International Student Enrollments and Selectivity: Evidence from the Optional Practical Training Program

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Abstract

We examine how the 17-month extension of the Optional Practical Training—a program that allows international students to practice their skills by temporarily working in the United States during or after their academic programs—made available to Science, Technology, Engineering and Math (STEM) graduates impacts their enrollments and selectivity. In addition to allowing them to extend their work experience opportunities, the OPT extension provides eligible international students an additional attempt at securing an H-1B visa. We find sizable positive treatment effects on both the number and quality of international students matriculating into U.S. higher education.

I. Introduction

The number of international students in the United States exceeded 1 million in 2018 for the third year in a row, even though new enrollments dropped by 6.6 percent in 2017/18 continuing a downward trend first observed in 2015/2016 (Open Doors Report, IEE 2018). The gains in overall students are primarily due to the increase in students participating in the Optional Practical Training (OPT) program, which allows international students to practice their skills by temporarily working in the United States during or after their academic programs (Brier 2020). OPT has sustained such growth that it has surpassed the H-1B visa as the nation's largest visa program for high-skill workers. Unlike H-1B visas, employer sponsorship is not required and there is no annual cap on the number of OPT approvals. Given the strict quotas on H-1B visas available each year, international students have increasingly turned to OPT to acquire U.S. work experience.

In this paper, we address how recent changes to the OPT program, extending its duration by 17-months to eligible STEM graduates, has impacted both international student enrollments and selectivity. In addition to allowing for extended work experience and U.S. wages,[1] the OPT extension provides international students with an additional chance to secure an H-1B visa. Yet, despite the tremendous growth of the OPT program in recent years, little is known about the impact of its reforms on the volume and selectivity of international students in U.S. higher education. We focus on three recent reforms to the OPT program that likely altered the returns to studying in the United States for STEM majors. In 2008, the duration of work authorization was extended from 12 to 29 months for international students graduating in select STEM fields. In 2011, and again in 2012, the list of STEM fields eligible for the 29-month extension was expanded.

[1] There are other financial considerations/benefits to both prospective employers and international students in OPT. For instance, employers do not pay a complete compensation package to OPT workers, who are still considered international students, and OPT workers do not pay social security and Medicare taxes given their nonresident status.

We contribute to the literature by examining how the unique incentives provided by the OPT reforms have affected both the size and selectivity of international enrollments. Prior studies have highlighted permanent U.S. employment opportunities (*e.g.* Bhagwati and Rao 1999, Chiswick 1999, Borjas 2002, and Rosenzweig 2006), and H-1B visa availability (*e.g.* Kato and Sparber 2013, Shih 2016) as important factors influencing matriculation from abroad. Additionally, Chen *et al*. (2020) show that delayed visa processing and high refusal rates can discourage foreign students from even trying to apply to U.S. universities. However, the impact of recent OPT reforms on the size and selectivity of international enrollments has not been examined yet despite the growth and unique traits of OPT. As noted earlier, while the H-1B visa has a tightly regulated annual limit, there is no government-imposed cap on the number of international students that come to study to the United States, and no cap on the number engaging in OPT. Furthermore, OPT does not require employer sponsorship nor a job offer, whereas the H-1B visa requires an applicant to first have a formal offer of employment and the employer must sponsor the applicant. These two features suggest that OPT reforms incentivizing foreign nationals to study in the United States have the potential to significantly contribute to the supply of skilled labor.[2]

By uncovering the effects of OPT reforms, we contribute to a literature examining how students respond to bundled incentives under great uncertainty (Kuka *et al*. 2020). The OPT reforms extending the duration of OPT and the number of STEM eligible majors provide two distinct incentives. First, conditional on finding a job, international students using the STEM OPT extension would gain almost an entire year and a half of U.S. work experience and wages. In

[2] Indeed, research has already begun to document the impacts of OPT induced labor supply shocks. For example, Demirci (2019) documents how the 2008 OPT extension increased the number of international students staying in the United States after graduation, which in turn, may have negatively impacted native workers.

addition to this short-run and temporary incentive, the OPT reforms provide a second long-run incentive —an extra chance at securing an H-1B visa to work more permanently in the United States. The quota on H-1B visas has been exhausted each year since 2004, and has been distributed by random lottery in 2007, 2008 and each year since 2013 (Mayda *et al.* 2018a, 2018b). Hence, the OPT reforms effectively granted international students in STEM fields an additional opportunity to secure an H-1B visa. International students have more time to conduct job searches, receive a formal job offer from an employer willing to sponsor them, and apply for an H-1B visa. Our analysis suggests that the opportunity to secure more permanent employment appears to be an important incentive for international students.

Our analysis draws upon various sources of data, including administrative data from the U.S. government obtained through a Freedom of Information Act (FOIA) request and institutional data from Integrated Postsecondary Education Data System (IPEDS). Using a difference-in-differences design, we compare how the quantity and type of international STEM students changed with the OPT extension and expansion reforms, relative to non-STEM students.

We find that international enrollments in STEM fields grew by 18 percent among students pursuing a bachelor's degree, and by 30 percent among master's students in response to the changes in the OPT program. The concentration of the OPT impacts among students pursuing these two programs is not surprising. One of the main benefits of the OPT extension is the additional chance to secure an H-1B visa. Associate degree holders do not qualify for an H-1B, whereas doctoral degree holders have the option of employment in the academic sector, which is exempt from the H-1B visa cap (Amuedo-Dorantes and Furtado, 2018). Placebo analyses using associate and doctoral degree holders further corroborate the relevance of having an additional chance to secure an H-1B visas as a likely key determinant of the growth in international enrollments in bachelor's and master's degree programs.

We also show that our findings are not driven by students switching from Business majors to eligible STEM majors, nor by universities reclassifying non-STEM majors as STEM. Results prove robust to using various control groups, including only Arts & Humanities majors–less likely to be conducive to switches to STEM or to be reclassified as STEM majors, as well as international STEM majors from 5 countries with alternative work visa programs. In additional robustness checks, we also account for the role that the Great Recession might have played in our estimates by controlling for major-specific unemployment rates, contrasting the impacts of the 2008 reform to those of the 2011 and 2012 reforms, and using a synthetic control group. Altogether, these results support the notion that our findings are not the byproduct of students switching majors, major reclassification, spurious trends or even macroeconomic shocks, such as the Great Recession or growing international student exchanges worldwide.

Finally, we also find suggestive evidence of the OPT reforms raising the selectivity of international students as captured by their enrollments at top research institutions, at institutions with low admissions rates, and at institutions spending more per student. In addition, enrollments grew more among students granted greater financial support in the form of scholarships and fellowships –allegedly more selective students.

In sum, the OPT reforms appear to have increased international enrollments among students in the right tail of the skill distribution. Understanding the role of recent changes in OPT policy on the scale and selectivity of international students' enrollments is relevant for several reasons. Secular declines in higher education funding have led institutions to turn to international students as an important source of revenue, especially for public universities (Bound *et al.* 2020).

The revenue provided by international students, in turn, helps cross-subsidize the education of domestic students (Shih 2017, Chen 2020). Hence, without greater government funding, the financial health of higher education institutions depends on their ability to attract and enroll international students. Understanding the effectiveness of OPT reforms not only provides much needed policy evaluation, but also helps clarify what incentives international students respond to.

Lastly, OPT policy requires students to work in an occupation directly related to their field of study. As such, the extension of OPT incentivizing STEM students to come to the United States can significantly impact the STEM labor supply. Over the 2003-2019 period, the top 10 employers of students on OPT were all technology-related companies and accounted for 26 percent of OPT employment among the top 200 employers.[3] Increases in the STEM workforce can foster innovation and entrepreneurism (Stephan and Levin 2001, Wadhwa *et al*. 2007, Hunt and Gauthier-Loiselle 2010, Anderson 2016), and generate productivity spillovers for native workers (Peri *et al*. 2015). In that regard, OPT may not only be a policy tool affecting higher education, but may also carry transformative downstream impacts on STEM innovation and labor supply.

The paper is organized as follows. Section II describes the institutional background and policy changes to OPT. Section III presents a random utility model to derive some predictions regarding scale and selection impacts to guide the empirical analysis. Section IV discusses the methodology, and Section V describes the data. Section VI contains a discussion of our findings on the impact of OPT reforms on international student enrollments –including identification and robustness checks, as well as potential mechanisms at play. Next, Section VII discusses our

[3] The top 10 employers ranked in order are: Amazon, Google, Intel Corporation, Microsoft Corporation, Deloitte, Facebook, Integra Technologies LLC, IBM, Apple Inc, and Qualcomm Technologies Inc. See data from ICE FOIA library: https://www.ice.gov/doclib/sevis/pdf/data_Top200_EmployersSTEM_OPT_Students2008_2019.pdf

findings on the impact of the OPT reforms on the quality of international student enrollments. Finally, Section VIII concludes the study.

II. Institutional Background

Optional Practical Training (OPT) allows international students on an F-1 visa to gain work experience. The program was only designed for temporary work as a form of training, allowing students to work for one year, after which they would need to either leave the country or switch to a different form of legal status. This work experience may be gained either prior to the degree completion, in which case it counts towards the overall OPT duration allowed for by law, or after completion of the degree –the most popular option, with students being able to apply up to 90 days prior to graduation until 60 days after graduation.

