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

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Abstract

Recent growth in international enrollment at US universities has raised controversy. While critics accuse international students of displacing American students, university administrators have tried to justify increased foreign enrollments by arguing 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 US 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 additional domestic students. This positive effect is pronounced at public universities where foreign students face tuition rates that are 2-3 times higher than those for domestic students.

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1 Introduction

The US has sustained an unprecedented influx 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 have argued that international students steal seats from Americans, and in some instances, these fears have led to legislative proposals to cap the number of noncitizen students. In contrast, university administrators have denied such accusations, arguing that international students provide much needed tuition 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. 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.

Focusing on graduate education also addresses several related issues. Graduate education produces skilled experts who research and innovate, thereby bolstering economic growth. However, recent statistics indicate high attrition rates–only 50-60% of Ph.D. students ever graduate (Sowell 2008)–and disinterest in STEM fields, which pose a threat to the size of the innovative workforce. Changes to domestic enrollment due to international student entry are especially relevant, as the international student visa program–the main pathway for foreign students–is one of the few immigration policies that has no cap. This contrasts with virtually all classes of work visas, especially those for skilled immigrants, which have strict limits and thereby create difficulty for international students to transition to the US workforce following

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

[2] Critics of international student entry recently created a legislative bill proposing limits on nonresident enrollment at the University of California System (http://www.latimes.com/politics/la-pol-sac-essential-politics-state-lawmakers-vote-for-10-c-1464807461-htmlstory.html). In contrast, others argue 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).

graduation. Therefore, if foreign students displace American students, immigration policy creates the necessary conditions to magnify such distortions into the labor market.[3]

Examining international students also informs debates over the impacts of international migration, which focus heavily on labor market consequences. In instances when the education sector is considered, rhetoric often steer towards the impacts of foreign students on native workers. For example, industry leaders argue that less restrictive employment pathways for foreign students will solve skill shortages, while skeptics counter that native workers would suffer. Curiously, however, few ask whether there are impacts on the education of domestic students, even though education is an important determinant of labor market success. Thus, without elucidating the effects on higher education, our understanding of labor market impacts remains incomplete. This paper contributes to research on the impacts of immigration by exploring the consequences for higher education.[4]

Existing research on international students in graduate education have been important in documenting their long-held and sizable presence (Bound et al. 2009, Freeman 2010). Furthermore, a small number of papers have provided initial empirical evidence on whether international students displace domestic students (Borjas 2007, Regets 2007, Zhang 2009). Interestingly, while these studies have produced quite conflicting findings, they are unified in how they conceptualize higher education. In these studies, the impact of international students on domestic enrollment depends on the number of seats available in graduate schools. This yields two possibilities: (1) if they are strictly limited, then increases in international students will displace or crowd-out domestic students, and (2) if they are not, then increases in international students will have no impact. Curiously, every existing study contains at least one empirical estimate suggesting that international students actually increase the enrollment of some domestic students, even though the intuition surrounding displacement does not provide a scenario wherein international students can actually raise domestic enrollment. Therefore, these positive findings are usually cited simply as evidence against displacement.

Borjas (2007) uses panel data on university enrollments to correlate the numbers

[3] For example, Finn (2003) estimates that roughly one-third of foreign doctoral recipients leave the US within two years from receiving their degree.

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

of foreign and domestic graduate students. Results from fixed effects regressions lead the author to conclude that international students crowd-out white native males in graduate programs, yet positive and significant effects for native asian and black students are reported. Using a similar panel approach focused on STEM programs, Regets (2007) interprets positive and significant effects for white natives in graduate STEM programs as evidence against displacement. Zhang (2009) also uses panel regressions to estimate significant positive correlations between the number of foreign and native Ph.D. recipients in STEM. These results are interpreted as indicating that "obviously, there is no crowding out" of native students.

This paper approaches the question of whether international students displace natives with a different view of higher education, motivated by recent stylized facts on international students and prior theoretical insight. Theoretical work has long recognized that although universities as non-profit organizations must equate total revenues and costs, individual activities or services within a university may not meet this binding constraint (James 1978, Winston 1999). This often is deliberate, as universities can satisfy important objectives that are not self-sustaining by offering profit-generating services that may have little relevance to their mission.

Furthermore, while graduate students compete for seats as consumers, they also serve as inputs to higher education (Rothschild & White 1995). Universities provide substantial subsidies (e.g. scholarships or fellowships) to graduate students, often in return for assistance in teaching or research. These subsidies may be so generous that some graduate students may contribute zero tuition on net, or even receive a positive subsidy. Therefore graduate programs, particularly those that are academic rather than professional, are likely not self-sustaining and may heavily rely on other profitable activities.

A set of stylized facts helps link this theory with international student entry. In many US universities, international students face higher tuition prices than domestic students. In particular, public universities price out-of-state tuition 2-3 times higher on average than the rate for domestic in-state residents (figure 2). Though domestic out-of-state residents also face higher tuition costs, many states allow them to claim in-state residency after 1 year.[5] Thus, the expected tuition revenue from domestic students for the duration of graduate school may still be conceivably lower than what

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

international students contribute.

Further evidence indicates that most international students are not supported by sizable subsidies from the university. Figure 3 illustrates that in 1995 only 34% of foreign graduate students reported their primary source of funds as coming directly from the university they attend, while 66% report outside sources–most of which come from personal/family funds. Therefore, high tuition payments from international students conceivably result in net revenue for universities.

Taken together, these ideas introduce a different conceptualization of the impact of international students. While international students compete for seats and may crowd-out domestic students, they also positively contribute to tuition revenue. If international students do not sufficiently contribute to resources, it is likely that domestic enrollment will fall in response to inflows from abroad. To the extent enrolling international students is a profitable endeavor, universities can utilize excess revenue to enroll additional domestic students–international students can cross-subsidize domestic students.

This paper utilizes this intuition to guide the empirical analyses. In addition to approaching this question from a different perspective, I develop novel instruments to assuage endogeneity concerns that likely created the many inconsistent findings in the prior studies described earlier. The setting for my analysis encompasses a dramatic increase in international enrollment at US graduate programs during the late 1990s which suddenly reversed following heightened scrutiny of student visa applications in the aftermath of 9/11. Uniquely, this boom and bust provides distinct sources of variation, enabling separate examination of both increases and decreases in international enrollment.

