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OPT policy changes and foreign born STEM talent in the U.S.[☆]

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ABSTRACT

Academia and the public media have emphasized the link between STEM majors and innovation as well as the need for STEM graduates in the U.S. economy. Given the proclivity of international students to major in STEM fields, immigration policy may be used to attract and retain high-skilled STEM workers in the United States. We examine the impacts of a 2008 policy extending the Optional Practical Training (OPT) period for STEM graduates. Using data from the National Survey of College Graduates, we find that, relative to other foreign-born U.S. college graduates, the foreign-born who first came on student visas were 18% more likely to have their degrees in STEM fields if they enrolled in their major after the OPT policy change. While part of this increase is likely due to the rather mechanical drop in return migration among STEM graduates following the OPT change, the policy also appears to have induced some international students, who may have otherwise chosen a different field, to major in STEM.

1. Introduction

For quite some time, the link between STEM majors and innovation, as well as the growing need for STEM graduates in the U.S. economy, have been repeatedly underscored in academia and the public media. Given the proclivity of international students, relative to native ones, to major in a STEM field (NSF Science and Engineering Indicators, 2012), immigration policy might be used as a tool to retain high-skilled immigrants educated and trained in the United States in these fields. One such policy is the extension of the Optional Practical Training (OPT) period for foreign-born STEM graduates who receive their degree from a U.S. university. This paper first explores the impact of this policy change on the likelihood that foreign-born college graduates living in the U.S. have a STEM degree. Subsequently, we examine whether any observed changes were partly driven by international students' increased tendencies to choose a STEM major.

OPT is a period during which international students in the United States are allowed to temporarily work on their student visas with the intent of gaining practical training to complement their education. While, in general, OPT lasts for one year, undergraduate and graduate students with STEM degrees became eligible for a 17-month extension starting in 2008, thus allowing them to work in the United States for a total of 29 months on their student visas.[1] Once the OPT period is exhausted, international students must transfer to another visa in order to remain in the United States. In many instances, they transfer to an H-1B visa -a non-immigrant visa for high-skilled workers.[2]

There are many benefits to both international students and their employers of having an additional 17 months of OPT before needing to transfer to a different visa. Students might benefit from an extended training period during which they can develop professional contacts, find a good job match and plan their next career move. In addition, U.S. employers benefit from having more time to evaluate the prospective

[1] The initial extension was extended to 24-months in 2016. Our data does not allow us, however, to examine this later extension. For more details on both extensions, see: https://studyinthestates.dhs.gov/stem-opt-extension-overview.

[2] There are various ways through which international students may remain in the United States once the OPT period has been exhausted. A predominant channel is obtaining an H-1B visa through a sponsoring employer, which allows foreign nationals to live and work in the United States for up to six years. Employers can later sponsor the worker for employment-based permanent residency. Another common alternative is being sponsored for permanent residency by an immediate family member who is a U.S. citizen (a spouse, child over 21, parent or sibling).

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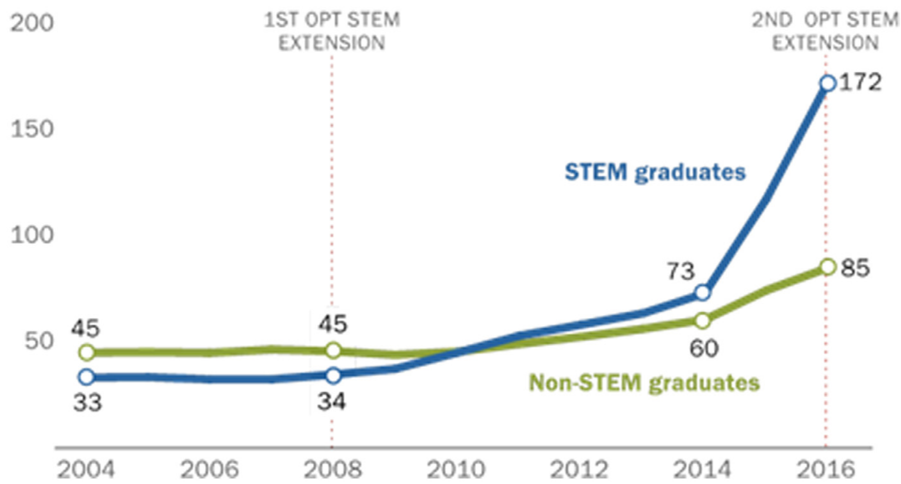

Fig. 1. Number of OPT approvals from 2004–2016, in thousands.
Notes: This figure is from Ruiz and Budiman (2018). In their report, the authors describe the plotted figures as "students with an associate degree or higher", whereas the STEM categories are "based on the fields outlined by the Department of Homeland Security." The plotted data originates from a Freedom of Information Act request filed by the Pew Research Center to U.S. Immigration Customs Enforcement.

employee's performance before sponsoring an H-1B visa. While both of these are important, the likely main benefit to both workers and employers of the extended OPT period, given the limited number of available H-1B visas in recent years, is that it allows employers to apply for an H-1B for a given worker in multiple years, before the worker must leave the country.[3]

There are several mechanisms through which the OPT extension may have increased the number of foreign-born U.S. STEM degree holders living in the United States after graduation. First, STEM students using the OPT extension were able to remain in the United States after graduation for a longer period while on OPT. This additional time would have made it easier to win the H-1B lottery or to transfer to another visa, such as a fiancé visa for those marrying a U.S. citizen. The decrease in return migration rates of STEM degree holders could have mechanically increased the number of STEM degree holders living in the United States after graduation.

A more interesting possibility is if the OPT extension changed students' decisions about pursuing a STEM degree in the United States. Another possibility for the international students determined to study in the United States is that the policy increased the likelihood of choosing a STEM major. While we are not able to perfectly distinguish between these mechanisms in this paper, all of which might play a role, we do provide evidence suggesting that some international students, who would have otherwise chosen a non-STEM major, responded to the policy change by pursuing a degree in STEM.

Consistent with the large response to the change in OPT policy, Fig. 1 shows that the number of foreign STEM graduates participating in OPT grew by over 400% between 2008 and 2016, while the corresponding number of non-STEM graduates grew by only 88% (Ruiz and Budiman, 2018). To put this in perspective, in the years leading up to the 2008 OPT extension, non-STEM graduates consistently had more OPT approvals than STEM graduates, but by 2016, STEM graduates had twice as many OPT approvals as non-STEM graduates (Ruiz and Budiman, 2018). Also consistent with a large policy impact, (Demirci, 2019) finds that the OPT extension available to STEM majors increased these students' likelihood of using OPT at all relative to non-STEM students. Since all international students were eligible for at least a year of OPT before and after the policy, his finding could be due to international students (or their employers) taking into account the likelihood of a more permanent stay in the United States when making work-related decisions. Finally, academia appears to have responded to the policy as well, with some economics departments changing the name of their major from "economics" (not considered a STEM field) to "econometrics and quantitative economics" (considered a STEM field) in order to attract more international students ("Economics Renames Itself to Appeal to International Students", 2018). While the increases in the number of STEM students using OPT, as well as the changing names of economics majors, are suggestive of the OPT policy having an impact, they are also consistent with an increase in labor demand for students with mathematical and science-related skills.

We use data from the 2003, 2010, 2013, and 2015 waves of the National Survey of College Graduates (NSCG) –a repeated cross-sectional biennial survey of the college-educated population in the United States, to estimate causal impacts of the policy. Specifically, we compare pre vs. post-OPT extension changes in the propensity to hold a STEM degree of foreign born individuals who first came to the United States on a student visa (treatment group), relative to other foreign-born U.S. college graduates (control group). The control group includes the foreign-born who first came to the United States on a permanent or temporary visa that allowed them to work. Like those in our treatment group, these foreign born individuals obtained their highest degrees in the United States and, therefore, are likely to have been similarly affected by any changing economic conditions (such as changes in firms' demand for STEM labor). They would not, however, benefit from the OPT STEM extension as the latter is only available to those with student visas. As such, we test if the foreign-born in our treatment group became more likely than the foreign-born in the control group to have a STEM major if they enrolled in their field of degree after the 2008 policy change.

We find that the OPT extension raised the propensity of holding a STEM degree by about 18% for those in our treatment group relative to those in our control group. To provide evidence that this baseline estimate can be interpreted as causal, we test for pre-trends, make changes to our control and treatment groups, and explore the robustness of our estimates to the addition of several control variables to our model. All of the checks support the interpretation of the OPT extension impacts as causal. Most of the impact originates from students with a terminal master's degree, for whom the likelihood of having a STEM major rose by 33%. We also explore which STEM fields were most affected by the OPT

[3] H-1B visas are generally awarded on a first come, first served basis up until the yearly cap has been reached. Starting in 2004, the H-1B visa cap has been reached every single year. To maximize the chances that the visa is awarded, firms typically apply for the visas at the earliest possible date—April 1st. In many years, the cap has been reached in the first week that the visas become available, and in these cases, all visas are awarded by lottery. During the 2018-2019 season, for example, H-1B candidates had a 38 percent chance of selection in the standard cap lottery with a slightly higher likelihood for those with a U.S. graduate degree (USCIS 2018). With an extended OPT period, STEM graduates have multiple chances to apply for the scarce H-1B visas.

policy change and find that the OPT extension increased the engineering workforce in the United States more than any other STEM field.

Data restrictions prevent us from distinguishing among all mechanisms potentially at play. Instead, we focus on the net effects of the policy change, but we are able to provide suggestive evidence that some students may be changing their majors as a result of the policy. We do this by examining whether the policy has had its strongest impact on individuals appearing only marginally committed to pursuing a STEM degree. To that end, we first look at whether the OPT extension induced double majors, with a non-STEM field listed as their first major, to hold a second major in a STEM field. We find that among international students with a master's degrees and a double major, the propensity to double major in STEM when their first major was in a non-STEM field increased 1.7 times as a result of the policy. For students listing a STEM field as a first major, the likelihood of a second major in a STEM field was actually smaller after the OPT policy change. In a similar vein, the OPT extension appears to have induced many non-STEM B.A. majors to pursue a master's degree in STEM, making such a transition 1.1 times more likely. In contrast, the policy does not seem to have had an impact on the likelihood of STEM B.A. majors pursuing master's degrees in STEM. Taken together, these results might be interpreted as suggestive evidence of the OPT extension inducing "marginal" STEM majors to pursue a STEM degree.

The remainder of the paper is organized as follows. In Section 2, we provide some background on the subject of study. In Section 3, we discuss the data and summary descriptive statistics. In Section 4, we present the methodology, and this is followed by a discussion of the main results in Section 5. Mechanisms are considered in Section 6. Section 7 concludes the study.

2. Background

International students in the United States are eligible for Optional Practical Training (OPT), a type of work authorization that allows international students to gain work experience in their field of study, for generally up to 12 months, while on their student visas. We are interested in assessing the effectiveness of the OPT STEM extension on increasing the number of STEM workers in the United States. The United States is an interesting case study for various reasons. First, it is the country with the most international students in the world, i.e. over 24% of the global international student population in the year 2017 (IIE Center for Academic Mobility Research and Impact, 2018).[4] Secondly, while the total numbers of international students coming to the United States is growing, the share of the world's international student population studying in the United States has been decreasing in recent years. Recent newspaper articles point to the increasing difficulty international students are facing transitioning to the U.S. labor market (e.g., Merrick, 2018). Meanwhile, many other countries are moving in the opposite direction, making it easier for international students to settle in their countries (Merrick, 2018). Hence, understanding the effectiveness of adopted policies at increasing the number of STEM workers who remain in the country is critical.