Up until 2008, the OPT period was limited to 12 months. However, in 2008, in response to increased lobbying by industry and high-tech companies, OPT was extended by 17 months, allowing for a total of 29 months. Importantly, this extension was limited to students in science, technology, engineering, and mathematics (STEM) fields. In 2011 and 2012, there were two additional reforms that extended the list of eligible majors for the OPT extension. For instance, STEM majors with 6-digit CIP codes ending in "99" —also known as "catch-all" majors that had been previously excluded in the 2008 OPT extension,[4] became eligible for the OPT extension in 2012.[5] In addition, there were other majors that gained eligibility, as they were deemed to have sufficient STEM content, including some in environmental studies (*e.g.* Urban Forestry) and quantitative intensive economics (*e.g.* Econometrics).

[4] CIP stands for Classification of Instructional Programs. It is used by the Department of Education to standardize and classify major fields of study. At the most disaggregate level, fields of study are represented by 6-digit CIP codes.

[5] An example of a "catch-all" CIP code ending in "99" would be a specialized type of biology major that does not fit into any of the already well-defined 6-digit CIP codes for Biology. A full list of expanded STEM degrees is available at https://www.dhs.gov/news/2012/05/11/dhs-announces-expanded-list-stem-degree-programs.

The intention of these reforms was to retain talent amidst concerns about the loss of U.S. trained talent in STEM fields due to students' inability to secure an H-1B visa. Amuedo-Dorantes, Furtado and Xu (2019) document how the 2008 OPT reform might have helped steer more students towards STEM fields, and Demirci (2019) documents how the 2008 reform increased the number of students remaining in the United States —likely working— after graduation. However, we still have limited understanding of how the policy might have impacted international students' educational enrollments and selectivity. The ability to extend the duration of their training may have encouraged more students to study in the United States, as well as altered the selection of students in a number of dimensions, as captured by the type of institution they attend and its traits (*i.e.* public and private-not-for-profit, research oriented, lower admission rates, greater expenditures per student, or larger institutional support offered to students). In addition, we assess whether the more recent OPT reforms in 2011 and 2012 produced different effects from the one in 2008. Our aim is to address this gap in the literature to enhance our understanding regarding the effectiveness of the various policy approaches in achieving their goal, as well as on their implications on the overall volume and selectivity of U.S. international student enrollments.

An important consideration for our analysis pertains to institutions reclassifying ineligible CIP codes to eligible CIP codes. For example, some economics departments changed the formal CIP code classification of their programs from the "Economics, general" code (45.0601) to the STEM OPT eligible CIP code for "Econometrics and Quantitative Economics" (45.0603), specifically to allow international students to qualify for the OPT extension.[6] Unfortunately, while the institutional response to the OPT reforms is an important consideration, there is no systematic

[6] See, for example, https://www.insidehighered.com/admissions/article/2018/02/19/economics-departments-reclassify-their-programs-stem-attract-and-help.

recording of program reclassifications. Nonetheless, reclassification is less likely to be a severe issue when using control groups that contain majors, such as Arts & Humanities, with no STEM eligible CIP code to reclassify to. Indeed, while “Economics, general” can conceivably be reclassified to “Econometrics”, it would be much harder for “French Literature” to be reclassified to a STEM eligible major. Robustness checks using only Arts & Humanities majors as a control show alike impacts, suggesting our findings are not merely the byproduct of reclassification.

III. Conceptual Framework

The literature has documented the various motives driving international students’ pursuit of an academic degree in the United States. Some studies emphasize the desire for students to pursue educational opportunities that are simply not available in their home countries or are hard to reach for several reasons, such as competition (Rosenzweig 2006, Hwang 2009, Bird and Turner 2014). Others underscore students’ desire to live and work in the United States after completion of their academic degrees as the main motive driving their choice to study in the United States (Kato and Sparber 2013, Bound *et al*. 2014). Finally, students may also come for other motives, such as family reunification, which might drive international students to come and complete their education, possibly staying in the United States thereafter.

We utilize a random utility model to highlight the incentives provided by OPT and derive some predictions on the scale and selection effects of the OPT reforms. To simplify, we focus on individuals in a home country. Conditional on deciding to pursue a higher education, students must choose amongst majors and destinations. We assume foreign individuals, indexed by i, decide on a major (STEM or non-STEM), indexed by m, and destination of study (United States or Home), indexed by d. In order to understand selection, we also allow for different types of individuals based on ability, which we index by j. Prospective students compare the expected return associated with each choice, which are a function of potential earnings and costs. Log wages are given by:

$$w_{imd}^{j} = \bar{w}_{md} + r_{md}^{j} D_{im}^{j} \quad (1)$$

All workers earn, at a minimum, the average major-specific wage in country d, given by $\bar{w}_{mD}$. In addition, they receive a major-specific ability premium, r_{mD}^{j}. The indicator variable, D_{im}^{j}, equals 1 if an individual of ability j graduates with a degree in major m from country d. For simplicity, we allow the ability premium to be increasing in j, such that $r_{md}^{a} > r_{md}^{b}$ for all $a > b$. Individuals pay the cost c_{d}^{j}, which includes education costs (*e.g.*, tuition, room and board, etc.), and migration costs (*e.g.*, travel costs, psychic costs of migration, etc.) for those studying in the United States. We allow these costs to vary across destinations and ability, but not across majors since tuition rates are generally set by the university for all students regardless of their study fields. Foreign students are not eligible for financial aid in the United States, but may receive scholarships and fellowships that reduce their net tuition costs.

The utility derived from studying in the United States or at home is linear in parameters and depends on both wages and costs. Furthermore, we allow for uncertainty in employment to vary across countries by defining: p_{md} –namely, the probability that an international student with major m can work in country d after graduation ($d = u$ or h, which stands for the United States or home, respectively). Since studying in the United States does not guarantee being able to work and earn U.S. wages, we define the probability of working in the United States as: $0 < \mathrm{p}_{mu} < 1$. Individuals return home after graduation if they cannot work in the United States with probability $(1 - \mathrm{p}_{mu})$. Furthermore, employment probabilities may differ by major, due to changing demands for skill, and with immigration policy, *e.g.* OPT. We do not allow these probabilities do differ with ability. While in practice higher ability individuals are more likely to be hired, the random lottery nature of the H-1B program tends to annul this relationship. For simplicity, we assume studying at home allows you to work and earn home country wages with certainty, but you cannot work in the United States, *i.e.* $\mathrm{p}_{mh} = 1$. Similarly, we segment labor markets entirely, so that individuals with a non-STEM degree cannot work in STEM occupation, and vice-versa.

With γ as the marginal utility of income, the expected utilities from pursuing a higher education in the United States and at home are given by equations (2) and (3), respectively:

(2) $$U_{imu}^{j} = \gamma\left(\left[\mathrm{p}_{mu} w_{imu}^{j} + (1 - \mathrm{p}_{mu}) w_{imh}^{j}\right] - c_{u}^{j}\right) + \varepsilon_{imu}^{j}$$

(3) $$u_{imh}^{j} = \gamma\left(w_{imh}^{j} - c_{h}^{j}\right) + \varepsilon_{imh}^{j}$$

If ε_{imd}^{j} is an i.i.d. error term with a type-I extreme value distribution, and we define V to represent observed utility (*i.e.* $u - \varepsilon$), the probability of studying major m in the United States and at home can be written as (McFadden 1974):

(4) $$P_{imu}^{j} = \frac{\exp\left(V_{imu}^{j}\right)}{\Sigma_{d}\Sigma_{m}\exp\left(V_{imd}^{j}\right)} \text{ and } P_{imh}^{j} = \frac{\exp\left(V_{imh}^{j}\right)}{\Sigma_{d}\Sigma_{m}\exp\left(V_{imd}^{j}\right)}$$

Focusing on the choice to study STEM in the United States, we can take logs on both sides of equation (4), yielding an expression that linearly relates the enrollment probability in U.S. STEM majors (*i.e.* $m = S$) to expected wages and costs. Probabilities can be expressed as population shares —the number of home country students studying a STEM major in the United States (E_{Su}^{j}) divided by the home country student population (pop_h), yielding:

(5) $$\log\frac{E_{Su}^{j}}{pop_{h}} = \gamma\left(\left[\mathrm{p}_{mu} w_{mu}^{j} + (1 - \mathrm{p}_{mu}) w_{mh}^{j}\right]\right) - \gamma c_{u}^{j} - \log\left(\Sigma_{d}\Sigma_{m}\exp\left(V_{md}^{j}\right)\right)$$

Intuitively, equation (5) reveals how the likelihood of studying in the United States is increasing in U.S. wages (w_{mu}) and the likelihood of finding employment in the United States

(p_{mu}). It is decreasing in home wages (w_{mh}) and the costs of studying in the United States (c_u). Additionally, enrollment is decreasing in the value of alternative options, which are captured by the term last term: $\log(\Sigma_d \Sigma_m\, exp(V_{md}))$.

