Do International Students Crowd-Out or Cross-Subsidize Americans in Higher Education?

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Abstract

Recent growth in international enrollment at U.S. universities has raised controversy. While critics accuse international students of displacing American students, university administrators have argued that they provide much needed tuition revenue. This paper examines how international students impact domestic enrollment, focusing on a unique boom and bust in international matriculation into U.S. graduate programs from 1995-2005. Overall foreign students appear to increase domestic enrollment. This positive effect is linked to cross-subsidization, whereby high net tuition payments from foreign students help subsidize the cost of enrolling additional domestic students.

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1 Introduction

The U.S. has sustained unprecedented inflows of students from abroad. International enrollment in post-secondary education grew by 122% between 2005 and 2015.[1] This rapid growth has sparked recent controversy. Critics argue that international students steal seats from Americans, and in some instances have called for caps on noncitizen student entry. In contrast, university administrators have defended international students, asserting that they provide much needed tuition revenue that helps subsidize the cost of domestic students.[2]

This paper examines how international students affect domestic matriculation in graduate education. While recent debates have arisen as a reaction to inflows at the undergraduate level, foreign students have long maintained a high presence in graduate education (Bound et al. 2009, Freeman 2010). In many doctoral programs such as engineering, economics, and even law, foreign-born students have outnumbered natives for several decades (see figure 1). Currently, 15% of all graduate students, and 1-in-3 degree recipients in Science, Technology, Engineering and Math (STEM) fields hail from overseas. Importantly, graduate education's long history with international students lends itself to study.

Graduate education produces of skilled experts whose research and innovations bolster economic growth. High attrition rates, especially in STEM fields, pose a threat to the innovative workforce. Distortions created by international students are especially important to identify as U.S. immigration policy places no caps on their entry. This contrasts with tight limits on virtually all classes of work visas. This dichotomy generates the potential for distortions in higher education to be magnified in the labor market. For example, if foreign students displace Americans from higher education, strict limits on work visas will reduce the supply of skilled workers.[3]

[1]See http://www.iie.org/Research-and-Publications/Open-Doors/Data/International-Students/New-International-Enrollment.

[2]Critics of international student entry successfully lobbied for a legislative bill that limits nonresident enrollment at the University of California System (http://www.latimes.com/local/education/la-essential-education-updates-southern-uc-regents-approve-first-ever-limit-on-1495123220-htmlstory.html). In contrast, others have argued that hard limits on the number of international students intending to boost domestic enrollment could actually have the opposite effect if universities cannot make up for revenue shortfalls (http://www.businessinsider.com/foreign-students-pay-up-to-three-times-as-much-for-tuition-at-us-public-colleges-2016-9).

[3]Recent statistics indicate only 50-60% of Ph.D. students ever graduate (Sowell 2008). Finn (2003) estimates that roughly one-third of foreign doctoral recipients leave the U.S. within two years

Examining international student entry also informs debates over the impacts of immigration, which focus heavily on labor market consequences. When the education sector is discussed, rhetoric often gravitates toward the impacts on labor markets. For example, industry leaders argue that raising work visa quotas for foreign students will solve skill shortages, while skeptics believe native workers would suffer. Curiously, few ask whether there are impacts on the education of domestic students, even though education is an important determinant of labor market success. This paper contributes to growing research on the impacts of immigration on domestic educational attainment.[4]

Existing research on whether international students impact domestic enrollment in graduate education has produced quite conflicting findings, despite their many similarities (Borjas 2007, Regets 2007, Zhang 2009). These studies all utilize panel fixed-effects regression techniques, and approach the issue with the same conceptual intuition – the supply of seats in higher education is fixed so crowd-out occurs when supply constraints bind. If universities have excess capacity, increased foreign enrollment should not impact natives. Curiously, each study contains at least one estimate suggesting that international students actually *increase* the enrollment of some domestic students. Without any intuition on how international students could crowd-in Americans, such positive findings are cast as evidence against displacement or ignored entirely.

Using panel data on university enrollments, Borjas (2007) finds that international students crowd-out white native males in graduate programs. The estimated magnitudes suggest that an additional 10 foreign students would reduce enrollment of native White males by 4. However, positive and significant effects for other native groups are not discussed. For example, estimates indicate that 10 additional international students would raise enrollment of native females, Asians, and Hispanics by roughly 2.

Regets (2007) analyzes panel data containing enrollment across STEM departments from the NSF Graduate Student Survey. In contrast with Borjas (2007), the results indicate that foreign students increase the enrollment of White natives. Magnitudes suggest 10 additional foreign students increase White enrollment by 3. Al-

from receiving their degree.

[4]See related studies by Hoxby (1998), Hunt (2012), or Jackson (2016), for example.

though small negative estimates for native Asians do appear, the author interprets the positive and significant effects for White natives in graduate STEM programs as evidence against displacement.

Focusing on Ph.D. completions, rather than enrollments, Zhang (2009) finds significant positive associations between the number of foreign and native students in STEM fields. Magnitudes indicate that 1 additional foreign Ph.D. recipient leads to 1 extra native Ph.D. recipient. These results are interpreted as indicating that "obviously, there is no crowding out" of native students in STEM fields. However, results for non-STEM fields indicate large and statistically significant displacement. Within Education, for example, each additional foreign Ph.D. recipient reduces the total number of native doctorates by 4 and the total number of native male doctorates by 9.

This paper improves upon the empirical identification of prior studies which rely solely on fixed effects to account for endogeneity bias. While fixed effects help control for time-invariant features of universities or departments that may be correlated with enrollment levels, factors that change within universities over time may bias results. Different from prior work, I utilize panel specifications that account not only for time-invariant university characteristics correlated with the level of enrollments, but also for university-specific features correlated with enrollment growth. Additionally, the unique setting for my analysis facilitates the construction of novel instruments that assuage lingering endogeneity concerns.

I focus on a dramatic increase in international enrollment at U.S. graduate programs during the late 1990s, which suddenly reversed following heightened scrutiny of student visa applications in the aftermath of 9/11. I develop instruments from supply shocks that helped fuel this boom and bust cycle. Specifically, rising college-age (18-30 year old) populations in foreign nations created a growing supply of students that spilled overseas, fueling international enrollment in the U.S. during the boom. The terrorist attacks of 9/11 led to policies that created a sudden and sharp reduction in student visa issuance, which generated declines in foreign enrollment (GAO 2005; Freeman 2010). Uniquely, this boom and bust also enables analysis of both increases and decreases in international enrollment.

Instruments are formed by apportioning these aggregate supply shocks – college-age population growth and declines in student visa issuance – to universities according to their historical presence of foreign graduate students, measured in 1993. These instruments strongly predict actual inflows of international students during the boom and bust period. Crucially, I show that these supply shocks were unrelated to other factors that might have simultaneously affected U.S. graduate education.

The primary findings reveal that international students actually raise domestic enrollment. Preferred estimates indicate that 10 additional international students increase domestic enrollment by roughly 8. Standard confidence intervals rule out 1-for-1 displacement, and estimates are mostly significant at the 5% level. This positive effect also appears during the bust period, indicating symmetric responses to increases and decreases in international matriculation.

These results indicate a different conceptualization of enrollment capacity in higher education. At the margin universities can charge international students high prices and use the profits to subsidize the cost of enrolling more domestic students. This "cross-subsidization" is likely to occur when universities care greatly about domestic enrollment numbers. If student quality is prioritized instead, any excess foreign student tuition revenue will be used to the benefit of existing students. In this case, international students will likely crowd-out new domestic students of marginal quality.

I provide multiple forms of evidence that indicate cross-subsidization underlies the crowd-in effects. The positive impacts appear to be driven by foreign Master's students, who pay full-sticker price tuition, rather than Ph.D. students, many of whom are also subsidized by universities. Additionally, the positive impacts are concentrated on domestic graduate students in academic programs, who require subsidies, and not in professional programs, which seldom provide subsidies. Further, the crowd-in effects are most pronounced among public universities which prioritize enrolling domestic students, pricing tuition below cost for state residents, while also charging foreign students tuition rates between 2 to 3 times higher.

Lastly, I develop a more direct measure of the scope for cross-subsidization based on comparing tuition and costs to foreign and domestic students. Cross-subsidization can only occur if tuition and costs are appropriately structured, with large net subsidies for domestic students and high net tuition for foreign students. For each university I develop a proxy for the average foreign net tuition relative to the average domestic subsidy, which I refer to as relative net tuition, measured prior to the boom and bust period. Heterogeneous analysis shows results consistent with cross-subsidization –

the positive effects on domestic enrollment increases in relative net tuition.

The next section further develops the conceptual intuition surrounding the impacts of international students. Section 3 details the boom and bust, which provide the empirical setting for the analysis, as well as the empirical strategy and data. Section 4 presents the main results, and provides various robustness checks of the instrumental variable strategy. Section 5 analyzes whether cross-subsidization is a primary mechanism underlying the findings. Section 6 concludes.

2 Rethinking Enrollment Fluctuations

While related studies conceptualize the impact of international student inflows as solely contingent on the number of seats available, prior theoretical work and recent stylized facts suggest a different view of higher education. As non-profit organizations, universities equate total revenues and costs. However, individual activities or services within a university need not meet this binding constraint (James 1978, Winston 1999). Universities often provide services that have little relevance to their mission, but generate substantial profit, to subsidize important activities that are not self-sustaining.

Graduate education is one such activity that is both important to universities and not usually self-sustaining. While graduate students compete for seats as consumers, they also serve as inputs to higher education (Rothschild & White 1995), and hence receive subsidies in the form of scholarships or research/teaching assistant positions. In practice, these subsidies may be so generous that graduate students end up paying zero net tuition. If universities prioritize educating American students, then other profitable activities will be required to subsidize their cost.

Enrolling international students may be one way to generate profits and to cross-subsidize domestic students. International students face very high tuition prices and are not often subsidized by institutions. For example, out-of-state tuition at public universities is 2-3 times higher on average than tuition for domestic residents (figure 2a). Though domestic out-of-state residents also face higher tuition costs, many states allow them to claim in-state residency after 1 year.[5] Figure 2b illustrates that only 34% of foreign students reported being primarily supported by the institution they attended, with 66% being supported by personal funds or other sponsors. These

[5]See http://www.finaid.org/otheraid/stateresidency.phtml for state-by-state residency rules.

stylized facts indicate that international students contribute positive net revenue to universities.

These ideas introduce a different framework for how exogenous increases in international students might impact domestic enrollment. If universities only prioritize student quality, inflows of foreign students will likely intensify competition and displace domestic students of marginal quality. Any extra revenue from foreign tuition might be used to the benefit of already enrolled domestic students. However, if universities care about the number of domestic students they educate, exogenous increases in foreign students can raise domestic enrollment, as net foreign tuition revenue can be used to cross-subsidize additional domestic students.

Several recent papers have lent credence to this view of higher education. Specifically, Bound et al. (2016) show that public universities facing large cuts to state funding purposefully enroll more international students to generate revenue. Shen (2017) finds that at highly selective universities international students displace domestic students at the undergraduate level, but increase in institutional grant aid to existing students. Additionally, a recent paper by Machin & Murphy (2017) finds positive effects of international students on domestic graduate enrollment in the United Kingdom. They speculate that international students may cross-subsidize natives, but do not provide any empirical evidence.