While our focus is on the U.S., the analysis herein should also be of interest to other nations with large international student populations, such as the United Kingdom (which hosts 11%), China (with 10%), or Australia, France, and Canada (each hosting 7%) (IIE Center for Academic Mobility Research and Impact, 2018).[5] Furthermore, several countries grant temporary work authorization to international students after graduation. For example, Canada allows international students, regardless of field, to work in the country for up to three years after graduation. In China, students can typically stay for a year on a worker's permit, but certain "talented workers" (usually researchers and engineers, i.e. STEM workers) can apply for a visa allowing them to stay in the country for up to five years. Furthermore, the country provides resettlement subsidies for people in highly skilled occupations (Klimaviciute, 2017). In that vein, other countries facilitate the permanent settlement of STEM graduates via other channels. For example, New Zealand relies on a point-based immigration system where almost half of the points needed to gain permanent residency can be gathered by having a job offer in a labor shortage field, such as a STEM field. In Australia, STEM master's and doctoral students get an additional 5 points (out of 60) toward permanent residency (Klimaviciute, 2017). In sum, while we examine the impact of extending the OPT period for graduates with STEM majors, our study has implications for any country considering making it easier for immigrants in certain fields to participate in a country's labor market.

What is OPT and how did it develop? The OPT program grew out of the Immigration and Nationality Act of 1952, which allowed international students to work in the United States whenever employment for practical training was required or recommended by the institution or place of study (for a history of the OPT program, see Miano (2017)). Because OPT is viewed as a type of training, the temporary employment must be directly related to the student's academic major, regardless of whether it is used while students are completing their studies or after graduation.[6]

On April 2, 2008, students with a STEM degree became eligible for a one-time 17-month extension of their OPT periods. Before applying for the extension, international students must first use the regular (12-month) period of OPT. While students can apply for a regular OPT without a job offer, a current or prospective employer must be specified as part of the STEM-extension application. Employers must be part of the E-Verify program -an easy to use online program that quickly expanded since 2008 from 88,116 participating employers to 749,923 by 2017.[7] The extension also allows for an additional 30 days of unemployment, beyond the 90 days granted to all students on OPT. As discussed previously, the OPT extension may have increased the share of STEM majors among international students living in the United States via three main mechanisms: return migration, the decision to pursue a post-secondary education in the United States, and the decision to major in a STEM field. We discuss each of these potential mechanisms in more detail below.

2.1. The OPT extension and return migration

The most obvious way the OPT STEM extension may have increased the likelihood that international students still living in the United States after graduation have a STEM degree is that the extension made it possible for them to extend their stays in the U.S. while still on their student visas. Using administrative data on international students studying in the United States, Demirci (2019) finds that the OPT extension increased the likelihood that STEM students used OPT at all compared to

[4] One of the reasons that the United States is home to so many international students is that it is a large country with a large population in higher education. When comparing the number of international students to the total population in higher education population in each country, Australia ranks highest with 23.8 percent, the UK and Canada follow at 21.1% and 15.2%, respectively, while the U.S. share is 5.3%. (See www.iie.org/projectatlas).

[5] Available at: www.iie.org/projectatlas.

[6] Before becoming eligible for OPT, a student must be registered as a full time student for at least one academic year at an accredited U.S. college or university. Any OPT used while students are completing their degrees is deducted from the generally 12-month OPT period available after graduation. After starting OPT, students can change jobs, but cannot be unemployed in between these jobs for more than 90 days. Students with multiple majors can work in jobs related to each of the fields, but still cannot work more than the 12 months. A student can use separate 12-month OPT periods for different levels of degrees: one for a bachelor's degree, another for a master's, and another for a doctoral degree. For more details, visit: https://www.uscis.gov/working-united-states/students-and-exchange-visitors/students-and-employment/optional-practical-training.

[7] See: https://www.e-verify.gov/about-e-verify/history-and-milestones.

non-STEM students. He also shows that the length of time STEM students were on OPT increased after the policy change suggesting that STEM students did take advantage of the extension. While he is not able to examine stays in the United States beyond the OPT period using his administrative data on international students, he shows using NSCG data (the data we use in our analysis) that higher shares of STEM students held a work visa three to six years post-graduation, relative to non-STEM students, after the STEM extension policy went into effect (Demirci, 2019).

Demirci's work certainly provides evidence that STEM students responded to the policy change relative to non-STEM students in terms of their return migration patterns. We complement his work by comparing student-visa arrivers to other foreign-born graduates of U.S. universities in terms of the likelihood of holding a STEM degree before vs. after the policy change. If STEM international students have become more likely to stay in the United States after graduation as a result of the policy, this certainly can be at least part of the reason why we see increased likelihoods of having a STEM major among the student-visa arrivers still living in the United States after graduation. However, using our identification strategy, we are also able to uncover other mechanisms through which the STEM extension may have increased the relative representation of STEM fields among the student-visa arrivers living in the U.S. after graduation. Specifically, it might have induced more STEM students to pursue their studies in the U.S. (as opposed to remaining in their home countries, for example), and it might have induced more international students to study a STEM field (as opposed to a non-STEM field).

2.2. Choice to pursue higher education in the United States

There is reason to believe that the OPT extension may also have increased the relative number of STEM students from abroad choosing to study in the United States. Rosenzweig (2006) puts forth two main models of the decision to study abroad. The *constrained domestic schooling* model emphasizes high returns to skill in home countries, combined with a scarcity of home country institutions of higher education able to produce that skill. The *migration model*, in contrast, points to a higher return to skill in the host country than in the home country. Studying in the host country opens doors for future employment in the higher wage host country. Using data to test the predictions of both of these models, he finds the evidence most consistent with the migration model.[8] If, indeed, the main purpose of studying in the United States is to gain access to the U.S. labor market, then a policy facilitating the school-to-work transition should increase the propensity of students targeted by the policy (namely, those with the interest and ability to study a STEM field) to pursue higher education degrees in the United States.

In line with this assessment, Bound et al. (2015) conclude that a U.S. degree is an important pathway to the U.S. IT labor market. They point to the very large wage premium in the U.S. IT labor market (Clemens, 2013), and suggest that U.S. employers are more likely to choose job market candidates with U.S. credentials because they are more familiar with U.S. institutions. Given the large share of international students who stay in the United States after completing their degrees to work (Bound et al., 2015),[9] and the fact that about a third of international students enter the U.S. labor market through the OPT program (Bound et al., 2015), their choice of major might be reasonably sensitive to OPT policy changes.

There is a growing literature showing that students consider ease of transitioning to the U.S. labor market when deciding whether to pursue their degrees at U.S. colleges and universities. To examine the impacts of a newly binding H-1B visa cap in 2004 making work in the U.S. more difficult for college-educated foreign nationals, several studies exploit the fact that trade agreements grant citizens from five countries (Canada, Mexico, Chile, Singapore, and Australia) access to work visas that are close substitutes to the H-1B, but that do not have binding caps (Amuedo-Dorantes and Furtado, 2016; Kato and Sparber, 2013; Shih, 2016). Shih (2016) shows that the number of international students from countries that lacked access to these alternative work visas dropped after 2004 relative to the number of students from the five countries with access to alternative work visas. In the seminal paper using this identification strategy, Kato and Sparber (2013) show that, after the visa cap became binding, SAT scores of foreign-born students without access to substitute visas decreased relative to the scores of students from countries with access to alternative work visas. This may be because the students of higher ability are more likely to consider future prospects of working in the United States when making the decision to study abroad. While the 2004 cut in the number of available H-1B visas impacted college-educated workers across all fields, the 2008 OPT extension made the transition to the U.S. labor market easier only for students with U.S. STEM degrees. Thus, we may expect an increase in the number of STEM students choosing to study in the United States.

2.3. Choice to major in a STEM field

A final mechanism through which the OPT extension may have increased the relative share of STEM majors among student-visa arrivers is via field of study choice. If access to the U.S. labor market is a major reason for studying in the United States, then students determined to study and eventually work in the United States may have become more likely to choose a STEM major after the policy change.

There is a rapidly expanding literature examining the determinants of college major choice—specifically, the choice of a STEM field as a major. Theory posits that this decision is made under uncertainty by weighing expected costs and benefits. The costs of pursuing a STEM degree depend both on the student's level of preparation before starting the program, as well as on the support received while completing the course work (e.g. Griffith, 2011; Price, 2011; Rask, 2011). Classroom environments may also influence students' decisions to major in a STEM field. Several researchers have shown that more competition from immigrant classmates results in fewer natives pursing STEM degrees (Orrenius and Zavodny, 2015; Anelli et al., 2017). Anelli et al. (2017) provide evidence suggesting changes in the communicative environment within classes drives their results. Since the OPT extension in itself is not likely to have had strong direct impacts on classroom environments, we turn to the literature on how expectations about future careers affect college major choice.[10]

Students' decisions to pursue engineering careers tend to be sensitive to career prospects in the engineering field (Ryoo and Rosen, 2004). While both males and females tend to consider future labor market issues when making college major choices, males tend to care more about the pecuniary returns to working in different fields, whereas females tend to place more weight on nonpecuniary attributes, such as enjoying the work assignment and the ability to reconcile work and family

[8] Bound *et al.* (2016) describe four main factors driving the variation in the number of foreign-born students studying at U.S. universities as follows: the affordability of U.S. tuition, the home country's educational preparation of students, the availability of quality institutions of higher education in home countries and, most importantly for our study, the value of accessing the U.S. labor market.

[9] Between 1999 and 2009, about a half of each graduating class of international students switched from student (F) visa status to H-1B status (Bound et al. 2015).

[10] If the OPT STEM extension induces enough additional international students into STEM courses and these students end up changing the classroom environment, natives and other foreign-born students may respond by increasingly majoring in non-STEM fields –a choice that would also have labor market implications later on. We view this competition impacts as a second order effect of the policy change since they first need to impact the treatment group, in order to have an impact on the control group.

(Zafar, 2013). For international students studying in the United States, the expected ability to work in the United States after graduation is also likely to play a strong role in their choice of college major. The 17-month extension of the OPT for STEM students from 2008 may have induced some of the students at the margin of choosing a STEM degree to choose the STEM major.

The focus of our paper will be on evaluating if the OPT extension for STEM graduates appears effective at increasing the number of foreign-born U.S. STEM degree holders living in the United States. While we are not able to distinguish between the three mechanisms discussed above, we will provide empirical evidence suggesting that the policy induced some international students, who are likely to have otherwise made a different field choice, to choose a STEM degree.