The empirical design relates changes to domestic graduate enrollment with foreign student inflows within US research universities over time. 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. I address further endogeneity concerns by developing instruments from supply shocks that helped fuel the boom and bust cycle. Crucially, these supply shocks were unrelated to other factors affecting graduate education.

Specifically, rising populations of college-age (18-30 year old) individuals in foreign nations created a growing supply of students that spilled overseas. The terrorist attacks on 9/11 and subsequent discovery that several hijackers exploited student visas led to more restrictive student visa processing, thereby reducing access to US universities (GAO 2005; Freeman 2010). Apportioning these aggregate supply shocks to universities according to their historical presence of foreign graduate students forms instruments for actual inflows of international students during the boom and bust period.

The findings reveal that international students actually raise domestic enrollment– a 1 standard deviation increase in foreign enrollment raises domestic enrollment by roughly 1/4th of a standard deviation. Results are nearly identical for the bust, indicating symmetric responses to declines in international matriculation. Coefficients are significant at the 5% level in preferred specifications, and standard confidence intervals rule out 1-for-1 displacement. Thus, on average, inflows of international students appear to increase, rather than decrease, domestic enrollment.

Guided by the theoretical intuition, I explore whether these positive findings can be explained by cross-subsidization. First, I develop a simple model that formalizes the intuition on cross-subsidization. International students can expand domestic enrollment if universities structure their tuition and costs such that international students provide positive net tuition payments that help subsidize the cost of enrolling more domestic students. Importantly, the model provides empirical tests to assess whether cross-subsidization underlies the results. Results show heterogeneous effects consistent with cross-subsidization. Those universities whose tuition and costs were structured to allow for cross-subsidization exhibit the largest positive effects of international students on domestic enrollment. Additionally, effects are concentrated in public universities, which generate high tuition revenue from international students, but are absent at private universities that do not charge foreign students higher tuition rates.

The next section describes the empirical strategy and data, providing a detailed look at the boom and bust in further detail. Section 3 presents the main results, and provides various robustness checks of the instrumental variable strategy. Section 4 examines whether the main results can be explained by cross-subsidization. Section 5 concludes.

2 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. Focusing on a uniquely volatile decade between 1995 and 2005 assists in abstracting from such confounding factors. The ensuing discussion describes the boom and bust in international enrollment in greater detail.

2.1 The Boom and Bust of 1995-2005

In the early 1990s, US universities faced great uncertainty over whether they would remain leaders in attracting students worldwide.[6] Unexpectedly, enrollment from abroad surged after 1995, lifting the number of international students from 170,000 to over 250,000 by the turn of the millennium (figure 4). 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 US fell (Chin 2005).

Importantly, two factors unrelated to US higher education helped fuel the boom and bust cycle. Through the 1990s, many nations saw expansions in the number of college-age individuals alongside improvements in their post-secondary education systems (e.g., Rosenzweig 2006, Bound et al. 2009). These demographic changes in college-age populations increased foreign enrollment in the US, as larger cohorts of students spilled overseas (Bird & Turner 2014, Shih 2016). Importantly, demographic changes abroad were highly unlikely to be driven by changes in US higher education.

The 9/11 attacks and subsequent discovery that several terrorists exploited student visas to enter the U.S. created a sudden shock that limited foreign student entry. Quickly enacted policies intensified the screening of student visa applications, generating lengthy wait-times (Wasem 2003; GAO 2005). Additionally, the mandatory implementation of the Student Exchange and Visitors Information Service (SEVIS)–a new digitized system to monitor foreign students–across colleges and universities in

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

2003 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]

Interestingly, graduate programs at research universities sustained most of the boom and bust. Figure 5 plots international enrollment from 1995-2005 by academic level (graduate in the top row and undergraduate in the bottom row) and by Carnegie Classification. Graduate enrollment at masters institutions, and undergraduate enrollment at all institutions also saw similar fluctuations, but on a far smaller scale. Importantly, this episode created unprecedented variation best suited to identify the effects of foreign students on domestic enrollment in graduate programs at research universities.

A final observation about this episode is that while their numbers changed dramatically, the composition of foreign students remained stable. Figure 6 examines the share of international students by country (panel A), and by field of study (panel B). Importantly, the composition across fields of study was relatively unchanged, with 40-50% of all foreign graduate students in STEM disciplines throughout the boom and bust. In addition, the boom and bust did not appear to be driven by any single foreign country. The composition across countries remained stable, with 40-50% hailing from Asia, and much smaller shares held by 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. The consistency of observable characteristics of international students 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.

[7] Conceivably, the surge after 2005 could also be studied, however, the period is complicated by the fact that undergraduate enrollment also began to surge. Additionally, the Great Recession in 2008 caused unusual changes to both domestic student's educational decisions and the endowment revenue of universities. Thus, limiting the scope to the 1995-2005 provides the advantage of focusing on cleaner variation in foreign graduate enrollments.

2.2 Empirical Specification

The impact of international graduate students on domestic graduate enrollment is estimated using the following specification:

$$\Delta D_{ut} = \alpha + \beta \Delta F_{ut} + \gamma_u + \gamma_t + \varepsilon_{ut} \tag{1}$$

I use year-on-year changes ($\Delta F_{ut} = F_{ut} - F_{ut-1}$) to measure the influx of international students at each university, u. The dependent variable is specified similarly to capture changes in domestic enrollment. In 1, β measures the marginal impact of an additional international student. If $\beta > 0$, each international student increases domestic enrollment. If $\beta < 0$, then foreign students crowd-out domestic students. $\beta = 0$ corresponds to no effect.

Notice that first-differencing enrollments effectively eliminates the influence of fixed university characteristics correlated with the level of enrollments, such as university quality. I further include additional university fixed effects (γ_u) to account for unobserved university characteristics correlated with enrollment growth.[8] Time-period dummies (γ_t) account for changes in aggregate shocks that affect all universities equally. Hence, the identifying variation in 1 relies on changes in changes of international graduate enrollment within universities. Lastly, ε_{ut} is a zero-mean error term.