Importantly, this intuition implies heterogeneity in responses along several dimensions which can be empirically verified. For example, public universities, whose interests are tied to those of the state legislature, may place high weight on domestic enrollment numbers. In contrast, private universities may care more about student quality. Alternatively, effects may be different for graduate programs that require substantial subsidies for their students relative to those that do not, such as professional degree programs. My empirical analysis will first estimate average effects, and then analyze several margins likely to exhibit heterogeneous responses consistent with cross-subsidization. The next section introduces the empirical methodology and setting for the analysis.

3 Methodology & Data

Estimating the impact of international students on domestic enrollment is challenging as it requires separating exogenous inflows from abroad from demand shocks that lead universities to expand in general. I focus on a uniquely volatile decade between 1995 and 2005 that assists in abstracting from such confounding factors. The ensuing discussion describes this decade in greater detail.

3.1 The Boom and Bust of 1995-2005

In the early 1990s, U.S. universities faced great uncertainty over their ability to continue attracting students worldwide.[6] Unexpectedly, foreign enrollment surged after 1995, increasing from 170,000 to over 250,000 by the turn of the millennium (figure 3). The 9/11 terrorist attacks brought this growth to an abrupt halt, and foreign enrollment declined in the following years. While the bust was much smaller than the late-90s boom, it marked the first time in three decades and only the second occurrence since the 1950s where the number of foreign students in the U.S. fell (Chin 2005).

Importantly, two factors unrelated to U.S. higher education helped fuel the boom and bust cycle. Through the 1990s, alongside improvements in post-secondary education systems, many nations saw expansions in their college-age populations (e.g., Rosenzweig 2006, Bound et al. 2009). This demographic growth generated larger cohorts of students that spilled overseas (Bird & Turner 2014, Shih 2016), increasing foreign enrollment in the United States.

While college-age population growth progressed around the world, a tremendous shock prevented continued spillovers of foreign students – the September 11th, 2001 terrorist attacks. The discovery that hijackers exploited student visas to enter the U.S. led to the quick enactment of policies which intensified screening and slowed student visa processing (Wasem 2003; GAO 2005). Additionally, legislation mandated that by 2003 universities must have implemented the Student Exchange and Visitors Information Service (SEVIS), a new digitized system to monitor foreign students. SEVIS was rife with glitches that led to further delays. Visa backlogs and SEVIS issues were resolved by 2005, after which graduate enrollment from abroad continued its upward climb (Alberts 2007, Freeman 2010).[7]

[6]For example, a New York Times article in 1995 expressed concern that increased competition from other nations would lower foreign enrollments in the United States. See http://www.nytimes.com/1995/11/24/us/fewer-foreigners-are-choosing-us-colleges.html.

[7]Conceivably, post-2005 could also be included. However, the period is complicated by surging foreign undergraduate enrollments. Additionally, the Great Recession in 2008 caused unusual changes to both domestic student's educational decisions and the endowment revenue of universities.

The analysis focuses on research universities, whom sustained most of the boom and bust. Figure 4 plots international enrollment from 1995-2005 by academic level, in rows, and by Carnegie Classification, across the columns. The solid line depicts enrollment in levels, corresponding to the left vertical axis. The dashed line indicates the intensity of such fluctuations by showing year-on-year changes in foreign enrollment as a percent of total enrollment, and corresponds to the right vertical axis. Research universities clearly experienced a dramatic boom and bust in foreign graduate enrollment, both in level and in intensity. Master's institutions saw some fluctuation, but on a far smaller scale. Additionally, foreign undergraduate enrollment did not exhibit any changes in baccalaureate, master's, or research universities.

A final observation about this episode is that while the numbers changed dramatically, the composition of foreign students remained stable. Figure 5 examines the share of international students by country (panel A), and by field of study (panel B). The distribution across fields was relatively unchanged, with 40-50% of all foreign graduate students in STEM disciplines throughout the decade. In addition, the boom and bust did not appear to be driven by any single country. Roughly 40-50% of foreign graduate students hailed from Asia throughout the period, with smaller shares coming from Europe, the Americas, the Middle East and Africa.

The stable nature of the boom and bust contrasts markedly with recent inflows that have been entirely driven by students from China (Shen 2017). This consistency during the boom and bust allows analysis of changes in scale that are less contaminated by changes in other characteristics of international students. The next section describes the empirical methodology to estimate the impacts on domestic enrollment.

3.2 Empirical Specification

The empirical setting incorporates two distinct periods with different types of variation – increases and decreases in international enrollment. I utilize a regression framework that is flexible enough to capture potential asymmetries in responses to increases and decreases. Additionally, as I construct a distinct instrument for each period (discussed in the next section), this initial separation allows for a transparent assessment of the different instruments. The following baseline specification measures the impact of international graduate students on domestic graduate enrollment:

$$\Delta D_{ut} = \alpha + \beta_1 \Delta F_{ut} + \beta_2 \Delta F_{ut} \times B + \gamma_t + \gamma_{uB} + \varepsilon_{ut} \quad (1)$$

In specification 1, the influx of international students at each university, u, is measured using year-on-year changes ($\Delta F_{ut} = F_{ut} - F_{ut-1}$). The dependent variable is specified similarly to capture yearly changes in domestic enrollment. B indicates the period, and is equal to 0 for the boom (1995-2001) and 1 for the bust (2002-2005). β_1 measures the marginal impact of an additional international student, and can also be interpreted as the effect during the boom period. $\beta_1 > 0$ would indicate that international students increase domestic enrollment, while $\beta_1 < 0$ would signify displacement. β_2, the coefficient on the interaction term of ΔF and B, indicates the differential effect during the bust period. The estimated impact for the bust period is the sum of β_1 and β_2.

Notice that first-differencing effectively eliminates the influence of fixed university characteristics correlated with the level of enrollments, such as university quality. Year dummies (γ_t) help absorb aggregate shocks affecting all universities. Including additional university-by-period fixed effects (γ_{uB}) after first-differencing accounts for unobserved university characteristics correlated with enrollment growth. Allowing them to vary across periods accounts for differential university-specific shocks during each period. This model is equivalent to stratifying the analysis by period, with the exception that pooling increases power and simplifies hypothesis testing of differences across periods. Finally, ε_{ut} is a zero-mean error term.

While specification 1 makes extensive use of fixed effects to account for potential endogeneity, unobserved factors that evolve within universities and correlate with enrollment changes remain a concern. For example, changes in university resources following the Dot-Com stock market crash in 2000 may have altered opportunities for domestic and international students alike. To help mitigate such concerns, I develop novel instruments from the aforementioned supply shocks that helped fuel the boom and bust cycle.

3.3 IV Strategy

College-age population growth in countries around the world generated supply spillovers of international students to U.S. universities during the boom period. The post-9/11 policies that limited student visa issuance not only halted spillovers from abroad, but actually reduced foreign enrollment.[8] Key to the identification is that

[8] As shown in appendix table A1, using a single IV based on college-age population growth for both the boom and bust periods is not viable as it has no predictive power during the bust period.

these aggregate shocks were not endogenously related to university-specific factors that affected graduate program size.

These supply shocks are transformed into instruments by interacting them with the historical presence of foreign graduate students at universities.[9] Historical familiarity with foreign students generates predictive power through strong networks (Beine, Noël & Ragot 2014) – previous students return home and inform young compatriots of their experience, building brand recognition. Future supply shocks disproportionately affect institutions that possess strong networks.

Since such networks operate strongly among students from the same country, I enhance instrument power by using restricted-access data that provides precise counts of graduate students at each university by country of origin. Each university's historical presence is measured in 1993, as it is the earliest data containing country of origin information. The instruments are constructed by apportioning future supply shocks according to each university's historical presence of foreign graduate students. Specifically,

$$\hat{F}_{ut} = \begin{cases} \sum_c \hat{F}^{POP}_{cut} = \sum_c \frac{F_{cu1993}}{POP_{c1993}} \cdot POP_{ct} = \sum_c S_{cu1993} \cdot POP_{ct} & if\, t \leq 2001 \\ \\ \sum_c \hat{F}^{9/11}_{cut} = \sum_c \frac{\hat{F}^{POP}_{cu2001}}{VISA_{c2001}} \cdot VISA_{ct} = \sum_c \hat{S}_{cu2001} \cdot VISA_{ct} & if\, t \geq 2002 \end{cases} \tag{2}$$

Historical presence of foreign graduate students is measured by the share of a country's total college-age population enrolled as graduate students at each university (S_{cu1993}). This is calculated for each university (u) by dividing its foreign graduate enrollment from country c by the total college-age population of country c as of 1993. As supply shocks lift the college-age population, future counts (POP_{ct}) are apportioned to universities according to their historical share in 1993. This procedure develops predictions of what the actual level of foreign enrollment from country c would be in any year t, at each university u, had the initial country enrollment proportions across universities remained fixed ($\widehat{F}^{POP}_{cut}$).

[9] This approach is similar to the classic "shift-share" instrument, which has been popularly used in various literatures. Notable examples in the immigration literature include Card (2001), Cortes (2008), and Peri et al. (2015). Specifically, these instruments holds fixed the share of immigrants in a pre-period and apportion future immigrant stocks according to the pre-period shares.

For the bust period, I use the foreign enrollment values predicted from college-age populations (i.e. $\hat{F}^{POP}_{cut}$) to measure each university's share of total student visa issuances by country in 2001, just before the bust. Future student visas issuances are then apportioned according to each university's share in 2001. This generates predictors of foreign enrollment by country of origin in each year during the bust. Summing across countries yields a prediction of total international enrollment in a given year, $\hat{F}_{ut}$. Since equation 1 specifies international graduate enrollment in first-differences, the instruments are formed by taking first-differences in predicted foreign graduate enrollment:

$$\Delta\hat{F}_{ut} = \hat{F}_{ut} - \hat{F}_{ut-1} \tag{3}$$

3.4 Data for Instruments

Restricted-use data on historical international enrollment by country for each university are obtained from the Institute of International Education (IIE). Specifically, I utilize data from the International Student Census surveys which IIE conducts each year and uses to publish its annual "Open Doors" reports. The earliest available foreign enrollment counts come from fall 1993.

To reduce dimensionality countries are collapsed into 17 nationality groups based on ethnic/regional similarity. The top 10 countries that send international students to the U.S. (China, India, South Korea, Japan, Thailand, Indonesia, Germany, Canada, Mexico, and Turkey) are each their own nationality group. The remaining countries are aggregated into 7 nationality groups: Rest of Asia, Rest of Americas, Middle East/North Africa, Eastern Europe, Western Europe, Africa, and Oceania.

College-age population counts are obtained from the UNESCO Institute of Statistics. Data on student visa issuance by country comes from the Department of State Non-Immigrant Visa Statistics. Because visas are issued while students are abroad and before they arrive on campus, issuances measure intent to enroll and are a cleaner measure of policy impacts than actual enrollment. For example, actual enrollment would reflect students who were issued visas but decided not to enroll due to other potentially endogenous factors. I utilize the primary class of students visas, the F-1 visa, though other classes exist, such as the J-visa for cultural exchange and M-visa for border commuters.[10]

[10]Visa issuances represent flows, but the instrument relies on shocks to total foreign enrollment

3.5 Data for Analysis

Data on domestic and foreign enrollment by university come from the Integrated Postsecondary Education Data System (IPEDS). Enrollment counts report the number of degree-seeking students by level during the fall of each academic year. IPEDS identifies international students via separate enrollment counts for "non-resident aliens", defined as persons who are not U.S. citizens, possess a temporary visa, and do not have the right to remain in the country indefinitely. Domestic enrollment comes from "resident" counts, which include U.S. citizens and permanent residents.

