ends in 2012, the fall 2006 entering cohort is the last one for which we can observe 6 year graduation outcomes. As such we limit the analysis to first-term freshmen in introductory math classes from fall 2000 through fall 2006.

Table 2 summarizes the background characteristics of undergraduate students. Column 1 and 2 refer to all domestic and foreign students enrolled during the period under analysis (2000-2006). Column 3 describes domestic first-term freshmen in introductory math courses, which represent our analytical sample. Column 4 displays statistics for foreign-born peers in the introductory math courses of domestic first-term freshmen.

While 56% of domestic students are female, only half of first-term domestic freshmen that enroll in introductory math courses are female. The same under-representation in the introductory math sample relative to their presence in the overall population is evident for domestic White and minority (Black and Latino) students. In contrast, domestic Asians appear to possess a strong predilection for taking introductory math courses early on. While Asians comprise only 37% of all domestic students, they represent roughly half of all the first-term freshmen enrolled in introductory math courses.

A similar pattern is observed for foreign students. The vast majority, nearly 80%, of all foreign students are Asian. The next most populous race groups among foreign-born are White students, followed by Latino students. The predominance of Asian students likely reflect the large immigration patterns from Asian countries to California, combined with higher rates of educational attainment for Asians overall.

Measures of background ability are provided in rows 7-11. High school GPA is measured on a scale from 0 to 4, SAT math and verbal scores range from 200-800, and the combined SAT score ranges from 0-1600. Also included is a weighted sum of various background ability and traits (composite score) calculated by the admissions office, which includes some measures available in our data and others that were not provided. The academic composite score ranges from 0-14,000. When comparing first-term freshmen in introductory math classes to the general student body, it is clear that domestic students taking math in their first term are more highly selected on all ability traits. Thus, students of higher preparedness are those likely to take the gateway math course in their first term.

Domestic and foreign students do not appear to be substantially different in terms of ability in the general student population. One exception is that foreign students exhibit lower SAT verbal scores, reflecting their lower English ability. This difference in English ability is magnified when comparing domestic first-term freshmen and their foreign peers in introductory math classes – SAT verbal scores of foreign peers are almost a full standard deviation below domestic students. Though differences in SAT verbal are the most salient, domestic freshmen outperform foreign peers in introductory math courses on all measures of background ability.

Columns 5 and 6 of Table 2 distinguish between international students on temporary visas and non-citizen immigrants, which may include permanent residents and undocumented students.[9] International students account for only 11% of foreign peers. The lower ability of foreign peers relative to domestic freshmen is driven by immigrant students. In contrast, international students appear at least as well prepared as domestic freshmen, and possess an absolute advantage in quantitative ability, as their SAT math scores exceed those of domestic freshmen by almost 0.5 of a standard deviation. The small sample of interntational students limits our ability to statistically distinguish effects of these two groups, but their characteristics are suggestive of potential differing impacts of immigrants and international student peers in the classroom.

Table 3 summarizes the key outcomes of interest for students in introductory math courses. The top panel provides major completion outcomes. Approximately 82% of entering domestic freshmen graduate within 6 years, whereas 18% dropout or take greater than 6 years. While domestic students graduate with an average GPA of 3.05, foreign students perform slightly lower. Students that graduate take slightly more than 16 terms, or 5.33 years to complete their degree.

STEM is the most popular major at graduation for domestic students that take introductory math as first-term freshmen, with 48% going on to complete a STEM degree in 6 years. Almost one-third of domestic freshmen taking introductory math end up graduating with a Social Science degree. Completion outcomes are similar for foreign born peers, although foreign students complete STEM degrees at a slightly lower rate. This suggests that if domestic students are displaced from STEM majors, foreign students would have to substantially increase their STEM completion rates to prevent the total number of STEM majors from declining.

3 Identification and Empirical Model

We aim to identify the causal impact of foreign peers on STEM degree attainment. We utilize idiosyncratic variation in peer composition (Hoxby, 2000; Carrell and Hoekstra, 2010; Anelli and Peri, 2017) in introductory math classes which creates treatments that are as good as randomly assigned. To estimate the impact of foreign peer exposure on the majors of domestic students, we

[9]Unfortunately, our data do not allow us to distinguish further between foreign-born permanent residents and undocumented students. However, it is unlikely that the foreign peers we study contain many undocumented immigrants as they disproportionately come from South and Latin America, with very few from Asia.

estimate the following linear probability model:[10]

$$Y_{icpt} = \alpha + \beta \frac{F_{cpt}}{N_{cpt} - 1} + \sigma_{ct} + \sigma_{cp} + \gamma_1 X_{cpt} + \gamma_2 X_i + \varepsilon_{icpt} \quad (1)$$

Equation 1 regresses individual outcome (Y_{icpt}) for student i attending introductory math course c with professor p in term t on the share of individual i's peers that are foreign ($\frac{F_{cpt}}{N_{cpt}-1}$). Our primary outcome is a binary measure of whether or not student i graduates with a STEM degree in a six-year time frame. We control for course-by-term indicators (σ_{ct}) and course-by-professor fixed effects (σ_{cp}). The empirical design therefore forces the identifying variation to come from changes in the foreign share within courses c taught by the same professor p over time t.

We also control for course level factors to account for common shocks: X_{cpt} includes peer ability measures, such as average peer SAT Math, SAT verbal, and high school GPA, and average peer race and gender composition. We also account for class size as Ballatore, Fort and Ichino (2015) finds that while inflows of foreign students in Italian primary schools raised the peer composition within classes, they also increased class size. X_i measures individual characteristics which include the race, gender, and ability variables described in Table 2. Finally, ε_{icpt} is a mean-zero error term. We cluster standard errors at the professor level. We also standardize the foreign share so that the primary coefficient of interest β can be interpreted as the impact of a 1 standard deviation increase in the foreign class share on the outcome, in units of Y.

Figure 3 visualizes our identifying variation. It shows within course-professor variation for a random sample of 10 course-professor pairs. Each point represents the foreign composition within a particular introductory math course taught by a particular professor in a given term. Connected lines facilitate visual tracking of course-professor pairs over time. Our analysis compares the outcomes of freshmen students enrolled in class A, against the outcomes of freshmen who enrolled in class B. Students across these two classes took the same course (introductory calculus), with the same professor, but were exposed to very different levels of foreign peers by virtue of entering the university and enrolling in introductory math in different terms. We argue that the differences in the class compositions of A and B are driven by random fluctuations, and that the freshmen students in the two classes are comparable.

[10]We performed robustness checks using logit and probit to evaluate the assumption of the linearity of the conditional expectation function. Results from logit and probit estimation (available on request) reveal that average marginal effects are very similar in size to estimates from OLS, and consistent across the distribution of the foreign share. However, several papers (e.g. Greene, 2004) have cautioned against using logit or probit estimation with fixed effects as it can generate biased and inconsistent results. Hence, we present our analysis using a linear probability model.

3.1 Selection, Common Shocks and Reflection

Estimating peer effects can be difficult due to three main issues: selection, common shocks and reflection (Manski, 1993; Moffitt, 2000; Sacerdote, 2011). We discuss in greater detail how our data, setting, and identification strategy allow us to overcome each of these issues.

Selection of students into classes that is related to the foreign peer composition would bias our estimates. We take several precautions to guard against selection. Qualitatively, we focus on first-term freshmen whom have little prior experience, or knowledge about professor reputation, course detail, and peer composition at the time of registration.[11] Additionally, we measure the peer composition of students registered for each course on the day prior to the first day of instruction. Thus, we measure foreign peers before students ever physically attend a class and meet their peers.

Further, our identifying variation in foreign peers comes from courses taught by the same professor over time. Endogenous selection in this context would manifest in students reliably predicting the current and future foreign composition, or any other characteristic correlated with the presence of foreign peers, and timing their enrollment in a course-professor pair accordingly. This is highly unlikely as instructor assignments to courses are decided only in the middle of the prior term, so that at the start of each term, instructors themselves are not necessarily aware of their future teaching assignments. Additionally, alongside tenured and tenure-track faculty, the usage of temporary lecturers and visiting professors to staff introductory courses makes predicting future instructors quite difficult.

We empirically test for selection on observables by examining whether domestic students who enroll in the same course-professor pair, but experience varying levels of foreign peer exposure, are different along observable background characteristics. Specifically, we estimate the following regression model:[12]

$$C_i = \alpha + \delta \frac{F_{cpt}}{N_{cpt} - 1} + \sigma_{ct} + \sigma_{cp} + \epsilon_{icpt} \quad (2)$$

Equation 2 regresses individual background characteristics of domestic student i (C_i), on the share of her peers that are foreign in the course ($\frac{F_{cpt}}{N_{cpt}-1}$). To force the identifying variation to come from changes in the foreign share within courses c taught by the same professor p across terms t, the model includes course-by-professor fixed effects σ_{cp} and course-by-term indicators σ_{ct}. Standard errors are clustered at the professor level. The foreign peer share is standardized, so

[11] Enrollment of freshmen for first-term courses is done online even before students are physically present on campus

[12] We also run a similar test where the dependent variable is the foreign share, and all background characteristics of domestic students are on the right hand side. The results are shown in Table A2. The F-test has a p-value of 0.15, showing no evidence of joint significance.

that the coefficients reflect the impact of a one standard deviation increase in the foreign share.