The analysis estimates 1 for the boom and bust periods, separately, to distinguish the effects of increases and decreases in foreign students. The boom covers 1995-2001, while the bust covers 2002-2005. While 1 controls for a wider array of potential factors, unobserved factors that evolve within universities and are correlated with university expansion remain a concern. Novel instruments developed from the aforementioned supply shocks help mitigate these remaining issues.

2.3 IV Strategy

College-age population growth in countries around the world generated supply spillovers of international students to US universities. Security measures after 9/11

[8]While this specification is more demanding than those used by prior studies, Peri & Sparber (2011) suggest dividing by lagged total enrollment to account for scale bias. However, doing so introduces further endogeneity bias. Results using the preferred specification by Peri & Sparber (2011) are similar and available upon request.

restricted student visa issuance, which lowered international graduate enrollment. Key to the identification is that these aggregate shocks were not endogenously related to university-specific factors that affect their 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 predictive power by obtaining access to restricted-use data that provides precise counts of graduate students at each university by country of origin. The instruments are constructed by propagating supply shocks across universities with varying intensity, based on each university's historical stock of foreign graduate students. Specifically,

$$\hat{F}_{ut} = \begin{cases} \sum_c \hat{F}^{pop}_{cut} = \sum_c F_{cuh} * g^{pop}_{ct} = \sum_c F_{cuh} * \left(\frac{pop_{ct}}{pop_{ch}}\right) & \textit{if } t \leq 2001 \\ \\ \sum_c \hat{F}^{9/11}_{cut} = \sum_c F_{cuh} * g^{pop}_{c2001} * g^{9/11}_{ct} = \sum_c \hat{F}^{pop}_{cu2001} * \left(\frac{visa_{ct}}{visa_{c2001}}\right) & \textit{if } t \geq 2002 \end{cases} \tag{2}$$

For each university (u), historical foreign graduate enrollment from country c, F_{cuh}, is multiplied by that country's college-age population growth factor ($g^{pop}_{ct} = \frac{pop_{ct}}{pop_{ch}}$). For the years during the bust period, aggregate reductions in student visa issuance by country since 2001 ($g^{9/11}_{ct} = \frac{visa_{ct}}{visa_{c2001}}$) are used instead. 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:

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

[9]This approach is often referred to as a "shift share" instrument, and has been popularly used in various literatures (e.g. Card 2001, Peri et al. 2015).

2.4 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, as data from prior years were lost.

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 US (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]

2.5 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 academic level during the fall of each academic year. IPEDS identifies international students via separate enrollment counts for "non-residents", defined as persons who are not US citizens or nationals and who are in

[10]Visa issuances represent flows rather than stocks, but the instrument relies on shocks to total foreign enrollment. 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 2 is computed as $visa_{ct} = visa^i_{ct} + visa^i_{ct-1} + visa^i_{ct-2} + visa^i_{ct-3}$. The idea in this exercise 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.

the country on a temporary visa and do not have the right to remain indefinitely. IPEDS' "resident" counts measure domestic enrollment, which include US 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 non-research universities (left panel), and the main sample of research universities (right panel). Comparisons reveal research institutions were much larger than non-research schools on average, both in terms of undergraduate and graduate enrollment. While nearly identical in the percentage of international undergraduates, the average percentage of international graduate students at research universities (11%) was nearly double that of non-research institutions (6%).

Additionally, research universities had a greater focus on graduate education, awarding over 10 times the number professional, master's, and Ph.D. degrees conferred at non-research institutions. The main sample of research universities comprised the bulk of US graduate education, awarding 52% of all professional degrees, 58% of masters degrees, and 83% of Ph.D. degrees. They accounted for 73% of all foreign graduate students and over half of all graduate students. The majority are public (62%), span the 50 states, and include elite ivy-league schools, public flagship universities and smaller private institutions.

[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.

2.6 First Stage Power

To examine first stage power, I regress actual changes in foreign graduate enrollment on changes predicted by the instrument as follows:

$$\Delta F_{ut} = \alpha + \beta_{\text{fs}} \Delta \hat{F}_{ut} + \gamma_u + \gamma_t + \epsilon_{ut} \tag{4}$$

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

Results are presented in table II, for the boom and bust periods separately. Column 1 uses the main sample of 258 research universities. Column 2 uses all research universities available in IPEDS, including those reporting extreme outliers. Column 3 uses the main sample but removes universities that ever had imputed records in IPEDS surveys over the 1995-2005 decade. Column 4 further removes universities in which the IIE data was imputed.[13]

Estimates indicate that the college-age population- and 9/11-based instruments 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. F-statistics are sufficiently large to avoid weak instrument bias (Staiger & Stock 1997), except when including universities reporting extreme outliers (column 2). While coefficients barely change, measurement error from outliers causes precision to fall sizably, creating potential weak instrument bias for the bust. To abstract from weak instrument issues, estimates from the main sample will be preferred.

Coefficients center around 4 for the boom and 1.5 for the bust. These magnitudes can be understood by visualizing the underlying data. Figure 7 plots actual changes in international enrollment within universities against changes predicted by the instrument, after partialling out university fixed effects and time period dummies. The regression line estimated in 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 same rate as 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

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

universities than they would have if college-age populations abroad and declines in student visa issuance were the only contributing factors.

3 The Impact of International Students on Domestic Enrollment

Results from two-stage least squares (2SLS) regressions of 1 are reported in table III. First stage F-statistics are reprinted for reference. Column 1 uses the main sample, column 2 includes outliers, column 3 removes institutions with imputed records in IPEDS, and column 4 removes universities with imputations in IPEDS or IIE data. Column 5 presents OLS results using the main sample. All specifications include university fixed effects and time period dummies. Standard errors are clustered at the university level.

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

Second, increases and decreases in international enrollment appear to have symmetric effects–the size and direction of point estimates are nearly identical across both periods. 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 more useful to assess magnitudes–the estimates indicate a 1 standard deviation rise in foreign enrollment increases domestic enrollment by roughly 1/4th of a standard deviation.[14]

A real example helps to make the magnitudes more concrete. Consider a public

[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: $0.80 \cdot \frac{87}{291} = .24$.