The analysis centers on research universities, defined by the Carnegie Classification.[11] Constructing the main sample for analysis requires identifying research universities consistently available in the IPEDS 1995-2005 surveys, and in the IIE 1993 survey. The main sample excludes institutions reporting extreme outliers to mitigate measurement error, resulting in a panel of 258 universities.[12] Sensitivity tests are performed by including universities with outliers, or further excluding universities that have imputed records.

Table I displays summary statistics, measured in 1995, for the main sample of research universities. Research institutions were quite large, with average undergraduate enrollment over 11,000 and graduate enrollment at nearly 4,500. Interestingly, the presence of international students increases in academic level. While the percentage of international students at the undergraduate level was only 3%, the average percentage of international graduate students at research universities was nearly three times higher at 11%. The share of degrees awarded to foreign students was 13% at the Master's level and 21% at the Ph.D. level.

The universities in the main sample are mostly public (62%), span the 50 states,

stocks. Therefore, I develop a stock measure of the total number of F-1 visas in each year by first aggregating visa issuances to the 17 nationality groups, and then cumulating F-1 visas issued to each nationality over the prior 3 years. Thus, $visa_{ct}$ in equation 2 is computed as $visa_{ct} = visa_{ct}^{issued} + visa_{ct-1}^{issued} + visa_{ct-2}^{issued} + visa_{ct-3}^{issued}$. The idea is that $visa_{ct}$ approximates the total stock of student visa holders in year t, as students issued new student visas in years $t-1$, $t-2$, and $t-3$ are likely still continuing their education in year t.

[11] Revisions of this classification, which categorizes institutions based on the number of degrees awarded in a reference year, occur routinely. Thus, the analysis focuses on a time-consistent group of institutions that are ever classified as a research institution in the 1994, 2000, 2005, or 2010 Carnegie classifications.

[12] Outliers are institutions reporting changes in foreign enrollment outside the 1st-99th percentile in the sample. For example, a prominent public university in Colorado reported roughly 500 foreign students in 1998, 0 in 1999, and 600 in 2000.

and include elite ivy-league schools, public flagship universities and smaller private institutions. These research institutions comprised the bulk of U.S. graduate education, accounting for 73% of all foreign graduate students and over half of all graduate students. Furthermore, they awarded 52% of all professional degrees, 58% of master's degrees, and 83% of Ph.D. degrees.

3.6 First-Stage Power

Instrument validity depends on both relevance and excludability. Instrument relevance requires that predicted changes foreign enrollment strongly correlate with actual changes in foreign enrollment. First-stage power can be assessed using a specification similar to equation 1:

$$\Delta F_{ut} = \alpha + \gamma_1 \Delta \hat{F}_{ut} + \gamma_2 \Delta \hat{F}_{ut} \times B + \gamma_t + \gamma_{uB} + \epsilon_{ut} \tag{4}$$

Specification 4 controls for university-by-period fixed effects and year dummies, as in equation 1. Standard errors are clustered at the university level to account for within-university correlation in residuals.

Results are presented in table II. Note that in specification 4, γ_1 is the first-stage coefficient for the boom period, and $\gamma_1 + \gamma_2$ is the first-stage coefficient for the bust period. The first row reports estimates of γ_1, while the second row shows estimates of $\gamma_1 + \gamma_2$. Column 1 uses the main sample of 258 research universities. Column 2 removes universities that ever had imputed records in IPEDS surveys over the 1995-2005 decade. Column 3 further removes universities in which the IIE data were imputed.[13] Column 4 uses all research universities available in IPEDS, including those reporting extreme outliers.

The instruments based on college-age population growth and post-9/11 reductions in student visa issuance are strong predictors of foreign student growth during the boom and bust, respectively. When using different samples across the columns, point estimates are virtually unchanged. Partial R-squared statistics help examine the predictive power of the instrument during each period individually, while the Cragg-Donald F-statistic gauges overall weak instrument bias. Note that the first-stage F is sufficiently large to avoid weak instrument bias (Staiger & Stock 1997). One exception is that when including universities reporting extreme outliers (column 4),

[13] See appendix A.1 for further description of imputations.

measurement error from outliers causes precision to fall sizably. The partial R-squared values and the first-stage F statistic decline by roughly 50%.

Coefficients center around 4 for the boom and 1.5 for the bust. These magnitudes can be understood by visualizing the data underlying the first-stage. Figure 6 plots actual changes in international enrollment within universities against the instrument, after partialling out university fixed effects and year dummies, separately for each period. The coefficients estimated in column 1 of table II (solid line) and a 45 degree line (dashed line) are also included. If actual foreign enrollment grew at exactly the rate of college-age populations abroad, and fell at the rate of student visa issuance, the regression line and 45 degree line would coincide in both graphs. However, the regression line is steeper indicating that actual international enrollment, on average, grew faster within universities than they would have if college-age populations abroad and declines in student visa issuance were the only contributing factors.

4 Main Results

Results from two-stage least squares (2SLS) regressions of equation 1 are reported in table III. Column 1 uses the main sample, column 2 removes institutions with imputed records in IPEDS, column 3 removes universities with imputations in IPEDS or IIE data, and column 4 includes extreme outliers. Column 5 presents OLS results using the main sample. Row 1 reports the coefficient β_1 which indicates the impact during the boom period. The second row reports the coefficient β_2 to assess whether there is a significant differential impact during the bust. Note that the estimated impacts during the bust period can be calculated by summing β_1 and β_2. Standard errors are clustered at the university level.

The analysis reveals four key findings. First, point estimates of β_1 are all positive, indicating that increases in foreign students actually raise domestic enrollment. The results are significant at the 5% level when using the main sample, and are generally significant at lower levels when removing imputed data or including extreme outliers. Standard confidence intervals rule out 1-for-1 displacement – the idea that each international student takes a seat from a domestic student.

Second, increases and decreases in international enrollment appear to have similar effects – there does not appear to be a significant difference during the bust period. The coefficient estimates of β_2 are small and never significantly different from 0 at any meaningful level of confidence. Therefore, during the boom, inflows of international students raised domestic enrollment. During the bust, declines in foreign students lowered domestic enrollment.

Third, the average effect size is around 0.80, indicating that an influx of 10 international students leads to 8 additional domestic students. Importantly, domestic enrollment is much larger and more variable than foreign enrollment, on average. Thus, standardized coefficients are helpful in assessing magnitudes – the estimates indicate a 1 standard deviation rise in foreign enrollment increases domestic enrollment by roughly 1/4th of a standard deviation.[14]

An example helps to make the magnitudes more concrete. Consider a public university situated at the median among research universities in terms of total and foreign graduate enrollment in 1995. Over the boom, foreign graduate enrollment grew from 258 to 400 students, a net increase of 142 students. Domestic graduate enrollment also expanded by 413 students, from 3,228 in 1995 to 3,641 in 2001. While domestic enrollment rose by an average of 70 students each year, the estimates indicate that only 19 ($\frac{\beta \cdot \Delta F}{6yrs} = \frac{(142)\cdot(0.80)}{6} \approx 19$) of these additional domestic graduate students were attributable to the increase in foreign students.

Finally, the OLS estimate of 0.21 in column 5 is also positive, but smaller in magnitude than its 2SLS counterpart in column 1. This is likely due to two factors. First, the instruments help reduce attenuation bias from measurement error still present after removing extreme outliers. Second, empirical and anecdotal evidence has indicated that shocks to revenue or demand often lead universities to recruit more foreign students to make up for declining domestic enrollment.[15] The instruments may alleviate downward bias caused by such endogenous shocks.

4.1 IV Validity & Robustness Checks

In addition to having strong first-stage power, instruments must also satisfy the exclusion restriction to provide causal inference. Specifically, the instruments must

[14]In the data, a standard deviation in the change of international amounts to approximately 87 students. A standard deviation in the change in domestic students is approximately 291 students. Using the coefficient of 0.80 from the main specification for the boom (column 1 row 1) of table III, we can calculate the standardized coefficient as: $0.80 \cdot \frac{87}{291} = .24$.

[15]For example, see http://www.wsj.com/articles/international-students-stream-into-u-s-colleges-1427248801. This has also been substantiated by recent evidence in Bound et al. (2016), which shows negative funding shocks lead universities to increase international student enrollment.

only affect actual international enrollment, remaining unrelated to other determinants of domestic enrollment. Because the instruments are derived from the interaction of historical university foreign graduate enrollment shares and aggregate supply shocks, each part must be unrelated to other factors that also affect domestic enrollment. As there is only one instrument for each period, the regression model is just-identified and directly testing the exclusion restriction is not possible. Nevertheless, several checks help rule out issues of first-order concern.

A primary concern is if the instrument fails to abstract from changes in undergraduate enrollment that might track changes in graduate enrollments. For example, if college-age population growth only caused increases in foreign undergraduate enrollment, both domestic and foreign graduate enrollment might have increased due to a greater need for teaching assistants. To address this concern, I demonstrate that the instruments do not have predictive power over enrollment changes at the undergraduate level, and also show the primary results remain robust when adding controls for movements at the undergraduate level.

Panel A of table IV presents these robustness checks. Columns 1 and 2 replace the dependent variable in specification 4 with the change in foreign and domestic undergraduate enrollment, respectively. Column 3 of panel B presents 2SLS results that include a control for movement in foreign undergraduate enrollment.[16] The results show no significant correlation between the instruments and undergraduate enrollment. Reassuringly, the point estimates when including the foreign undergraduate control are quite similar to those reported from table III.

Another concern is if universities' foreign enrollments in 1993 embodied potentially endogenous shocks that had lingering impacts during the 1995-2005 period. As a simple check, I assess whether results remain robust when constructing the instrument with earlier data. As the IIE does not maintain data prior to 1993, I utilize the IPEDS 1980 survey. IPEDS does not contain information on origin country, and so I construct the instrument by apportioning total worldwide (net of the U.S.) college population growth and total declines in student visa issuance according to each university's foreign graduate enrollment share in the world college-age population as of

[16] Including actual changes in undergraduate enrollment as a control risks introducing further endogeneity. Instead, an exogenous control variable is used that is almost identical to the instrument, with the exception that the count of foreign undergraduates by university and nationality from the 1993 IIE survey are used in place of the count of foreign graduate students.

1980.

Column 4 in panel B of table IV performs this check using the main sample. Instrument power falls and the 2SLS estimates become less precise. Because the instruments derive power from persistent networks between former and prospective students from the same country, using longer lags and removing the country of origin variation reduces this power. Importantly, however, the point estimates are virtually unchanged.

Alternatively, college-age population growth or declines in student visa issuances may have stemmed from other endogenous aggregate shocks. In particular, during the 1995-2005 decade the U.S. also sustained a dramatic rise and fall in the stock prices of internet-based firms known as the "Dot-Com" boom and bust (figure 7A), rapid increases in federal funding to higher education (figure 7B), and an expansion and subsequent contraction in H-1B visa limits for foreign skilled workers (figure 7C). These other factors exhibit fluctuations that similarly align with the boom and bust in foreign graduate enrollment, and may have had impacts on graduate education.

To address these concerns I develop controls for each of these phenomena.[17] As stock market fluctuations affect university endowments (Kantor & Whalley 2014, Brown et al. 2014), I create a control for the Dot-Com boom and bust by interacting endowment per student values in 1993 with growth in the Nasdaq Composite Index. I develop a control for changes in federal R&d funding from the interaction of research funding per student in 1993 with aggregate federal R&D outlays to universities. Because changes in H-1B policy may affect skilled labor markets and the returns to education, I interact foreign graduate enrollment by nationality in 1993 with nationality-specific growth in aggregate H-1B visa issuances.[18] Finally, I control for state specific shocks, such as declines in state appropriations to higher education (Bound et al. 2016), by including state-by-year fixed effects. Columns 5-8 of table IV present the results when individually incorporating these controls. The results remain robust indicating that the instrument is unlikely to be contaminated by such factors.