The results of these tests are displayed in Table 4. Each column corresponds to a regression of $\frac{F_{cpt}}{N_{cpt}-1}$ on a different individual background characteristic (C_i).[13] None of the estimates are statistically distinguishable from zero at any meaningful level of confidence, nor are they economically significant. The coefficient estimate in column 7, for example, indicates that a one standard deviation increase in the foreign share is associated with an increase in a domestic student's SAT math score of 1.76 points (only 0.02 of a standard deviation in the same score). Given that a standard deviation on the SAT Math exam is 75 points, this estimate is economically insignificant. Thus, the results do not provide any evidence of selection on the basis of observable background characteristics. To further limit the scope of potential selection bias in our analyses of outcomes, we will include these individual background characteristics as controls to check whether their inclusion alters the estimated effects.[14]

Our approach addresses issues of reflection that occurs when explanatory peer measures can potentially be influenced by individuals. This usually is problematic when the peer measures is the average *outcome* of one's peers. However, we examine a peer background trait – citizenship – that is measured before students meet their peers. Thus, it is highly unlikely that domestic students could reasonably affect the citizenship status of their foreign peers before they even physically enter the classroom.[15]

Because we do not include peer outcomes, $\bar{Y}_{-icpt}$, in our specification, this also means that our model estimates a combination of the endogenous and exogenous peer effects (Carrell, Sacerdote and West, 2013), rather than attempting to separate the two. Mechanisms driving peer effects are often blends of these two channels anyways, so we do not feel that estimating a combination of the two channels detracts from the model. Moreover, the aggregate peer effect we estimate is the relevant one for policy.

Common shocks represent non-peer phenomena that impact all students in a class such as teacher quality or bad lighting in a classroom. In studies that use peer average outcome mea-

[13]The sample of 25,912 include both the 16,830 domestic first-term freshmen, and other domestic students (i.e. non-first-term freshmen, sophomores, juniors, and seniors) enrolled in the introductory math courses.

[14]We also check whether foreign students are selecting on observables based on the foreign peer composition in appendix Table A1. In Table A1, the same ten specifications as Table 4 are estimated, but instead focusing on the 3,840 foreign students taking an introductory math course. Out of ten coefficients, only SAT Verbal is significantly different from zero. A one standard deviation increase in foreign peers in a class is associated with a 14 point lower SAT Verbal score. Despite the statistical significance, the magnitude is relatively small (one-tenth of a standard deviation), such that we do not believe this small amount of selection is evident to students or making a meaningful difference in the classroom environment.

[15]Additionally, because domestic and foreign students are mutually exclusive groups, our analysis does not suffer from more recent concerns of mechanical negative bias (e.g. Guryan, Kroft and Notowidigdo, 2009; Fafchamps and Caeyers, 2016).

sures, common shocks create a spurious positive correlation between Y_i and $\bar{Y}_{cpt}$ without any real peer-effect occurring. By focusing only on the peer effects associated with pre-determined characteristics, we avoid this mechanical upward bias in our results. Controlling for course-by-term fixed effects accounts for both aggregate university shocks, such as changes in admission committee decisions on student composition, and course specific shocks, such as changes in grading standards or required instruction. Additionally, course-by-professor fixed effects help account for fixed differences, such as difficulty levels or pedagogical technique. Many types of class-level shocks are pseudo-random in nature and unlikely to be correlated with $\frac{F_{cpt}}{N_{cpt}-1}$.

4 Results

Table 5 shows the effects of foreign peers in introductory math courses on the eventual completed majors of domestic first-term freshmen, from Equation 1.[16] The outcome variable is an indicator equal to 1 if the student graduated with a STEM major within 6 years, and 0 otherwise. Column 1 includes the baseline peer ability, peer race and gender composition controls. Column 2 adds a control for course size. Column 3 controls for individual characteristics.[17] All models include course-by-term and course-by-professor fixed effects.

Panel A considers domestic students. The coefficient estimates in the first row indicate that foreign peers are negatively associated with the likelihood of completing a STEM major. A 1 standard deviation rise in the foreign class share reduces the probability of graduating with a STEM major by 3 percentage points. All estimates are statistically significant at the 5% level and robust to the addition of various controls. The coefficient is roughly 6% of the mean STEM graduation rate of 48%. By way of comparison, the magnitude of our estimate is equal in size to 1/2 of the US White-Black STEM gap and 1/5th of the STEM gap across genders.[18] We can also size our estimates by calculating the number of students displaced for a class that has all characteristics fixed at the means in our sample – 9 additional foreign students would displace between 3 and 4 domestic freshmen from STEM majors.[19]

[16]Among the various control variables used, we only report coefficients for peer ability measures due to space constraints. Results of the coefficients on other control variables are available upon request from the authors.

[17]Race, gender, and ability variables described in Table 2

[18]Data from the National Science Foundation show that the share of bachelors' degrees earned by White students that were in STEM fields was roughly 17% in 2011. The same share for Black students was 11%. The male STEM graduation rate in 2011 was 25% compared with only 11% for females. Hence, the White-Black STEM gap is around 6 percentage points, while the STEM gap between males and females is 14 percentage points. See (`https://www.nsf.gov/statistics/seind14/index.cfm/chapter-2/c2s2.htm#s2`).

[19]The mean size of introductory math classes is approximately 230 students. If this course had the average foreign share (approximately 13%) and the average share of domestic first-term freshmen (approximately 56%), it would comprise of roughly 30 foreign students and 129 domestic freshmen. Given that domestic freshman graduate in STEM

Column 4 provides a further test to ensure our foreign peer impacts are identified from exposure in introductory math courses. We include the foreign peer composition across all other classes taken by domestic first-term freshmen, excluding the introductory math class, as a control. The results are virtually unchanged. This indicates that the transmission of foreign peer impacts on STEM major choice occurs within introductory math classes, as opposed to in other courses.

Panel B considers the impacts of foreign peer exposure on foreign students. Results in all specifications are not statistically significant, perhaps do to the smaller sample size, but suggesting that foreign students do not respond to increased exposure to foreign peers. Thus, the displacement we observe for domestic students is not offset by an increased likelihood of foreign students persisting in STEM.[20] As a result, we should expect the total number of STEM graduates to decline with increases in foreign-born peers in classes.

In Table 6, we examine displacement outcomes. Our preferred specification from column 3 of Table 5, which includes all peer composition and individual level controls, is reprinted in column 1. Columns 2 and 3 examine the likelihood of completing a Social Science degree and Arts & Humanities degree, respectively. Column 4 examines the likelihood of dropping out.

The estimates show that the decline in graduating with a STEM major is offset by similar increases in graduating with a Social Science major. A one standard deviation increase in foreign peers is associated with a 2.2 percentage point increase in the likelihood of graduating with a Social Science major. Though the effect is imprecise, it borders on significance at the 10% level (p-value=0.15). The coefficients on graduating in Arts & Humanities and dropout are positive, but much smaller in magnitude and statistically indistinguishable from zero.

While we do not observe labor market outcomes directly[21], we can link each student's major at graduation (we observe 151 different majors of graduation in our data) to measures of the expected earnings for that major, and use this as the outcome variable.[22] In columns 5-8 of Table 6 we thus estimate the implications of the displacement from STEM on expected earnings. Although STEM

at the mean rate of 48%, we would expect 62 STEM graduates from this group. A one standard deviation increase in foreign peers amounts to roughly 9 additional foreign students. Recall our effect is 6% of the mean graduation rate. Multiplying 0.06 times 62 (the number of domestic students expected to graduate in STEM) yields approximately 3.7 domestic students displaced from STEM.

[20]Effects on foreign students are similarly insignificant in all subsequent heterogeneity analysis. Due to no apparent "own" effect of foreign share on the likelihood of foreign students persisting in STEM in any of our specifications, we focus analysis and additional specifications on domestic students. Additional specifications for the foreign-born population are available upon request.

[21]Unfortunately, given the high confidentiality and the exceptional granularity of the registrar student data we use for this paper, we did not receive permission to link labor market outcomes to individual university data

[22]These measures are provided by the Hamilton Project (Hershbein and Kearney, 2014) and estimated using American Community Surveys data. Data include estimates for initial earnings, earnings at 6, 11-15, and 26-30 years after graduation. Dropouts are assigned the average earnings of students with some college who did not complete a degree.

graduates earn more on average than non-STEM graduates[23], the aggregation of outcomes into four groups (STEM, Social Science, Arts & Humanities, Dropout) may mask heterogeneity within STEM and non-STEM majors, and potentially important margins of adjustment. For example, a student may be displaced from a high earning STEM major to a very low earning Social Science major or vice-versa. We utilize the expected earnings associated with each major, which provides a sufficient statistic for much of the relevant qualities and characteristics of majors. The results on major expected earnings are statistically and economically insignificant. For example, the estimate in column 5 indicates that a one standard deviation increase in the share of foreign peers is associated with a decrease in initial earnings of \$95 against a mean of \$23,230 – less than 0.5%.[24] The estimates on longer-run expected earnings are larger, but remain roughly equal to 1% of the mean.

While separate analysis for each of the 100+ different STEM and non-STEM majors is not feasible, Figure 4 visualizes the relationship between major earnings and displacement. All STEM and non-STEM majors get a rank, r, by expected earnings 11-15 years after graduation from 1 to R, with 1 being the highest-earning major. The x-axis shows where 20 of the most popular majors fall in this spectrum, but all majors are included in the analysis. Separately for STEM and non-STEM majors, for each rank, we rerun our main specification 1 with the outcome being the probability of graduating in a major ranked 1 through r. For STEM (non-STEM), each point on the figure can be thought of as the effect of a 1 standard deviation increase in foreign peers on the likelihood of graduating with a STEM (non-STEM) major with earnings ranked r or higher. 95% confidence intervals are also plotted. This shows that the bulk of the STEM displacement occurs in STEM majors with relatively low annual expected earnings (lower than \$57,000). The displacement effects grows when including lower and lower earning STEM majors and reaches the 3 percentage points effect of our main estimate when including STEM majors that pay as low as \$45,000 11-15 years after graduation. At the same time, the switch into non-STEM majors is driven by relatively high earning Social Science majors and is already substantial when including majors such as Business, which has expected annual earnings of \$61,000. Taken together, Table 6 and Figure 4 clearly suggest that displaced students are leaving relatively low earning STEM majors and choosing relatively high earning Social Science majors.

Finally, we expect displacement from STEM major to systematically affect the supply of STEM workers in the labor market. Failure to obtain a STEM degree represents indeed a large obstacle to working in STEM occupations. While many STEM graduates work in non-STEM sectors (e.g.

[23]In our data expected earnings of STEM graduates 11-15 years after graduation are 22% higher than those of non-STEM graduates.