3. Data and descriptive statistics

We use data from the 2003, 2010, 2013, and 2015 waves of the National Survey of College Graduates (NSCG). For the purpose of our analysis, we focus on foreign-born individuals ages 16–64 who received their terminal degrees in the United States on or after 1995. To clearly differentiate between those who came on student visas (and so were directly affected by OPT policy) from other foreign born U.S. graduates who first arrived with work authorization, we dropped from the sample the foreign born who first arrived on temporary visas other than for those granted to work or to study. Because of trade agreements, nationals of five countries (Canada, Mexico, Chile, Singapore, and Australia) have access to work visas, similar to the H-1B, without binding caps. International students from these countries are thus not as dependent on the H-1B or OPT to work in the United States. Thus, to make clear comparisons, we drop them our baseline sample. We also drop the very few in the sample who were not living in the United States at the time of the survey.

The NSCG collects information on up to 142 majors, which we categorize into two field groups: STEM and non-STEM, according to the 2008 STEM Designated Degree Programs list provided by U.S. Immigration and Customs Enforcement (ICE).[11] Our treatment group consists of the foreign-born who first entered the United States, for more than six months, on a temporary resident visa for study or training. Our control group is comprised of other foreign-born U.S. college graduates who first entered the United States either with a permanent resident visa or with a temporary work visa.[12] In our final sample, 89% of the control group came with a permanent visa and 11% with a work visa. Those arriving on a permanent visa (also known as an immigrant visa or 'green card') would not need student visas to obtain their degrees; they are allowed to live and work permanently in the United States. Those entering on a temporary work visa may have pursued higher education part time while working, or they may have obtained their degrees after obtaining a work-sponsored or fiancé-sponsored green card. Some of these individuals in our sample may have switched to a student visa in order to study full time (and so would have benefited from the extended OPT), but this would only make it more difficult for us to find an effect of the policy.

Fig. 2 shows the share of our sample with a STEM major according to whether the individuals are in the control or treatment group and by whether their enrollment year was before or after the OPT extension in 2008. It is interesting to see how the share of foreign born U.S. college graduates with a STEM major had been dropping, regardless of their visa at entry, prior to the change in the OPT policy. In other words, the two groups exhibited similar pre-trends. However, the trend reversed for those who first came with a student visa after the policy change, while the share of other foreign-born individuals with a STEM major continued the downward trend after the policy change. The patterns in Fig. 2 certainly point to the potential role of the OPT extension, but they may also be explained by other changes in immigration policy affecting the composition of the control group (for example, limits on the number of H-1B visas that became binding for the first time in 2004). To address this issue, we replace our control group of foreign-born U.S. graduates with native-born college graduates and construct a similar figure. As can be seen in Fig. 3, natives display the same STEM degree patterns as the foreign born in our control group.

To further examine whether changing individual-level characteristics are likely to be driving these patterns, we present some basic descriptive statistics of our control and treatment samples. According to Panel A of Table 1, the share of student-visa arrivers with a STEM major is about twice as large for individuals in our treatment group (52%) compared to their counterparts in the control group (25%). Those in the treatment group are also more likely to be male, married, and live in the South and North Central regions of the country than those in the control group. The racial and ethnic composition of the two groups also varies significantly. Asian students are more highly represented in the treatment group, whereas there is a greater share of whites, blacks and Hispanics in the control group. Finally, the two groups also differ significantly with respect to their highest degree. Almost 80% of the individuals in the treatment group completed either a master's or a doctoral degree (57% indicate their highest terminal degree was a master's and for 21% it is a doctoral degree). In contrast, less than half of those in the control group have received a master's or doctoral degree (30% indicate having a master's degree as their terminal degree and 3% indicate having a doctoral degree).

Because our identification strategy relies on comparing treatment and control groups depending on whether they are likely to have enrolled in the field before or after the OPT policy change, Panel B of Table 1 further splits the sample according to whether individuals are likely to have enrolled prior to 2008.[13] As can be seen therein, the differences between treatment and control groups predated the change in the OPT policy, emphasizing the need to control for such differences in the regression analysis.[14]

[11] The 2008 list can be accessed at the link, http://www.nafsa.org/uploadedFiles/dhs_stem_designated_degree_2.pdf. It is also available from the authors upon request. There were other qualifying majors added to the STEM list in 2012, but our designation is based solely on the 2008 list.

[12] Those that first entered with a temporary visa for studying or training likely arrived with an F-1 or J-1 visa. Examples of temporary work visas include the H-1B, H-2A, H-2B as well as L-1A and L1B visas. Examples of visas for permanent stays include the DV, K-1, and E-1 visas. For a full list and description of available visas, visit the U.S. Department of State's travel website: https://travel.state.gov/content/travel/en/us-visas/visa-information-resources/all-visa-categories.html.

[13] We do not have detailed information on enrollment dates. Instead, as discussed in the next section, we estimate enrollment years based on graduation years.

[14] Panel A of Table A1 in the appendix further provides the descriptive statistics for the two subgroups in the control group -namely, those who entered on a temporary work visa and those who first arrived on a permanent visa. There are some notable differences between the two groups that the analysis will account for, including the fact that those who first entered on a temporary visa were more likely to have a STEM major. Other differences include being older, more likely to be male, married, and Asian. They are also more likely to have earned a master's or Ph.D. degree than those who entered with a permanent visa. This makes sense in that most temporary work visas require a college degree. Thus, those who first arrived with a work visa and then subsequently obtained another degree in the U.S would most likely obtain a graduate degree. Panel B of Table A1 in the appendix shows some of the changes in personal traits of individuals in our control group, before and after the policy change, according to whether they first entered on a temporary or permanent visa. Among those enrolling in their majors after 2008, there was a notable decrease in the propensity of pursuing a STEM degree among foreign-born students entering the country on a temporary visa. In addition, the share of Hispanics in that group rose significantly.

Fig. 2. Share of STEM majors by entering visa type and year of enrollment.
Notes: The sample consists of foreign-born individuals with a degree from a U.S. college or university ages 16–64, who either came to the United States on a student visa or on a visa, temporary or permanent, that allowed them to work. The vertical line depicts 2008, the year of the OPT extension.

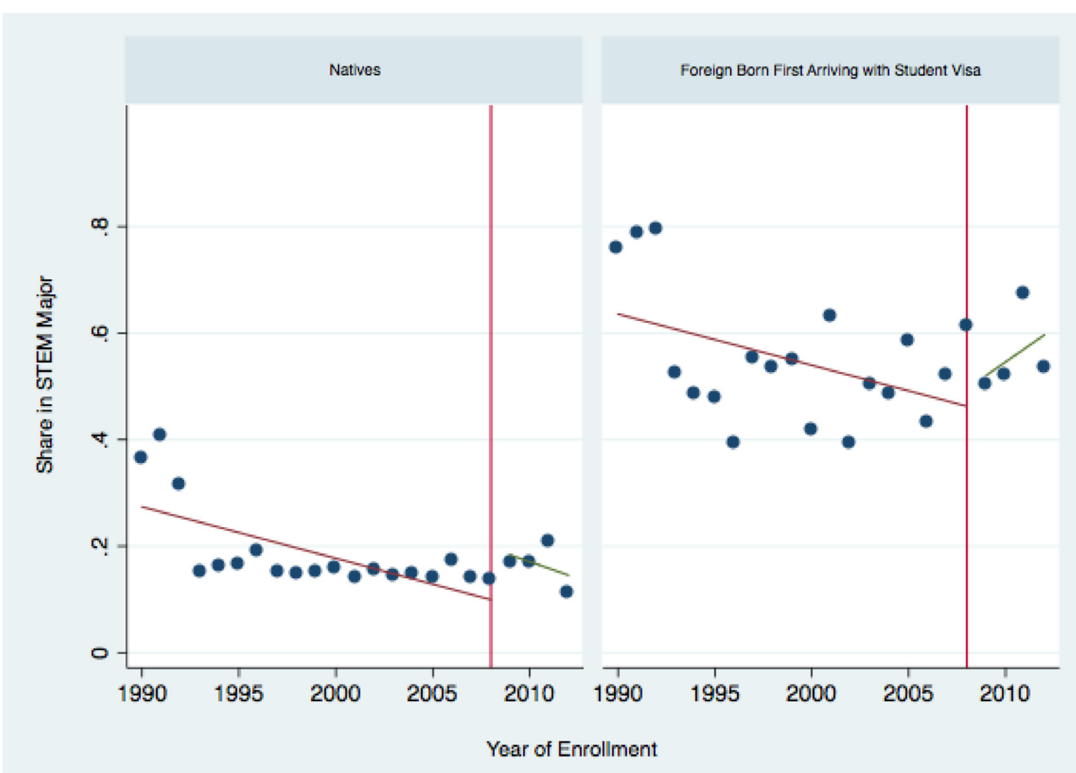

Fig. 3. Share of STEM majors by visa status and year of enrollment.
Notes: The sample consists of natives and foreign-born individuals with a degree from a U.S. college or university ages 16–64, who came to the United States on a student visa. The vertical line depicts 2008, the year of the OPT extension.

Table 1
Descriptive statistics.

Panel A	Full Sample Period					
Sample	Full Sample		First Arriving with Student Visa		First Arriving with Alternative Visa with Work Authorization	
Statistic	Mean	S.D.	Mean	S.D.	Mean	S.D.
STEM Major	0.36	0.48	0.52	0.50	0.25	0.44
Age	37.66	8.90	37.68	8.49	37.65	9.18
Male	0.51	0.50	0.61	0.49	0.44	0.50
White	0.21	0.40	0.19	0.39	0.22	0.41
Black	0.13	0.33	0.10	0.30	0.14	0.35
Asian	0.54	0.50	0.64	0.48	0.48	0.50
Hispanic	0.10	0.30	0.07	0.25	0.13	0.33
Married	0.65	0.48	0.70	0.46	0.62	0.49
Bachelor's Degree.	0.43	0.49	0.19	0.39	0.59	0.49
Master's Degree	0.41	0.49	0.57	0.49	0.30	0.46
Ph.D. Degree	0.10	0.30	0.21	0.40	0.03	0.17
Professional Degree	0.06	0.23	0.03	0.18	0.07	0.26
Highest Degree's Graduation Year	2004	5.55	2004	5.59	2004	5.51
East	0.27	0.45	0.23	0.42	0.30	0.46
West	0.31	0.46	0.30	0.46	0.32	0.47
South	0.29	0.45	0.31	0.46	0.27	0.45
North Central	0.12	0.33	0.15	0.36	0.10	0.30
Observations	21,103		11,251		9852	