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, column 5 presents OLS estimates corresponding to the main specification in column 1. Notice OLS estimates–0.21 for the boom and 0.41 for the bust–are also positive, but smaller in magnitude than their 2SLS counterparts. This is likely due to two factors. First, the instruments help reduce attenuation bias from remaining measurement error–removing extreme outliers may not cleanse the data from all measurement error. Second, university administrators have admitted that shocks to revenue or demand often lead them to recruit more foreign students to make up for declining domestic enrollment.[15] 2SLS estimates may be larger than OLS if the instruments mitigate negative downward bias caused by such endogenous shocks.

3.1 Robustness Checks

Section 2.6 demonstrated the instruments have strong first stage power. This alone, however, is insufficient for the instruments to provide causal inference. Importantly, they must also remain immune to exclusion restriction violations. The instruments must embody supply shocks that only affect actual international enrollment, remaining unrelated to any other determinants of domestic enrollment. Recall that the instruments are derived from the interaction of two variables–historical foreign graduate enrollment by university and nationality, and aggregate supply shocks by nationality. Therefore, each piece must be unrelated to other factors that also affect domestic enrollment. As there is only one instrument for actual changes in domestic enrollment, the regression model is just-identified, and hence it is not possible to directly test the exclusion restriction. Nevertheless, several checks help rule out issues of first-order concern.

A first concern is in the use of historical foreign enrollment from 1993. Although it

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

is the earliest available survey with international graduate student enrollment counts by country of origin from the IIE, its proximity to the period under study raises particular issues. For example, institutions with high foreign graduate enrollment in 1993, may have also been looking to expand. Thus, historical features of universities in 1993 may persist and endogenously influence actual changes in enrollment during the boom and bust period.

The empirical specification 1 is suited to address much of these concerns. Using first-differences, instead of levels, removes time-invariant university-specific factors that might be correlated with foreign enrollment levels in 1993, such as the desire to grow graduate programs. The inclusion of *additional* university fixed effects also eliminates the influence of university-specific features associated with enrollment growth. This forces the key identifying variation to come from changes in changes within universities over time, abstracting from historical features that have constant effects on future growth in university characteristics, such as enrollment or quality.

Importantly, the instruments will lead to biased estimates if factors in 1993 are correlated with future changes in university features that do not evolve linearly. A classic solution to break this persistent endogeneity is to use very long lags. In doing so, researchers face a trade-off between instrument power and bias. Because the instruments derive power from persistent information networks between former and prospective students from the same country, using longer lags will reduce this power. To the extent bias from persistent factors is large, point estimates should change noticeably when using longer lags.

While the IIE does not have data available prior to 1993, IPEDs surveys are available as far back as 1980. However, IPEDS surveys only measure total foreign graduate enrollment by university, providing no information on countries of origin. Nonetheless, the IPEDS 1980 data is used to construct an alternative instrument that interacts foreign graduate enrollment in 1980 with the supply shocks–college age population growth, and declines in student visa issuance– measured in terms of their growth factor from 1980 to the years in the sample. Because there is no country variation, total worldwide (net of the US) college population growth and total declines in student visa issuance are used. Yearly changes in these predictions from 1980 data are then taken to form the instrument.

Row 3 of table IV performs this check using the main sample.[16] Results for the boom are reported in column 1 and for the bust in column 2. First stage F-statistics appear in the adjoining columns. Importantly, the point estimates are virtually unchanged from the main results, reported in the bottom row for reference. Confounding endogenous factors in 1980 are unlikely to have persistent impacts on graduate enrollments in the mid-90s and 2000s. However, notice that the power of the instruments falls sizably. During the bust the instrument becomes at risk for weak instrument bias. Since later analysis examines smaller samples, and stratifies on particular university characteristics, it is crucial to utilize the primary instruments using 1993 graduate enrollments by country and university to ensure sufficient power.

Two additional checks can further assuage concerns regarding the persistence of historical endogenous factors. Persistent university characteristics, such as the desire to expand or historical prestige, will be observed in future growth in enrollment overall. The instrument is specifically designed to only predict foreign graduate enrollment. Correlation between the instrument and foreign or domestic undergraduate enrollment would signal potential lingering persistent factors. This can be empirically checked by regressing domestic or foreign undergraduate enrollment on the instrument.

Examining the correlation between the instrument and undergraduate enrollments also provides a check on a second concern regarding the instruments. The second part of the instrument–the supply shocks–may also introduce issues if they are endogenously related to growth in domestic graduate enrollment within universities. For example, college age population growth or post-9/11 visa tightening may have generated supply shocks to universities in both graduate and undergraduate enrollment from abroad. Undergraduate enrollment fluctuations, in turn, endogenously alter the number of graduate students, as universities may require more teaching assistants or graders for undergraduate courses. Assessing whether the instrument correlates with undergraduate enrollments also clarifies whether the supply shocks correlate with confounding changes in undergraduate populations within universities.

Rows 1 and 2 of table IV perform these checks by replacing the dependent variable in 4 with the change in foreign or domestic undergraduate enrollment ($\Delta X_{ut}^{ug} =$

[16]Results from specifications using the sample without imputed data are virtually unchanged and are available upon request.

$X_{ut}^{UG} - X_{ut-1}^{UG}$, where $X = D, F$). The results show no significant correlation between the instruments and undergraduate enrollment. Thus, it appears unlikely that foreign graduate enrollment in 1993 or the supply shocks were endogenously related to domestic graduate enrollment through changes in the undergraduate population.

Finally, to reassure that the main findings are not contaminated by endogenous changes in foreign undergraduate enrollment, row 4 performs the 2SLS regressions, incorporating a control for undergraduate enrollment. Including actual changes would risk introducing further endogeneity. Instead, an exogenous control variable is constructed by interacting foreign undergraduate enrollment in 1993 with the supply shocks.[17] Although first stage power is weakened due to the incorporation of an exogenous control that is highly similar to the instrument, the findings do not substantially differ from the main results. Reassuringly, the point estimates still fall within the range of those reported from table III.