[17] Specific details on the construction of these control variables and their data sources are provided in section A.2 of the appendix.

[18] H-1B policy has been shown to alter labor market returns for highly educated workers (Peri et al. 2015), which in turn may influence schooling decisions. As indicated by Kato & Sparber (2013) and Shih (2016), H-1B policy directly affects foreign student entry.

Table V provides some final robustness checks. Column 1 ensures the results are not driven by endogenous changes within a few large universities, by removing 8 universities that are consistently ranked in the top 10 in terms of international graduate enrollment in each year from 1995-2005. Columns 2-5 demonstrate the results do not simply reflect the performance of universities that host large numbers of students from particular nations.[19] Results in column 2 are stable when constructing the instrument without the nationality dimension, simply interacting total foreign enrollment shares in 1993 with worldwide college-age populations and total student visa issuance. Columns 3 and 4 show the results are similar after excluding the two largest foreign student groups – India and China – from the analysis. Finally, column 5 shows results are not affected when removing students from predominantly Muslim nations, whom received heightened attention after 9/11.

These robustness checks provide a consistent message. International students expand domestic enrollment at the graduate level. The instruments help mitigate endogeneity bias and stand-up to potential exclusion restriction violations. Given that no differential impacts are found during the bust period, the remaining analyses impose symmetry across periods by dropping the interaction term ($\Delta F \times B$).

5 Mechanisms

Why do international students appear to expand domestic enrollment? As discussed in section 2, if universities have an interest in maintaining domestic enrollment and when international students pay high tuition, there may be scope for cross-subsidization – net tuition from foreign students can subsidize additional domestic students. I provide several pieces of empirical evidence that highlight cross-subsidization behavior.

First, while disaggregated university level data on subsidies and tuition payments are not available, the National Postsecondary Student Aid Survey (NPSAS) provides relevant information for a sample of U.S. citizens at research universities in 1996, 2000, and 2004 – roughly aligning with the beginning, middle, and end of the boom and bust cycle. While sample sizes render NPSAS data useless for my research design, they can be used to generate national level descriptive evidence.

[19] For example, aggregate declines in student visas issued to Indians could simply reflect declining quality among universities that host large numbers of Indian students.

Figure 8 displays averages of net tuition and institutional aid for U.S. citizens in graduate school from the NPSAS sample.[20] The top figure shows that over the boom, average net tuition payments of U.S. citizens actually fell from $6,618 in 1996 to $4,596 by 2000 – an average decrease of roughly $1,000 per student. Similarly, net tuition payments of U.S. citizens increased over the bust, as international enrollment declined. The bottom figure reveals that changes in net tuition payments over the boom and bust were due to changes in institutional aid rather than reduced tuition rates. This pattern is consistent with the idea that exogenous inflows of foreign students generated additional net revenue, which universities used to subsidize the enrollment costs of more domestic students.

While descriptive patterns are useful, I provide more rigorous empirical checks consistent with cross-subsidization. In particular, crowd-in is likely to occur when universities prioritize domestic enrollment. While determining the true importance universities place on domestic enrollment is difficult, it is likely that public universities strongly prioritize this as they are beholden to the interests of state legislatures and residents. Additionally, figure 2a revealed that tuition rates at public universities are nearly 2-3 times higher for foreign students than domestic residents. Thus, finding strong positive impacts on domestic enrollment at public universities would be consistent with cross-subsidization. The case for private universities is less clear since they are less tied to state interests and observing sticker price tuition rates cannot confirm or deny price discrimination between foreign and domestic students.

Additionally, cross-subsidization should occur in programs that actually require subsidies for domestic students. There is substantial variance across graduate programs in this regard. For example, professional degree programs[21] often provide few subsidies and charge full sticker price tuition to domestic and foreign students alike. In contrast, academic and research oriented programs require substantial subsidies for their students. Thus, inflows of foreign students are unlikely to lead to cross-subsidization and increased domestic enrollment in professional programs. The estimated positive effects should be found for domestic students in academic programs.

[20] Averages are calculated using U.S. citizens enrolled in graduate programs at research universities in each of the 1996, 2000, and 2004 NPSAS surveys. The 95% confidence intervals are provided for reference. Institutional aid includes grants, scholarships, fellowships, tuition waivers, loans or other support from the university.

[21] Professional degree programs include those that require a professional license to practice, such as Law, Medicine and Physical Therapy.

Finally, while foreign graduate students generally pay high tuition, differences may exist by level. Data from the 2015 Survey of Earned Doctorates shows that only 3% of international Ph.D. recipients draw upon their own resources to support their studies, with over 70% relying on paid research and teaching positions. As these figures only reflect the financial assistance of degree recipients, it is still conceivable that exogenous inflows of new foreign students into Ph.D. programs can generate initial positive net revenue. Nonetheless, it is more likely that foreign Master's students, who seldom receive institutional support, are the primary contributors to the positive impact on domestic enrollment.

Table VI examines heterogeneous impacts along these margins, where crowd-in due to cross-subsidization is likely to occur. Columns 1 and 2 estimate the impact of international students on domestic enrollment, separately for public universities and private universities. Impacts on domestic enrollment in academic programs and professional programs are shown in columns 3 and 4, respectively. Finally, column 5 splits the change in foreign enrollment into two components: changes in foreign master's students ($\Delta F_{Master's}$) and changes in foreign Ph.D. students (ΔF_{PhD}).[22] The analyses in table VI are similar to specification 1 except that I omit the interaction term ($\Delta F \times B$), since earlier analysis found no evidence of differential effects during the bust. Hence, β_1 is the coefficient of interest reported in the rows.

The findings in table VI provide evidence in support of cross-subsidization. The positive impact on domestic students appears to be strongly significant within public universities. The estimate for private universities is imprecise, so that confidence intervals cannot rule out displacement. Additionally, positive impacts appear for domestic enrollment in academic programs that often require substantial subsidies for students. There is no discernible impact when examining domestic enrollment in professional programs that charge high tuition and provide few subsidies. Finally, column 5 indicates that the positive impact on domestic enrollment appears to be driven by foreign Master's students, while no impact is found for foreign Ph.D. students.

As a final exercise, I develop an empirical test to assess the scope of cross-subsidization across universities. The intuition for this can be understood by considering a univer-

[22]Unfortunately, the only available data with enrollment counts of international Master's and Ph.D. is from IIE surveys. The data is only available for 145 universities from 1998-2005 and contains substantial imputations. The constructed instruments are not powerful enough to predict foreign Master's or PhD enrollments, and therefore OLS results are presented.

sity's budget constraint. Universities enroll domestic students (D) and foreign students (F), and earn revenue by charging them tuition rates t_D and t_F, respectively. Other non-variable (fixed) revenue (FR) comes from government appropriations and endowment payouts. Expenses include fixed costs (FC), such as building operation costs, and variable costs represented by $c(q)$, the per student cost of delivering education of quality level q. These costs include expenditures related to instruction, and subsidies given to students in the form of grants and other aid.

Given their non-profit status, universities must ensure total revenues equate total costs:

$$FC + c(q)D + c(q)F - t_D D - t_F F - FR = 0 \tag{5}$$

We can evaluate how universities face trade-offs between domestic and foreign students by differentiating the budget constraint with respect to D and F, holding all else constant, which yields the following relationship,

$$\frac{dD}{dF} = \frac{t_F - c(q)}{c(q) - t_D} \tag{6}$$

Equation 6 provides a simple formalization of the scope for cross-subsidization. The numerator represents the net tuition revenue from an international student (i.e. tuition less subsidies and other costs). The denominator represents the net subsidy given to a domestic student. This ratio, which I refer to as *relative net tuition*, indicates how many additional domestic students a university could enroll with the net revenue from one additional international student. For example, if net international tuition is \$1000 and the net domestic subsidy is \$ 500 then one additional foreign student provides enough net revenue to enroll two additional domestic students.

How universities actually decide to trade-off domestic and foreign students depends also on their preferences. Those that place heavy weight on domestic numbers will engage in cross-subsidization, while others may utilize additional tuition revenue to improve quality. Nonetheless, relative net tuition provides an empirical means to assess the scope for cross-subsidization behavior. Specifically, if cross-subsidization is a primary mechanism underlying the findings, then on average, universities with higher relative net tuition should exhibit greater crowd-in effects from foreign students.

For each university I construct a single relative net tuition statistic. In-state and out-of-state tuition rates from IPEDS proxy for t_D and t_F, respectively.[23] To proxy for graduate student costs $c(q)$, I utilize data from the Delta Cost Project (Lenihan 2012) to calculate average variable costs over all students in the university, which include expenses such as grant/fellowship aid and instructional costs. I then calculate relative net tuition for each university in every year from 1990-1994, and then take a simple average over the 1990-1994 period to derive a single statistic. Importantly, this is measured prior to the period under analysis and therefore is not affected by the boom and bust.

Because of the inherent measurement error in calculating relative net tuition, I bin universities into quartiles according my relative net tuition proxy. I then perform 2SLS regressions, interacting the foreign share with dummies for each quartile, with the instrument set including interactions with the instrument and dummies for each quartile. The combined effects at each quartile are reported in table VII. While the equality of the coefficients cannot be rejected, the findings do support the intuition regarding cross-subsidization. The positive impact of international students on domestic enrollment increases in relative net tuition.

While the evidence has indicated that cross-subsidization is a key mechanism underlying the findings, the partial equilibrium nature of the analysis only highlights university behavior. A different explanation might be that international students actually change domestic student demand. For example, domestic students may have preferences over studying with international student peers. Alternatively, international student competition may alter the expected returns to education. Although the available data are not suited to explore these different mechanisms, they cannot be ruled out.

[23] At public universities domestic out-of-state students may face t_F. In this case, cross-subsidization should only lead to increased enrollment of domestic in-state students. Unfortunately, existing data does not distinguish enrollment by residency. However, at some public universities there is evidence that most graduate students hail from in-state or may claim state residency. For example, among all University of California campuses, out-of-state domestic students only account for roughly 8% of graduate enrollment (see https://www.universityofcalifornia.edu/infocenter/fall-enrollment-glance). At the State University of New York campuses, only 6% of students are from out-of-state (see http://www.suny.edu/media/suny/content-assets/documents/FastFacts2016.pdf). Additionally, many state laws allow out-of-state domestic students to claim residency after 1-year. Thus, if we consider t_D to be roughly similar to average tuition rates they face over the duration of graduate school, then foreign students can still lead to increases in both domestic in- and out-of-state students.

6 Conclusion

For decades, international students have maintained a large and growing presence in U.S. higher education. This growth has generated concern that fixed resources become diluted among a larger populace and lead to the displacement of domestic students. However, the effects of this internationalization are poorly understood, and in particular, the consequences for domestic students remain unclear.

This paper demonstrates that at the graduate level, international students do not crowd-out, but actually increase domestic enrollment. Such positive effects are attributable to cross-subsidization, whereby foreign student tuition revenue is used to subsidize the cost of enrolling additional domestic students. However, heterogeneity does exist across higher education institutions. Those that prioritize domestic enrollment, like public universities who must consider the welfare of state residents, are likely to engage in cross-subsidization of domestic students. Universities that prioritize quality are unlikely to increase domestic enrollment following inflows of foreign students.