Panel B	Pre-2008 Period						Post-2008 Period					
Sample	Full Sample		First Arriving with Student Visa		First Arriving with Alternative Visa with Work Authorization		Full Sample		First Arriving with Student Visa		First Arriving with Alternative Visa with Work Authorization	
Statistic	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
STEM Major	0.37	0.48	0.51	0.50	0.27	0.44	0.36	0.48	0.57	0.49	0.21	0.41
Age	38.97	8.43	39.21	7.93	38.80	8.76	32.70	8.91	31.68	7.93	33.36	9.44
Male	0.52	0.50	0.62	0.49	0.45	0.50	0.47	0.50	0.59	0.49	0.40	0.49
White	0.20	0.40	0.18	0.39	0.22	0.41	0.21	0.41	0.20	0.40	0.22	0.41
Black	0.11	0.32	0.11	0.31	0.12	0.33	0.17	0.38	0.09	0.28	0.23	0.42
Asian	0.57	0.50	0.64	0.48	0.51	0.50	0.46	0.50	0.62	0.48	0.35	0.48
Hispanic	0.10	0.29	0.06	0.24	0.12	0.32	0.13	0.34	0.09	0.28	0.16	0.37
Married	0.71	0.45	0.76	0.42	0.67	0.47	0.43	0.50	0.45	0.50	0.42	0.49
Bachelor's Degree.	0.43	0.49	0.19	0.39	0.60	0.49	0.42	0.49	0.20	0.40	0.56	0.50
Master's Degree	0.39	0.49	0.54	0.50	0.28	0.45	0.51	0.50	0.70	0.46	0.39	0.49
Ph.D. Degree	0.12	0.33	0.24	0.43	0.04	0.19	0.03	0.18	0.07	0.25	0.01	0.11
Professional Degree	0.06	0.24	0.03	0.17	0.08	0.28	0.04	0.19	0.04	0.19	0.04	0.19
Highest Degree's Graduation Year	2002	4.43	2002	4.57	2002	4.33	2012	1.37	2012	1.38	2012	1.35
East	0.26	0.44	0.22	0.42	0.28	0.45	0.34	0.47	0.25	0.43	0.39	0.49
West	0.34	0.47	0.30	0.46	0.36	0.48	0.22	0.41	0.30	0.46	0.17	0.37
South	0.28	0.45	0.32	0.47	0.26	0.44	0.32	0.46	0.28	0.45	0.34	0.47
North Central	0.12	0.33	0.15	0.36	0.10	0.30	0.13	0.33	0.17	0.37	0.10	0.30
Observations	17,589		9294		8295		3514		1957		1557	

Notes: The sample consists of foreign-born individuals with a degree from a U.S. college or university ages 16–64, who either came to the United States on a student visa or on a visa, temporary or permanent, that allowed them to work. We drop from the sample those who first arrived as dependents, and those that arrived on other temporary visas. All estimates are calculated using sample weights.

4. Methodology

Given the range of factors potentially responsible for the change in STEM field patterns by group and whether the enrollment year is before or after the 2008 policy, we next examine the impact of the OPT extension more thoroughly by estimating the following benchmark model:

$$Y_{i,v,e,t} = \alpha + \beta OPT_{v,e} + X_i\gamma + \delta_v + \delta_e + \delta_t + \epsilon_{i,v,e,t} \quad (1)$$

where $Y_{i,v,e,t}$ equals 1 if foreign-born student i who entered with a visa status v, and who enrolled in calendar year e, has a terminal degree in a STEM field when observed in survey year t; otherwise, it equals 0.

Our key regressor, *OPT,* equals 1 if the individual is in our treatment group and if enrollment in the major likely occurred after the 2008 OPT extension. The variable equals zero otherwise. It is worth noting that, while the NSCG contains information on graduation years, it does not contain information on the date in which the individual chose her/his major. Therefore, we proxy for this date. We set it equal to two years prior to graduation date if the terminal degree is a bachelor's, master's or professional degree. It is set equal to five years prior to graduation if the terminal degree is a Ph.D.[15] The main coefficient of interest, β, gauges how the OPT extension might have impacted the likelihood that the student-visa arrivers still reside in the United States hold STEM degrees compared to the other foreign born graduates of U.S. colleges and universities.

The vector X accounts for a number of individual level characteristics such as age, age squared, gender, race, ethnicity, marital status and highest educational degree. It also includes a series of country of origin fixed effects intended to capture idiosyncratic STEM preferences and preparation. The model also includes time-invariant fixed effects for the visa that the foreign-born used when they came to the United States for the first time (δ_v). We distinguish between three visa category statuses: (1) first entered on a permanent visa, (2) first entered on a temporary visa with work authorization; and (3) first came on a student visa.

To account for labor market opportunities faced by students during the year they enrolled in the major, which could potentially impact their choice of major, we also include enrollment cohort fixed-effects (δ_e). Finally, Eq. (1) incorporates fixed effects for the year in which individuals were surveyed (δ_t). Standard errors are clustered on cells constructed based on whether the enrollment year was before vs. after 2008, visa status at first entry, and country of origin. Our baseline specification includes 690 clusters.

5. Did the OPT extension generate more foreign-born STEM degree holders?

5.1. Main findings

Table 2 presents the results from estimating several specifications of the model in Eq. (1) that progressively add controls for the highest degree held and a number of demographic controls. A few findings are worth discussing. First, the magnitude of the estimated coefficient of interest increases when we add controls for the highest degree completed. Adding further controls for demographic characteristics, such as age and marital status, yields estimated policy impacts that are slightly smaller, but not very different. Our final and preferred model, shown in column 3 of Table 2, suggests that the OPT extension significantly raised the likelihood of holding a STEM degree by 9.4 percentage points, or 18%, among those who first came to the United States on student visas.

Several traits, such as the student's gender, race, marital status and the highest degree held, also play an important role in raising her/his likelihood of holding a STEM degree. As can be seen in the last column of Table 2, males are 18.5 percentage points (36%) more likely to have a STEM major than females.[16] Additionally, those with a doctoral degree are 25 percentage points (49%) more likely to hold a STEM degree than their counterparts with a bachelor's degree. In contrast, older individuals and those with a professional degree appear less likely to have a STEM degree than their younger counterparts and those with a bachelor's degree. Specifically, those with professional degrees are 31 percentage points (60%) less likely than those with a bachelor's degree to hold a STEM degree.

We next explore the robustness of our findings in Table 2 to address potential concerns about identification and interpretation. For example, some may be concerned that our estimated policy impacts are driven by changes over time in the characteristics of the foreign-born in our control group. If this were the case, however, we would expect our estimates to be very sensitive to even small changes in our control group. To explore this possibility, we consider two alternative control groups.

As described in more detail by Kato and Sparber (2013), free trade agreements allowed citizens from five countries to apply for close H-1B visa substitutes (Kato and Sparber, 2013; Shih, 2016; Amuedo-Dorantes and Furtado, 2016). These visas are similar to the H-1B, but lack binding caps. Therefore, nationals of these five countries are not likely to be as dependent on the OPT extension to work in the United States after

Table 2
Impacts of STEM extension on STEM major choice – dependent variable: STEM major.

Column/Model Specification:	(1)	(2)	(3)
Student Visa * Enroll 2008 or Later	0.070	**0.110****	**0.094*****
	(0.044)	**(0.044)**	**(0.036)**
Age			−0.031***
			(0.011)
Age Squared			0.000*
			(0.000)
Male			0.185***
			(0.014)
Black			0.042
			(0.067)
Asian			0.111***
			(0.039)
Hispanic			0.037
			(0.071)
Married			0.025
			(0.015)
Master's Degree		−0.005	0.041
		(0.028)	(0.028)
Ph.D. Degree		0.218***	0.248***
		(0.040)	(0.036)
Professional Degree		−0.350***	−0.306***
		(0.025)	(0.028)
Visa F.E.	Y	Y	Y
Enrollment Year F.E.	Y	Y	Y
Country of Origin F.E.	Y	Y	Y
Survey Year F.E.	Y	Y	Y
Observations	21,103	21,103	21,103
R-squared	0.216	0.256	0.313
Pre-2008 D.V. mean for those arriving with student visas	0.5084	0.5084	0.5084

Notes: Dependent variable: Highest degree being in a STEM field. See notes underneath Table 1 for details on sample. All regressions include a constant term. All estimates are calculated using sample weights. Standard errors are clustered on cells constructed based on whether the enrollment year was before vs. after 2008, visa status, and country of origin.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

[15] Later on, we test the robustness of our findings to the use of different approximations of the field choice date, which we refer to as the "enrollment year".

[16] In additional analyses available from the authors, we explore if OPT had a differential impact in the choice of a STEM major made by men and women. We found no significant gender differences in their response to the policy.

Table 3
Robustness checks – dependent variable: STEM major.

Column: Model Specification:	(1) Add Five Substitute Visa Countries	(2) Use Native Students as Control	(3) Exclude China from the Sample	(4) Exclude India from the Sample	(5) Exclude China and India from the Sample	(6) Control for the Growth Rate of Per Capita GDP	(7) Use Different Enrollment Year	(8) Drop Recession Years
Student Visa * Enroll 2008 or Later	**0.101******	**0.062******	**0.083*****	**0.099******	**0.077****	**0.114******	**0.086*****	**0.103****
	(0.029)	**(0.023)**	**(0.039)**	**(0.037)**	**(0.041)**	**(0.036)**	**(0.036)**	**(0.060)**
Age	−0.025**	−0.011***	−0.035***	−0.017*	−0.019*	−0.025**	−0.031***	−0.034***
	(0.010)	(0.002)	(0.012)	(0.010)	(0.011)	(0.011)	(0.011)	(0.012)
Age Squared	0.000	0.000***	0.000**	0.000	0.000	0.000	0.000**	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male	0.187***	0.129***	0.179***	0.184***	0.179***	0.185***	0.186***	0.179***
	(0.013)	(0.004)	(0.015)	(0.016)	(0.018)	(0.013)	(0.014)	(0.015)
Black	0.004	−0.021***	0.046	0.032	0.036	0.064	0.043	0.012
	(0.060)	(0.007)	(0.066)	(0.063)	(0.061)	(0.059)	(0.068)	(0.070)
Asian	0.048	0.129***	0.100***	0.104***	0.092***	0.078**	0.113***	0.143***
	(0.032)	(0.019)	(0.035)	(0.040)	(0.035)	(0.037)	(0.041)	(0.048)
Hispanic	0.022	−0.028***	0.079	0.035	0.076	0.066	0.038	0.034
	(0.063)	(0.007)	(0.067)	(0.071)	(0.068)	(0.071)	(0.070)	(0.083)
Married	0.019	−0.004	0.027*	0.018	0.020	0.017	0.026*	0.030*
	(0.014)	(0.006)	(0.016)	(0.017)	(0.017)	(0.015)	(0.016)	(0.017)
Master's Degree	0.014	−0.046***	0.028	0.027	0.007	0.029	0.041	0.036
	(0.027)	(0.006)	(0.030)	(0.023)	(0.021)	(0.029)	(0.028)	(0.032)
Ph.D. Degree	0.215***	0.162***	0.244***	0.294***	0.305***	0.229***	0.252***	0.245***
	(0.033)	(0.011)	(0.044)	(0.031)	(0.037)	(0.036)	(0.036)	(0.041)
Professional Degree	−0.305***	−0.197***	−0.305***	−0.290***	−0.288***	−0.333***	−0.320***	−0.314***
	(0.025)	(0.003)	(0.028)	(0.029)	(0.029)	(0.024)	(0.028)	(0.029)
Visa F.E.	N	N	Y	Y	Y	Y	Y	Y
Enrollment Year F.E.	Y	Y	Y	Y	Y	Y	Y	Y
Country of Origin F.E.	N	Y	Y	Y	Y	Y	Y	Y
Survey Year F.E.	Y	Y	Y	Y	Y	Y	Y	Y
Country by Visa F.E.	Y	N	N	N	N	N	N	N
Observations	22,668	146,354	17,994	16,904	13,795	19,145	21,103	17,243
R-squared	0.343	0.113	0.278	0.297	0.234	0.321	0.313	0.318
Pre-2008 D.V. mean for those arriving with student visas	0.4878	0.5082	0.4579	0.4535	0.3709	0.5042	0.5074	0.5076

Notes: All specifications are based on the baseline model as in Table 2 Column 3. See notes underneath Table 1 for details on sample. In Specification (1), individuals from Canada, Mexico, Chile, Australia, and Singapore, are added to the control group regardless of whether they first arrived with a student visa. Country by visa two-way fixed effects are included in this specification. Specification (2) uses the native-born as the control group. Specifications (3), (4), and (5) exclude Chinese individuals, Indian individuals, and both Chinese and Indian individuals, respectively. Specification (7) uses proxy enrollment dates given by: "BA = graduation year - 1" "MA = graduation year - 1" "PhD = graduation year - 4" "Prof. Dgr = graduation year - 2". Specification (8) drops students who enrolled in recession years (2007, 2008, and 2009). All regressions include a constant term. All estimates are calculated using sample weights. Standard errors are clustered on cells constructed based on whether the enrollment year was before vs. after 2008, visa status, and country of origin.