The period under analysis raises several additional first-order concerns regarding the supply shocks used to generate the instrument. During the boom and bust in foreign graduate enrollment, the US also sustained a dramatic spike and fall in the stock prices of internet-based firm known as the "Dot-Com" boom and bust (figure 8A), rapid increases in federal funding to higher education (figure 8B), and an expansion and subsequent contraction in H-1B visa limits for foreign skilled workers (figure 8C). These other factors exhibit fluctuations that similarly align with the boom and bust in foreign graduate enrollment, and are particularly worrisome if the instruments are unable to abstract from their influence.

Separately accounting for each of these phenomena in rows 5-7 of table IV helps examine the sensitivity of the instruments.[18] To account for the Dot-Com boom and bust, I draw on prior literature which has shown stock market fluctuations impact universities by altering endowments (Kantor & Whalley 2014, Brown et al. 2014). Therefore, interacting historical university endowment per student values, measured in 1993, with growth in the Nasdaq Composite Index helps capture effects of the Dot-Com boom and bust on universities. The change in predicted endowment per

[17]This procedure is almost identical to the construction of the instrument, with the exception that the count of foreign undergraduates by university and nationality from the 1993 IIE survey is used in the interaction.

[18]Detailed descriptions of these control variables and their data sources are provided in section A.2 of the appendix.

student values is included as a control in 2SLS regressions in row 5.

The dramatic growth in federal research funding through the turn of the millennium likely increased both foreign and domestic enrollment. To account for this we interact historical levels of university research funding per student, measured in 1993, with aggregate growth in federal R&D outlays to universities. Changes in predicted research funds per student are incorporated as controls in 2SLS regressions in row 6.

Finally, H-1B policy may alter labor market returns for highly educated workers (Peri et al. 2015), which in turn may influence the schooling decisions of domestic students. As indicated by Kato & Sparber (2013) and Shih (2016), H-1B policy can directly affect higher education by altering foreign student entry. To capture the influence of H-1B changes on universities, I interact historical foreign graduate enrollment by nationality with nationality-specific growth in H-1B visa issuances. Summing these interactions across nationalities and then taking first-differences yields a control variable that helps accounts for the influence of H-1B policy. This is included in 2SLS regressions in row 7.

Importantly, the central findings remain robust when incorporating these controls. Point estimates remain positive and are close in value to the main findings–coefficients range from 0.59-1.74. Further, they are nearly always statistically significant at the 10% level. Thus, other phenomena during the boom and bust period do not appear to contaminate the estimates.

Table V provides some final robustness checks. Row 1 ensures that the results are not driven by endogenous changes within a few large universities. Specifically, I remove the 8 universities that are consistently ranked in the top 10 in terms of international graduate enrollment in each year from 1995-2005. Rows 2-5 check if the results simply reflect the performance of universities that host large numbers of students from particular nations. For example, aggregate declines in student visas issued to Indians could simply reflect declining quality among universities that host large numbers of Indian students. Row 2 utilizes a similar instrument that eliminates the nationality dimension, simply interacting total foreign graduate enrollment in 1993 with growth in the world's college-age population and total 9/11-induced declines in student visas. Rows 3 and 4 reconstruct the instruments, excluding the two largest foreign student groups–India and China, respectively. Finally, row 5 reconstructs the instruments, removing students from predominantly Muslim nations to examine whether the post-9/11 declines were driven by the heightened attention toward this group.

The results from table V provide a consistent message. International students expand domestic enrollment at the graduate level. The instruments are useful in mitigating endogeneity bias and stand-up to various exclusion restriction violations. Overall, these checks have shown that the instruments do not appear to be endogenously correlated with changes in undergraduate enrollments within universities. Furthermore, they are not confounded by simultaneous aggregate shocks that also had a boom and bust pattern in the US.

4 Mechanisms

How do international students expand domestic enrollment? As discussed earlier, cross-subsidization is one such mechanism that has both intuitive appeal and anecdotal support. High net tuition revenue from international students can be used to offset the costs of enrolling another domestic student. A direct way to test for cross-subsidization would be to show that international students do contribute positively to resources via their tuition payments, and that domestic students receive higher subsidies as a result. However, universities do not publicly report net tuition revenues, subsidies (e.g. institutional aid, fellowships, grants, etc.) separately for international and domestic students. Thus, identifying cross-subsidization requires alternative methods.

First, though the required data from research universities during the boom and bust periods are not available, the National Postsecondary Student Aid Survey (NPSAS) provides relevant information on tuition payments and subsidies received from a random sample of graduate students. While NPSAS student sample sizes and coverage of research universities are too small to be useful for more rigorous analysis, some descriptive evidence is enlightening. We assess information on the sample of US citizens at research universities from the 1996, 2000, and 2004 NPSAS surveys–years that roughly align with the beginning, mid-point, and end of the boom and bust cycle.

Figure 9 displays average net tuition, total institutional aid (which includes grants, scholarships, fellowships, tuition waivers, loans or other support from the university), and total grant aid of US citizen students in the NPSAS sample. In particular, the averages are calculated using US citizens enrolled in graduate programs at research universities in each of the NPSAS survey years 1996, 2000, and 2004. The 95% confidence intervals are provided for reference.

The top figure shows that average net tuition payments of US citizens in graduate school actually fell by roughly $\$1,000$, from an average of $\$6,618$ in 1996 to $\$4,596$ by 2000. This coincides directly with the boom in international enrollment, and is consistent with the idea that universities used additional foreign tuition to subsidize the enrollment of more domestic students. Increases in net tuition payments of US citizens from 2000-2004 are consistent with the idea that as international enrollment shrank during the bust, so did the extra revenue from foreign students.

The bottom figures show that the decline in net tuition payments were due to changes in actual subsidies given to students–what would be expected with cross-subsidization–rather than lowering tuition rates. Average total institutional aid and grant aid (e.g. fellowships, teaching assistant and research assistant positions, etc.) for citizens grew during this period. By 2004, the average institutional aid to citizens declined slightly, as international enrollment decreased.

The evidence presented thus far has been descriptive. Without detailed data on net tuition and aid separated for domestic and international students, direct tests of cross-subsidization are not feasible. Thus, I draw on theory, which helps provide a structure for different empirical tests of cross-subsidization. In what follows I present a basic sketch and relegate the details to the section A.3 in the appendix.