[24]Alternatively, this magnitude represents 1.3% of the average earnings gap of STEM vs non-STEM majors (around \$7000 annually at labor market entrance).

business and finance), only fewer than 9% of all individuals with a college degree in a non-STEM field report working in a STEM occupation.[25] While we cannot track the actual occupation of each graduate in our data, it is very unlikely that the domestic students displaced from STEM graduation manage to find a STEM occupation. We thus believe our results have crucial and direct implications for the supply of STEM workers on the US labor market and ultimately on innovation and growth.

4.1 Heterogeneity

4.1.1 Race and Gender

Table 7 explores whether there are heterogeneous responses across different types of domestic students. Each estimate is from a separate regression using our preferred specification. Research on the gender gap in STEM education has uncovered various factors, such as confidence and role-models, as important for the retention of female students (e.g. Gneezy, Niederle and Rustichini, 2003; Niederle and Vesterlund, 2007; Carrell, Page and West, 2010). We assess whether foreign peers may more strongly affect domestic females relative to males. Columns 1 and 2 show that females are not strongly impacted by foreign peers. Instead, the STEM crowd-out effect is driven by domestic male students.

In columns 3-5, we stratify on domestic students' race/ethnicity. Similar to the gender gap in STEM, the minority gap in STEM has also received much academic attention. Our results show that foreign peers have strong negative impacts on non-minority groups (White and Asian). In contrast, there is no detectable negative impact on minorities (Black and Latino). One interesting insight is that foreign peers appear to have strong impacts on inducing domestic minorities to remain in school rather than dropping out. This leads to domestic minorities graduating in majors with higher expected earnings, both in the short and long run. In contrast, the strong displacement of domestic Asian students (the largest ethnic group among domestic students in introductory math classes) from STEM results in movement towards Social Science, but also towards dropping out. This in turn results in significant negative impacts on expected earnings.

4.1.2 Baseline Ability

To better characterize displacement from STEM we assess whether marginal students are those with relatively low baseline comparative ability or absolute ability in STEM. We empirically assess

[25] Authors' tabulations from individuals age 30 and under, reporting both college major and occupation in the 2009-2016 ACS. STEM occupations categorized according to the Bureau of Labor Statistics' classification: `https://www.bls.gov/soc/Attachment_C_STEM.pdf`.

this idea using a local linear regression. We define a measure of comparative advantage in STEM for each domestic student using their SAT Math and Verbal scores relative to the average SAT Math and Verbal scores of all the peers in their cohort, and regress STEM graduation on the share of foreign peers at each percentile.[26] Figure 5 plots coefficients from our main specification, and shows that students with low comparative advantage in STEM (low percentiles) experience strong displacement from STEM. The bottom third of students have an average coefficient of -0.07, while for the top third it is -0.02. Consistent with comparative advantage driving specialization, the students most at risk are those with the highest relative ability in non-STEM fields.

To measure absolute advantage, we estimate the ex-ante likelihood that a student will graduate with a STEM major. We regress STEM graduation on all background characteristics (gender, race, SAT, etc.) and year fixed effects. We then use the regression coefficients to predict each student's likelihood of graduating with a STEM major. Our measure is relatively simple, but represents the type of prediction policymakers or education administrators may use when trying to determine what factors lead to STEM persistence.

The bottom panel of Figure 5 presents local linear regression estimates based on absolute advantage. There is little difference in the effect for domestic students with high and low absolute STEM ability. All point estimates are contained within the confidence interval for all others. Using this measure, we cannot reject that students are equally displaced from STEM.

5 Exploring Mechanisms

Why do foreign peers lead to lower STEM completion among domestic students? We hypothesize three mechanisms. First, changes in the communicative environment within classrooms following the entry of many non-fluent English speakers may reduce the scope for knowledge spillovers that arise from questions asked during lecture, or from peer-to-peer interaction. Alternatively, instructors may respond by altering the delivery of the course, thereby affecting student's relative learning and or enjoyment.

A second hypothesis is that foreign peers in introductory math classes may provide students with a local assessment of their relative ability. As the introductory math class is often the first STEM class that students take, they may perceive their relative ability in that class as a signal of their ranking among all STEM majors. As foreign students have a comparative advantage in STEM

[26] To construct our measure of comparative advantage, we separately standardize students SAT math and verbal scores at the cohort level to have mean 0 and standard deviation of 1. Then, students are ranked based on the difference in their standardized math and verbal test scores. Local linear regressions of Equation 1 are estimated at every percentile using a one-standard deviation bandwidth and Epanechnikov kernel weighting. 95% confidence intervals are constructed from 250 bootstrapped repetitions, sampled at the class (i.e. math lecture) level.

relative to non-STEM fields, their presence may lead domestic students to update their perceptions of how their own comparative advantage in STEM ranks among other students.

The final mechanism we explore is simple distaste. If domestic students do not enjoy the presence of foreign students and/or update their beliefs about the presence of foreign workers in STEM occupations based on the foreign share observed in the introductory math courses, they may seek alternate classes or majors by means of avoidance.

5.1 Short-run impacts

To begin to shed light on mechanisms, Table 8 examines short-term outcomes that describe when and why students get displaced. The first row examines whether foreign peers impact the likelihood of withdrawing from the course after the first day of instruction. Positive effects would indicate that students select out of math very soon after meeting their peers. Results, however, indicates there is no effect of foreign peers on the likelihood of withdrawing from the course.[27]

Row 2 shows that overall there is no impact of foreign peers on introductory math grades received by domestic first-term freshman, conditional on remaining in the class.[28] Importantly, however, heterogeneous analysis revealed only particular groups were affected – non-minorities and those with low comparative advantage. Further analysis on these subgroups in columns 2-8 indicates that those groups that experience displacement do see a decline in grade performance. In the bottom row, we examine whether foreign peers affect the likelihood students retake the same course in the future. Evidence indicates a small increase in the likelihood of retaking the course.

5.2 Linguistic Dissonance

Though our data comes from a single university, national studies have similarly concluded that foreign-born college students overall appear to be negatively selected. In particular, foreign students lack English proficiency, come from low income backgrounds, require high levels of financial assistance, and are likely to work part-time during college (Erisman and Looney, 2007).[29] In part because of lower English ability, and also possibly due to cultural differences in learning, education research has consistently found that foreign students in the classroom setting are reticent, and effort has been devoted to understanding how to foster communication (e.g. Horwitz, Horwitz and

[27] In specifications not shown, we also separately examined immediate withdraws (one week or less into a course) and late withdraws (likely after receiving graded work) and found no significant effects.

[28] Grades have been standardized to have mean of zero and standard deviation equal to one within courses.

[29] An extensive report on foreign-born individuals in higher education (Erisman and Looney, 2007) found that 53% delayed entry into college after high school, 33% supported dependents, 66% indicated English was not their primary language, and 62% were in the two lowest income quintiles.

Cope, 1986; Rodriguez and Cruz, 2009; Stebleton, Huesman Jr and Kuzhabekova, 2010; Stebleton, 2011; Yamamoto and Li, 2011).

If the increased foreign presence within a classroom lowers socialization and discussion during classes, this may reduce positive externalities arising from peer-to-peer or peer-to-instructor interaction. Lower English language ability may lead instructors to alter instruction, or substitute time away from helping domestic students towards helping foreign students (Diette and Oyelere, 2012; Geay, McNally and Telhaj, 2013).

We use several proxies to measure the English communicative ability of each foreign student. First, we use the SAT verbal score to proxy for English fluency. Specifically, we calculate the average SAT verbal scores among foreign students in a given cohort, and then divide foreign students at the median. Individuals above the median are classified as having "high" fluency while those at and below the median to have "low" fluency. We then repeat regressions of equation 1, splitting the overall foreign share in the class into the shares with high and low fluency.

The results from this exercise are reported in panel A of Table 9. The displacement from STEM is larger for domestic students that experience increases in foreign peers with low fluency. A one standard deviation rise in the share of peers low fluency peers reduces the likelihood of completing STEM majors by 4 percentage points. An equivalent increase in peers with high fluency has no significant effect. Peers with low fluency displace domestic students primarily towards Social Science.

As SAT Verbal scores may be an imperfect proxy for communicative ability or reticence, we pursue a second attempt to identify linguistic dissonance using measures of language distance developed by Chiswick (2001). While the details of how linguistic distance are described in Chiswick and Miller (2005), the measure is based on the difficulty an English speaker faces in learning the foreign language.[30]

We then assign this language distance measure to each foreign student. This involves first assigning the primary language to each student's nationality, and then linking in linguistic distance measures from Chiswick and Miller (2005). Foreign students are then divided accordingly to whether their linguistic distance from English is above ("high distance") or below ("low distance") the median score of all foreign students. We measure the share of foreign peers with linguistic distance scores above the median, and below the median. These two different shares are used as explanatory variables in regressions, in place of the overall foreign share.

[30]The scores range on a scale from 1 to 3, where 3 indicates languages close in proximity to English, and 1 indicates languages distant from English. We transform these to distance measures from English, by assigning English a value of 4 and subtracting the language proximity scores. Hence, our distance measure ranges from 0 to 3, with lower scores representing close proximity to English. Note that a score of 0 means that the primary language of a foreign student's country of origin is English. This occurs for countries such as Canada, the United Kingdom, and Australia.

The results, provided in panel B of Table 9, similarly corroborate the notion of language dissonance. While the coefficients are not statistically different from one another, they qualitatively suggest that foreign peers that speak languages highly distant from English have a stronger displacement effect than foreign peers that speak languages similar to English.

Overall, these results identify the increased presence of foreign students with low fluency in English as a relevant environmental factor in determining domestic student displacement from STEM. We seek validation of this communication/interaction channel by exploring whether the reduced peer-to-peer or peer-to-instructor interaction in classes with a high share of foreign peers is exacerbated/limited by the level of English fluency of instructors. In particular, native English speaking professors might be more equipped to alter the pace of instruction and use different syntax or vocabulary to compensate the lower average communicative skills of students in the class and the reduced peer-to-peer interactions. To the contrary, foreign professors with a low level of English fluency may reduce peer-to-instructor interaction and positive externalities even further. In Table 10, we thus interact the foreign share with indicators for whether the instructor is English native speaker or foreign. Results indicate that the displacement of domestic students from STEM majors in classes with a high share of foreign peers is particularly strong in courses taught by instructors who do not speak English as their first language. As anecdotal evidence consistent with our empirical results, we have searched the public website www.ratemyprofessors.com and looked up students' reviews and open comments for the specific courses taught by foreign instructors in our analysis and found a high number of negative comments about the low level of English fluency of the instructor.