We now derive some predictions regarding the impact of the OPT reforms on enrollments. OPT reforms increased the probability of being able to work in the United States for STEM majors, assuming wages and costs remain unchanged.[7] The reforms initially extended the OPT duration by 17 months and, later, expanded the number of majors eligible for the extension. In so doing, they conferred international students an additional chance to secure an H-1B visa –the main path of entry into the U.S. labor market for international students who received their college degrees in the United States. The H-1B visa program has been tightly capped at 85,000 visas per year, and this cap has been exhausted every year since 2004 (Mayda *et al*. 2018a). In response to overwhelming demand for H-1B visas, lotteries have been held to determine their recipients in 2007, 2008 and from 2014 onward (Mayda *et al*. 2020). Prior to 2008, STEM students only had 12-months of optional practical training, providing them with one chance to secure an H-1B visa. The 17-month extension effectively doubled their chances by allowing them to enter the visa lottery twice. As such, the reform raised international students' odds to be able to work legally in the United States on a more permanent basis upon graduation.

As our current focus is on scale, we drop the j superscripts, and differentiate equation (5) with respect to the probability of working in the United States:

(6a)
$$\frac{d\log\frac{E_{Su}}{pop_h}}{d\mathrm{p}_{Su}} = (w_{Su} - w_{Sh}) - \frac{\exp(V_{Su})}{\Sigma_d \Sigma_m\, exp(V_{md})}(w_{Su} - w_{Sh})$$

[7] For simplicity, we assume no general equilibrium impacts on wages. However, prior research has found that natives' wages and employment opportunities might have been negatively affected by the 2008 OPT extension (Demirci 2019).

(6b) $$\Delta\log\frac{E_{Su}}{pop_h} = (w_{Su} - w_{Sh})(1 - P_{Su})\Delta \mathrm{p}_{Su}$$

(6c) $$\log E_{Su}^{\text{post}} - \log E_{Su}^{\text{pre}} = (w_{Su} - w_{Sh})(1 - P_{Su})\left(\mathrm{p}_{Su}^{\text{post}} - \mathrm{p}_{Su}^{\text{pre}}\right)$$

Equation (6b) follows from substituting $P_{Su} = \frac{\exp(V_{Su})}{\Sigma_d \Sigma_m \exp(V_{md})}$, which stands for the fraction of home country students studying STEM in the United States, along with changes (Δ) to provide the discrete analogue to differentials. Equation (6c) follows by further mapping equation (6b) to a difference-in-difference framework, considering the change from before to after the OPT reform, and assuming the home country student population is large enough to not change substantially.

The resulting equation (6c) reveals that the increase in international STEM student enrollments depends on the extent to which OPT alters the probability of being able to work in the United States. This impact is scaled by the size of the wage gap between the United States and the home country, such that large changes in the probability of working in the United States due to OPT reforms are further magnified if wage gaps (*i.e.* returns to working in the United States vs. the home country) are large. In addition, the impact is further weighted by the initial fraction of home country student population studying in the United States. Intuitively, the increase will be larger if there are few home country students studying in the United States prior to the reform. In contrast, the reform will have no impact if all home country students were already studying in the United States (*i.e.* $P_{Su} = 1$). We anticipate estimated treatment effects to be positive, given that U.S. average wages exceed those in many of the top sending countries (*e.g.* China and India), and the share of students already studying in the United States is well below 1 for many of the large sending countries (*e.g.* China and India).

We can also use this framework to gather some insights into the impact of OPT reforms on the selectivity of international STEM students, reintroducing subscript j, which indexes ability.

Specifically, we examine equation (6c) and compare them for students of two different ability levels, a and b, where $a > b$, as follows:

$$\log \frac{E_{Su}^{a,\text{post}}}{E_{Su}^{b,\text{post}}} - \log \frac{E_{Su}^{a,\text{pre}}}{E_{Su}^{b,\text{pre}}} = \left[(w_{Su}^{a} - w_{Sh}^{a})(1 - P_{Su}^{a}) - \left(w_{Su}^{b} - w_{Sh}^{b}\right)(1 - P_{Su}^{b})\right]\left(\text{p}_{Su}^{\text{post}} - \text{p}_{Su}^{\text{pre}}\right) \tag{7}$$

Equation (7) reveals that the relative enrollment of high ability (a) to low ability (b) students depends on the difference in relative returns to ability in the United States versus the home country, and the initial fractions of home country students of each ability type in the United States. The probability of working in the United States is constant across ability types –a reasonable assumption given that capped H-1B visas were distributed by a lottery during most of the period under examination. For illustrative purposes, suppose the baseline probabilities of studying STEM in the United States are identical for students of abilities a and b, such that $P_{Su}^{a} = P_{Su}^{b}$. Then, positive selection will occur if: $(w_{Su}^{a} - w_{Sh}^{a}) > (w_{Su}^{b} - w_{Sh}^{b})$ –that is, when the returns to studying in the United States are larger for students of higher ability (a condition guaranteed by equation 1). Negative selection can occur if the initial fraction of high ability (a) students in the United States is very large relative to lower ability (b) students, *i.e.* $P_{Su}^{a} > P_{Su}^{b}$ —that is, if all of the high ability home country students were already in the United States, their response to the OPT reforms will be null. Only low ability students would react to the policy.

For simplicity, we only model the supply side of international student decisions. However, it is also important to recognize the important influence of demand side features (*e.g.* Mayda 2010). University admission policies governing international enrollments can play an important role, even if they do not change in response to OPT reforms. For example, consider a university that already has met its international student quota prior to the OPT reform. In that case, OPT reforms might have no impact on its international enrollment.

In addition to providing some testable hypotheses, this model is useful in guiding our empirical approach. Equations (6c) and (7) motivate our difference-in-differences approach, indicating that the enrollment growth and changes in selection due to the OPT reforms should be observable by taking the pre-post differences in enrollments. We can then compare these differences against pre-post differences in enrollments of control groups to net out other potential confounding factors unrelated but simultaneous to the OPT reforms.

IV. Empirical Methodology

We rely on a difference-in-differences approach to estimate the effects of the OPT reform on international student enrollments. Since eligibility for the OPT extension depends on the type of major pursued and year in question, we track student cohorts by major (*m*) and matriculation year (*t*). In addition, we distinguish by gender (*g*) given the distinct incidence of STEM fields among men and women. To that end, we begin by estimating the following benchmark model specification:

$$\log(E_{gmt}) = \alpha + \beta(treat_{mt}) + \gamma_{gm} + \gamma_{gt} + \varepsilon_{gmt} \quad (8)$$

where the dependent variable, E, is the number of international students of gender g, in major m, starting a U.S. degree in year t. To address zeros in students per gender-major-year cells, the dependent variable is transformed using an inverse hyperbolic sine function.[8] The treatment indicator, $treat_{mt}$, takes a value of 1 when major *m* becomes eligible for the extended OPT following the reform in year *t* (*i.e.* 2008, 2011, or 2012), and 0 otherwise. Equation (8) also

[8] The inverse hyperbolic sine transformation is given as: $\sinh^{-1} E = \log(E + \sqrt{E^2 + 1})$. Gelber (2011) uses the inverse hyperbolic sine transformation and provides more details about its properties in relation to logs. All the analyses use balanced gender-major-year cells over time, unless otherwise stated. As a robustness check, we also estimate our models taking the natural log of enrollments. Results, available upon request, remain robust even though over half of the major-gender cells are dropped due to zeros.

includes major-by-gender fixed effects (γ_{gm}) to account for time-invariant differences across major-gender pairs. Additionally, cohort-by-gender indicators (γ_{gt}) control for aggregate shocks/trends that may differ by gender. Standard errors are clustered at the major-gender level.

Our interest is on the coefficient β, which captures the estimated impact of the OPT reforms on international STEM enrollments. When examining selection effects, we restrict our attention to certain groups of students (*e.g.* those receiving more university funding or enrolling in selective universities with low admissions rates or more funds per student), comparing changes in the type of international student eligible for the OPT extension to changes in those who are not.

Causal inference in a difference-in-differences framework relies on student enrollments in the control group representing an appropriate counterfactual for student enrollments in eligible majors in the absence of OPT extensions. We thus examine the suitability of different control groups among the international student population ineligible for the OPT extensions. In addition to using a control group composed of all ineligible, non-STEM international students, we experiment with using Business majors as a control group due to their similarities to STEM majors at baseline. More importantly, enrollment trends in Business majors closely track enrollments trends in STEM majors in the pre-reform period. However, STEM fields may be considered a closer substitute for Business than non-STEM majors, such as Art. If that is the case, treatment effects could be biased upwards if OPT reforms induce potential Business majors to switch to STEM majors. To assess the scope of substitution bias, we experiment with alternative control groups less prone to substitution, including international students with non-Business majors, international students with Arts & Humanities majors, and international students with STEM majors who have alternative employment authorizations and are not reliant on the H-1B visa.

Another important concern in our setting is the timing of the OPT reforms; especially in the case of the first 2008 OPT reform, which coincided with the Great Recession. Treatment effects for that reform may be confounded by the impact of the downturn on international student enrollments and its potentially distinct impacts on STEM and non-STEM fields. While including year dummies should help absorb aggregate fluctuations, we perform several checks to address this concern.