Consider a non-profit university that aims to educate students and provide high quality education, described by an objective function,

$$U(D, F, q)$$

D and F denote domestic and foreign graduate enrollment, respectively, and q denotes quality. Universities benefit from higher quality and educating domestic students, so that $U_q, U_D > 0$.[19] We make no assumptions on preferences for foreign students, so that $U_F \gtreqless 0$. The aim is to maximize their objectives subject to a non-profit

[19]This is a reasonable assumption given that universities receive substantial funding from the government. Thus, to a certain extent their goals will reflect the domestic taxpayer's preferences.

constraint, whereby total revenues must equate total costs:

$$FC + c(q)D + c(q)F - t_D D - t_F F - FR = 0$$

Tuition rates for domestic and international students are t_D and t_F, respectively, and are considered to be exogenous. Other non-variable (fixed) revenue (FR) comes from government support and endowment payouts. Expenses include fixed costs (FC), such as building operation costs, and variable costs represented by the per unit student cost of education, $c(q)$, where $c'(q) > 0$. This includes expenditures related to instruction, and subsidies given to students in the form of grants and other aid.

Solving the university's optimization problem, detailed in the appendix, yields the following relationship for how domestic enrollment would change given one additional international student:

$$\frac{\partial D}{\partial F} = \frac{t_F - c(q)}{c(q) - t_D} \tag{5}$$

Equation 5 provides a simple formalization of cross-subsidization. The numerator in 5 represents the net tuition revenue received from an international student (i.e. tuition less subsidies and other costs). If foreign student tuition exceeds their marginal cost ($t_F > c(q)$), the numerator is positive. The denominator represents the net subsidy given to a domestic student, which is positive when marginal costs exceed the domestic tuition rate. For simplicity, I refer to the ratio in 5 as *relative net tuition*.

Relative net tuition has an intuitive interpretation: it indicates how many additional domestic students the university could enroll with one additional international student. For example, consider a university where net tuition per international student is \$1000 and the net subsidy per domestic student is \$ 500. Equation 5 indicates that one additional foreign student would provide enough net tuition to enroll two additional domestic students ($\frac{\$1,000}{\$500} = 2$). Hence, at this hypothetical university, domestic enrollment would rise by 2 with each additional international student.

This framework provides the insight for a first test for cross-subsidization. Recall figure 2 showed that sticker price tuition rates do not differ for domestic and foreign students at private universities. In contrast, foreign tuition rates are nearly 2-3 times higher, on average at public universities. Therefore, equation 5 predicts that international students should crowd-out domestic students at private universities, as the numerator will equal the inverse of the denominator. At public universities, international students may increase domestic enrollment if foreign tuition payments are significantly greater than costs. I assess this empirically by replicating the analysis separately for private and public universities.

Figure 10 shows the results when running regressions of specification 1, separately for public and private universities, with full details in table VI. The point estimates and 90% confidence intervals presented use the preferred sample that excludes outliers. The findings support the general intuition from the model. The positive effects found earlier appear to be concentrated among public universities. The point estimates for private universities are actually negative, indicating that international students might displace domestic students. However, the coefficients are not statistically different from zero. These results support the idea that international students at public universities pay high net tuition that helps subsidize the cost of enrolling additional domestic students. Private universities that do not price discriminate may see displacement of domestic students following inflows from abroad.

A more complete test for cross-subsidization using the model's insights can be performed by actually calculating measures of relative net tuition at each university and interacting these with the inflow of international students in regressions. If cross-subsidization indeed drives the results, there should be a larger positive impact on domestic enrollment for universities with high relative net tuition–these universities have structured tuition and costs in such a way as to allow for the greatest amount of cross-subsidization.

IPEDS provides in-state and out-of-state tuition rates at each university, which are used for t_D and t_F, respectively. If domestic out-of-state students only face t_F, the model indicates international students can only increase enrollment of domestic in-state students through cross-subsidization. Furthermore, the model then also suggests that exogenous increases in domestic out-of-state students would also increase domestic in-state enrollment.

Unfortunately, existing data does not provide graduate enrollment counts by state residency to test for such differences. However, at some public universities that publicly provide such figures, most graduate students hail from in-state.[20] Additionally,

[20]For example, the University of California system reports that among all 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

many state laws allow out-of-state domestic students to claim in-state residency after 1-year. Thus, if we consider t_D to be roughly similar to expected tuition rates they face over the duration of graduate school, the model would then suggest that foreign students can still lead to increases in both domestic in- and out-of-state students.

While tuition prices are accurately tracked, measures of graduate student costs $c(q)$ are not available. Therefore, I construct a proxy for $c(q)$ by calculating average variable costs, which include expenses that vary with enrollment, like grant and fellowship aid, and instructional costs. Since available data does not differentiate costs for undergraduate and graduate students, I calculate average variable costs over all students at each university using data from the Delta Cost Project (Lenihan 2012).

For each university I construct a single, time-invariant measure of relative net tuition. First, I 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 measure for each university. Importantly, this measure is calculated prior to the period under analysis and therefore is not affected by the subsequent boom and bust. This relative net tuition measure indicates which universities were most primed to engage in cross-subsidization during the boom and bust cycle.

The empirical test interacts the measure of relative net tuition with the change in international students at each university. In particular, I implement a fully-interacted regression model of the form:

$$\begin{aligned}\Delta D_{ut} = \ & \alpha + \beta_1 \Delta F_{ut} + \beta_2 (\Delta F_{ut})(RNT_u) \\ & + \gamma_u + \gamma_u (RNT_u) + \gamma_t + \gamma_t (RNT_u) + \varepsilon_{ut}\end{aligned} \tag{6}$$

As the minimum value of relative net tuition in the sample is -1, we add 1 to the relative net tuition measure allowing β_1 to reflect the effects for those universities that have relative net tuition equal to -1, and $\beta_1 + \beta_3 RNT_u$ to reflect the differential additional effect for universities with relative net tuition greater than -1. Note that the main effect for relative net tuition (RNT_u) is absorbed by the fixed effect γ_u. Importantly, the interaction $(\Delta F_{ut})(RNT_u)$ is an additional endogenous variable, and therefore is instrumented with $(\Delta \widehat{F}_{ut})(RNT_u)$–the interaction of the main instrument with the relative net tuition measure.

campuses, only 6% of students are from out-of-state (see http://www.suny.edu/media/suny/content-assets/documents/FastFacts2016.pdf).