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

graduation, regardless of whether they first came on student visas. After all, they can do so under one of those alternative work visas. While sample sizes of nationals of these five countries are too small to exclusively use them as a control group, we can add students from these countries to our control group to see if the change affects our estimates. We do so in column (1) of Table 3, which also replaces the visa and country of origin fixed effects with visa by country of origin fixed effects. Our findings remain practically unchanged.

Next, in column (2), we repeat our estimation, this time replacing our original control group with a much larger group –namely, similarly aged U.S.-born college graduates that we used to construct Fig. 3. Doing so does not alter the sign or statistical significance of the estimated OPT policy impact in Table 2, although the magnitude of the effect decreases by a few percentage points. As already hinted by Fig. 3, we view these results as quite convincing evidence that our main findings are not driven solely by characteristics and behaviors of the foreign-born in our control group.

We next examine whether nationals of specific countries are driving our findings. We start by conducting the analysis excluding Chinese students from our sample. China is the top origin country of foreign students in the United States (Ruiz, 2014). Hence, if a policy or institutional change in China drove Chinese students to specialize in STEM fields in the United States after 2008 for reasons unrelated to the OPT extension, we may be overestimating the impact of the OPT policy change. As seen in column (3) of Table 3, results remain very similar to those using our baseline sample. Likewise, in column (4) of Table 3, we experiment with excluding Indians from our sample since India is the second largest source country for international students in the United States (Ruiz, 2014). The estimate of interest remains practically unchanged. In column (5) of Table 3, we drop both Chinese and Indian respondents from our sample. The sample size becomes significantly smaller, leading to higher standard errors. Nevertheless, while it is only statistically different from zero at the 10% level, the magnitude of our estimate of interest does not differ much from our baseline estimate in the last column of Table 2.

We also consider the possibility that home country economic conditions, in nations other than China and India, are driving our findings. If, for example, richer countries can afford to send more students to the United States, and per capita GDP was growing faster after 2008 in countries that typically send STEM students to study in the United States, then our results may be explained by changes in home country economic environments as opposed to OPT policy. To address this concern as well as any other impacts driven by home country economies,[17] we calculate the growth rate of per capita gross domestic product (GDP) for each enrollment year and country of origin and add it as a control to our baseline specification. As seen in column (6) of Table 3, adding the growth rate of per capita GDP does not significantly alter our findings.

As discussed earlier on, we do not have precise information on the exact date individuals in our sample were deciding to pursue a STEM degree in the United States. As another robustness check, we experiment with using an alternative proxy for the enrollment date. We set the date equal to 1 year prior to graduation if the terminal degree is a B.A. or a master's degree, two years prior to graduation if the terminal degree is a professional degree, and four years prior to graduation if the terminal degree is a Ph.D.[18] As shown in column (7) of Table 3, we continue to find that the OPT policy change raised the relative likelihood that international students living in the United States after graduation hold a STEM degree by 8.6 percentage points (16.9%).

Lastly, in column (8) of Table 3, we address concerns related to the role that business cycles might have played on our estimate. To that end, we drop the years around the Great Recession (2007, 2008 and 2009). As shown therein, we continue to find a similar impact of the OPT extension to the one revealed in Table 2.[19]

Next, given that holders of certain graduate degrees are significantly more likely to major in STEM than those with bachelor's degrees (see Table 2), we re-estimate our main model separately for respondents whose highest degree is a bachelor's, those with a master's and those with a doctoral degree. If our estimated increase in STEM majors were due, exclusively, to mechanical changes in return migration rates due to the extension of the OPT period, we may not observe large differences in the impact across the various degrees. After all, regardless of the degree, all STEM students get the same 17-month extension.

Table 4 shows that our estimates of the impacts of the OPT extension are driven by master's degree holders. Specifically, while there is no impact of the STEM extension on bachelor's degree recipients (the point estimate is practically zero and not statistically significant), recipients of terminal master's degrees appear 16 percentage points (33%) more likely to have pursued a STEM degree after 2008 if they arrived with a student visa. In other words, the OPT extension doubled the relative likelihood that student-visa arriving terminal master's degree recipients were in STEM fields. This finding is consistent with prior descriptive work by Ruiz and Budiman (2018), who point out that the largest growth in OPT approvals between 2004 and 2016 occurred for master's students. They also note that the increase primarily took place after the 2008 STEM extension; in particular, the number of master's degree OPT participants decreased by 7% between 2004 and 2007, but increased by 322% between 2008 and 2016. One potential explanation for the larger impacts among masters' students is that access to the U.S. labor market is a main motivating factor for pursuing this degree. A master's degree is possibly the most efficient way of achieving that end given the lower time costs of a master's degree relative to a bachelor's or Ph.D. degree. Thus, the decisions of master's students (either about where to study or what to study) may be more responsive to policies making it easier to work in the U.S. after graduation.

Table 4
Heterogeneous impacts by highest educational degree.

Dependent Variable:	STEM Major		
Column:	(1)	(2)	(3)
Sample:	B.A.	M.A.	Ph.D.
Student Visa * Enroll 2008 or Later	0.038	**0.161*****	**−0.197***
	(0.074)	**(0.059)**	**(0.113)**
Age	−0.014	−0.041**	−0.016
	(0.012)	(0.018)	(0.015)
Age Squared	0.000	0.000*	−0.000
	(0.000)	(0.000)	(0.000)
Male	0.257***	0.160***	0.115***
	(0.025)	(0.023)	(0.025)
Black	0.073	0.006	−0.049
	(0.080)	(0.064)	(0.147)
Asian	0.027	0.265***	−0.041
	(0.035)	(0.062)	(0.101)
Hispanic	0.034	−0.023	0.135
	(0.106)	(0.081)	(0.141)
Married	0.041*	0.007	−0.010
	(0.024)	(0.024)	(0.028)
Visa F.E.	Y	Y	Y
Enrollment Year F.E.	Y	Y	Y
Country of Origin F.E.	Y	Y	Y
Survey Year F.E.	Y	Y	Y
Observations	5745	10,854	3761
R-squared	0.321	0.316	0.345
Pre-2008 D.V. Mean for those arriving with student visas	0.3132	0.4890	0.7655

Notes: Analysis is performed separately for each highest degree completed. We do not show results for those with a professional degree because of the small number of observations. See notes underneath Table 1 for details on sample. Dependent variable: Highest degree being in a STEM field. All regressions include a constant term. All estimates are calculated using sample weights. Standard errors are clustered on cells constructed based on whether the enrollment year was before vs. after 2008, visa status, and country of origin.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Strangely, the point estimate suggests that doctoral graduates became less likely to hold a STEM degree if they enrolled after the OPT extension, but this effect is not statistically significant at conventional levels. This might be partially reflective of the fact that many doctoral recipients pursue careers in the academic sector, where the H-1B visa has not been capped since the year 2000 (Amuedo-Dorantes and Furtado, 2016). Therefore, their transitions to the U.S. labor market should not be as influenced by OPT policy extensions. Additionally, it is possible that some international students who originally come to the U.S. for undergraduate or master's degrees pursue PhDs in the U.S. as a way to remain in the U.S. for additional time without requiring a U.S. job offer. If the OPT extension increased the likelihood that STEM holders obtained initial job offers, doctoral studies would become relatively less attractive for these students.

5.2. Further identification tests

A threat to our empirical approach is that some other factor, occurring around 2008, differentially affected the STEM-related career decisions of individuals in our treatment and control groups. For example, given that the lower H-1B visa quota of 2004 decreased the number international students pursuing their studies in the U.S. (Shih, 2016), we might be concerned that H-1B visa scarcity had a stronger deterring impact on non-STEM students compared to STEM students. This seems unlikely given Kato and Sparber's (2013) finding that the decrease was driven by students with higher SAT scores. Nevertheless, to investigate

[17] Because STEM degree holders tend to be less sensitive to economic conditions than other college graduates (Altonji, Kahn, and Speer 2016), it is also possible that students from countries with smaller GDP growth rates are more likely to major in STEM once they arrive in the United States. Another possibility is that GDP growth rates are associated with differential return migration rates by field of study.

[18] The test is not performed with using earlier approximate enrollment dates due to few observations left in the treatment group.

[19] We also experimented with splitting our control group into two subgroups (those who entered on a temporary visa and those who did so on a permanent visa) and using them independently. As shown in Table A2 in the appendix, our sample drops by half when we restrict our control group to foreign-born students who first entered the country on a temporary visa that allowed them to work. The estimated coefficient is not significantly different in magnitude from our baseline estimates, but we do lose statistical significance with the smaller sample. Next, in column (2), we show the regressions results when we use the much larger control group of foreign-born students who first entered the country on permanent visas. We find a similar impact to the one shown in Table 2.

Table 5
Tests for differential pre-trends.

Dependent Variable:	STEM Major	
Column:	(1)	(2)
Sample:	All Degrees	Terminal Degree: Masters
Panel A: Full Sample Period		
Student Visa * Enroll Two Years Prior 2008	−0.097	−0.051
	(0.068)	(0.079)
Student Visa * Enroll One Year Prior 2008	0.029	−0.009
	(0.088)	(0.124)
Student Visa * Enroll 2008 or Later	**0.089****	**0.156****
	(0.037)	**(0.061)**
Personal Characteristic Controls	Y	Y
Visa F.E.	Y	Y
Enrolment Year F.E.	Y	Y
Country of Origin F.E.	Y	Y
Survey Year F.E.	Y	Y
Observations	21,103	10,854
R-squared	0.314	0.314
Pre-2008 D.V. mean for those arriving with student visas	0.5084	0.4890
Panel B: Pre-2008 Sample Period		
Student Visa * Time Trend	0.004	−0.002
	(0.005)	(0.006)
Time Trend	Y	Y
Personal Characteristic Controls	Y	Y
Visa F.E.	Y	Y
Enrolment Year F.E.	Y	Y
Country of Origin F.E.	Y	Y
Survey Year F.E.	Y	Y
Observations	17,589	8410
R-squared	0.304	0.303
Pre-2008 D.V. mean for those arriving with student visas	0.5084	0.4890

Notes: Dependent variable: Highest degree being in a STEM field. All regressions include a constant term. All regressions include a constant term. All estimates are calculated using sample weights. See notes underneath Table 1 for details on sample restrictions. Standard errors are clustered on cells constructed based on whether the enrollment year was before vs. after 2008, visa status, and country of origin. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

whether this or any other change in policy occurring just before 2008 should be a matter of concern in our case, we construct new indicators for those who first arrived on a student visa and who enrolled one and two years prior to the OPT extension (that is, in 2006 and in 2007). We then include the placebo terms, along with the true policy indicator, in a model similar to the one in Eq. (1). If the impact shown in Table 2 predated the policy change, we would expect the placebo terms to have statistically significant estimated coefficients in the same direction of the OPT extension impact in Table 2.