First, we control for major-specific unemployment rates and major-specific linear trends. Second, we gauge the impact of the various reforms. If the observed impacts of the 2008 OPT reform primarily reflected the impact of the 2008 Great Recession, we should expect distinct results from the 2011 and the 2012 OPT reforms as they occurred outside of the height of recessionary pressure. To that end, we modify equation (8) to add interaction terms between the various post-policy indicators and the OPT_m dummy. The interaction terms take the value of 1 for majors that became eligible under the specified reform. Our new model specification is given by:

$$\log(E_{gmt}) = \alpha + \beta_1(OPT_m \times Post08) + \beta_2(OPT_{m'} \times Post11) + + \beta_3(OPT_{m''} \times Post12) + \gamma_{mg} + \gamma_{gt} + \varepsilon_{gmt}, \quad (9)$$

where the coefficients β_1, β_2, and β_3 capture the impact of the three reforms, respectively.

Finally, if the impacts attributed to the 2008 OPT reform were solely the byproduct of the economic downturn, we should expect similar trends for associate and doctoral degree holders – groups that should be much less responsive, or even non-responsive, to the OPT extensions due to program stipulations and the availability of other work visa pathways for these individuals.[9] In

[9] As noted earlier, one of the main benefits from the OPT extension is the possibility to double the chances of getting an H-1B visa by participating in the lottery more than once. Since Associate degree holders do not qualify for an H-1B and many doctoral degree holders are able to find employment in the academic sector, which is exempt from the H-1B visa cap (Amuedo-Dorantes and Furtado, 2018), the OPT extension should have a zero to negligible impact on their enrollments and selectivity.

separate analyses, we show that international STEM enrollment in associate's and doctoral programs did not see large impacts after 2008, even though we observe impacts for students pursuing bachelor's or master's degrees. Taken together, these checks help support the notion that estimated impacts do not entirely measure recessionary effects.

V. Data and Descriptive Evidence

A) Data

We gather data on international student enrollments from various sources. Data from the Student Exchange and Visitors Information Service (SEVIS) on all international students entering U.S. higher education institutions from 2004-2016 was acquired through a freedom of information act request. Each record contains both demographic, educational, and funding information. The demographic variables include the country of origin, gender, and birth date of each student. The educational information includes the institution, level of study, anticipated start and end dates, and major field of study disaggregated at the 6-digit CIP code level. We use the student's primary major for our analysis.[10] Additionally, we have funding information, which includes self-reported amounts of tuition and expenses students anticipate paying, and the source and amount of funds they have at their disposal. We collapse the information into gender-major-year cells for the analysis.

We also gather information on institutional traits. Specifically, we merge data from the Integrated Postsecondary Educational Data System (IPEDS), which is maintained by the Department of Education. We classify institutions based on their ownership/control (public, private-for-profit, private-not-for-profit) and Carnegie Classification (research-oriented

[10] Students seldomly report a second major. Only 3.2 percent of all students and 2.4 percent of those reporting a STEM eligible primary major report a second major. Therefore, our estimates are not likely to be driven by students who report having both a STEM and a non-STEM major.

universities, master's programs universities, Baccalaureate programs universities).[11] We also rank institutions by their admissions rates and total funds they receive per student.[12]

Some descriptive statistics on international students in the SEVIS dataset are reported in Table 1. We show mean student characteristics at baseline (prior to 2008), separately for STEM majors eligible for the 2008, 2011, and 2012 extensions (*i.e.* "STEM" in column (1)), and for our preferred control group of Business majors in column (2). A few differences are noteworthy. First, consistent with the notion that many STEM fields are male dominated, about 58 percent of students in Business majors are male relative to 71 percent of students in STEM majors. Additionally, students in STEM majors are more likely to be from China or India, the top two senders of international students to the United States, than their control group counterparts.

There are also differences across fields of study. Students in STEM majors are less represented in undergraduate programs and more in doctoral programs than Business majors. This translates into a slightly longer average duration of schooling among STEM majors, who are enrolled for 3 years versus 2 in the case of Business majors.

In terms of student quality, STEM and Business students appear equally likely to enroll in highly selective institutions as captured by institutions with admissions rates ranking in the 1st quartile, although STEM students receive greater financial support than Business and other non-STEM major students.[13] Finally, even though STEM students appear more likely to use the OPT program than Business majors (67 percent of STEM students use it compared to 47 percent of Business majors), the two are more alike than STEM and non-STEM majors (see column (4)).

[11] Definition follows the 2005 Basic Carnegie Classification.

[12] Average admission rates are calculated using IPEDS information from the 2004/05 through 2007/08 academic years. Total funds per student are gathered from IPEDS' 2004 Fiscal Year information.

[13] Financial support is measured by the ratio of external finance (from school or other sources) a student received out of all sources of finance (*i.e.* external and own sources of finance).

B) Descriptive Evidence

Figure 2 shows trends in average international student matriculation in STEM (eligible) and non-STEM (ineligible) 6-digit CIP code majors over time. Trends in international student enrollments in bachelor's degree programs (Figure 2a) moved in a parallel fashion for STEM and non-STEM majors prior to the first OPT reform in 2008. The trends start to diverge in 2010, with STEM majors outpacing non-STEM. Enrollments in master's degrees in STEM majors (Figure 2b) also outpaced enrollments in non-STEM majors. However, the divergence began earlier, around 2006, and sharply widened after 2012. These trends hint on OPT reforms potentially encouraging international STEM enrollments. Alternatively, they may capture other factors, such as the role of the Great Recession, or, in the case of master's degree enrollment, potential pre-existing differential trends.

We also examine the evolution of international matriculation in associate and doctoral programs, which should have been less affected by the OPT reforms. As noted earlier, an important benefit of the OPT extension is the ability to participate multiple times in the H-1B lottery. However, associate degree holders do not qualify for an H-1B visa. Similarly, doctoral degree holders are not as dependent on the H-1B lottery, as many find employment at Universities and research institutes exempt from H-1B limits (Amuedo-Dorantes and Furtado, 2018). Figure 2c shows that international enrollments in STEM and non-STEM majors move in a similar fashion throughout the time period for associate degree programs, with little suggestive evidence of a rise in STEM majors in response to the OPT reform. For doctoral programs (Figure 2d), STEM enrollment moves in a pattern that appears countercyclical to the Great Recession, while non-STEM enrollments remain very low and flat. Hence, the trends in Figures 2c and 2d are less supportive of OPT reforms having a significant impact on international enrollments in either associate or doctoral degree programs.

In what follows, we more formally assess the effect of the OPT extensions on international student enrollments and selectivity. Given the empirical evidence provided above, we focus on students in bachelor's and master's programs, who are more likely to respond to changes in the OPT program. We use students in associate and doctoral degree programs, who were largely unaffected by the OPT reforms, to run placebo checks and assess the mechanisms likely responsible for international students' response to the policy change.

VI. Assessing the Impact of OPT Reforms on International Student Enrollments

A) Main Findings

To learn about the impacts of the various OPT reforms on international student enrollments in STEM, we start by estimating equation (8) using data on STEM and Business majors (our primary control group) from SEVIS. As discussed earlier, Figure 2a and 2b show that there were significant increases in international student enrollments in bachelor's and master's degrees around the period following one or more of the OPT reforms. Table 2 shows the results from estimating equation (8) for international student enrollments in those two programs. In the case of bachelor's degrees, international enrollments in STEM rose by 18 percent following the OPT reforms (Panel A of Table 2). The increase was somewhat larger for men (22 percent) than women (14 percent). The growth was also remarkable in master's programs, where international enrollments in STEM grew by 30 percent –32 percent for men and 27 percent for women. In what follows, we assess the degree to which these impacts can be interpreted as causal.

B) Identification and Robustness Checks

i. Pre-trends

An immediate concern with the difference-in-difference estimates in Table 2 refers to the possibility of pre-existing differential trends in international student enrollments in STEM relative to non-STEM fields driving the results. To gauge if that is the case, we conduct an event study analysis for international matriculation in bachelor's and master's programs by estimating:

$$\log(E_{gmt}) = \alpha + \sum_{i=-3}^{5} \phi_i 1(T_{mt} = i) + \gamma_{mg} + \gamma_{gt} + \varepsilon_{gmt}, \quad (10)$$

where T_{mt} denotes the event year. We include up to 3 years prior and 5 years post each OPT reform. We choose this interval as the fall in the H-1B cap in 2004, which occurred 4 years prior to the 2008 reform, had sizable impacts on international student enrollment (Kato and Sparber 2013, Shih 2015). Note that $T = 0$ for enrollments taking place during the year that major m is affected by the OPT extension, $T = 1$ for enrollments occurring one year after the OPT extension affecting major m, and so on. Because event study analysis requires enrollments to be centered on event time, only STEM majors affected by a reform are included—Business majors (or other possible counterfactual majors) never experience an "event". Coefficients are measured relative to one year prior to the OPT reform impacting the major in question, *i.e.* T =-1. We include major-gender fixed effects and gender-cohort fixed effects. Figure 3 plots the estimated coefficients ϕ_i from estimating equation (10), along with the corresponding 95% confidence intervals. There seems to be evidence of generally higher international student enrollments in bachelor's and master's degrees after the OPT reforms, but not before. Both bachelor's and master's degrees international enrollments were not distinguishable from zero prior to the OPT reforms.