This research indicates that efforts to limit nonresident enrollment based on fears of domestic displacement, such as the University of California System which recently approved a cap on non-citizen enrollment, may be misguided. Given that a large body of research has found that foreign students contribute positively to research and innovation (Chellaraj et al. 2008, Black & Stephan 2010, Stuen et al. 2012), my findings suggest such benefits may not come at the expense of domestic students.

Importantly, this research has focused exclusively on quantities. Understanding foreign student quality and its consequences for domestic students is equally crucial (e.g. Gaule & Piacentini 2013). The selection of foreign students has important implications for how social interactions ultimately affect domestic peers (e.g. Anelli et al. 2017). Continued research on the role of international students is needed to inform policy and expand our understanding of higher education.

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Table I: Summary Statistics of Research Universities, 1995

	Mean	Std. Dev.
Undergraduates		
Total	11,184	8,017
International	3%	4%
Domestic	93%	8%
Graduates		
Total	4,490	3,219
International	11%	8%
Domestic	85%	10%
White	69%	15%
Asian	4%	5%
Minority	11%	12%
1st Prof. Degrees		
Total	157	198
International	2%	4%
Domestic	96%	6%
Masters Degrees		
Total	903	709
International	13%	8%
Domestic	83%	11%
Ph.D. Degrees		
Total	146	174
International	21%	14%
Domestic	76%	15%
# of Universities	258	
Type		
Public	62%	
Private	38%	
For Profit	0%	
Share of Total:		
International Graduates	73%	
Graduate Enrollment	56%	
1st Prof. Degrees	52%	
Masters Degrees	58%	
Ph.D. Degrees	83%	

Note: Statistics are calculated from IPEDS 1995 Fall Enrollment, Completions, and Institutional Characteristics surveys. Research universities are defined by the Carnegie Classification. International and domestic percentages do not sum to 100% as there is a small portion of enrollments whose status are unknown.

Table II: First-Stage Instrument Power

	(1)	(2)	(3)	(4)
IV - Boom	4.04***	4.10***	4.12***	3.88***
	(0.46)	(0.48)	(0.50)	(0.67)
IV - Bust	1.56***	1.55***	1.67***	1.41**
	(0.24)	(0.25)	(0.28)	(0.56)
First-Stage Diagnostics:				
Partial R2 - Boom	0.12	0.11	0.12	0.05
Partial R2 - Bust	0.12	0.12	0.13	0.06
Cragg-Donald F	134	124	105	57
Obs.	2,580	2,480	1,930	2,920
Universities	258	248	193	292
Removes Outliers	X	X	X	
Removes IPEDS Imputations		X	X	
Removes IIE Imputations			X	

Note: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. All specifications include university-by-period fixed effects and year dummies. Standard errors are clustered at the university level.

Table III: 2SLS Results for Domestic Enrollment

	(1)	(2)	(3)	(4)	(5)
ΔF	0.80**	0.81*	0.94**	0.81*	0.21
	(0.40)	(0.43)	(0.46)	(0.44)	(0.15)
$\Delta F \times B$	0.02	-0.02	-0.43	0.28	0.19
	(0.59)	(0.62)	(0.64)	(1.15)	(0.25)
First-Stage F	134	124	105	57	
Obs.	2,580	2,480	1,930	2,920	2,580
Universities	258	248	193	292	258
Removes Outliers	X	X	X		X
Removes IPEDS Imputations		X	X		
Removes IIE Imputations			X		

Note: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. All specifications include university-by-period fixed effects and year dummies. Standard errors are clustered at the university level. Columns (1)-(4) present 2SLS results. Column (5) presents OLS results.

Table IV: Instrument Validity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A: 1st Stage, dep. var.:	*intl. ug.*	*doms. ug.*						
IV - Boom	0.51	-2.26						
	(0.40)	(3.63)						
IV - Bust	0.11	1.51						
	(0.13)	(1.17)						
B: 2SLS, w/ various controls								
ΔF			0.93**	0.73	0.85*	0.84**	0.62	0.85**
			(0.45)	(0.58)	(0.45)	(0.40)	(0.61)	(0.39)
$\Delta F \times B$			-0.34	0.12	0.14	0.01	1.12	-0.31
			(0.57)	(0.94)	(0.61)	(0.60)	(1.06)	(0.52)
Controls:								
Intl Ug Enrollment			X					
Lag 1980 IV				X				
Dot Com Boom/Bust					X			
Fed. Funding						X		
H-1B Policy							X	
StateXYear FEs								X
Partial R2 - Boom	0.00	0.00	0.08	0.07	0.11	0.11	0.05	0.14
Partial R2 - Bust	0.00	0.00	0.10	0.07	0.11	0.12	0.04	0.13
First-Stage F	1	1	92	72	101	130	40	121
Obs.	2,510	2,510	2,510	2,490	2,160	2,550	2,580	2,580
Universities	251	251	251	249	216	255	258	258

Note: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. All specifications include university-by-period fixed effects and time period dummies. Standard errors are clustered at the university level. The dependent variable in columns 1 and 2 are changes in international and domestic undergraduate enrollment, respectively. Columns 3-7 incorporate control variables described in the text. Changes in the number of universities in the sample are due to the availability of data. For example, column 4 only has 249 of the 258 universities as only 249 reported endowment values needed to construct the control.

Table V: Robustness Checks

	(1) Removes Top 8 Univ.	(2) IV without country dimension	(3) Removes India from IV	(4) Removes China from IV	(5) Removes Muslim nations from IV
ΔF	0.80*	0.78*	0.80**	0.67	0.79**
	(0.43)	(0.46)	(0.40)	(0.46)	(0.40)
$\Delta F \times B$	0.15	0.29	-0.04	0.27	0.04
	(0.65)	(0.82)	(0.64)	(0.66)	(0.59)
Partial R2 - Boom	0.10	0.10	0.12	0.10	0.11
Partial R2 - Bust	0.12	0.09	0.11	0.11	0.12
First-Stage F	116	96	131	119	133
Obs.	2,500	2,580	2,580	2,580	2,580
Universities	250	258	258	258	258

Note: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. All specifications include university-by-period fixed effects and year dummies. Standard errors are clustered at the university level.

Table VI: Heteroegneous Effects

Model Specification:	(1) Public Universities only	(2) Private Universities only	(3) Domestic Academic Enrollment	(4) Domestic Professional Enrollment	(5) Int'l by level (OLS)
ΔF	0.88***	0.63	0.68**	0.06	
	(0.32)	(1.00)	(0.28)	(0.11)	
$\Delta F_{Master's}$					0.15***
					(0.05)
ΔF_{PhD}					-0.01
					(0.04)
First-Stage F	205	30	243	87	
Obs.	1,610	970	2,580	1,150	1,305
Universities	161	97	258	115	145

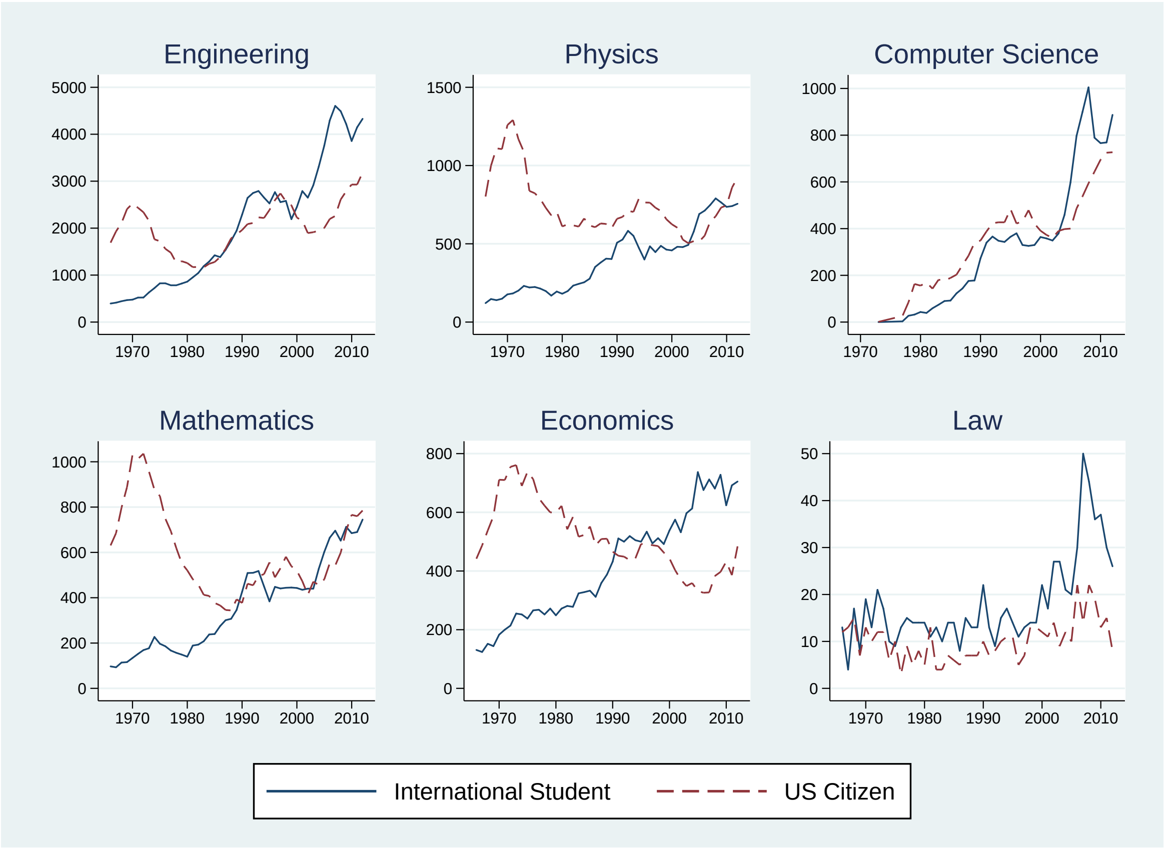
Note: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. All specifications include university-by-period fixed effects and year dummies. Standard errors are clustered at the university level. Table shows results from stratified analyses in columns 1-4. Only 115 of the 258 universities report having professional enrollment. Foreign Master's and Ph.D. enrollment come from IIE surveys, which contain substantial imputations and are only available for 145 universities and for the 9 years between 1997-2005. Hence the number of observations is 145 $\times$ 9 = 1,305.

Table VII: Impacts by Relative Net Tuition Quartiles

Effect for universities in the:	
RNT 1st Quartile	0.71
	(0.88)
RNT 2nd Quartile	0.81*
	(0.45)
RNT 3rd Quartile	0.92**
	(0.40)
RNT 4th Quartile	1.48**
	(0.58)
First-Stage F	19
Obs.	2,580
Universities	258

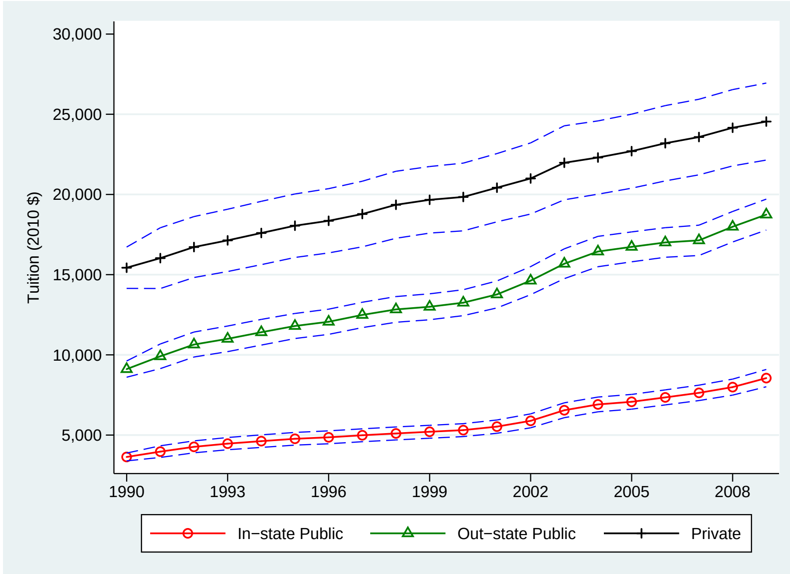
Note: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. All specifications include university-by-period fixed effects and year dummies. Standard errors are clustered at the university level. Reported coefficients are the combined estimates from regressions that include an interaction terms of ΔF and indicators for each quartile of RNT. The instrument set also includes interactions of $\Delta\widehat{F}$ and the RNT indicators.