The results of this test are documented in column (1), Panel A of Table 5. The estimated coefficients on the placebo terms are not statistically different from zero. As such, the impact of the OPT extension in Table 2 does not appear to have predated the policy change. Furthermore, despite the inclusion of the placebo terms, the true policy estimate continues to be statistically significant, suggesting an increased likelihood of choosing a STEM field by 8.9 percentage points or 17.5%.

To offer further reassurance that the results are not driven by a longer trend prior to the implementation of the OPT extension policy, we restrict our sample to those enrolling in their majors during the pre-policy period, namely before 2008. Then, we create a time trend for the period under consideration, and interact it with a dummy variable equal to one for those who first came to the United States on student visas. Column (1) in Panel B of Table 5 displays the results from this exercise. Consistent with the parallel trends assumption, as well as with the pre-trends depicted in Fig. 2, we find no evidence of a pre-existing trend driving our results, as the estimated coefficient on the interaction term is small and not statistically different from zero.

Given that students with terminal master's degrees drive our baseline estimates (see Table 4), we conduct the prior identification tests on our sample of master's degree holders. As shown in column (2) in Panels A and B of Table 5, we find no evidence of a pre-existing positive trend driving our findings. The placebo term is non-statistically different from zero. Importantly, the policy impact itself remains different from zero and positive. Likewise, when we restrict our sample to those individuals enrolling prior to 2008 and include an interaction term like the one in column (1) of that same Panel B, we find that the term is not statistically different from zero, hinting at the lack of predated impacts.

5.3. Heterogeneous impacts by field of expertise

Finally, we explore whether there are systematic differences in the impact of the OPT extension by type of STEM field. In other words, did the policy result in larger increases in the relative share of student-visa arrivers with specific STEM majors compared to other majors? To answer this question, Table 6 displays the results from estimating Eq. (1), where the dependent variable is now the likelihood of having chosen a particular STEM field vs. any other field, regardless of whether the other field is in STEM. Specifically, we consider the following fields: computer and mathematical sciences, life and related sciences, physical and related sciences, social sciences, engineering, or science and engineering related fields.[20] According to the estimates in Table 6, the 2008 OPT extension appears to have made the largest impact on the likelihood that international students hold engineering degrees, making them 5 percentage points (26%) more likely to have engineering as their degree major. Estimated impacts on other STEM fields are all rather small and statistically insignificant.

Since the increased tendency to choose a STEM field as a major following the OPT policy change is primarily observed among students with a terminal master's degree (see Table 4), we further zoom into this group to see their STEM field preferences. As shown in Table 7, the point estimates continue to suggest the same large increases in the relative share of international students holding engineering degrees but in this smaller sample, the estimate is not statistically significant. In contrast, estimated coefficients increase in magnitude for the life science and social science degrees and so despite the smaller sample sizes, these estimates become statistically significant in the master's degree sample.

6. Mechanisms

As discussed previously, the most obvious way the OPT extension may have increased the relative share of STEM graduates among student visa arrivers is by decreasing their return migration rates. The STEM extension made it more likely that STEM majors who arrived as international students are still living in the U.S. at the time of the survey both because they may still be on their (extended) OPT periods at the time of the survey and because the extended OPT gives them more time to transfer to a more permanent visa. Demirci (2019) presents results pointing to both of these impacts. Unfortunately, because the National Survey of College Graduates is survey of college graduates living in the United States at the time of the survey, we cannot determine with our data the extent to which our results are due to selective out-migration and other

[20] This last category includes the following fields: audiology and speech pathology, health services administration, health/medical assistants, health/medical technologies, medical preparatory programs, medicine, nursing, pharmacy, physical therapy and other rehabilitation, other health/medical sciences, computer teacher education, mathematics teacher education, science teacher education, social science teacher education, computer programming, data processing, electrical and electronic technologies, industrial production technologies, mechanical engineering-related technologies, other engineering-related technologies, architecture/environmental design, and actuarial science.

Table 6
Heterogeneous impacts by STEM field.

Dependent Variable:	Chosen STEM Field					
Column:	(1)	(2)	(3)	(4)	(5)	(6)
Field:	Computer and Math Sciences	Life Sciences	Physical Sciences	Social Sciences	Engineering	Science and Engineering Related Fields
Student Visa * Enroll 2008 or Later	0.015	0.027	−0.006	0.004	**0.053***	0.002
	(0.025)	(0.040)	(0.007)	(0.002)	**(0.031)**	(0.010)
Age	0.003	−0.018***	−0.003*	−0.000	−0.012	−0.002
	(0.006)	(0.006)	(0.002)	(0.000)	(0.007)	(0.002)
Age Squared	−0.000	0.000**	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male	0.073***	−0.030***	−0.001	−0.002	0.141***	0.004
	(0.009)	(0.011)	(0.003)	(0.001)	(0.011)	(0.004)
Black	0.001	0.026	0.021*	−0.013	−0.013	0.018*
	(0.031)	(0.020)	(0.012)	(0.008)	(0.036)	(0.011)
Asian	0.043**	0.018	0.026	−0.006	0.022	0.009
	(0.021)	(0.016)	(0.018)	(0.008)	(0.022)	(0.010)
Hispanic	−0.007	0.054	0.013	−0.005	−0.008	−0.010
	(0.026)	(0.046)	(0.010)	(0.003)	(0.029)	(0.009)
Married	0.014	−0.002	0.006*	−0.001	0.015*	−0.006
	(0.009)	(0.007)	(0.004)	(0.001)	(0.008)	(0.006)
Master's Degree	0.007	−0.016	0.004	0.001	0.034**	0.012*
	(0.017)	(0.014)	(0.003)	(0.001)	(0.016)	(0.007)
Ph.D. Degree	−0.077***	0.147***	0.094***	0.008**	0.076***	0.000
	(0.025)	(0.018)	(0.010)	(0.003)	(0.025)	(0.006)
Prof. Degree	−0.121***	−0.068***	−0.013***	−0.000	−0.092***	−0.012***
	(0.012)	(0.012)	(0.003)	(0.001)	(0.015)	(0.004)
Visa F.E.	Y	Y	Y	Y	Y	Y
Enrolment Year F.E.	Y	Y	Y	Y	Y	Y
Country of Origin F.E.	Y	Y	Y	Y	Y	Y
Survey Year F.E.	Y	Y	Y	Y	Y	Y
Observations	21,103	21,103	21,103	21,103	21,103	21,103
R-squared	0.109	0.155	0.083	0.224	0.159	0.057
Pre-2008 D.V. mean for those arriving with student visas	0.1580	0.0827	0.0388	0.0016	0.2008	0.0265

Notes: Dependent variable: Highest degree being a particular STEM field (1 = *a* particular STEM field, 0 = any other STEM or non-STEM field). See notes underneath Table 1 for details on sample. All regressions include a constant term. All estimates are calculated using sample weights. Standard errors are clustered on cells constructed based on whether the enrollment year was before vs. after 2008, visa status, and country of origin.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

factors. What we can do, however, is to compare the characteristics of the student visa arrivers in the NSCG to those of the population of international students studying in the U.S. at the time the NSCG student-visa arrivers were pursuing their degrees. If selective return migration plays a very large role, we might expect substantial differences in the (exogenous) characteristics of respondents in these two samples. If instead, our sample of international students remaining in the U.S. is more or less representative of the population of international students, then we should not expect differences across the two data sources.

For information on the population of international students studying in the U.S. in different years, we download tables from the Open Doors Data Portal (Institute of International Education Center for Academic Mobility Research and Impact, 2018). These tables are constructed using administrative data (SEVIS data) on the population of students on student visas-primarily F (student) and J (exchange visitor) visas. These statistics are not ideal because, in addition to the students enrolled for academic credit at U.S. colleges or universities, they also include students on OPT. Nevertheless, they allow us to make important comparisons.

For example, if return migration rates were completely random, the country of origin composition of the international student population in the early 2000s should be very similar to the country of origin composition of student visa arrivers in our sample who enrolled in their degree in the early 2000s. If on the other hand, there is a significant amount of selective return migration, there is no reason to expect the country of origin composition to be the same. If, in particular, the OPT extension had strong impacts on the types of international students staying in the U.S. after graduation, we may expect rather large differences in the country of origin compositions in the two data sources depending on whether individuals were pursuing their degrees before vs. after 2008.

Panel A of Table 8 shows the country of origin composition of the student-visa arrivers in our NSCG sample separated by year of degree enrollment. As can be seen therein, the overwhelming majority come from Asia regardless of the year of graduation. Panel B of Table 8 shows the country of origin composition of all international students by year using administrative data downloaded from the Open Boarders Data Portal. While again, the overwhelming majority of international students come from Asia, we note that there are relatively more Asian students in our NSCG sample than in the Open Doors sample, suggesting that Asians are more likely to stay in the United States after graduation. There are also more North Americans in the Open Doors sample than in the NSCG, suggesting that many Canadians (and/or Mexicans) come to study in the United States, but return home.

For evidence of strong selective return migration after the OPT policy change, however, we would expect to see larger differences in the country of origin composition in the two data sources after 2008 than before. Comparing Panels A and B of Table 8, we see no obvious change after starting in 2008. Therefore, while we certainly cannot rule out a role of selective return migration as a contributor to the increase in

Table 7
Heterogeneous impacts by STEM field for those with master's degrees.

Dependent Variable:	Chosen STEM Field					
Column:	(1)	(2)	(3)	(4)	(5)	(6)
Field:	Computer and Math Sciences	Life Sciences	Physical Sciences	Social Sciences	Engineering	Science and Engineering Related Fields
Student Visa * Enroll 2008 or Later	0.032	**0.066***	−0.004	**0.003***	0.059	0.004
	(0.031)	**(0.036)**	(0.009)	**(0.002)**	(0.048)	(0.014)
Age	0.003	−0.010	−0.004*	−0.000	−0.026**	−0.005
	(0.010)	(0.008)	(0.002)	(0.000)	(0.012)	(0.003)
Age Squared	−0.000	0.000	0.000*	0.000	0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male	0.076***	−0.043**	0.002	−0.001	0.132***	−0.006
	(0.015)	(0.018)	(0.003)	(0.001)	(0.013)	(0.005)
Black	−0.008	0.011	0.016*	−0.012	−0.040	0.038*
	(0.046)	(0.013)	(0.010)	(0.010)	(0.029)	(0.022)
Asian	0.141***	0.028	0.012	−0.022	0.073**	0.032
	(0.035)	(0.019)	(0.007)	(0.023)	(0.030)	(0.022)
Hispanic	0.027	−0.036	−0.000	−0.010	−0.012	0.008
	(0.049)	(0.023)	(0.007)	(0.008)	(0.033)	(0.014)
Married	0.003	0.003	0.005	−0.001	0.004	−0.006
	(0.016)	(0.009)	(0.004)	(0.001)	(0.014)	(0.011)
Visa F.E.	Y	Y	Y	Y	Y	Y
Enrolment Year F.E.	Y	Y	Y	Y	Y	Y
Country of Origin F.E.	Y	Y	Y	Y	Y	Y
Survey Year F.E.	Y	Y	Y	Y	Y	Y
Observations	10,854	10,854	10,854	10,854	10,854	10,854
R-squared	0.126	0.178	0.052	0.030	0.175	0.112
Pre-2008 D.V. mean for those arriving with student visas	0.2000	0.0322	0.0170	0.0000	0.2109	0.0288

Notes: Sample: Holders of master's degrees. See notes underneath Table 1 for more details on other sample restrictions. Dependent variable: Highest degree being a particular STEM field (1 = *a* particular STEM field, 0 = any other STEM or non-STEM field). All regressions include a constant term. All estimates are calculated using sample weights. Standard errors are clustered on cells constructed based on whether the enrollment year was before vs. after 2008, visa status, and country of origin.