While useful, recent literature suggests event studies are not sufficient to rule out biases from pre-existing differential trends (*e.g.* Freyaldenhoven, Hansen and Shapiro, 2019). Hence, we conduct two additional checks. *First*, we control for major-specific linear trends in our primary difference-in-differences analysis, reported in Panel A of Table 3. We continue to find evidence of a positive and significant increase in bachelor's and master's enrollments following the OPT reforms. However, point estimates shrink substantially as major trends absorb much of the variation in enrollments (Wolfers, 2006). *Second*, we use the method of Abadie *et al.* (2015) to construct a synthetic control group, which represents a weighted average of various ineligible major groups, designed to closely match eligible STEM majors during the pre-treatment period.[14] Once more, the results in Panel B of Table 3 confirm our main findings in Table 2.

ii. Great Recession

Another first-order concern is the overlap of the first OPT extension of 2008 with the Great Recession, which could have impacted STEM and non-STEM enrollments differently, by altering the demand for such skills and, in turn, the returns to those educational investments. To address this concern, we first control for major-specific unemployment rates to capture field-specific changes in economic conditions within the United States.[15] Panel A of Table 4 provides the results from such an exercise. Our findings prove robust with point estimates that are only slightly smaller from those in Table 2.

[14] The synthetic major is constructed using the synthetic control method and consists of all the non-zero weighted non-STEM majors. For the bachelor's, these majors and their CIP codes are Natural Resource Economics (03.0204), Forestry, Other (03.0599), Computer and Information Sciences and Support Services, Other (11.9999), Bilingual and Multilingual Education (13.0201), Pharmacy, Pharmaceutical Sciences, and Administration, Other (51.2099), Logistics and Materials Management (52.0203), Finance and Financial Management Services, Other (52.0899), Insurance (52.1701). For the Master's, these majors and their CIP codes are Natural Resource Economics (03.0204), Urban Education and Leadership (13.0410), Economics, Other (45.0699), Logistics and Materials Management (52.0203), Investments and Securities (52.0807), Finance and Financial Management Services, Other (52.0899), Construction Management (52.2001).

[15] We construct major specific unemployment rates by first calculating unemployment rates in each SOC occupation for the years of analysis (2004-2016), from the American Community Surveys. We then use a crosswalk from SOC occupation codes to 6-digit CIP codes, provided by the Department of Education (see: https://nces.ed.gov/ipeds/cipcode/resources.aspx?y=56). Because the crosswalk is a many-to-many crosswalk, we than average all SOC unemployment rates within a single 6-digit CIP code, to obtain the major specific unemployment rate for a given year.

Another way to gauge the influence of the Great Recession is to separately examine the impact of the various OPT reforms. If the results from Table 2 were entirely a byproduct of the 2008 Great Recession, the later OPT reforms of 2011 and 2012 should have a null impact on international student enrollments. To separately measure the impact of the 17-month extension and the expansion of STEM designated-degree programs in 2011 and 2012, we create three dummy variables that identify the major affected by each reform. These OPT reform indicators are then interacted with the respective dummies for post treatment years (*i.e.* 2008, 2011, or 2012). We include all these interactions in the model, along with the baseline controls shown in equation (9).

Panel B in Table 4 displays the estimated impact of each OPT reform on the matriculation of international students in bachelor's and master's programs. The 2008 OPT reform had the smallest impact of the three OPT reforms in expanding international enrollments, raising those in bachelor's degrees by 11 percent, and those in master's by 24 percent. In contrast, the 2011 and 2012 OPT reforms raised enrollments in bachelor's programs by roughly 26 percent, and those in master's programs by 43 and 33 percent, respectively. Overall, the larger (if not similar) impact of the 2011 and 2012 reforms on international student enrollments suggests that the effect measured in Table 2 is unlikely to have been the byproduct of the 2008 Great Recession.

iii. Reclassification Bias

Are the findings capturing an increase in international enrollments? Or, rather, are they capturing students switching majors or the reclassification of majors from non-STEM to STEM? Students shifting from non-STEM to STEM fields would represent a substitution rather than an actual increase in scale and, thereby, bias our estimates upwards. Likewise, anecdotal evidence of universities reclassifying fields from non-STEM to STEM eligible CIP codes is suggestive of possible substitution biases. To gauge these issues, we experiment with using alternative counterfactual groups of students –some of them in majors more distant from STEM fields that are less likely to be reclassified as STEM and, by the same token, less prone to have students switching from non-STEM to STEM.

First, we start by checking the sensitivity of our findings to generalizing the control group to all non-STEM, as well as to assess how they depend on using Business majors as a control. These checks are performed in columns (1) and (2) of Table 5. Next, we consider using international students in Arts & Humanities majors as the control group –this is a group of students less likely to switch to a STEM major, as well as students in majors unlikely to be reclassified as STEM by universities. This is done in column (3) of Table 5. In all instances, the estimated impacts in columns (1) through (3) in Table 5 are not significantly different from those in column (1) of Table 2. In fact, point estimates are larger as opposed to smaller, as we would expect if our main estimates were seriously affected by substitution and reclassification biases.

To further address any remaining concerns regarding the potential for our results to be driven by students switching from non-STEM to STEM majors, we experiment with using only STEM students and include in our control group those who, nonetheless, might not be strongly impacted by the OPT extension, such as international STEM students from five countries (Chile, Singapore, Australia, Canada, and Mexico).[16] Students from those five countries enjoy alternative pathways to employment in the United States outside the H-1B program.[17] As described in Kato and Sparber (2013), those countries have alternative work visa agreements with the United States.

[16] We also experiment with using native students in STEM majors as the control group using data from the National Survey of College Graduates (NSCG). However, due to limitations of the NSCG, we can only gauge the impact of the 2008 reform. While native and international students are distinct, we still observe a significant increase in international student enrollments in response to the OPT reform.

[17] Alternative work visas include the H-1B1 visa for Singaporeans and Chileans, the TN visa for Canadians and Mexicans, and the E3 visa for Australians. Shih (2015) documents that when the quota for H-1B visas contracts, and the number of H-1B visas issued to individuals from these countries falls, the work visa issuances in these alternative classes rises.

This implies that skilled workers from those nations are not entirely reliant on the H-1B visa and, in turn, would be less responsive to the OPT reforms (*i.e.* short-run work experience and wages, and long-run increased opportunity at securing an H-1B visa). Column (4) of Table 5 displays the results using that alternative control group. The estimated impacts are only slightly larger than those in Table 2, reinforcing the notion that our findings are not likely to be driven by reclassification of majors or by the switching of international students from non-STEM to STEM.

C) Mechanisms

Having established that the OPT reforms significantly raised international student enrollments, we turn to examining its underlying causes or mechanisms. As stated earlier, OPT reforms provided two important benefits to eligible international students. *First*, it enabled them to extend the duration of their practical training in the United States by 17 months, which implied being able to gain more U.S. work experience and earn more U.S. wages. *Second*, the reforms granted international students in STEM an additional chance to secure an H-1B visa. During the additional 17 months, students can conduct job searches, receive a job offer from an employer willing to sponsor them, and apply for an H-1B visa, which have been distributed by lottery since 2013 due to the strict quota and high demand.

While distinguishing these two incentives is not completely feasible, we conduct a placebo test that suggests the ability to secure permanent employment through an H-1B visa as a critical factor in explaining the observed international student response. As noted earlier in the paper, STEM students in associate and doctoral degree programs could also be incentivized by the OPT reforms, albeit to a smaller extent. Even though they benefit from the extended employment experience and U.S. wages, they either do not qualify for the H-1B program (as in the case of students with an associate degree) or enjoy employment opportunities exempt from the H-1B quota (as in the case of doctoral students).[18] Table 6 displays the estimated impact of the OPT reforms among both groups. Using business majors as a control group, international student enrollments in associate degree programs did not significantly change following the OPT reforms. Even if international student enrollments in doctoral programs rose in the baseline model (column 3), the observed impact dissipates once we account for major specific time trends in column (4). Consistent with findings from previous research (*e.g.* Rosenzweig 2006, Shih 2015), this check supports the notion that long-run employment opportunities in the United States might be responsible for the differential response of international STEM enrollments in bachelor's and master's programs to the OPT reforms.

VII. Assessing the Impact of OPT Reforms on International Student Selectivity

The OPT policies might have altered, as well, the composition of international student enrollments in STEM. To explore this possibility, we make use of international student data from SEVIS and institutional information from IPEDS. Specifically, to learn about potential selection effects stemming from the OPT reforms, we explore how OPT reforms appear to have altered international student enrollments in STEM across academic institutions with distinct traits –some of which can be interpreted as indicators of *quality*, as well as based on the institutional support received by students.

Table 7 reports our findings based on the type of institutional control and the institution's Carnegie classification. According to the estimates in Panel A of Table 7, the OPT reforms resulted in significant enrollment growth in STEM in both public and private not-for-profit

[18] Indeed, students enrolling in an Associate's may go on to pursue a bachelor's degree and become eligible to apply for an H-1B visa. recent study indicated that 40 percent of Associate degree recipients go on to complete a bachelor's degree within 6 years (http://nscresearchcenter.org/wp-content/uploads/SnapshotReport19_DegreePathways.pdf). The fraction for those initially enrolling in associate degree programs is likely lower.

institutions. In public institutions (columns (1) and (4)), enrollments in bachelor's and master's programs rose by 13 percent and 27 percent, respectively. The growth was also significant among private not-for-profit institutions (columns (2) and (5)), where enrollments in bachelor's and master's programs increased by 12 percent and 22 percent, correspondingly.