Figure 11 displays the point estimates from this exercise, while table VII provides the full results. The vertical axis measures the marginal effect (i.e. the combined effect $\beta_1 + \beta_3 RNT_u$), while the horizontal axis measures relative net tuition. The marginal effects are plotted for the ventiles of relative net tuition (i.e. the relative net tuition measures at the 5th, 10th, 15th,..., 90th, and 95th percentiles). Importantly, the 0-40th percentile values are all equal to -1. Hence, the point at relative net tuition value equal to -1 represents the 0-40th percentiles, while the second point represents the 45th percentile, third point represents the 50th percentile, and so forth.

The results support the model's intuition regarding cross-subsidization. The positive impact of international students on domestic enrollment increases in the university's relative net tuition. Universities that receive extremely high levels of foreign student tuition, relative to their cost are able to use those resources to provide subsidies to enroll more domestic students. Importantly, the pattern is evident in both the boom and bust periods, although weak instruments during the bust tend to inflate point estimates.

While the evidence has indicated that cross-subsidization is a key mechanism underlying the central findings, it should only be recognized as a partial equilibrium analysis that highlights university behavior. A different explanation might be that international students actually change domestic student demand. For example, domestic students may have preferences for or against studying with international students. Alternatively, international student competition may alter the returns to education. Thus, while the available data are not suited to explore this mechanism, we do not rule out that domestic demand may itself depend on foreign student peers.

4.1 Extensions

While the empirical analysis has shown that international students can increase domestic enrollment, the type or quality of these additional domestic students remains unclear. Importantly, the exact form in which cross-subsidization manifests matters greatly for understanding more about the domestic students most likely to benefit from international students. For example, the reallocation of foreign tuition revenue may be unequal across fields of study. If universities prioritize education in STEM disciplines, increases in foreign students may have little effect on domestic enrollment in the Humanities. Differently, some universities may allocate foreign tuition towards academic scholarships for domestic students. In this case, the increase in domestic enrollment would likely be accompanied by increases in domestic student quality.

While lack of data restricts the ability to explore this in great detail, one interesting margin of adjustment can be examined. In particular, foreign tuition may be reallocated quite differently towards academic and professional programs.[21] If universities prioritize academic graduate education, growth in international students would result in little change in domestic enrollment in professional programs. Furthermore, professional programs tend to charge very high tuition with few subsidies to students, and often are a key source of revenue for universities. In this sense, international students would not need to cross-subsidize professional programs if they are self-sustaining. In this case, the positive impacts should be concentrated on domestic enrollment in academic programs.

The top panel in table VIII shows results when examining changes in domestic graduate enrollment in academic programs as the dependent variable. The bottom panel shows results when the outcome is changes in domestic enrollment in professional programs. The results reveal that the positive impacts are concentrated in academic programs, with little impact on enrollment in professional programs. Thus, on average it appears that universities do prioritize academic programs and utilize net foreign tuition to expand the number of domestic students pursuing academic degrees.

5 Conclusion

For decades, international students have maintained a large and growing presence in US higher education. However, the effects of this internationalization are poorly understood, and in particular, the consequences for domestic students remain unclear. This paper provides insight into these issues by assessing the impact of foreign students on domestic enrollment in graduate education.

An unusual boom and bust cycle in foreign graduate enrollment over the 1995-2005 decade, driven in part by exogenous supply shocks, provide a means to empirical identification. Interacting historical foreign graduate enrollment in 1993 with these supply shocks–growth in the college-age population in sending countries during the boom,

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

and declines in student visa issuance after 9/11 during the bust–forms instruments to estimate causal effects.

The analysis reveals that increases in foreign students expand domestic enrollment. Decreases in foreign enrollment have symmetric effects. Point estimates indicate that a one standard deviation rise in international enrollment increases domestic enrollment by roughly 1/4th of a standard deviation. Preferred estimates are statistically significant at 5% levels.

A simple model of university behavior reveals that foreign students can expand domestic enrollment if they pay high net tuition relative to domestic students (relative net tuition). Empirical tests of the model's insights reveal that cross-subsidization indeed appears to be an underlying mechanism–the estimated effects of international students on domestic enrollment increase with a university's relative net tuition.

Understanding how cohort size affects educational achievement has been a subject of great importance. Students that are part of larger cohorts are likely to experience crowd-out and lower attainment as fixed resources are diluted among a larger populace. This paper shows that expansions due to international student entry are distinct from general demographic expansions, because of the manner in which universities differentially structure net tuition for domestic and foreign students.

These results also contribute to research showing positive contributions of foreign graduate students to innovation (Chellaraj et al. 2008, Black & Stephan 2010, Stuen, Mobarak, & Maskus 2012). Given that international students do not appear to displace domestic students from graduate education, their benefit to innovation may come at little cost. Additionally, in the face of declining revenue, administrators may turn to foreign students to bolster resources for additional domestic enrollment.

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

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Table I: Summary Statistics of Research Universities, 1995

Academic Level	Non-Research		Research	
	Mean	Std. Dev.		Std. Dev.
Undergraduates				
Total	1,570	2,617	11,184	8,017
International	4%	9%	3%	4%
Domestic	94%	13%	93%	8%
Graduates				
Total	340	688	4,490	3,219
International	6%	12%	11%	8%
Domestic	90%	19%	85%	10%
White	73%	26%	69%	15%
Asian	4%	10%	4%	5%
Minority	12%	19%	11%	12%
1st Prof. Degrees				
Total	15	54	157	198
International	5%	13%	2%	4%
Domestic	93%	16%	96%	6%
Masters Degrees				
Total	69	167	903	709
International	8%	16%	13%	8%
Domestic	88%	20%	83%	11%
Ph.D. Degrees				
Total	2	12	146	174
International	12%	22%	21%	14%
Domestic	83%	27%	76%	15%
# of Universities	2,448		258	
Type				
Public	18%		62%	
Private	74%		38%	
For Profit	7%		0%	
Share of Total:				
International Graduates	20%		73%	
Graduate Enrollment	40%		56%	
1st Prof. Degrees	43%		52%	
Masters Degrees	38%		58%	
Ph.D. Degrees	10%		83%	

Note: Statistics calculated from IPEDS 1995 Fall Enrollment, Completions, and Institutional Characteristics surveys. Non-research institutions include those that provide baccalaureate level education or higher, and are not classified as research universities.