Figure 1: Doctoral Degree Awards to U.S. Citizens and International Students, 1966-2012

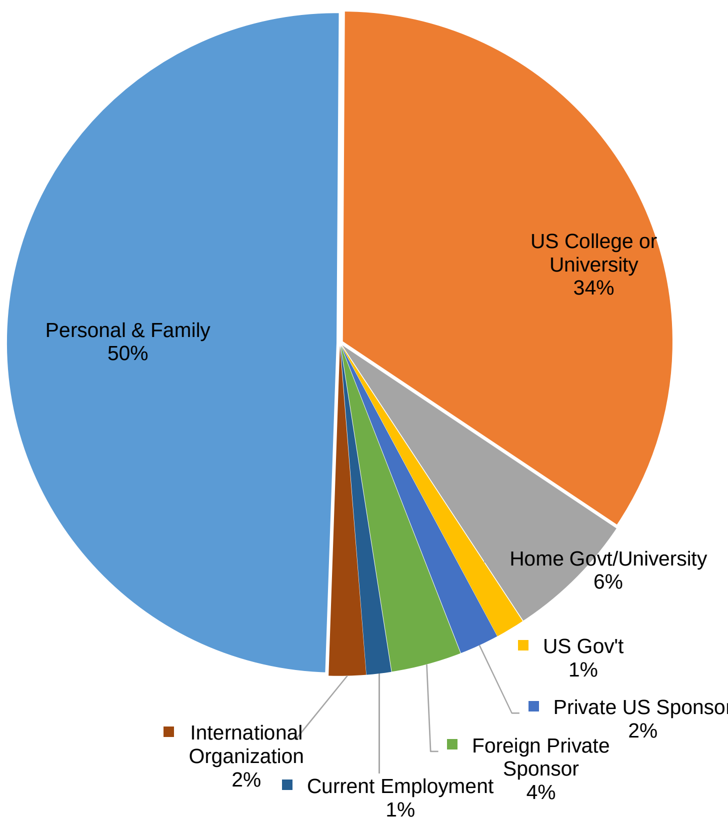


Note: Data shows doctoral degree awards by field. Solid line indicates awards to US citizens, while the dashed line indicates awards to international students. Data comes from the Survey of Earned Doctorates public-use data, available from the National Science Foundation's WebCASPAR, see: https://ncsesdata.nsf.gov/webcaspar/.

Figure 2: International Student Tuition and Funding



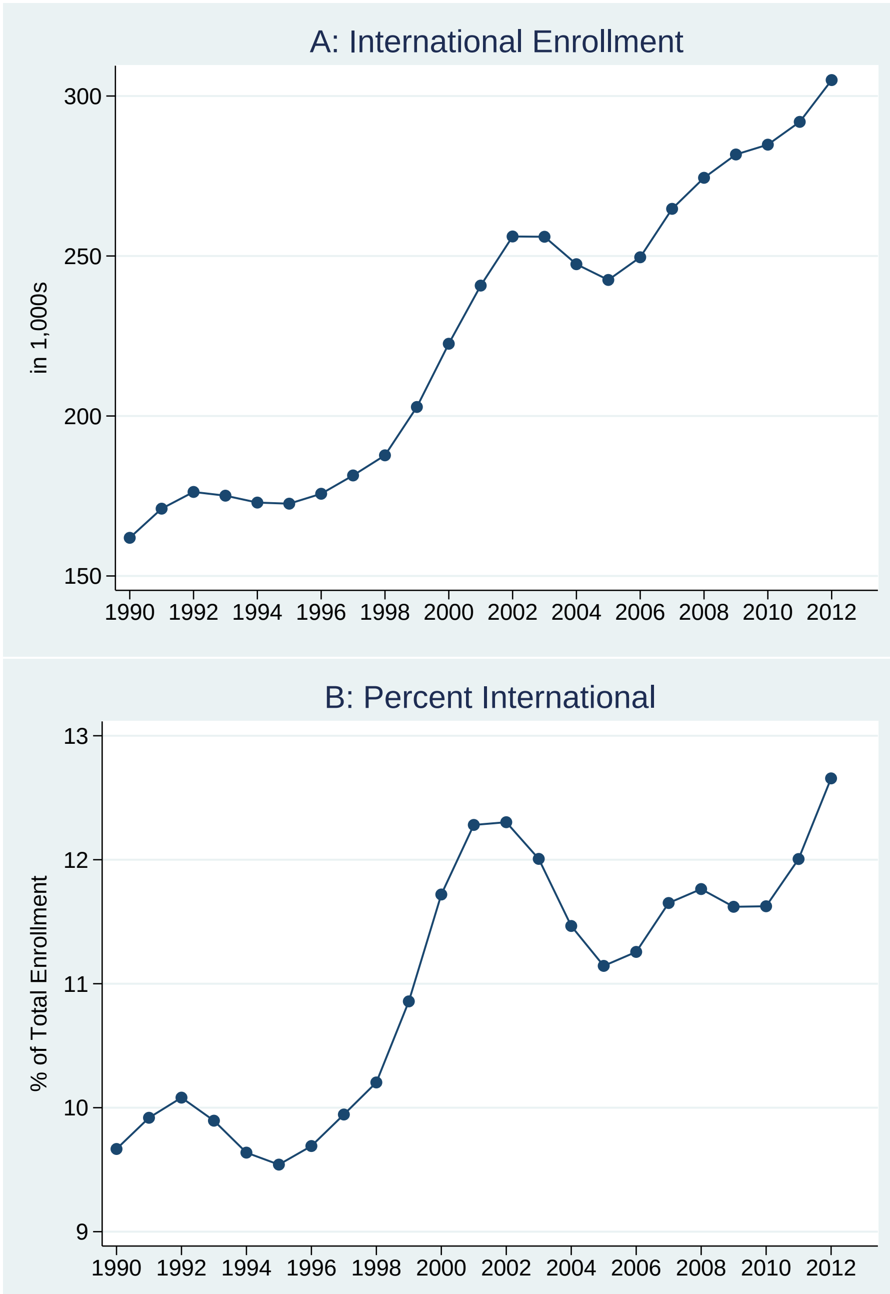
(a) Sticker Price Tuition Rates at Research Universities , 1990-2009



(b) Primary Source of Funding for International Graduate Students, 1995

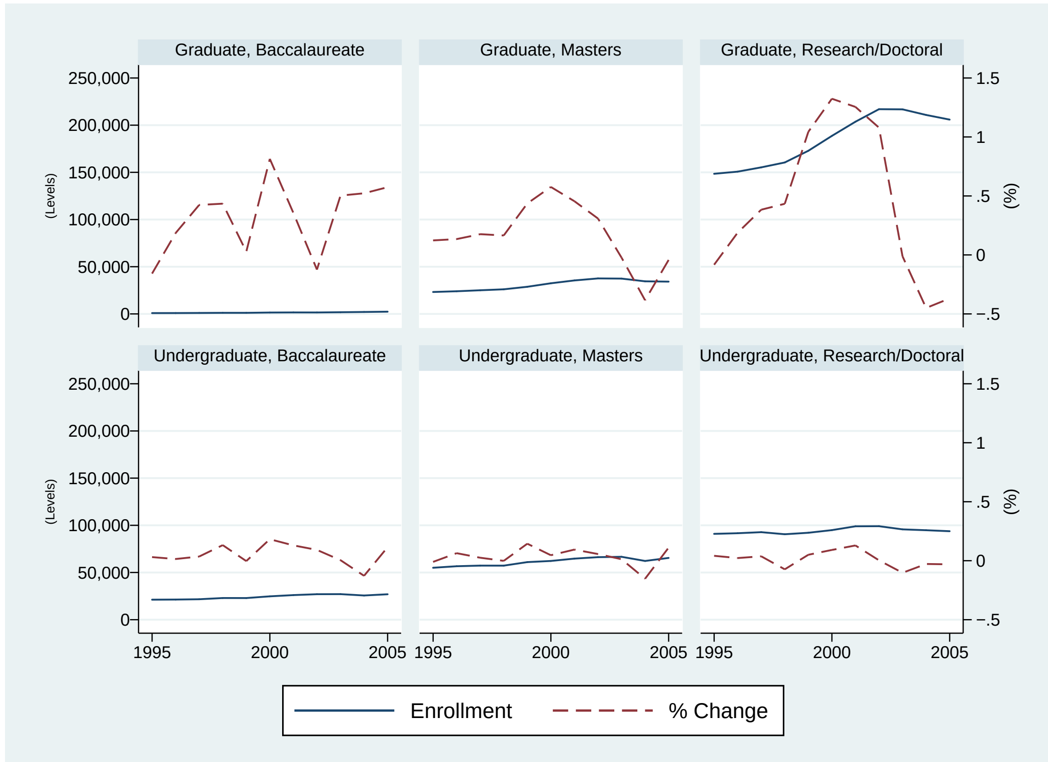
Note: (a) shows average in- and out-of-state tuition at public universities, and average tuition at private universities. Dashed lines represent 95% confidence intervals. Data comes from the IPEDS Delta Cost Project (Lenihan 2012). Dollar amounts have been converted to constant 2010 $. (b) shows the fraction of foreign graduate students reporting each category as the main source of support to finance their education. Data from IIE Open Doors report for the 1995-1996 academic year (Davis 1996).

Figure 3: Trends in International Graduate Enrollment in the U.S., 1990-2013



Note: Series constructed from IPEDS Fall Enrollment Surveys, 1990-2013. Figures above include total international graduate enrollment (in Panel A) and international graduate enrollment as a percent of total graduate enrollment (Panel B).