If we focus on the Carnegie classification of institutions attended by international students (Panel B of Table 7), we observe the most significant STEM enrollment growth in institutions with the highest research activity. While almost all institutions experienced significant growth, enrollments in bachelor's and master's programs grew by the largest amount at Research I universities (columns (1) and (4)), by 15 percent and 29 percent, respectively, following the OPT reforms.[19]

Next, we utilize alternative institutional traits reflective of the selectivity of matriculated students –such as the institution's admissions rates and available funds per student– as well as information on the financial support that students report receiving. In Panel A of Table 8, we group institutions into categories of selectivity based on whether their admission rates fell within the first, second, third or fourth quartile of the distribution. Lower values of admissions rates are more selective. As shown therein, international student enrollments in bachelor's degrees grew the most among the selective institutions, whereas they dropped among the least selective institutions. Similarly, we observe greater growth in international student enrollments in master's programs at more selective institutions than at the least selective institutions.

[19] We categorize IPEDS institutions according to the 2005 Basic Carnegie Classification definition. In Panel B of Table 7, the *Research* category includes Research Universities (very high research activity), Research Universities (high research activity), and Doctoral/Research Universities; the *master's* category includes Master's Colleges and Universities (larger programs), Master's Colleges and Universities (medium programs), and Master's Colleges and Universities (smaller programs); the *Baccalaureate* category includes Baccalaureate Colleges, Associate's, and Special Focus Institutions.

In panel B of Table 8, we use a different measure of institution quality –namely, its available funds per student.[20] Once more, we group universities into quartiles based on this measure, with higher values of funds per student indicating greater selectivity. Again, we find that international student enrollments in STEM bachelor's degrees appear to have grown the most in very selective universities. In the case of master's degree programs, we observe the largest growth in enrollments among the very selective institutions, hinting once more on the OPT reforms raising the quality of international student enrollments.

Finally, in Panel C of Table 8, we gauge the impact of the OPT reforms on international student enrollments in bachelor's and master's degrees according to the financial support students received in the form of scholarships, fellowships, other university funds, or external sources. Again, as with admission rates and the available funds per student, the estimates are suggestive of international student enrollments rising, primarily, among very selective students as captured by those receiving the largest financial support.[21] This is particularly true for enrollments in bachelor's degree programs, where the reforms appear to have raised enrollments by 16 percent among very selective students. In contrast, enrollments at the least selective tier only rose by 7 percent. In the case of master's degree programs, international student enrollments rose across the board. Yet, the enrollment impacts among the least selective tier averaged 12.5 percent, whereas they reached 29 percent among the very selective tier.

[20] Total funds available to each student is calculated using an institution's total revenue in 2004 Fiscal Year (excluding tuition and fees) divided by its enrollment. Total revenue as reported in IPEDS includes tuition and fees, government appropriations, grants and contracts, contributions from affiliated entities, investment return, sales and services of educational activities and auxiliary enterprises, and other revenue.

[21] Student financial support measures the proportion of financial support a student received from school or other external source out of all sources of finance (*i.e.* any external funds and student own personal funds). All funds refer to 2004, which is the year the sample period starts.

Overall, these results in Tables 7 and 8 are suggestive of OPT reforms raising the quality of international student enrollments, as captured by the traits of the institutions they attend –namely, not-for-profit research institutions with lower admission rates and more funds per student– and among most promising students –as captured by those receiving the most financial support.

VIII. Summary and Conclusions

The United States remains the top host of international students globally. This paper examines how policies affecting the return to studying in the United States might affect international student enrollments –both in terms of scale and selectivity. Specifically, we examine the impact of the 2008, 2011 and 2012 OPT policy changes, which lengthened the training period of international graduates in STEM fields from 12 to 29 months, and expanded the list of eligible STEM majors, respectively. Using a difference-in-differences design that compares international STEM majors to non-STEM majors, we find positive treatment effects on both scale and selection. Specifically, the OPT reforms raised international student enrollments in bachelor's and master's programs by 18 and 30 percent, respectively, and increased the quality of students as captured the traits of the institutions they attend –namely, not-for-profit research institutions with lower admission rates and more funds per student; and by the financial support received by students attending those institutions.

International students have a significant impact on the United States. In 2017, they contributed $42.4 billion through tuition, room and board, and other expenses, according to the U.S. Department of Commerce. Foreign students' tuition fees have proven crucial in subsidizing the cost of enrolling additional native students (*e.g.* Shih 2017, Bound *et al*. 2020, Chen 2020). In addition, the presence of more STEM graduates in the workforce has been shown to have positive externalities, significantly raising wages of other college-educated individuals in the metropolitan area (Peri, Shih and Sparber, 2015), and to contribute to the exchange of ideas, innovation, and economic growth (Stephan and Levin, 2001; Wadhwa *et al.* 2007; Hunt and Gauthier-Loiselle 2010; Anderson, 2016). Given these positive impacts and externalities associated to international enrollments and to their posterior labor force engagement, gaining a better understanding of how immigration policy can help attract more and possibly higher quality international students is well-warranted.

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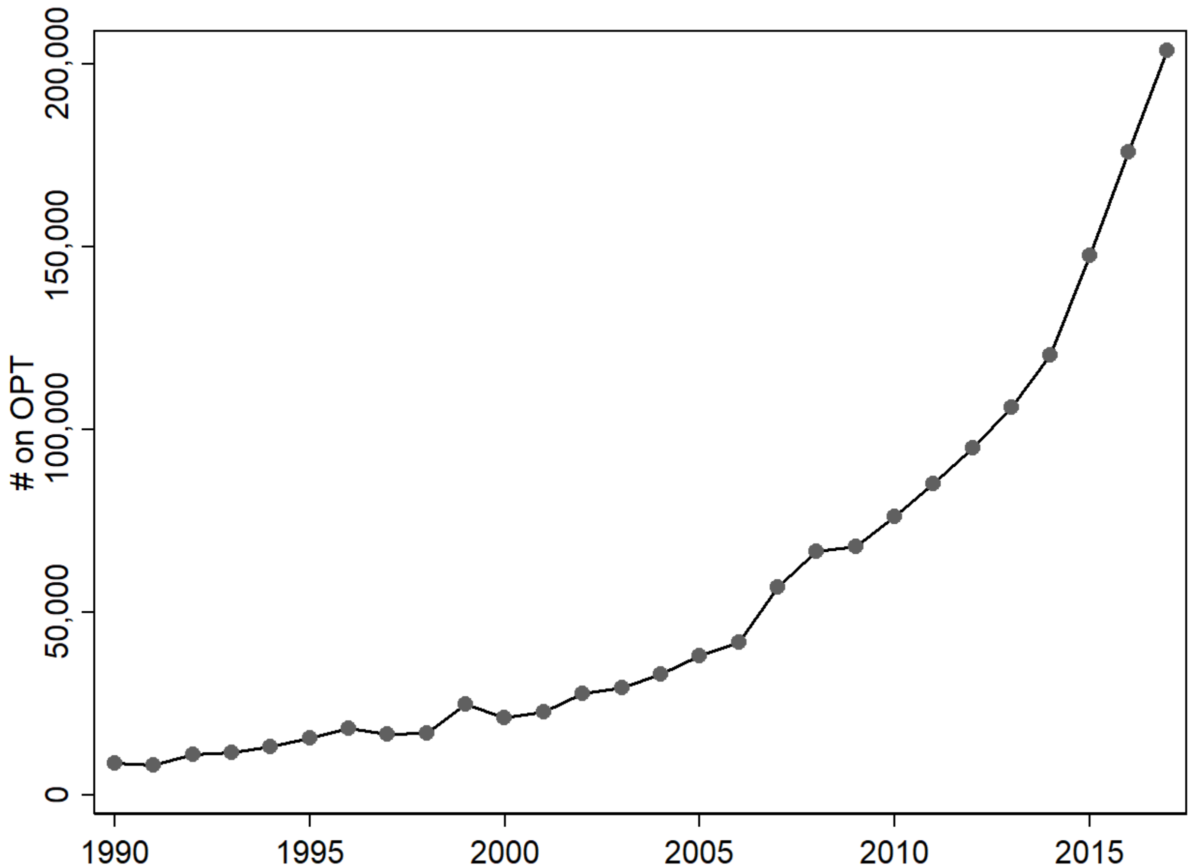
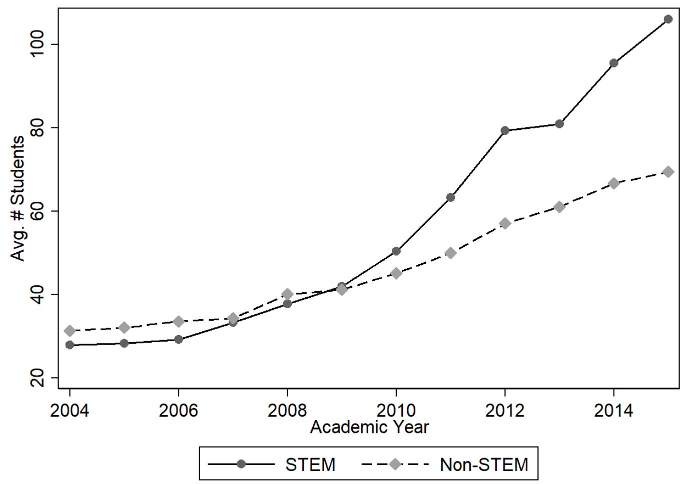
Figure 1: International Students on OPT, 1990-2017

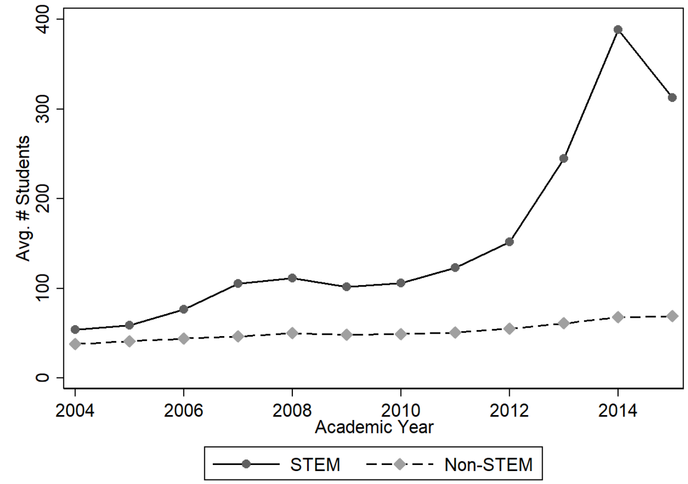


Notes: Figures plots total number of international students using the OPT program by year. Data from the Institute of International Education, accessed from: https://opendoorsdata.org/data/international-students/.