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Table 8
Share of international students by country of origin.

Panel A. National Survey of College Graduates Country of Origin	Enrollment Year												
	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
Europe	12.5	17.1	9.8	10.1	10.1	9.5	7.5	8.9	8.8	8.3	7.6	9.8	9.4
Asia	75.0	67.1	78.1	73.8	78.1	73.6	70.3	74.9	75.9	74.0	74.9	74.1	73.3
North America	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.4	0.0	0.0	0.0	0.0	0.0
Central America	0.7	2.4	1.3	0.9	1.5	2.8	2.7	2.6	1.7	1.4	0.0	1.0	1.8
Caribbean	1.3	2.4	2.3	1.6	1.8	2.5	2.5	2.6	1.2	3.2	5.0	2.1	3.2
South America	4.0	7.3	3.5	4.6	3.4	4.4	7.9	4.8	6.1	7.1	5.6	6.4	9.2
Africa	6.6	3.7	5.0	9.1	5.1	6.7	8.9	5.8	6.1	6.0	6.7	6.6	3.2
Oceania	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.2	0.0	0.4	0.0	0.0
Total (%)	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Panel B. Open Doors Report on International Educational Exchange Country of Origin	**Academic Year Starting in**												
	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
Europe	10.5	11.2	11.7	12.3	13.1	13.5	14.2	15.0	12.7	12.9	13.3	14.0	14.7
Asia	72.8	71.5	69.7	67.9	66.1	65.0	62.9	61.2	63.1	62.2	62.6	62.3	61.9
North America	3.3	3.5	3.9	4.1	4.5	4.7	4.9	5.1	5.1	4.8	4.6	4.6	4.7
Central America	2.6	2.7	2.8	2.9	3.2	3.3	3.4	3.5	3.4	3.4	3.2	3.2	3.1
Caribbean	1.4	1.5	1.6	1.9	2.0	2.0	2.4	2.5	2.5	2.7	2.5	2.4	2.6
South America	4.2	4.3	4.4	4.7	4.9	5.0	5.3	5.5	5.8	6.1	6.0	6.1	5.9
Africa	3.7	3.9	5.1	5.4	5.5	5.7	6.1	6.4	6.4	6.7	6.9	6.5	6.2
Oceania	0.7	0.7	0.8	0.7	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8
Total (%)	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Notes: Panel A statistics are calculated by authors using our NSCG sample data. It consists of foreign-born individuals with a degree from a U.S. college or university ages 16 to 65, who first came to the United States on a student visa. Estimates calculated using sample weights. Panel B statistics are reported by the Institute of International Education (2010) - "International Student Totals by Place of Origin", Open Doors Report on International Educational Exchanges. These data were retrieved from http://www.iie.org/opendoors. Annual data not available before 2000. All numbers are in percentages.

Table 9
Impact of OPT extension on the likelihood that second major is in a STEM field among double majors.

Dependent Variable:	Second Major in STEM			
Sample:	Double Majors with Bachelor's Degrees as Highest Degree		Double Majors with Master's Degrees as Highest Degree	
Column:	(1)	(2)	(3)	(4)
Subsample:	First Major Non-STEM	First Major STEM	First Major Non-STEM	First Major STEM
Student Visa * Enroll 2008 or Later	−0.118	0.224	**0.113****	**−0.517*****
	(0.137)	(0.196)	**(0.057)**	**(0.188)**
Age	0.023	0.083	−0.002	−0.065**
	(0.016)	(0.069)	(0.010)	(0.032)
Age Squared	−0.000	−0.001	0.000	0.001*
	(0.000)	(0.001)	(0.000)	(0.000)
Male	−0.006	0.265***	0.011	0.219**
	(0.044)	(0.095)	(0.044)	(0.084)
Black	0.107	0.528***	−0.030	−0.147
	(0.168)	(0.196)	(0.060)	(0.420)
Asian	0.162	0.087	−0.043	0.499**
	(0.194)	(0.292)	(0.063)	(0.250)
Hispanic	0.022	0.629***	−0.083	−0.571**
	(0.151)	(0.211)	(0.075)	(0.228)
Married	0.004	−0.226**	−0.019	0.044
	(0.032)	(0.098)	(0.033)	(0.072)
Enrollment Year F.E.	Y	Y	Y	Y
Visa F.E.	Y	Y	Y	Y
Country of Origin F.E.	Y	Y	Y	Y
Survey Year F.E.	Y	Y	Y	Y
Observations	423	389	599	574
R-squared	0.687	0.687	0.412	0.596
Pre-2008 D.V. mean for those arriving with student visas	0.0328	0.6165	0.0657	0.7421

Notes: Sample: Individuals who list both a primary and secondary major for their highest degree. The dependent variable for all specifications in this table takes on the value one if a person's secondary major is in a STEM field. Thus, specifications (1) and (3) examine the likelihood that individuals with a non-STEM first major have a STEM second major while specifications (2) and (4) examine the likelihood that individuals with a STEM first major also have a STEM second major. See notes underneath Table 1 for further details on sample restrictions. All regressions include a constant term. All estimates are calculated using sample weights. Standard errors are clustered on cells constructed based on whether the enrollment year was before vs. after 2008, visa status, and country of origin.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

STEM degree holders in the United States after the OPT extension, we conclude from this analysis that there may be other mechanisms also at play.

As discussed previously, the STEM extension may have increased the likelihood that STEM students pursue higher education in the U.S. as opposed to remaining in their home countries or even studying in a different country. In addition, the policy may have increased the likelihood of choosing a STEM field, as opposed to a non-STEM field, by students already intent on pursuing degrees in the United States. While we cannot evaluate the extent to which the OPT extension might have attracted some international students interested in specializing in STEM fields to come to the United States, we can assess if the OPT policy change induced international students with some experience with non-STEM fields to now pursue a STEM field. These are the very students who may be swayed to choose a STEM field by the change in immigration policy. Larger impacts on these marginal students may be viewed as evidence that the policy change did induce some students to study a STEM field who may have otherwise not chosen STEM. If instead, estimates are similar among the marginal and determined STEM students, it is less likely that are our baseline impacts are driven by students' field of study choices.

We have two ways to identify students at the margin of majoring in a STEM field. The first way is by focusing on double majors who list a non-STEM field as their first major. A second way is by considering field of study choices among master's students who had a bachelor's degree in a non-STEM field or among doctoral students who had a master's degree in a non-STEM field. In what follows, we examine if the OPT extension led to more double majors consisting of a non-STEM first major and a STEM second major, as well as if the OPT extension induced more transitions into STEM fields among students pursuing a higher-level degree after earning lower-level degrees in non-STEM fields.

6.1. Did the OPT extension induce a second major in STEM?

We start by restricting our sample to a subgroup of foreign-born U.S. college graduates with double majors. Subsequently, we model their likelihood of choosing a second major in a STEM field. We do so separately for those whose first major is in a STEM field, and for those whose first major is in a non-STEM field. We assume that those with a non-STEM first major are not as devoted to the STEM field as those with a STEM first major. Thus, if the OPT extension is indeed inducing students to study STEM, it would have a larger impact on those marginally interested in STEM students –namely, those whose first major is a non-STEM field—compared to those who are more devoted to a STEM major—those whose first major is in a different STEM field.[21]

Table 9 reports the results from this exercise. Our dependent variable takes the value 1 if the double-major graduate reports having chosen a STEM field for the second major, whereas it takes the value 0 if the graduate's second major was in a non-STEM field. The table shows results separately for students with a bachelor's degree as their highest degree and for students with a master's degree as their highest degree. Because of the very small number of doctoral degree holders with double majors, we only estimate the model for those whose highest degrees are

[21] At this juncture, it is worth noting that the OPT policy change decreased the likelihood of double majoring. Results are available from the authors. One potential explanation for this might be that STEM courses are more intense or time consuming, making it difficult for students to pursue a double major.

Table 10
Impact of OPT extension on the likelihood that the higher degree is in a STEM field.

Dependent Variable:	Master's Degree in a STEM field		PhD in a STEM field	
Column:	(1)	(2)	(3)	(4)
Sample:	Non-STEM BA	STEM BA	Non-STEM MA	STEM MA
Student Visa * Enroll 2008 or Later	**0.111***** **(0.033)**	−0.033 (0.051)	−0.044 (0.116)	−0.093 (0.095)
Age	0.019* (0.010)	−0.065*** (0.018)	−0.045* (0.027)	−0.005 (0.011)
Age Squared	−0.000** (0.000)	0.001*** (0.000)	0.000 (0.000)	−0.000 (0.000)
Male	−0.009 (0.020)	0.066** (0.027)	0.019 (0.038)	0.052* (0.027)
Black	0.065 (0.041)	0.173* (0.103)	0.004 (0.081)	0.151** (0.073)
Asian	0.015 (0.055)	0.186** (0.078)	0.102 (0.108)	−0.023 (0.071)
Hispanic	−0.095* (0.052)	0.248*** (0.070)	0.030 (0.089)	−0.031 (0.082)
Married	−0.036 (0.025)	0.008 (0.025)	0.045 (0.034)	−0.021 (0.017)
Enrollment Year F.E.	Y	Y	Y	Y
Visa F.E.	Y	Y	Y	Y
Country of Origin F.E.	Y	Y	Y	Y
Survey Year F.E.	Y	Y	Y	Y
Observations	2480	5732	790	2015
R-squared	0.246	0.349	0.418	0.189
Pre-2008 D.V. mean for those arriving with student visas	0.0988	0.8240	0.1653	0.9609

Notes: Sample in columns (1) and (2): Individuals with master's degrees as highest degree. Sample in columns (3) and (4): Individuals with doctoral degrees as highest degree. The dependent variable for all specifications takes on the value one if a person's highest degree is in a STEM field and zero otherwise. Thus, specifications (1) and (3) examine the likelihood that individuals with a non-STEM lower degree studied a STEM field for the highest degree while specifications (2) and (4) examine the likelihood that individuals with a STEM lower degree also studied a STEM field for the higher degree. See notes underneath Table 1 for further details on sample restrictions. All regressions include a constant term. All estimates are calculated using sample weights. Standard errors are clustered on cells constructed based on whether the enrollment year was before vs. after 2008, visa status, and country of origin.