Finally, to corroborate the language dissonance channel further, we add an extra level of interaction in our regression model by splitting the overall foreign share in the class into the shares with high and low fluency foreign peers and interacting both shares with indicators for whether the instructor is English native speaker or foreign. Table 11 shows that the large majority of the overall displacement effect is concentrated in courses with a large share of low-fluency foreign peers taught by instructors who are not native English speaker. Overall, these results constitute robust evidence that the Linguistic Dissonance mechanism and the missed peer-to-peer and peer-to-instructor positive externalities are a primary channel of displacement of domestic students from STEM majors.

5.3 Believes on own Comparative Advantage in STEM majors

The movement of domestic students away from STEM fields may be a response to competition arising from the changing comparative advantage of peers. Related literature has shown that changes in rankings within a classroom environment, due to the entry of different peers, can affect educational choices and outcomes (Murphy, Weinhardt et al., 2014; Elsner and Isphording, 2017; Cicala, Fryer and Spenkuch, 2017). Peri and Sparber (2009, 2011) show that the entry of immigrants with high comparative advantage in manual tasks leads natives to switch to occupations requiring more communication-intensive skills. In our context, domestic students may perceive their comparative advantage in STEM fields fall with more foreign peers, and respond accordingly by switching to non-STEM majors.

The summary statistics presented in Table 2 indicate that foreign peers likely possess a comparative advantage in STEM fields. Their relative SAT Math to Verbal score is higher than that of domestic freshmen. Given that SAT Math and Verbal scores have been shown to be decent predictors of STEM and non-STEM major choice (Turner and Bowen, 1999), we believe relative scores are a good proxy for comparative ability in STEM and non-STEM fields. This feature is unlikely to be institution specific – foreign-born college educated individuals in the labor market are highly over-represented in STEM fields and STEM majors (Gambino and Gryn, 2011; Peri, Shih and Sparber, 2015).

To measure the comparative advantage in STEM of each individual, we follow the traditional definition of comparative advantage outlined in Sattinger (1975), and use the insight from Turner and Bowen (1999) that SAT Math and Verbal scores are good predictors of ability in STEM and non-STEM majors, respectively. We define individual's ability in STEM (Non-STEM) *relative* to their cohort, by calculating the distance in standard deviations of the individual's SAT Math (Verbal) score from the average SAT Math (Verbal) score of their cohort (which is standardized to 0). Our measure of comparative advantage in STEM is then the difference between an individual's relative ability in STEM and non-STEM. We refer to this as cohort-level comparative advantage.

We then also construct these measures of comparative advantage within the individual's introductory math class, by measuring relative to the class SAT averages rather than the cohort averages, which we refer to as class-level comparative advantage. This allows us to first measure whether exposure to foreign peers in introductory math classes actually provides a different signal of an individual's comparative advantage in STEM rather than their cohort-level comparative advantage.

Column 1 of Table 12 performs this check. We utilize our baseline specification, and replace the dependent variable with the measure of individual comparative advantage in STEM relative to the class. Additionally, we also control for the cohort-level comparative advantage, so that regressions are identified from individuals with the same cohort-level comparative advantage but different exposure to foreign peers. Results indicate that foreign peers strongly reduce the class-level comparative advantage in STEM for domestic students.[31] This is consistent with the idea that

[31]Note that this specification is still holding individual and peers' SAT math and SAT verbal constant. This means

foreign peers, on average, have a greater comparative advantage in STEM. Hence, an increased share foreign students will drive down the average class-level comparative advantage of domestic students.

Columns 2 and 3 check whether this is a mechanism by which the estimated STEM displacement effects. Column 2 estimates effects for domestic students who had large (above the median) declines between cohort-level and class-level comparative advantage. Domestic students who experienced high changes in comparative advantage responded similarly to students who had small changes in comparative advantage, shown in Column 3. Although the displacement magnitude is larger for domestic individuals that saw small changes in comparative advantage (-0.04), it is not statistically different from the effect for those who had larger changes in comparative advantage (-0.029). Hence, we conclude that while changes in comparative advantage rank might be an operative mechanism, it appears to account only marginally for the observed displacement.

5.4 Social Preferences

A final reason for displacement may be due to preferences over peers in the classroom. While estimating preferences is difficult, we take a different approach by seeing if future peer exposure indicates revealed preference against taking classes with foreign peers. Specifically, we replace the dependent variable in equation 1 with the foreign peer share in all classes taken in following terms. We examine future foreign peer shares among all classes by term. We perform this analysis for up to 12 terms, or 4 years, since many students graduate and drop out of the sample after 4 years.

The results of this exercise are shown in Figure 6. Point estimates are indicated by the dots and 95% confidence intervals are provided for reference. The vertical axis measures the effect of a 1 standard deviation increase in the foreign peer share on the foreign peer share in all classes in future terms. The results indicate no pattern of avoidance of foreign students overall.

Aside from avoidance, foreign peers might alter engagement in a course, resulting in students being more/less likely to form social ties. As an additional check, Table A3 of the appendix examines the impact of foreign peers on future social connections. Specifically, each course has several different registration numbers associated with it. For example, a math course with 200 students, has around 10 different "sections" of the math course assigned to a distinct teaching assistant. We measure the number of peers from introductory math courses that are enrolled together with an individual, not only in the same course, but the same section in the following term. This measure is our proxy for social connections, since two students in the same introductory math course registering for the same section the following term is substantially less likely to occur by chance than

that domestic students with same ability in courses with similar overall average ability can have very different within-class comparative advantage standings according to the foreign share in the course.

two students registering for the same course. Results from this exercise show negligible effects. Overall, these results appear to exclude a role of preferences towards immigrants as a mechanism for domestic students' crowd-out.

6 Conclusion

Disinterest in STEM throughout the education pipeline has been a great concern in the U.S. for several decades. At the same time, globalization has increased the number of foreign-born students in higher education institutions. This paper explores whether the rising presence of foreign-born peers can explain high attrition rates of domestic students from STEM majors in college.

Using administrative records from a large, selective public university, we find that higher exposure to foreign peers in the introductory math classes reduces the likelihood that American students eventually complete a STEM degree. Displaced domestic students adjust by moving to high paying Social Science majors so that their earnings prospects are not hindered.

Our results are identified from idiosyncratic variation in foreign peers within courses taught by the same professor over time. Focusing on domestic first-term freshmen helps assuage selection concerns, as they register for classes in the summer prior to formally entering the college. We also measure the class composition from registration records of students enrolled just prior to the first day of instruction. This ensures the students in our class have not had the opportunity to observe their peers and then withdraw. Balancing tests demonstrate that there appears to be no selection along observable characteristics. Results remain robust to controls for common shocks to classes that might alter peer ability, peer race/gender, or class size. Finally, we show that findings are due to exposure in introductory math classes and not in other classes taken during the first-term.

To further elucidate these findings, we test multiple plausible channels that could explain displacement. Among the several possible mechanisms, we find compelling empirical evidence about changes to the communicative environment within the classroom being the most important underlying cause for STEM displacement. Analysis shows that foreign students who possess weak English language skills appear to have stronger impacts than those who possess fluency in English. The negative effect of low-fluency foreign peers is shown to be exacerbated when the instructor is not an native English speaker and the overall class communicative level decreases further. Foreign students possessing very low levels of English proficiency may be less likely to engage in communication in the class. Fewer productive peer-to-peer and instructor-to-peer interactions may increase disinterest in STEM or affect learning for domestic students.

From a policy perspective, our analysis has clear implications for interventions aimed at preventing attrition from STEM majors. For instance, given that changes to the communicative environment appears to be the most important mechanism, interventions that improve or facilitate interaction and communication of foreign students (e.g. compulsory attendance of pre-college English courses) may help improve peer-to-peer learning and instructor-to-peer interaction. Alternatively, distributing foreign students with very poor English fluency more homogenously across courses and avoiding their concentration in courses taught by foreign instructor, might reduce the negative impact on the overall class communicative environment.

Though this study was performed on a single university, our findings carry implications for aggregate welfare. Our results may indicate that foreign peers induce specialization based on comparative advantage, without negative consequences for individual earnings potential. While this could be efficiency enhancing, our results also indicated that the total number of STEM graduates is likely to fall – the displacement we observe for domestic students is not offset by an increased likelihood of foreign students persisting in STEM. The aggregate welfare implications are further amplified if foreign-born students exhibit high return migration rates. Though evidence on return migration rates of foreign-born college students are very limited, recent policies limiting work visas have made it more difficult for international students to transition to the US labor market (Shih, 2016). The future U.S. aggregate supply of STEM skills may shrink substantially.

In the face of increasing globalization, understanding the impacts of foreign peers in college remains an important undertaking. This paper is the first to explore whether foreign peers affect college major and, consequently, career occupational choices. Future research that further explores the mechanisms underlying such impacts would be of great value for education administrators and policymakers alike.