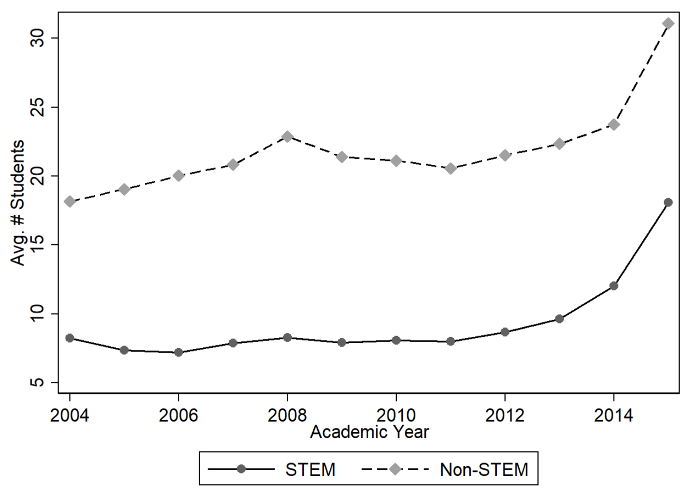
Figure 2: STEM vs. Non-STEM Enrollments by Level



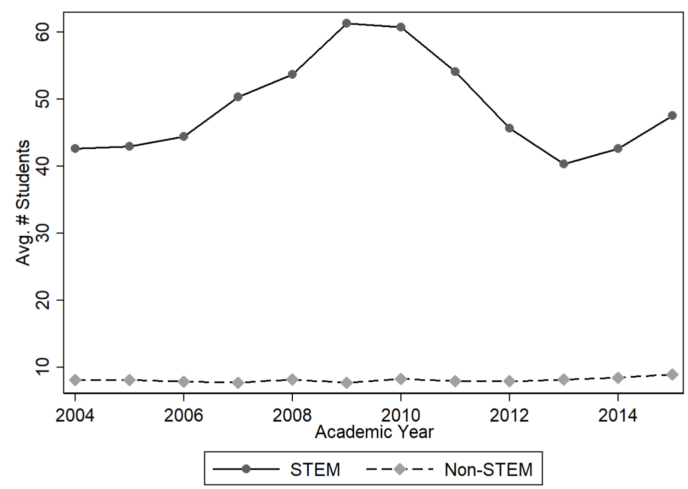
(a) Bachelor's



(b) Master's



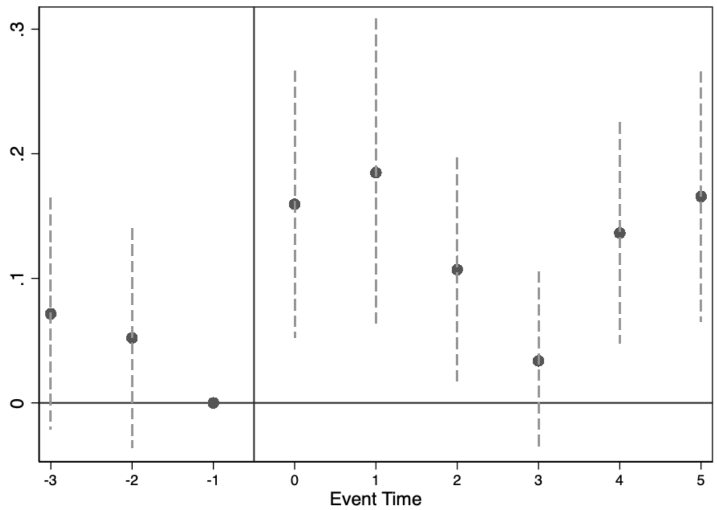
(c) Associate's



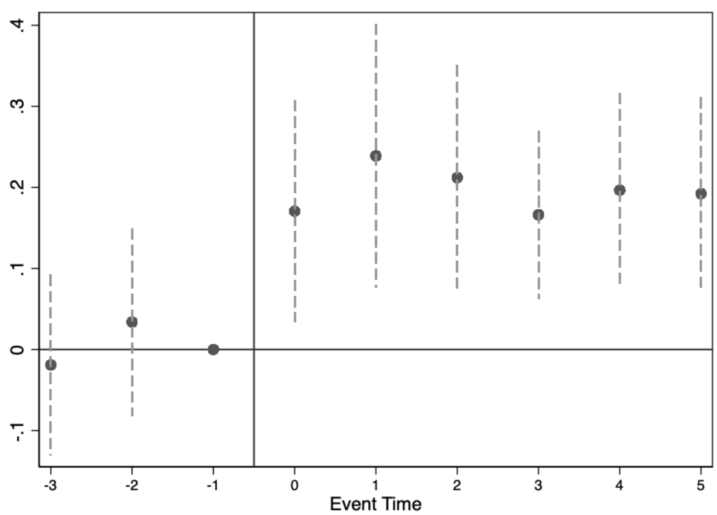
(d) Doctorate

Notes: Figure shows average starting enrollment for each academic year across STEM and non-STEM majors and also by academic level. Total international student enrollment is calculated for each major, which is defined by a 6-digit CIP code. These counts are then averaged across STEM and non-STEM majors.

Figure 3: Effect of OPT on STEM Enrollments by Level



(a) Bachelor's



(b) Master's

Notes: Figure shows the coefficients and 95% confidence intervals from event study regressions that estimate average starting enrollment for each academic year across STEM majors and also by academic level.

Table 1: Summary Statistics of Internatioal Students 2004-2007

	(1) STEM	(2) Business	(3) Diff. (2)-(1)	(4) Other Non-STEM	(5) Diff. (4)-(1)
F-1 Visa	1.00	1.00		1.00	
	(0.00)	(0.00)		(0.00)	
			0.00		0.00
Male	0.71	0.58		0.42	
	(0.46)	(0.49)		(0.49)	
			-0.14***		-0.29***
Age at Entry	24.47	24.89		25.53	
	(4.17)	(5.02)		(6.36)	
			0.39***		1.16***
China/India	0.52	0.21		0.12	
	(0.50)	(0.41)		(0.32)	
			-0.31***		-0.39***
Associate's	0.00	0.02		0.03	
	(0.06)	(0.14)		(0.16)	
			0.10***		0.14***
Bachelor's	0.23	0.46		0.46	
	(0.42)	(0.50)		(0.50)	
			0.17***		0.16***
Master's	0.46	0.50		0.36	
	(0.50)	(0.50)		(0.48)	
			-0.00*		-0.14***
Doctorate	0.31	0.02		0.15	
	(0.46)	(0.15)		(0.36)	
			-0.27***		-0.16***
Duration	3.16	2.35		2.78	
	(1.90)	(1.36)		(1.78)	
			-0.75***		-0.40***
Selective Institution	0.36	0.37		0.43	
	(0.48)	(0.48)		(0.49)	
			0.01***		0.07***
Financial Support	0.83	0.72		0.71	
	(0.35)	(0.42)		(0.42)	
			-0.10***		-0.12***
OPT	0.67	0.47		0.37	
	(0.47)	(0.50)		(0.48)	
			-0.22***		-0.32***
Students	228,521	158,057	386,578	252,354	480,875

Notes: Table provides summary statistics of international students from SEVIS using years prior to the 2008 OPT reform, 2004-2007. The STEM majors are those on the list of approved for the OPT extensions in 2008, 2011 and 2012. Business majors and Other non-STEM majors are those that are ineligible. * p<0.10, ** p<0.05, *** p<0.01,

Table 2: Difference-in-differences Results on Enrollment, by Level and Gender

	(1) All	(2) Male	(3) Female
A: Bachelor's			
treat	0.177***	0.219***	0.135***
	(0.036)	(0.052)	(0.050)
Obs	12,402	6,201	6,201
M-G Cells	954	477	477
Y Mean	1.57	1.75	1.40
B: Master's			
treat	0.294***	0.324***	0.265***
	(0.051)	(0.072)	(0.072)
Obs	12,402	6,201	6,201
M-G Cells	954	477	477
Y Mean	1.90	1.96	1.84

Notes: Table shows difference-in-differences estimates of the impact of the OPT reforms. International enrollments in STEM fields are considered the treated group, while international enrollments in Business fields serve as the control. Results are shown for all enrollments, and separately for male and female. Enrollments are specified in inverse hyperbolic sine. Specifications include major-by-gender fixed effects and cohort-by-gender dummies. Standard errors are clustered at the major-gender level. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 3: Robustness Checks for Pretrends

	(1) Bachelor's	(2) Master's
A: Control for Major Trends		
treat	0.057*	0.226***
	(0.030)	(0.041)
Obs	12,402	12,402
M-G Cells	954	954
Y Mean	1.57	1.90
B: Use Synthetic Non-STEM Control		
treat	0.120***	0.253***
	(0.037)	(0.048)
Obs	10,322	10,296
M-G Cells	794	792
Y Mean	1.45	1.83

Notes: Table shows difference-in-difference results under various robustness checks. Panel A includes major-specific linear trends. Panel B uses a synthetic non-STEM major as the control group constructed by the synthetic control approach. Enrollments are specified in inverse hyperbolic sine. Specifications include major-by-gender fixed effects and cohort-by-gender dummies. Standard errors are clustered at the major-gender level. * p<0.10, ** p<0.05, *** p<0.01.