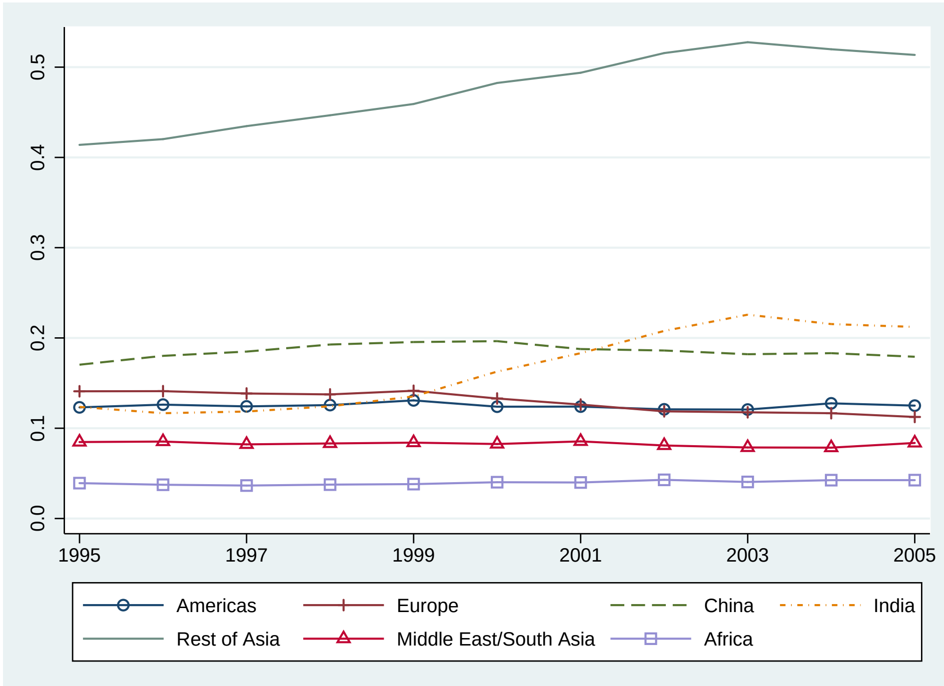
Figure 4: International Enrollment by Academic Level and University Type, 1995-2005



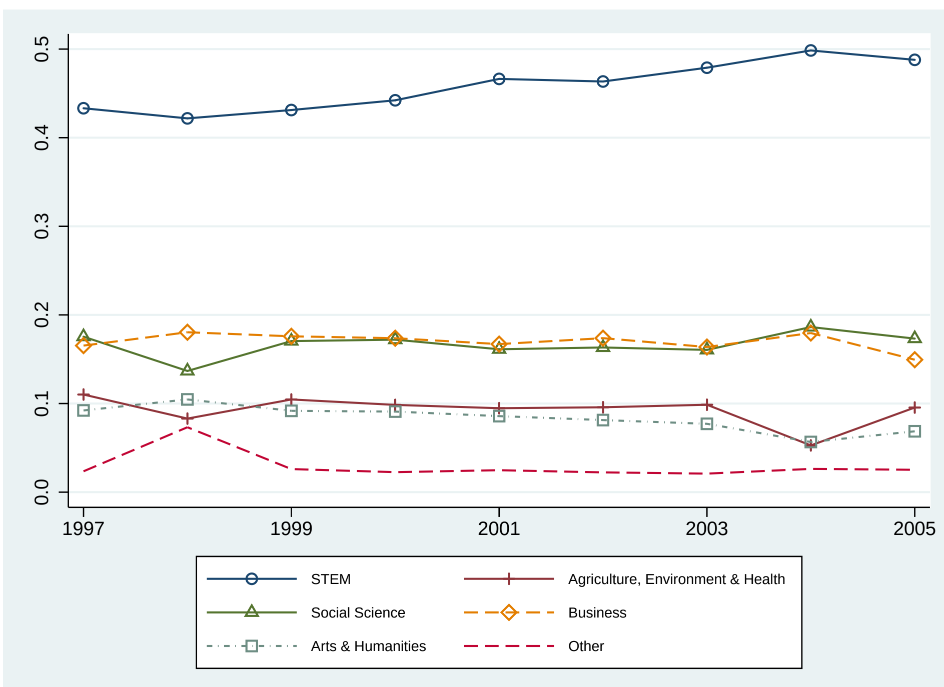
Note: Series constructed from IPEDS Fall Enrollment Surveys, 1995-2006. Figures above include total international undergraduate and graduate enrollment in baccalaureate, master's, and research/doctoral universities as defined by the 2000 Carnegie Classification. Solid lines indicate enrollment in levels, and corresponds to the left vertical axis. Dashed lines indicate year-on-year changes in foreign enrollment standardized by total enrollment, and corresponds to the right vertical axis.

Figure 5: Composition of International Students, 1995-2005

A: Country of Origin

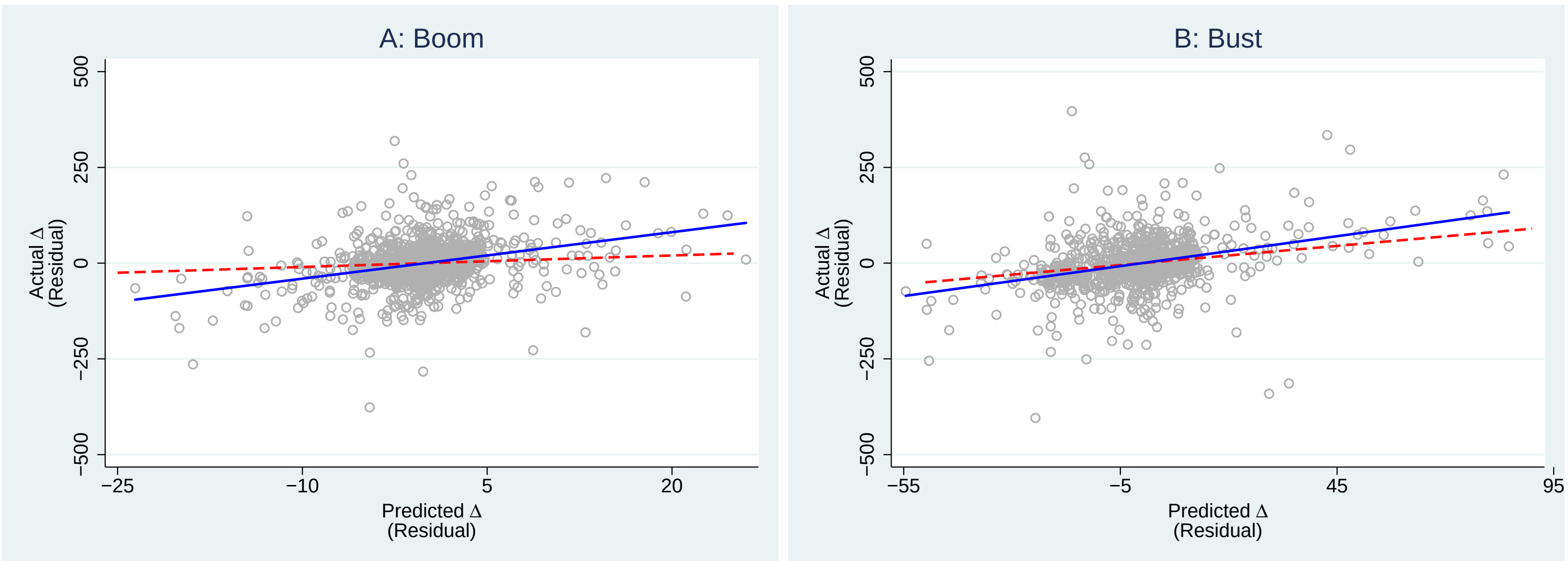


B: Field of Study



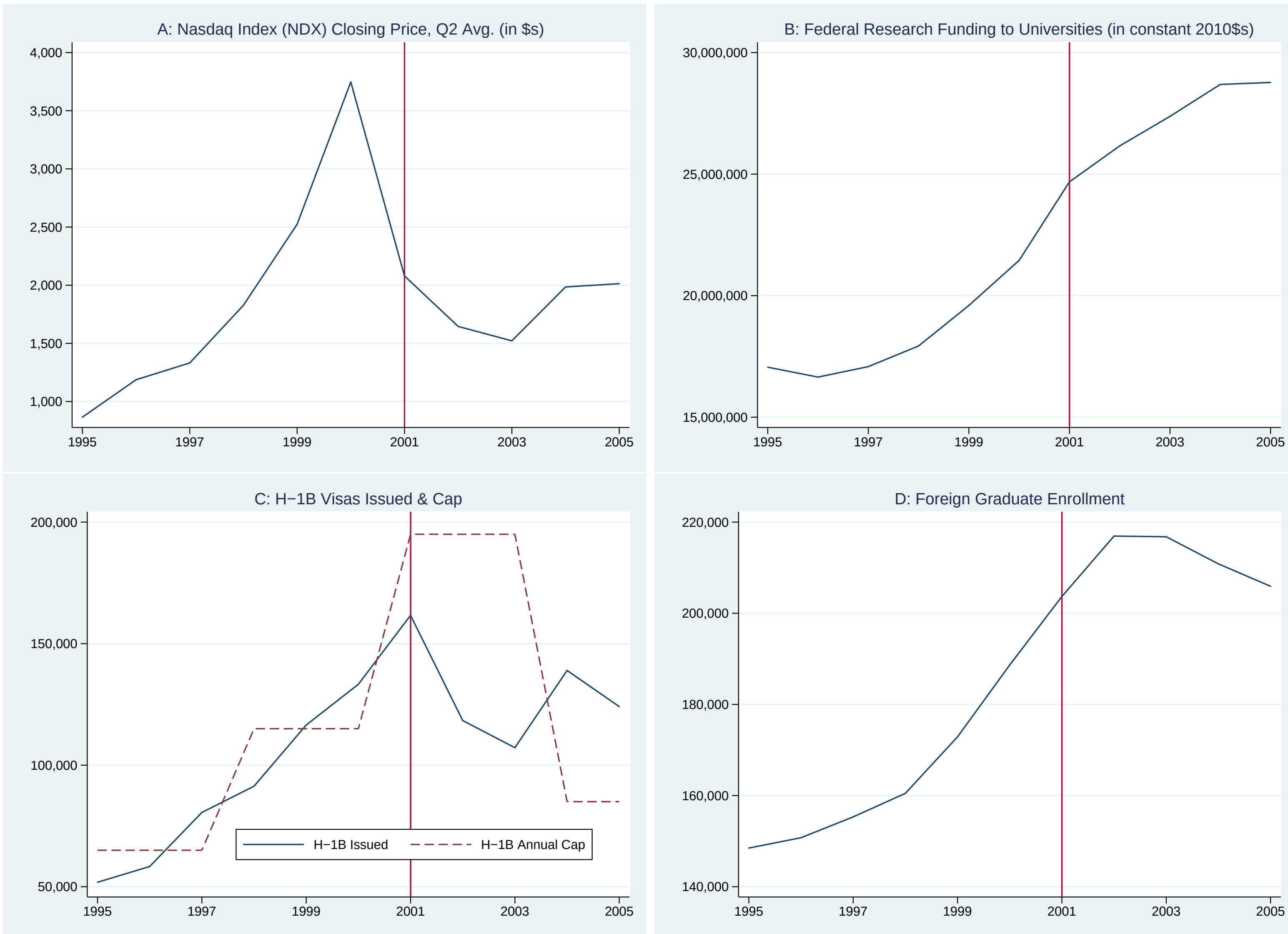
Note: Series constructed from IIE International Student Census restricted-use data from 1995-2005. Graduate enrollment by field of study was available only from 1997 on.