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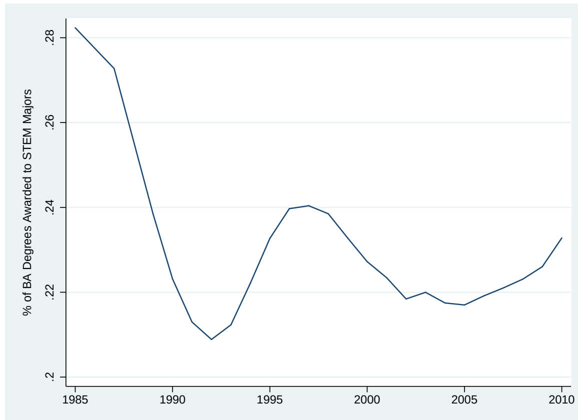
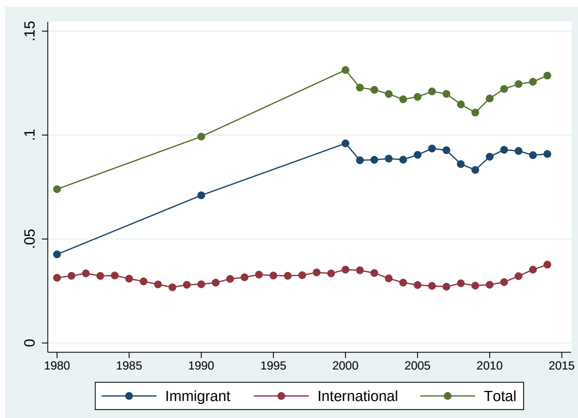
Figures & Tables

Figure 1: Trends in STEM Majors and Foreign Enrollment



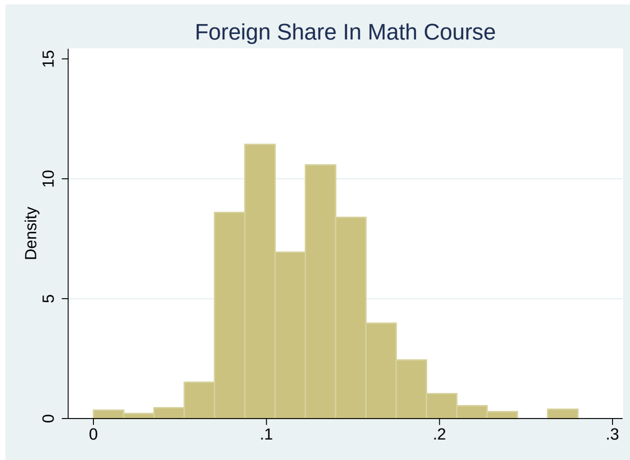
(a) Share of BA Degrees in STEM Fields



(b) Foreign Enrollment as Share of Total

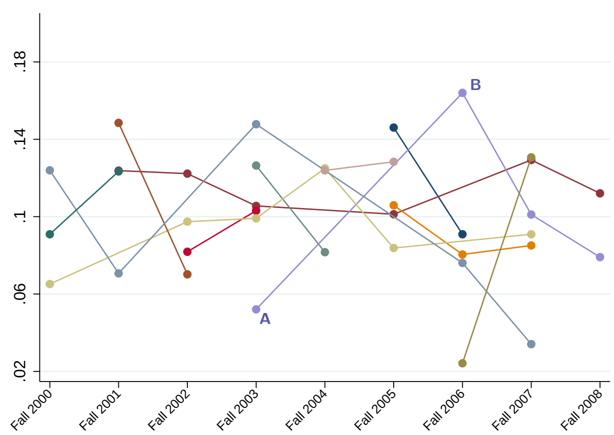
Note: Data on bachelor's degrees awarded by field of study come from the Integrated Postsecondary Education Data System (IPEDS). Data on foreign-born enrollment in higher education comes from the 1990, 2000 Censuses, and the 2001-2014 ACS. Data represents foreign-born individuals resident in the U.S. and enrolled in undergraduate studies. Because the year 1990 is missing college attendance, we instead calculate the number of students that have at least a high school degree, but less than a bachelor's degree that are enrolled in school. International Student data series comes from Institute of International Education, "International Students by Academic Level" (2016) and represents alien foreign born students enrolled in undergraduate studies.

Figure 2: Variation in foreign share in introductory math courses



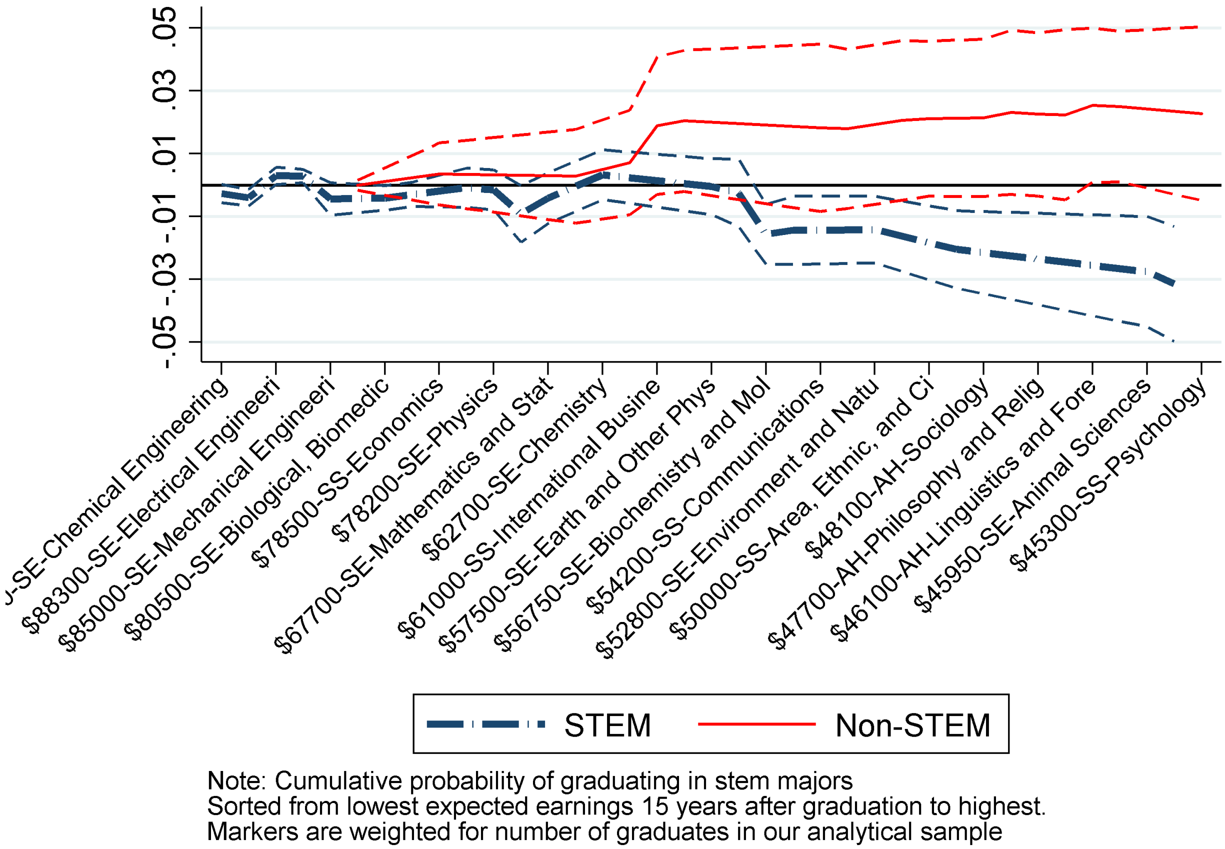
Note: Each observation in the distribution refers to an introductory math class in the university under analysis. Introductory math classes are defined by unique course, professor, and term combinations.

Figure 3: Foreign Share variation within professor-course pairs over time



Note: Terms are displayed on the horizontal axis and share of foreign students in the class on the vertical axis. Each line represent a Calculus I course taught by the same professor. The idiosyncratic variation within across terms and within professors represents the identifying variation in our paper.

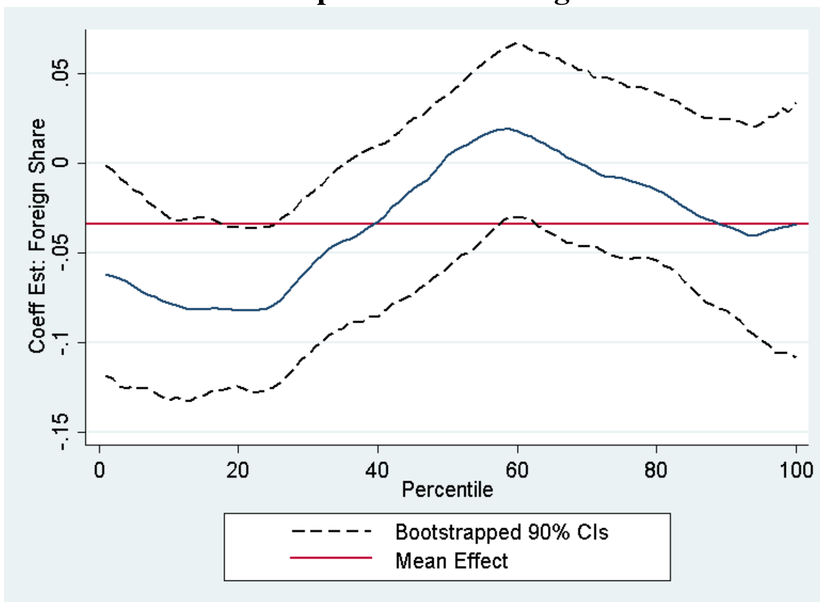
Figure 4: Effect of Foreign Peers on cumulative Major Choice by Expected Earnings