Table 4: Robustness Checks for Confounding Factors

	(1) Bachelor's	(2) Master's
A: Control for Unemployment Rate		
treat	0.146***	0.261***
	(0.037)	(0.053)
Obs	11,570	11,570
M-G Cells	890	890
Y Mean	1.59	1.92
B: Distinguishing OPT Reforms		
2008 Reform	0.107**	0.240***
	(0.045)	(0.059)
2011 Reform	0.264***	0.427***
	(0.101)	(0.108)
2012 Reform	0.257***	0.327***
	(0.076)	(0.114)
Obs	12,402	12,402
M-G Cells	954	954
Y Mean	1.57	1.90

Notes: Table shows difference-in-difference results under various robustness checks. Panel A includes major-specific unemployment rates, calculated by linking occupation specific unemployment rates, to majors using an occupation-major crosswalk. Panel B displays regression results that separately examine the effect of the 2008 policy, which extended the work duration, and the 2011 and the 2012 policy which expanded the list of eligible STEM majors. Enrollments are specified in inverse hyperbolic sine. Specifications include major-by-gender fixed effects and cohort-by-gender dummies. Standard errors are clustered at the major-gender level. * p<0.10, ** p<0.05, *** p<0.01.

Table 5: Robustness Checks using Different Control Groups

	(1) All Non-STEM	(2) Non-STEM Non-Business	(3) Arts and Humanities	(4) International STEM with Alternative Work Visa
A: Bachelor's				
treat	0.324***	0.330***	0.261***	0.379***
	(0.031)	(0.031)	(0.035)	(0.027)
Obs	37,830	35,542	17,446	18,746
M-G Cells	2,910	2,734	1,342	778
Y Mean	1.20	1.13	1.44	0.96
B: Master's				
treat	0.453***	0.464***	0.405***	0.529***
	(0.040)	(0.040)	(0.042)	(0.038)
Obs	37,830	35,542	17,446	18,746
M-G Cells	2,910	2,734	1,342	778
Y Mean	1.41	1.35	1.62	1.12

Notes: Table shows difference-in-differences estimates using different control groups. Column 1 uses all non-STEM majors in the control group. Column 2 uses non-STEM majors excluding Business major as the control group. Column 3 uses only Arts and Humanities related majors as the control group. Column 4 compares international STEM students needing H-1B work visa to international STEM students from Australia, Canada, Chile, Mexico, and Singapore who have alternative work visas. Enrollments are specified in inverse hyperbolic sine. Specifications include major-by-gender fixed effects and cohort-by-gender dummies. Standard errors are clustered at the major-gender level. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 6: Placebo Checks Using Associate and Doctoral Degree Enrollment

	Associate		Doctorate	
	(1)	(2)	(3)	(4)
	Base	+Major Trends	Base	+Major Trends
treat	-0.038	-0.022	0.055**	0.011
	(0.030)	(0.023)	(0.026)	(0.031)
Obs	12,402	12,402	12,402	12,402
M-G Cells	954	954	954	954
Y Mean	0.86	0.86	1.40	1.40

Notes: Table shows difference-in-differences estimates of the impact of OPT reforms. International enrollments in STEM fields are considered the treated group, while international enrollments in Business serve as the control. Results are shown for enrollment in Associate's and Doctoral programs, separately. Enrollments are transformed with inverse hyperbolic sine, to approximate logs and include cells with 0. Specifications include major fixed effects and cohort-by-gender dummies. Standard errors are clustered at the major-gender level. * p<0.10, ** p<0.05, *** p<0.01.

Table 7: Difference-in-differences Results on Enrollment, by Institution Type

	Bachelor's			Master's		
	(1)	(2)	(3)	(4)	(5)	(6)
A: Institution Control	*Public*	*Private*	*For-Profit*	*Public*	*Private*	*For-Profit*
treat	0.134***	0.118***	-0.007	0.270***	0.220***	0.022
	(0.033)	(0.031)	(0.016)	(0.041)	(0.050)	(0.022)
Obs	12,402	12,402	12,402	12,402	12,402	12,402
M-G Cells	954	954	954	954	954	954
Y Mean	1.23	0.92	0.17	1.41	1.25	0.16
B: Carnegie Classification	*Research*	*Master's*	*Baccalaureate*	*Research*	*Master's*	*Baccalaureate*
treat	0.150***	0.010	0.072***	0.288***	0.146***	0.072***
	(0.034)	(0.027)	(0.026)	(0.050)	(0.039)	(0.027)
Obs	12,402	12,402	12,402	12,402	12,402	12,402
M-G Cells	954	954	954	954	954	954
Y Mean	1.19	0.78	0.57	1.58	0.90	0.33

Notes: Estimates are based on SEVIS international enrollments and IPEDS institutional information. The sample covers years 2004-2016. Dependent variable is the inverse hyperbolic sine of enrollments in a specified type of institution in the gender-year-major cell. Specifications include major-by-gender fixed effects and cohort-by-gender dummies. Standard errors are clustered at the major-gender level. * p<0.10, ** p<0.05, *** p<0.01.

Table 8: Difference-in-differences Results on Enrollment, by Institution and Student Ranking

	Bachelor's				Master's			
	(1) *Least Selective*	(2) *Less Selective*	(3) *Selective*	(4) *Very Selective*	(5) *Least Selective*	(6) *Less Selective*	(7) *Selective*	(8) *Very Selective*
A: School Admissions Rate								
treat	-0.047**	0.079***	0.138***	0.119***	0.054**	0.211***	0.201***	0.192***
	(0.023)	(0.030)	(0.030)	(0.030)	(0.027)	(0.036)	(0.040)	(0.051)
Obs	12,402	12,402	12,402	12,402	12,402	12,402	12,402	12,402
M-G Cells	954	954	954	954	954	954	954	954
Y Mean	0.47	0.80	0.93	0.82	0.46	0.86	1.14	1.14
B: School Funds per Student								
treat	-0.054***	0.012	0.073***	0.170***	-0.026	0.094***	0.152***	0.279***
	(0.014)	(0.024)	(0.028)	(0.035)	(0.022)	(0.032)	(0.035)	(0.050)
Obs	12,402	12,402	12,402	12,402	12,402	12,402	12,402	12,402
M-G Cells	954	954	954	954	954	954	954	954
Y Mean	0.14	0.48	0.81	1.24	0.15	0.56	0.91	1.56
C: Student Financial Support								
treat	0.069**	0.002	0.016	0.161***	0.124***	0.128***	0.119***	0.291***
	(0.028)	(0.016)	(0.015)	(0.035)	(0.044)	(0.023)	(0.025)	(0.046)
Obs	12,402	12,402	12,402	12,402	12,402	12,402	12,402	12,402
M-G Cells	954	954	954	954	954	954	954	954
Y Mean	0.66	0.22	0.22	1.46	1.01	0.33	0.39	1.72

Notes: Estimates are based on SEVIS international enrollments and IPEDS institutional information. The sample covers years 2004-2016. Dependent variable is the inverse hyperbolic sine of enrollments in a specified type of category in the gender-year-major cell. Admissions rates from very selective to the least selective are: 1st quartile 0%-57%, 2nd quartile 57%-73%, third quartlie 73%-86%, 4th quartile above 86%. School funds per student measures the total funds per student held by a school in 2004 Fiscal Year. Ranges of funds from the least selective to very selective are: 1st quartile \$0-\$4,168, 2nd quartile \$4,168-\$13,514, 3rd quartile \$13,514-\$55,626. 4th quartile above \$55,626. Student financial support measures the ratio of external support a student received out of all sources of finance (i.e. the ratio is external support from school or other sources out of external and own sources of finance), all dollars denominated to 2004. From the least selective to very selective, the ratios are: less than 25%, between 25% and 50%, between 50% and 75%, and greater than 75%. Specifications include major-by-gender fixed effects and cohort-by-gender dummies. Standard errors are clustered at the major-gender level. * p<0.10, ** p<0.05, *** p<0.01.