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

bachelor or master's degrees. All other controls remain the same as in our prior specifications.

Columns (1) and (2) in Table 9 show that for students with double majors but completing only a bachelor's degree, the OPT extension had no statistically significant impact on the likelihood that the second major was in a STEM field, regardless of whether the first major was in a STEM field. This is not surprising given the results in Table 4 showing that the individuals whose highest degree is a bachelor's degree do not appear very sensitive to the change in OPT policy in the first place.

However, for students with double majors in a master's degree, the OPT extension increased their likelihood of choosing a STEM field as their second major when their first major was in a non-STEM field. In particular, column (3) shows that the new policy raised that propensity by 11 percentage points –thus making the share of international M.A. students with a STEM field as their second degree approximately 1.7 times larger. While it is telling that these marginal STEM students became so much more likely to choose a STEM field as a second major after the OPT extension, it is possible that all students (not just the marginal STEM students) became more likely to have STEM fields as their second majors after the extension. Yet, column (4) shows that the extension resulted in fewer, not more, STEM fields as second majors among master's students with STEM fields as their first major. Altogether, the results are consistent with the OPT extension inducing students who might not otherwise obtain a degree in a STEM field, to do so.

6.2. Did non-STEM B.A.'s pursue a post-B.A. STEM specialization after the policy?

Next, we define marginal STEM students as those with prior degrees in non-STEM fields and consider whether they became more likely than those with prior degrees in STEM fields to pursue higher level STEM degrees. More specifically, focusing on master's students decision to pursue a STEM field, we examine if the change in the OPT policy had a larger impact on non-STEM bachelor's degree students than on STEM bachelor's degree students. Similarly, we examine if impacts on the decisions of doctoral students to hold STEM degrees were stronger for students with non-STEM master's degrees than those with STEM master's degrees.

Starting with a sample of students with master's degrees, columns (1) and (2) of Table 10 compare the likelihood of choosing a STEM degree separately for students with a non-STEM bachelor's degree (column 1) and students with a STEM bachelor's degree (column 2). As can be seen from the pre-policy means shown at the bottom of Table 10, of the students with master's degrees, STEM BA holders are substantially more likely to pursue a STEM master's degree than are non-STEM BA holders. That said, the OPT extension appears to have had a significant impact on the choice to transition from a non-STEM B.A. to a STEM master's degree. International master's degree holders with a non-STEM B.A. became 1.1 times more likely to choose a STEM field for their M.A. post-2008. In contrast, as shown in column (2) of Table 10, the OPT extension had no statistically significant impact on the likelihood that students with STEM bachelor's degrees pursued STEM master's degrees as opposed to non-STEM master's degrees. This is certainly suggestive of students changing their field of study for their master's degrees in response to the policy. In columns (3) and (4), we conduct a similar analysis focusing on the international students who completed a Ph.D. The OPT extension does not appear to have significantly altered international students' propensity to hold a STEM doctoral degree regardless of whether their master's degrees were in STEM fields.

In sum, the results in Tables 9 and 10 suggest that the strongest influences of the OPT policy change may have been on students who may not have otherwise pursued a STEM degree. Taken together, we view the results as suggestive evidence that the OPT policy change had an effect on the field choice of students determined to study in the United States, in addition to also potentially affecting the choice of whether or not to study in the United States and the likelihood of remaining in the U.S. after graduation.

7. Summary and conclusions

Using data from the National Survey of College Graduates, we find that the OPT extension raised the relative likelihood that student visa arrivers hold a STEM degree by 18%, with engineering as the STEM field benefiting the most from the policy change. Most of the impact appears to be originating from students with terminal master's degrees, for whom the likelihood of holding a STEM degree rose by 33%.

To examine the mechanisms driving this result, we explore whether we see large increases in the likelihood of pursuing STEM degrees among students who do not appear overly committed to studying only a STEM field. In particular, we look at whether the OPT extension induced some of international students to double major in a STEM field, even though their first major was in a non-STEM field. We find evidence that, indeed, that was the case. Specifically, among international students with a master's degree, the propensity to double major in a STEM field when their first major was in a non-STEM field increased 1.7 times. Furthermore, among master's degree holders, transitions from non-STEM B.A. majors to STEM masters became 1.1 times more likely following the OPT policy change with no corresponding change in the likelihood that STEM B.A. majors chose a STEM master's major as opposed to a non-STEM major.

Rothwell (2013) estimates that roughly 20% of all U.S. jobs require knowledge in a STEM field. In the same vein, it has been estimated that American companies will be hiring an additional 1.6 million workers in the next 5 years, with 945,000 of them requiring basic STEM literacy and 635,000 demonstrating advanced STEM skills (Business Roundtable and Change the Equation, 2014). Given the growing reliance of businesses on individuals with skills in STEM fields and the promotion of these fields in our educational system, increased awareness of the effectiveness, or lack of, of these policies in promoting those specialization choices is crucial. Our findings suggest that indeed the OPT extension was an effective way to increase the STEM workforce in the United States, not only through the mechanical extension of their legal stay in the country, but also by inducing them to major in STEM.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.labeco.2019.101752.

Appendix

Table A1, Table A2.

Table A1
Descriptive statistics of the control group.

Panel A	Full Sample Period					
Sample	All Foreign Born in Control Group		Foreign Born who Arrived with Temporary Visas		Foreign Born who Arrived with Permanent Visas	
Statistic	Mean	S.D.	Mean	S.D.	Mean	S.D.
STEM Major	0.25	0.44	0.37	0.48	0.24	0.43
Age	37.65	9.18	40.26	8.75	37.38	9.18
Male	0.44	0.50	0.64	0.48	0.42	0.49
White	0.22	0.41	0.20	0.40	0.22	0.41
Black	0.14	0.35	0.07	0.25	0.15	0.36
Asian	0.48	0.50	0.58	0.49	0.47	0.50
Hispanic	0.13	0.33	0.13	0.34	0.13	0.33
Married	0.62	0.49	0.78	0.42	0.60	0.49
Bachelor's Degree.	0.59	0.49	0.26	0.44	0.62	0.48
Master's Degree	0.30	0.46	0.64	0.48	0.27	0.44
Ph.D. Degree	0.03	0.17	0.08	0.28	0.03	0.16
Professional Degree	0.07	0.26	0.01	0.11	0.08	0.27
Highest Degree's Graduation Year	2004	5.51	2006	5.46	2004	5.49
East	0.30	0.46	0.28	0.45	0.31	0.46
West	0.32	0.47	0.29	0.45	0.32	0.47
South	0.27	0.45	0.29	0.45	0.27	0.45
North Central	0.10	0.30	0.14	0.34	0.10	0.30
Observations	9852		1083		8769	

Panel B	Pre-2008 Period						Post-2008 Period					
Sample	All Foreign Students in the Control Group		Foreign Students with Temporary Visas		Foreign Students with Permanent Visas		All Foreign Students in the Control Group		Foreign Students with Temporary Visas		Foreign Students with Permanent Visas	
Statistic	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
STEM Major	0.27	0.44	0.43	0.50	0.25	0.43	0.21	0.41	0.25	0.43	0.21	0.40
Age	38.80	8.76	40.99	8.48	38.61	8.75	33.36	9.44	38.69	9.13	32.52	9.22
Male	0.45	0.50	0.65	0.48	0.43	0.50	0.40	0.49	0.60	0.49	0.37	0.48
White	0.22	0.41	0.19	0.39	0.22	0.41	0.22	0.41	0.22	0.42	0.22	0.41
Black	0.12	0.33	0.09	0.29	0.12	0.33	0.23	0.42	0.01	0.12	0.26	0.44
Asian	0.51	0.50	0.62	0.49	0.50	0.50	0.35	0.48	0.51	0.50	0.32	0.47
Hispanic	0.12	0.32	0.09	0.28	0.12	0.33	0.16	0.37	0.23	0.42	0.16	0.36
Married	0.67	0.47	0.77	0.42	0.66	0.47	0.42	0.49	0.79	0.41	0.36	0.48
Bachelor's Degree.	0.60	0.49	0.27	0.44	0.63	0.48	0.56	0.50	0.25	0.44	0.61	0.49
Master's Degree	0.28	0.45	0.62	0.48	0.25	0.43	0.39	0.49	0.67	0.47	0.35	0.48
Ph.D. Degree	0.04	0.19	0.09	0.28	0.03	0.17	0.01	0.11	0.07	0.26	0.00	0.05
Professional Degree	0.08	0.28	0.02	0.14	0.09	0.29	0.04	0.19	0.00	0.03	0.04	0.20
Highest Degree's Graduation Year	2002	4.33	2003	4.49	2002	4.31	2012	1.35	2011	1.49	2012	1.33
East	0.28	0.45	0.25	0.43	0.28	0.45	0.39	0.49	0.35	0.48	0.40	0.49
West	0.36	0.48	0.35	0.48	0.36	0.48	0.17	0.37	0.15	0.36	0.17	0.37
South	0.26	0.44	0.24	0.43	0.26	0.44	0.34	0.47	0.40	0.49	0.33	0.47
North Central	0.10	0.30	0.16	0.36	0.10	0.30	0.10	0.30	0.09	0.29	0.10	0.30
Observations	8295		885		7410		1557		198		1359	

Notes: The sample consists of foreign-born individuals with a degree from a U.S. college or university ages 16–64, who came to the United States on a visa, temporary or permanent, that allowed them to work. We drop from the sample those who first arrived as dependents, and those that arrived on other temporary visas. All estimates are calculated using sample weights.

Table A2
Estimates of STEM extension using separate control groups.

Dependent Variable:	STEM Major	
	(1) Control: Temporary Visa Only	(2) Control: Permanent Visa Only
Student Visa * Enroll 2008 or Later	0.120	**0.098*** **
	(0.104)	**(0.036)**
Age	−0.048***	−0.027**
	(0.016)	(0.012)
Age Squared	0.000**	0.000
	(0.000)	(0.000)
Male	0.202***	0.184***
	(0.019)	(0.015)
Black	0.084	0.036
	(0.060)	(0.071)
Asian	0.132*	0.115***
	(0.072)	(0.040)
Hispanic	−0.092	0.031
	(0.083)	(0.074)
Married	0.021	0.023
	(0.027)	(0.016)
Master's Degree	0.071	0.055*
	(0.052)	(0.029)
Ph.D. Degree	0.280***	0.263***
	(0.035)	(0.037)
Professional Degree	−0.347***	−0.300***
	(0.034)	(0.028)
Visa F.E.	Y	Y
Enrollment Year F.E.	Y	Y
Country of Origin F.E.	Y	Y
Survey Year F.E.	Y	Y
Observations	12,334	20,020
R-squared	0.355	0.320
Pre-2008 D.V. mean for those arriving with student visas	0.5084	0.5084

Notes: All specifications are based on the baseline model as in Table 2 Column 3. See notes underneath Table 1 for details on sample. In specification (1) the control group includes individuals who came to the United States on a temporary visa that allowed them to work. In specification (2) the control group includes individuals who came to the United States on a permanent visa. All estimates are calculated using sample weights. Standard errors are clustered on cells constructed based on whether the enrollment year was before vs. after 2008, visa status, and country of origin.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

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