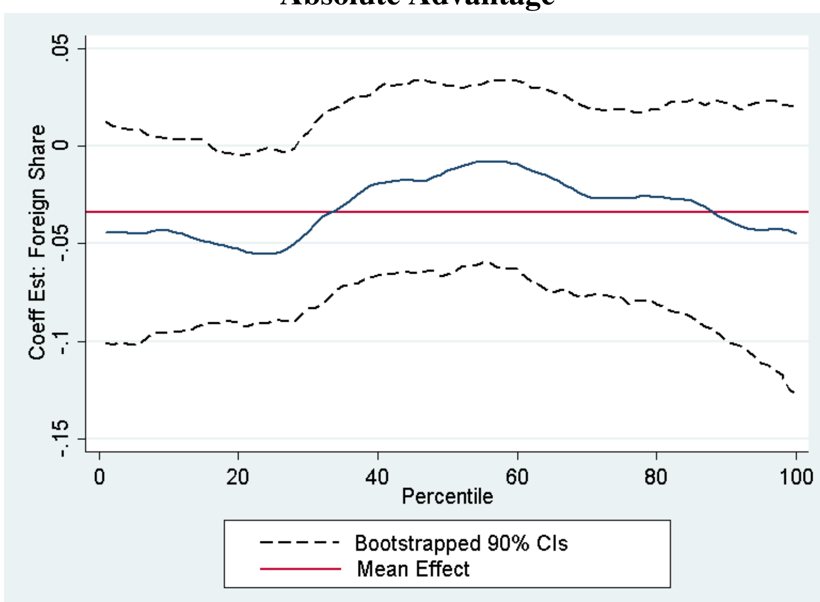
Note: Results show coefficient estimates from regressions of Equation 1 with the outcome being probability of graduating in majors 1 to r with r being the rank position of each major in the earnings scale. Majors are ranked by expected earning 11-15 years after graduation (Earnings from the Hamilton Project using ACS data) separately for STEM ("SE" code on x axis) and non-STEM ("SS" code for Social Sciences and "AH" code for Arts and Humanities on x axis)

Figure 5: Local Linear Regression Results

Comparative Advantage

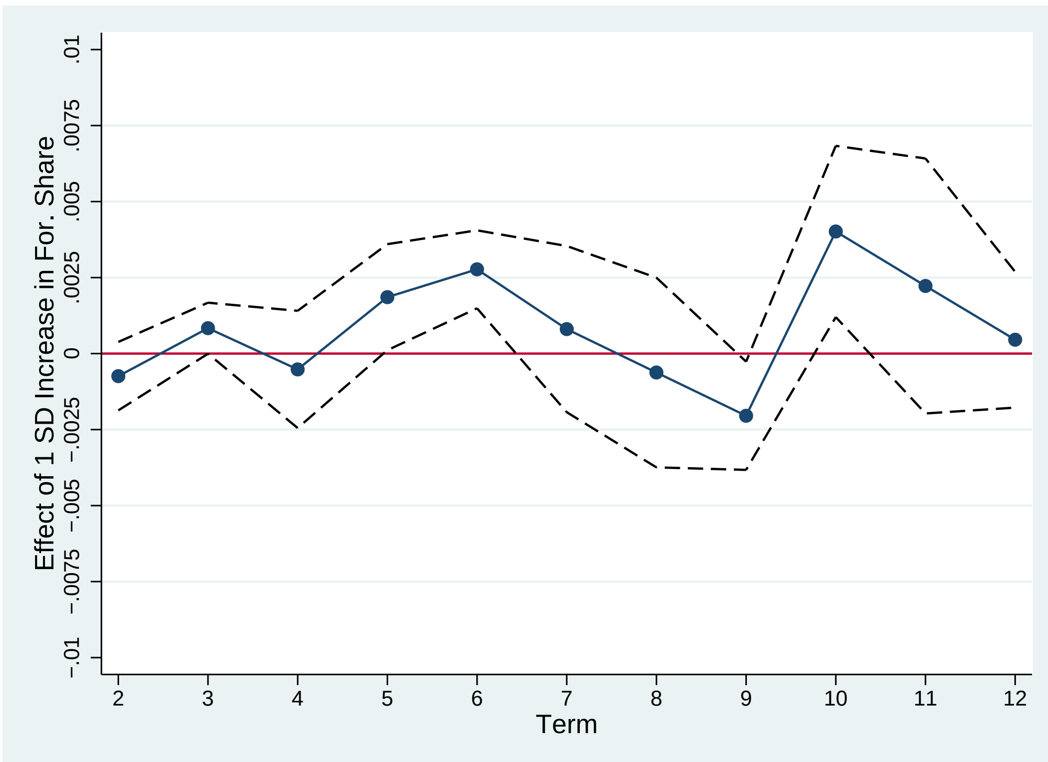


Absolute Advantage



Note: Results show coefficient estimates from local linear regressions of Equation 1 with STEM graduation as the outcome. Students in core sample are ranked from 1 to 16,830 based on a measure of comparative advantage (top) and absolute advantage (bottom). Lower percentile represents lower inclination towards STEM. Each graph plots 99 estimates from local linear regression centered at each percentile using Epanechnikov kernel weighting. Confidence intervals (dashed lines) derived from 5th and 95th percentile of 250 bootstrapped estimations, resampled at the course level. See text for details on calculation of comparative and absolute advantage. Red line shows mean effect from Column 4 of Table 5

Figure 6: Effect on Future Foreign Peer Exposure



Note: Results show coefficient estimates from regressions of Equation 1 with the outcome being the share of foreign peers in all classes in each term after the first. 95% confidence intervals are provided for reference. We show results up to 12 terms out, which represents 4 years, as many students graduate and leave the sample after 4 years.

Table 1: List of Math Courses

Title	Domestic First-Time Freshmen	Avg. Class Size	Avg. Percent Foreign
Precalculus	1,838	307	0.096
		(69.6)	(0.023)
Calculus I	7,031	247	.103
		(81.7)	(0.029)
Calculus I (Advanced)	4,965	208	0.152
		(53.9)	(0.036)
Calculus I (for Scientists)	1,287	232	0.114
		(41.4)	(0.025)
Calculus II	394	197	0.107
		(58.3)	(0.032)
Calculus II (Advanced)	922	148	0.174
		(33.7)	(0.041)
Calculus III	54	215.7	0.113
		(58.34)	(0.029)
Calculus III (Advanced)	299	148	0.152
		(43.4)	(0.041)
Calculus IV (Advanced)	40	135	0.145
		(48.0)	(0.064)
Total/Average	16,830	233	0.123
		(77.1)	(0.041)

Note: List of introductory mathematics courses offered by the university under analysis. Advanced courses cover similar material to non-advanced ones, but with greater depth. Sample includes 16,380 freshmen domestic students enrolling in introductory math courses in their first term of college attendance. Standard deviations in parentheses

Table 2: Background Summary Statistics

	(1) Domestic All	(2) Foreign All	(3) Domestic Freshmen	(4) Foreign Peers	(5) Imm Peers	(6) Intl Peers
Female	0.56	0.53	0.50	0.48	0.48	0.49
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
White	0.47	0.16	0.41	0.12	0.12	0.12
	(0.48)	(0.33)	(0.48)	(0.30)	(0.30)	(0.29)
Asian	0.37	0.71	0.48	0.78	0.77	0.78
	(0.46)	(0.43)	(0.49)	(0.40)	(0.40)	(0.39)
Minority	0.15	0.13	0.10	0.11	0.11	0.10
	(0.35)	(0.32)	(0.29)	(0.30)	(0.30)	(0.28)
Black	0.03	0.02	0.02	0.02	0.02	0.01
	(0.17)	(0.13)	(0.13)	(0.13)	(0.13)	(0.11)
Latino	0.12	0.11	0.08	0.09	0.09	0.08
	(0.31)	(0.29)	(0.27)	(0.28)	(0.28)	(0.26)
High School GPA	3.70	3.70	3.76	3.72	3.71	3.79
	(0.30)	(0.26)	(0.33)	(0.30)	(0.31)	(0.27)
SAT Math	599.45	599.62	629.36	617.89	611.64	667.00
	(74.99)	(76.40)	(71.90)	(87.09)	(87.31)	(67.66)
SAT Verbal	562.90	510.62	573.83	491.18	486.25	529.88
	(79.63)	(90.42)	(84.48)	(104.15)	(104.19)	(95.44)
SAT Composite	1160.18	1105.63	1200.32	1099.42	1088.71	1195.38
	(136.34)	(138.31)	(135.62)	(162.82)	(162.29)	(133.69)
Composite Adm. Score	7394.68	7429.27	7510.59	7397.73	7390.23	7456.56
	(758.58)	(715.93)	(831.30)	(914.90)	(884.44)	(1125.18)
Obs	45,293	7,165	16,830	3,840	3,406	434

Note: Means for enrolled students from fall 2000-fall 2006. Standard deviations in parentheses. Column 3 refers to our analysis sample of 16,830 domestic students who attended an intro math course as freshmen in the first year of college enrollment. Composite Admission Score is calculated by the admissions office using a weighted sum of various background ability and traits, which includes some measures available in our data and also other ability measures that are not available.

Table 3: Outcome Summary Statistics for Introductory Math Sample

	(1) Domestic Freshmen	(2) Foreign Peers
Graduation Outcomes in 6 Yrs		
Graduate	0.82	0.78
	(0.38)	(0.42)
Dropout	0.18	0.22
	(0.38)	(0.42)
Time to Degree (terms)	16.41	16.37
	(2.48)	(3.09)
Graduation GPA	3.05	2.96
	(0.44)	(0.45)
Graduate STEM	0.48	0.44
	(0.50)	(0.50)
Graduate Social Sciences (SS)	0.27	0.27
	(0.44)	(0.44)
Graduate Arts & Humanities (AH)	0.08	0.06
	(0.26)	(0.24)
Obs	16,830	3,840

Note: Column 1 refers to our analysis sample of 16,830 domestic freshmen enrolling in introductory math courses in their first term of college attendance. Column 2 refers to the foreign peers of domestic freshmen enrolling in introductory math courses in their first term of college attendance.

Table 4: Exogeneity of Foreign Class Share

	(1) Female	(2) White	(3) Asian	(4) Minority	(5) Black	(6) Latino	(7) SAT Math	(8) SAT Verbal	(9) High School GPA	(10) Composite Admission Score
Foreign Sh.	-0.01	-0.01	0.01	-0.01	-0.00	-0.00	1.76	-1.08	0.01	21.11
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(1.67)	(1.97)	(0.01)	(14.53)
Mean(Y)	.49	.41	.46	.12	.02	.1	618.36	567.3	3.73	7414.36
Std(Y)	.5	.48	.48	.32	.15	.29	74.98	83.85	.32	829.08
Obs.	25,912	25,912	25,912	25,912	25,912	25,912	25,912	25,912	25,912	25,912
R-sq	0.11	0.02	0.02	0.02	0.01	0.01	0.15	0.03	0.02	0.28

Note: Sample is all domestic students attending introductory math courses. The table displays estimates from equation 2 and shows the mean and standard deviation of each outcome variable. Regressions include controls for course-by-term and course-by-professor fixed effects. Standard errors in parentheses are clustered by professor. Significance levels: *0.10, ** 0.05, ***0.01.