Figure 6: Visual First-Stage Estimates



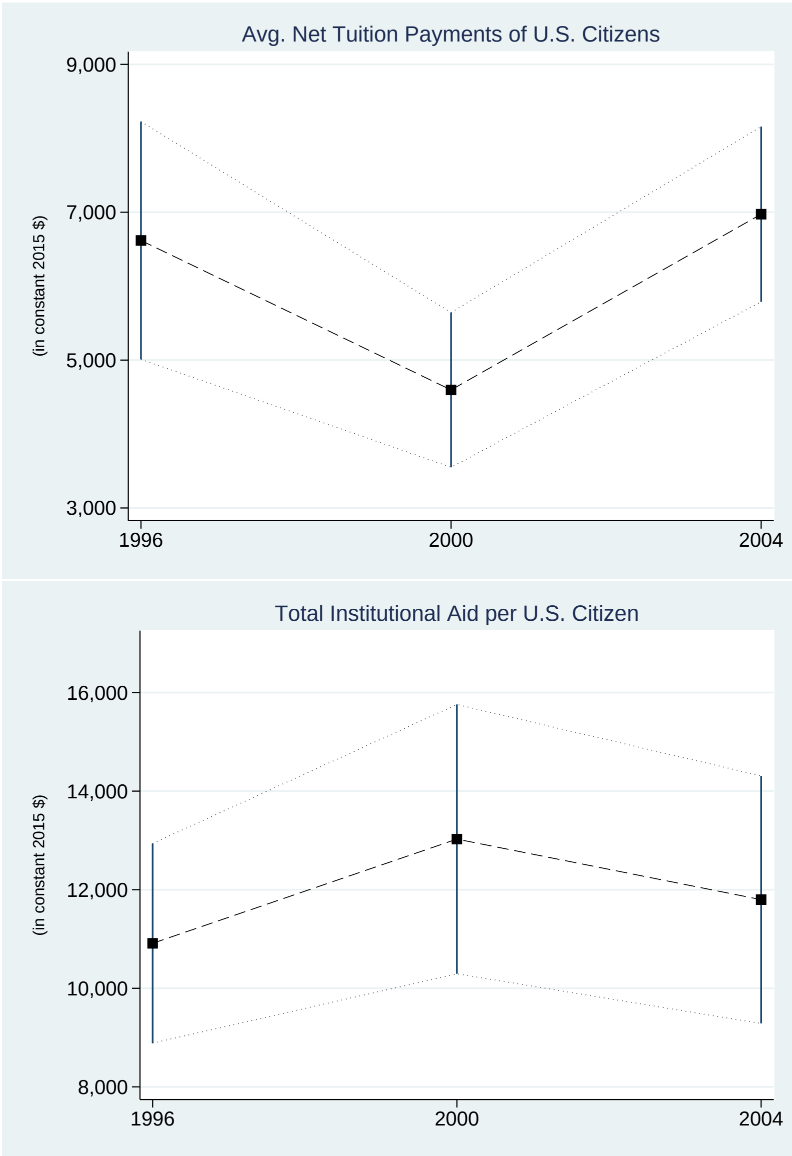
Note: Figure plots the actual change in foreign enrollment over the boom (left) and bust (right) against the change predicted by the instrument for each university in the main sample. For reference, the 45-degree line is represented by the dashed line. The regression line is represented by the solid line.

Figure 7: Coincident Shocks During the Boom and Bust



Note: Panel A: Nasdaq Composite Index stock prices are from Yahoo Finance Historical Prices and reflect the average daily closing price over the 2nd quarter, when students generally make enrollment decisions. Panel B shows data from the NSF on total federal research and development obligations to universities and colleges excluding FFRDCs in constant 2010 dollars. Panel C: H-1B visas issued are from the Department of States Non-immigrant Visa Statistics.

Figure 8: Net Tuition and Institutional Aid, U.S. Citizens in the NPSAS Sample



Note: Figure reflects average net tuition, institutional aid, and institutional grant aid in constant 2015 dollars for U.S. citizens enrolled in graduate programs at research universities from the 1996, 2000, and 2004 NPSAS surveys. Data retrieved from the National Center for Education Statistic's Data Lab (https://nces.ed.gov/datalab/).

A Appendix

A.1 Imputations to 1993 IIE Data

Only 201 of these 258 research universities provided enrollment counts by country of origin and academic level in the 1993 IIE survey. Thus, imputations of the IIE graduate and undergraduate enrollments by country of origin for the 57 non-respondents are necessary to include them in the analysis.

Imputations are performed by using data from non-research universities that did respond to the survey. These include master's and baccalaureate level institutions, and also community colleges and vocational colleges. In what follows, I describe the imputation procedure for graduate enrollments by country of origin. The procedure for undergraduate enrollments is identical, the only difference being that I use available data on undergraduate enrollments rather than graduate enrollments.

To impute graduate enrollment by country of origin, I obtain total graduate enrollment in 1993 from the IPEDS Fall Enrollment survey for each of the 57 universities missing in the IIE data. Using only non-research universities in the 1993 IIE data, I calculate the share of graduate enrollment from each country of origin by state. This procedure involves first aggregating graduate enrollment by country of origin (c) for all non-research universities (i) within the same state (s),

$$F^c_{s1993} = \sum_i F^c_{is1993} \tag{A.1}$$

Hence, I obtain the total enrollment by country of origin in non-research universities for each state. Next, enrollments by country of origin for each state are then aggregated across all countries of origin,

$$F_{s1993} = \sum_s F^c_{s1993} = \sum_s \sum_i F^c_{is1993}$$

Dividing the state level country of origin enrollment by total foreign enrollment in that state yields the share of students from country c in each state in 1993,

$$sh^c_{s1993} = \frac{F^c_{s1993}}{F_{s1993}}$$

I then multiply total enrollment in 1993, measured from IPEDS, with the share of students by country of origin in the corresponding state.

$$\widehat{F}^c_{u1993} = F_{u1993} * sh^c_{s1993}$$

To be precise, the state share assigned to the university is that of the state in which the university is located. Lastly, I aggregate the country of origin imputations to the 17 nationality groups. These imputations of graduate enrollment by nationality in 1993 for each university are then interacted with the supply shocks to form the instruments, as detailed in equations

2 and 3.

A.2 Construction of control variables

This section describes, in further detail, the construction of the various different control variables used in the analysis, and the data sources. These include variables that control for contemporaneous phenomena that may have affected U.S. graduate education during the 1995-2005 decade.

H-1B Control

To account for possible influence of national changes to H-1B program, I develop a control. The first step requires calculating the number of H-1B visas issued to each nationality for 1993 and the sample years 1995-2005. Data on H-1B visa issued by country of origin is available from 1997-2005 from the Department of State.[24] Lack of data prior to 1997 poses an issue for constructing this control for 1993, 1995, and 1996. However, yearly data on the total number of H-1B visas issued from 1990-2005 are available. This allows imputation of H-1B visas issued by country of origin in the missing years (i.e. 1993, 1995, 1996), as follows:

$$S^n_{97-05} = \frac{\sum_{t=1997}^{2005} H1B_{nt}}{\sum_{t=1997}^{2005} H1B_t}$$

$$\widetilde{H1B}_{n\tau} = S^n_{97-05} * H1B_{n\tau} \qquad for\ \tau = 1993, 1995, 1996$$

I first calculate the share of all H-1B visas awarded to each nationality group n from 1997 to 2005 (S^n_{97-05}). This is done by cumulating all visas issued to that nationality group ($H1B_{nt}$) and dividing by the total H-1B visas awarded over the 1997-2005 period. The second step imputes the number of H-1B visas issued to each nationality group in the years prior to 1997 ($\widetilde{H1B}_{n\tau}$) by interacting the share of all H-1B visas awarded to that nationality group over the 1997-2005 period with the total number of H-1B visas in missing years.

I then calculate the aggregate growth rates of H-1B workers by nationality from 1993 to each of the sample years.

$$g^{H1B}_{n,93-t} = \frac{H1B_{nt}}{H1B_{n1993}}$$

This growth factor is then interacted with the historical foreign graduate enrollment across

[24] Data comes from the FY1997-2012 NIV Detail Table, available at https://travel.state.gov/content/visas/en/law-and-policy/statistics/non-immigrant-visas.html.

universities, and these predictions are then aggregated across all nationalities,

$$\widehat{F}_{ut}^{H1B} = \sum_n \widehat{F}_{nut}^{H1B} = \sum_n F_{nu93} \cdot g_{n,93-t}^{H1B} = \sum_n F_{nu93} \cdot \frac{H1B_{nt}}{H1B_{n1993}}$$

Similar to equation 2 in the paper, this procedure yields a variable that captures the contribution of changes in H-1B policy on foreign graduate enrollment. Formalizing this into a control for 2SLS regressions requires taking first-differences:

$$\Delta \widehat{F}_{ut}^{H1B} = \widehat{F}_{ut}^{H1B} - \widehat{F}_{ut-1}^{H1B}$$

The Dot Com Boom and Bust

The Dot-Com boom and bust dramatically altered the stock prices of internet based firms. To capture these fluctuations I use the Nasdaq Composite Index (NCI), which is comprised of 3,000+ actively traded securities on the Nasdaq stock exchange, and is often used to track the performance of technology-based companies.

I compute a simple average of the NCI daily closing price over the 2nd quarter of each year, around when universities offer admissions to students. I correct these values for inflation, and calculate growth in the average NCI values from 1993 to each of the years in the sample (1995-2005),

$$g_{93-t}^{NCI} = \frac{NCI_t}{NCI_{1993}}$$

Since fluctuations in equity prices during the Dot-Com episode materialized as shocks to university endowments, I interact these growth rates with average per student endowment funds for each university in 1993,

$$\widehat{eps}_{ut} = \frac{endowment_{u93}}{E_{u93}^{total}} \cdot g_{93-t}^{NCI}$$

Endowment per student values are constructed for each university by dividing ending market value of endowment assets ($endowment_{u93}$) by total enrollment (E_{u93}^{total}), available from IPEDS data.

The control used in 2SLS is the change in Dot-Com-predicted endowment per student,

$$\Delta \widehat{eps}_{ut} = \widehat{eps}_{ut} - \widehat{eps}_{ut-1}$$

Federal R&D Funding to Universities

Data on Federal funding to universities comes from the National Science Foundation. To measure Federal funding to universities I use total Federal R&D outlays to Colleges and Universities, excluding Federally Funded Research and Development Centers from 1993-2005.[25] I adjust these values for inflation by transforming all data into constant 2010$.

To measure the impact of these aggregate changes in Federal funding on each university, I first define each university's historical reliance on Federal funds. I capture historical reliance as Federal research funding per student measured in 1993, using IPEDS data, calculated by dividing the total value of Federal grants and contracts by total enrollment ($\frac{FedFunds_{u93}}{E^{total}_{u93}}$),

I then interact historical Federal funds per student with growth in total Federal R&D outlays,

$$\widehat{fps}_{ut} = \frac{FedFunds_{u93}}{E^{total}_{u93}} \cdot gr^{FedR\&D}_{93-t} = \frac{FedFunds_{u93}}{E^{total}_{u93}} \cdot \frac{FedR\&D_t}{FedR\&D_{1993}}$$

The control variable is the change in predicted federal funds per student,

$$\Delta\widehat{fps}_{ut} = \widehat{fps}_{ut} - \widehat{fps}_{ut-1}$$

[25]Data retrieved from https://ncsesdata.nsf.gov/webcaspar/OlapBuilder.

B Appendix - Tables

Table A1: First-Stage Power Using IV Based on College-Age Population for Boom and Bust

	(1)	(2)	(3)	(4)
IV Coll. Pop. Only - Boom	4.04***	4.10***	4.12***	3.88***
	(0.46)	(0.48)	(0.50)	(0.67)
IV Coll. Pop. Only - Bust	1.91	-0.06	-0.17	3.35
	(3.80)	(3.74)	(3.95)	(7.14)
First-Stage Power:				
Partial R2 - Boom	0.12	0.11	0.12	0.05
Partial R2 - Bust	0.00	0.00	0.00	0.00
Cragg-Donald F	1	0	0	2
Obs.	2,580	2,480	1,930	2,920
Universities	258	248	193	292
Removes Outliers	X	X	X	
Removes IPEDS Imputations		X	X	
Removes IIE Imputations			X	

Note: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. All specifications include university fixed effects and year dummies. Standard errors are clustered at the university level. The instrument used in this analysis is constructed using college-age population growth for both the boom and bust periods.