Table 5: Effects on STEM Graduation

	(1)	(2)	(3)	(4)
Panel A: Domestic Students				
Foreign Sh.	-0.035***	-0.036***	-0.033***	-0.034***
	(0.011)	(0.012)	(0.011)	(0.012)
Mean(Y)	.48	.48	.48	.48
Obs.	16,830	16,830	16,830	16,830
R-sq	0.05	0.05	0.10	0.10
Panel B: Foreign Students				
Foreign Sh.	0.012	-0.022	-0.003	0.009
	(0.042)	(0.030)	(0.032)	(0.029)
Mean(Y)	.44	.44	.44	.44
Obs.	3,840	3,840	3,840	3,840
R-sq	.09	0.10	0.10	0.11
σ_{ct}	x	x	x	x
σ_{cp}	x	x	x	x
Peer Chars.	x	x	x	x
Course Size		x	x	x
Ind. Controls			x	x
For. Non-Math				x

Note: Panel A sample is domestic freshmen students attending an introductory math course in their first term of college. Panel B is analogous for foreign students. Regressions include course-by-term and course-by-professor fixed effects. The foreign share is standardized to have mean 0 and standard deviation 1. Peer ability includes average standardized SAT Math, SAT Verbal, and high school GPA of peers. Peer Characteristics include share of students from each race and share of females. Individual controls include a female indicator, race dummies, SAT Math and Verbal scores, and high school GPA. Foreign Share Non-Math refers to the average foreign share in non-math classes attended by first-term domestic freshmen. Standard errors in parentheses are clustered by professor. Significance levels: *0.10, **0.05 ***0.01.

Table 6: Effects on Graduation Outcomes and Expected Earnings

	(1) Grad STEM	(2) Grad SS	(3) Grad AH	(4) Dropout	(5) Earn 0	(6) Earn 6	(7) Earn 11-15	(8) Earn 26-30
Foreign Sh.	-0.033***	0.022	0.0053	0.0043	-94.8	-296.8	-366.7	-566.9
	(0.011)	(0.015)	(0.0063)	(0.0091)	(325.0)	(518.9)	(640.3)	(521.3)
Mean(Y)	.48	.27	.08	.18	23230.85	38552.17	49729.47	52760.8
σ_{ct}	x	x	x	x	x	x	x	x
σ_{cp}	x	x	x	x	x	x	x	x
Peer Ability	x	x	x	x	x	x	x	x
Peer Chars.	x	x	x	x	x	x	x	x
Course Size	x	x	x	x	x	x	x	x
Ind. Controls	x	x	x	x	x	x	x	x
Obs.	16,830	16,830	16,830	16,830	16,830	16,830	16,830	16,830
R-sq	0.10	0.06	0.03	0.06	0.10	0.08	0.08	0.10

Note: Sample is domestic freshmen students attending an introductory math course in their first term of college. Regressions include course-by-term and course-by-professor fixed effects. Foreign Share is standardized to have mean 0 and standard deviation 1. Peer ability includes average SAT Math, SAT Verbal, and high school GPA of peers. Peer Characteristics include share of students from each race and share of females. Individual controls include a female indicator, race dummies, SAT Math and Verbal scores, and high school GPA. Expected earning in columns 5-8 have been assigned to each student based on their graduation major. Earnings estimates come from calculations done by the Brookings' Hamilton Project and refer to median earnings calculated on U.S. Census Bureau's American Community Survey data at different years after college graduation. Standard errors in parentheses are clustered by professor. Significance levels: *0.10, **0.05 ***0.01.

Table 7: Foreign Peer Effects on Different Domestic Groups

	(1) Female	(2) Male	(3) White	(4) Asian	(5) Minority
Grad STEM	0.00	-0.05***	-0.02**	-0.07***	0.01
	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Grad SS	-0.02	0.06***	0.01	0.04**	0.03
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Grad AH	0.01	-0.01	0.01	0.00	0.03
	(0.01)	(0.01)	(0.02)	(0.00)	(0.02)
No Grad	0.01	0.00	-0.00	0.03***	-0.07***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Earn 0	58.16	135.00	-86.55	-722.00*	2288.17***
	(311.90)	(573.02)	(357.62)	(405.67)	(800.31)
Earn 6	207.00	-303.57	-165.97	-1309.33**	3338.21**
	(445.47)	(921.24)	(576.86)	(555.41)	(1270.74)
Earn 11-15	230.14	-364.49	24.24	-1918.34***	4366.76***
	(544.66)	(1156.19)	(743.25)	(658.16)	(1631.64)
Earn 26-30	-14.49	-280.05	-64.98	-1778.08**	4485.75**
	(587.69)	(1065.63)	(702.95)	(745.94)	(1935.69)
σ_{ct}	x	x	x	x	x
σ_{cp}	x	x	x	x	x
Peer Ability	x	x	x	x	x
Peer Chars.	x	x	x	x	x
Course Size	x	x	x	x	x
Ind. Controls	x	x	x	x	x
Obs.	8,355	8,475	6,483	7,667	1,606

Note: Sample is domestic freshmen students attending an introductory math course in their first term of college. Each column presents our analysis on domestic first-term freshmen, stratified by the characteristics indicated in the column headers. Minority refers to Latino and African-American students. Regressions include course-by-term and course-by-professor fixed effects. Foreign Share is standardized to have mean 0 and standard deviation 1. Peer ability includes average SAT Math, SAT Verbal, and high school GPA of peers. Peer Characteristics include share of students from each race and share of females. Individual controls include a female indicator, race dummies, SAT Math and Verbal scores, and high school GPA. Standard errors in parentheses are clustered by professor. Significance levels: *0.10, **0.05 ***0.01.

Table 8: Short-Run Effects

	(1) All	(2) Female	(3) Male	(4) White	(5) Asian	(6) Minority	(7) Low CA	(8) Hi CA
A: Drop Course								
Foreign Sh.	0.02	0.05**	-0.02	0.02	0.01	-0.01	0.01	0.02
	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.04)	(0.01)	(0.02)
Mean(Y)	.12	.13	.11	.1	.13	.17	.13	.11
Obs.	16,830	8,355	8,475	6,483	7,667	1,606	8,823	8,007
R-sq	0.05	0.06	0.07	0.05	0.07	0.13	0.06	0.06
B: Std. Grade								
Foreign Sh.	-0.01	0.00	-0.02	-0.07***	0.01	0.13	-0.05**	0.05*
	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.15)	(0.02)	(0.03)
Mean(Y)	.13	.18	.07	.18	.15	-.13	.04	.22
Obs.	14,801	7,286	7,515	5,866	6,672	1,328	7,687	7,114
R-sq	0.21	0.24	0.20	0.24	0.21	0.28	0.22	0.21
C: Retake								
Foreign Sh.	0.02*	0.03*	0.01	0.01	0.03**	0.03	0.02	0.02*
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.04)	(0.01)	(0.01)
Mean(Y)	.11	.1	.12	.1	.11	.17	.12	.1
Obs.	16,830	8,355	8,475	6,483	7,667	1,606	8,823	8,007
R-sq	0.07	0.09	0.07	0.08	0.07	0.13	0.08	0.07
σ_{ct}	x	x	x	x	x	x	x	x
σ_{cp}	x	x	x	x	x	x	x	x
Peer Ability	x	x	x	x	x	x	x	x
Peer Chars.	x	x	x	x	x	x	x	x
Course Size	x	x	x	x	x	x	x	x
Ind. Controls	x	x	x	x	x	x	x	x

Note: Sample is domestic freshmen students attending an introductory math course in their first term of college. Regressions include course-by-term and course-by-professor fixed effects. Foreign Share is standardized to have mean 0 and standard deviation 1. Panel A measures if a student dropped the intro-math course after the first day. Panel B assesses grades (e.g. A, A-, B+, etc.) in the intro math course, standardized within course-professor-term and conditional on not dropping. Panel C examines whether students retake an intro math course. Peer ability includes average SAT Math, SAT Verbal, and high school GPA of peers. Peer Characteristics include share of students from each race and share of females. Individual controls include a female indicator, race dummies, SAT Math and Verbal scores, and high school GPA. Standard errors in parentheses are clustered by professor. Significance levels: *0.10, **0.05 ***0.01.

Table 9: Testing the Classroom Communication Mechanism - Foreign Peers' Fluency

	(1) Grad STEM	(2) Grad SS	(3) Grad AH	(4) Dropout	(5) Earn 0	(6) Earn 6	(7) Earn 11-15	(8) Earn 26-30
Panel A - SAT Verbal:								
Foreign Share Low Fluency	-0.040**	0.043**	0.010**	-0.013	416.5	661.5	841.3	148.2
	(0.018)	(0.017)	(0.0051)	(0.011)	(407.7)	(620.7)	(782.0)	(811.3)
Foreign Share High Fluency	0.0027	-0.019	-0.0050	0.020	-586.4	-1116.0	-1405.7	-882.3
	(0.021)	(0.026)	(0.0050)	(0.013)	(475.5)	(761.6)	(920.2)	(798.3)
Panel B - Chiswick (2001) Linguistic Distance:								
Foreign Share High Distance	-0.025*	-0.0042	0.0067	0.022**	-385.2	-942.2*	-1167.9*	-758.0
	(0.014)	(0.017)	(0.0049)	(0.0094)	(352.2)	(522.7)	(634.3)	(598.4)
Foreign Share Low Distance	-0.017**	0.019**	0.0016	-0.0049	68.6	116.8	145.8	-164.0
	(0.0082)	(0.0083)	(0.0039)	(0.0055)	(184.5)	(291.7)	(367.7)	(407.4)
Mean(Y)	.48	.27	.08	.18	23230.85	38552.17	49729.47	52760.8
σ_{ct}	x	x	x	x	x	x	x	x
σ_{cp}	x	x	x	x	x	x	x	x
Peer Ability	x	x	x	x	x	x	x	x
Course Size	x	x	x	x	x	x	x	x
Ind. Controls	x	x	x	x	x	x	x	x
Peer Chars.	x	x	x	x	x	x	x	x
Obs.	16,830	16,830	16,830	16,830	16,830	16,830	16,830	16,830
R-sq	0.10	0.06	0.03	0.06	0.10	0.08	0.08	0.10

Note: Sample is domestic freshmen students attending an introductory math course in their first term of college. In Panel A we split foreign share into the share of foreign peers with SAT verbal below median (Low Fluency) and the share of foreign peers with SAT verbal above median (High Fluency). In Panel B we split foreign share into the share of foreign peers speaking languages very distant from English and the share of foreign peers speaking a language that is closer to English. All foreign shares are standardized to have mean 0 and standard deviation 1. Regressions include course-by-term and course-by-professor fixed effects. Peer ability includes average SAT Math, SAT Verbal, and high school GPA of peers. Peer Characteristics include share of students from each race and share of females. Individual controls include a female indicator, race dummies, SAT Math and Verbal scores, and high school GPA. Standard errors in parentheses are clustered by professor. Significance levels: *0.10, **0.05 ***0.01.

Table 10: Testing the Classroom Communication Mechanism - Interaction with Instructor English Fluency

	(1)	(2)	(3)	(4)
Foreign Sh.X(Prof. Native English Speaker=1)	-0.024	-0.020	-0.024	-0.025
	(0.023)	(0.024)	(0.024)	(0.024)
Foreign Sh.X(Prof. Foreign Speaker=1)	-0.047*	-0.059**	-0.047	-0.047
	(0.024)	(0.030)	(0.029)	(0.029)
Mean(Y)	.48	.48	.48	.48
σ_{ct}	x	x	x	x
σ_{cp}	x	x	x	x
Peer Ability	x	x	x	x
Peer Chars.	x	x	x	x
Course Size		x	x	x
Ind. Controls			x	x
For. Non-Math				x
Obs.	16,830	16,830	16,830	16,830
R-sq	0.05	0.05	0.10	0.10

Note: Sample is domestic freshmen students attending an introductory math course in their first term of college. Regressions include course-by-term and course-by-professor fixed effects. The foreign share is standardized to have mean 0 and standard deviation 1. It is interacted with a dummy taking value 1 if the Instructor is a native English speaker. Peer ability includes average standardized SAT Math, SAT Verbal, and high school GPA of peers. Peer Characteristics include share of students from each race and share of females. Individual controls include a female indicator, race dummies, SAT Math and Verbal scores, and high school GPA. Foreign Share Non-Math refers to the average foreign share in non-math classes attended by first-term domestic freshmen. Standard errors in parentheses are clustered by professor. Significance levels: *0.10, **0.05 ***0.01.

Table 11: Testing the Classroom Communication Mechanism - Foreign Peers'/Instructor English Fluency interaction

	(1) Grad STEM	(2) Grad SS	(3) Grad AH	(4) Dropout
For. Sh. Low FluencyX(Prof. Native English Speaker=1)	-0.018	-0.0018	0.0077	0.013
	(0.023)	(0.019)	(0.0085)	(0.014)
For. Sh. Low FluencyX(Prof. Foreign Speaker=1)	-0.061***	0.078***	0.014**	-0.032***
	(0.017)	(0.024)	(0.0064)	(0.0097)
For. Sh. High FluencyX(Prof. Native English Speaker=1)	-0.0092	-0.012	-0.0019	0.021
	(0.019)	(0.025)	(0.0061)	(0.013)
For. Sh. High FluencyX(Prof. Foreign Speaker=1)	0.057*	-0.047	-0.020	0.0097
	(0.032)	(0.035)	(0.014)	(0.012)
Mean(Y)	.48	.27	.08	.18
σ_{ct}	x	x	x	x
σ_{cp}	x	x	x	x
Peer Ability	x	x	x	x
Course Size	x	x	x	x
Ind. Controls	x	x	x	x
Peer Chars.	x	x	x	x
Obs.	16,830	16,830	16,830	16,830
R-sq	0.10	0.06	0.03	0.06

Note: Sample is domestic freshmen students attending an introductory math course in their first term of college. Regressions include course-by-term and course-by-professor fixed effects. We split foreign share into the share of foreign peers with SAT verbal below median (Low Fluency) and the share of foreign peers with SAT verbal above median (High Fluency). The foreign shares are standardized to have mean 0 and standard deviation 1. The shares are interacted with a dummy taking value 1 if the Instructor is a native English speaker. Peer ability includes average standardized SAT Math, SAT Verbal, and high school GPA of peers. Peer Characteristics include share of students from each race and share of females. Individual controls include a female indicator, race dummies, SAT Math and Verbal scores, and high school GPA. Standard errors in parentheses are clustered by professor. Significance levels: *0.10, **0.05 ***0.01.

Table 12: Comparative Advantage Mechanism

	(1) Course Rank (CR)	(2) STEM, CR High	(3) STEM, CR Low
Foreign Sh.	-0.054***	-0.029**	-0.040**
	(0.016)	(0.014)	(0.017)
σ_{ct}	x	x	x
σ_{cp}	x	x	x
Cohort Rank	x	x	x
Peer Chars.	x	x	x
Course Size	x	x	x
Ind. Controls	x	x	x
Obs.	16,830	8,270	8,560
R-sq	0.61	0.11	0.10

Note: Sample is domestic freshmen students attending an introductory math course in their first term of college. In column 1 the dependent variable is a measure of within-course comparative advantage in math. In columns 2 and 3 we replicate our main specification separately for students who had a drop in within-math course comparative advantage measure (with respect to her/his own university-level comparative advantage) above and below the median drop respectively. Regressions include controls for course-by-term and course-by-professor fixed effects, peer ability, peer characteristics, course size, and individual controls. Importantly, all specifications control for the cohort-level measure of comparative advantage in math. Standard errors in parentheses are clustered by professor. Significance levels: *0.10, **0.05 ***0.01.

A Appendix

Table A1: Exogeneity of Foreign Class Share: Foreign Students

	(1) Female	(2) White	(3) Asian	(4) Minority	(5) Black	(6) Latino	(7) SAT Math	(8) SAT Verbal	(9) High School GPA	(10) Composite Admissions Score
Foreign Sh.	-0.00	-0.01	0.00	0.00	-0.01	0.01	2.76	-14.19***	-0.02	-52.13
	(0.04)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(4.85)	(4.11)	(0.02)	(31.70)
Mean(Y)	.48	.12	.78	.1	.02	.09	617.89	491.18	3.72	7397.73
Std(Y)	.5	.3	.4	.3	.13	.28	87.09	104.15	.3	914.9
σ_{ct}	x	x	x	x	x	x	x	x	x	x
σ_{cp}	x	x	x	x	x	x	x	x	x	x
Obs.	3,840	3,840	3,840	3,840	3,840	3,840	3,840	3,840	3,840	3,840
R-sq	0.12	0.05	0.06	0.07	0.04	0.08	0.19	0.05	0.05	0.39

The table displays estimates from equation 2 run on Foreign Students instead of Domestic ones and shows mean and standard deviation of each variable. Regressions include controls for course-by-term and course-by-professor fixed effects. Standard errors in parentheses are clustered by professor. Significance levels: *0.1, ** 0.05, ***0.01.

Table A2: Joint Exogeneity Check

	Foreign Share
Female	-0.485
	(0.407)
Asian	0.647
	(0.449)
Minority	0.302
	(0.623)
SAT Math	0.005
	(0.004)
SAT Verbal	-0.004*
	(0.002)
HS GPA	0.751
	(0.518)
Composite Adm. Score	0.000
	(0.000)
σ_{ct}	x
σ_{cp}	x
Obs.	25,911
F-Stat	1.474
Pr > F	0.19

Note: The table displays estimates from equation 1 using individual background characteristics and fixed effects. F-stat and Pr > F refer to the joint F-statistic on individual background characteristics and the corresponding p-value. Standard errors in parentheses are clustered by professor. In this specification, foreign share is scaled x100 for readability. Significance levels: *0.10, **0.05 ***0.01.

Table A3: Impacts on Social Connections

	T+1	T+2	T+3
Any Future Course - All			
Foreign Sh.	0.354	0.172	0.031
	(0.241)	(0.166)	(0.105)
Mean(Y)	7.10	6.18	3.78
Obs.	16,830	16,830	16,830
Any Future Course - Domestic			
Foreign Sh.	0.218	0.080	0.006
	(0.209)	(0.139)	(0.086)
Mean(Y)	6.15	5.36	3.31
Obs.	16,830	16,830	16,830
Future Math Course			
Foreign Sh.	-0.069	-0.013	-0.000
	(0.089)	(0.074)	(0.076)
Mean(Y)	4.98	3.41	1.16
Obs.	14,132	14,132	14,132
σ_{ct}	x	x	x
σ_{cp}	x	x	x
Peer Ability	x	x	x
Ind. Ability	x	x	x
Peer Chars	x	x	x
Ind. Chars	x	x	x
Course Size	x	x	x

Note: Sample is Domestic freshmen students attending an introductory math course in their first term of college. The dependent variable is the total number of overlapping students in future course *discussion sections*. Discussion sections are 20-50 student subsets of courses that meet once per week with a teaching assistant. For our primary sample, we count how many peers from their introductory are registered for the same discussion sections in future terms. Registering for the same discussion section is our proxy a social tie between students. Columns 1, 2, 3 look one, two and three terms into the future, respectively. Row 1 considers both foreign and domestic peers from intro math courses. Row 2 considers overlaps only with domestic students. Row 3 limits the sample to those students who take another math course at some point and counts only overlaps in math courses. Regressions include controls for course-by-term and course-by-professor fixed effects, number of domestics in the initial course, peer ability, peer characteristics, course size, and individual controls. Standard errors in parentheses are clustered by professor. Significance levels: *0.10, **0.05 ***0.01.