Table II: First Stage Instrument Power

	(1)	(2)	(3)	(4)
Boom (1995-2001)				
$\Delta\ \hat{F}$	4.04***	3.88***	4.10***	4.12***
	(0.41)	(0.60)	(0.43)	(0.45)
F-Statistic	97.79	42.29	91.47	83.80
N	1,548	1,752	1,488	1,158
Bust (2002-2005)				
$\Delta\ \hat{F}$	1.56***	1.41***	1.55***	1.67***
	(0.21)	(0.50)	(0.23)	(0.25)
F-Statistic	53.37	7.94	47.12	44.67
N	1,032	1,168	992	772
# of Universities	258	292	248	193
Sample:				
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 time period dummies. Standard errors are clustered at the university level.

Table III: 2SLS Results for Domestic Enrollment

	(1)	(2)	(3)	(4)	(5)
Boom (1995-2001)					
ΔF	0.80**	0.81*	0.81*	0.94**	0.21
	(0.40)	(0.44)	(0.43)	(0.46)	(0.14)
N	1,548	1,752	1,488	1,158	1,548
F-Statistic	97.79	42.29	91.47	83.80	
Bust (2002-2005)					
ΔF	0.82**	1.09	0.79*	0.51	0.40**
	(0.39)	(0.90)	(0.41)	(0.41)	(0.18)
N	1,032	1,168	992	772	1,032
F-Statistic	53.37	7.94	47.12	44.67	
# of Universities	258	292	248	193	258
Sample:					
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 fixed effects and time period dummies. Standard errors are clustered at the university level.

Table IV: Instrument Validity

		Boom (1995-2001)		Bust (2002-2005)	
		(1)		(2)	
Model	Specification	Main	1st Stage F-Statistic	Main	1st Stage F-Statistic
1st Stage	Int'l Undergrad. (Dep. Var.)	0.51 (0.36)	2.0	0.11 (0.12)	0.8
	Domestic Undergrad. (Dep. Var.)	-2.26 (3.25)	0.5	1.51 (1.04)	2.1
Two-Stage Least Squares (2SLS)	Lag 1980 IV	0.73 (0.58)	30.5	0.84 (0.62)	9.8
	Control for Int'l Undergrad. Enrollment	0.93** (0.45)	67.3	0.59 (0.39)	44.7
	Control for Dot Com Boom/Bust	0.85* (0.45)	92.4	0.99** (0.42)	50.8
	Control for Fed. Funding	0.84** (0.40)	99.1	0.85** (0.41)	50.5
	Control for H-1B Policy	0.62 (0.61)	40.7	1.74** (0.80)	17.9
	Main (from Table 3)	0.80** (0.40)	97.8	0.82** (0.39)	53.4

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

Table V: Robustness Checks

	Boom (1995-2001)		Bust (2002-2005)	
	(1)		(2)	
Specification	Main	1st Stage F-Statistic	Main	1st Stage F-Statistic
Remove Top 8 Universities	0.80* (0.43)	96.9	0.95** (0.45)	60.9
IV w/out country dimension	0.78* (0.46)	64.5	1.07* (0.61)	12.1
IV w/out India	0.80** (0.40)	98.6	0.76* (0.45)	34.4
IV w/out China	0.67 (0.46)	66.2	0.95** (0.43)	44.8
IV w/out Muslim nations	0.79** (0.40)	96.7	0.83** (0.39)	54.4

Note: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. All specifications include university fixed effects and time period dummies. Those specifications with imputed data include an additional 65 universities. Standard errors are clustered at the university level.

Table VI: Impacts on Domestic Enrollment at Public vs. Private Universities

	Public		Private	
	(1)	(2)	(3)	(4)
	Main	No Imputed Data	Main	No Imputed Data
Boom: 1995-2001				
ΔF	1.53***	1.74***	-0.78	-1.02
	(0.41)	(0.44)	(0.69)	(0.89)
1st Stage F-Statistic	52.3	47.6	55	43
Bust: 2002-2005				
ΔF	1.64**	1.27*	-0.23	-1.23
	(0.66)	(0.76)	(1.18)	(1.78)
1st Stage F-Statistic	21.1	13.8	3.4	1.8
# of Universities	161	127	97	66

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

Table VII: Heterogeneous Effects by Relative Net Tuition

		Independent Variable	Boom	Bust
			(1)	(2)
		ΔF	-0.48	-2.40
			(0.92)	(28.58)
		ΔF X (RNT+1)	3.70	9.04
			(2.82)	(76.77)
		F-statistic	5.33	0.86
RNT Percentile	RNT Value	*Marginal Effects:*		
0-41st	-1	ΔF X (RNT+1=0)	-0.48	-2.40
			(0.92)	(28.58)
45th	-0.766	ΔF X (RNT+1=0.234)	0.39	-0.28
			(0.45)	(10.62)
50th	-0.671	ΔF X (RNT+1=0.329)	0.74*	0.58
			(0.44)	(3.36)
55th	-0.619	ΔF X (RNT+1=0.381)	0.93*	1.05
			(0.50)	(0.91)
60th	-0.542	ΔF X (RNT+1=0.458)	1.22*	1.75
			(0.64)	(6.64)
65th	-0.46	ΔF X (RNT+1=0.54)	1.52*	2.49
			(0.83)	(12.93)
70th	-0.38	ΔF X (RNT+1=0.62)	1.81*	3.20
			(1.03)	(19.01)
75th	-0.281	ΔF X (RNT+1=0.719)	2.18*	4.10
			(1.29)	(26.63)
80th	-0.18	ΔF X (RNT+1=0.82)	2.55	5.02
			(1.56)	(34.38)
85th	0	ΔF X (RNT+1=1)	3.22	6.64
			(2.05)	(48.19)
90th	0.405	ΔF X (RNT+1=1.405)	4.71	10.30
			(3.18)	(79.29)
95th	0.918	ΔF X (RNT+1=1.918)	6.61	14.94
			(4.62)	(118.67)

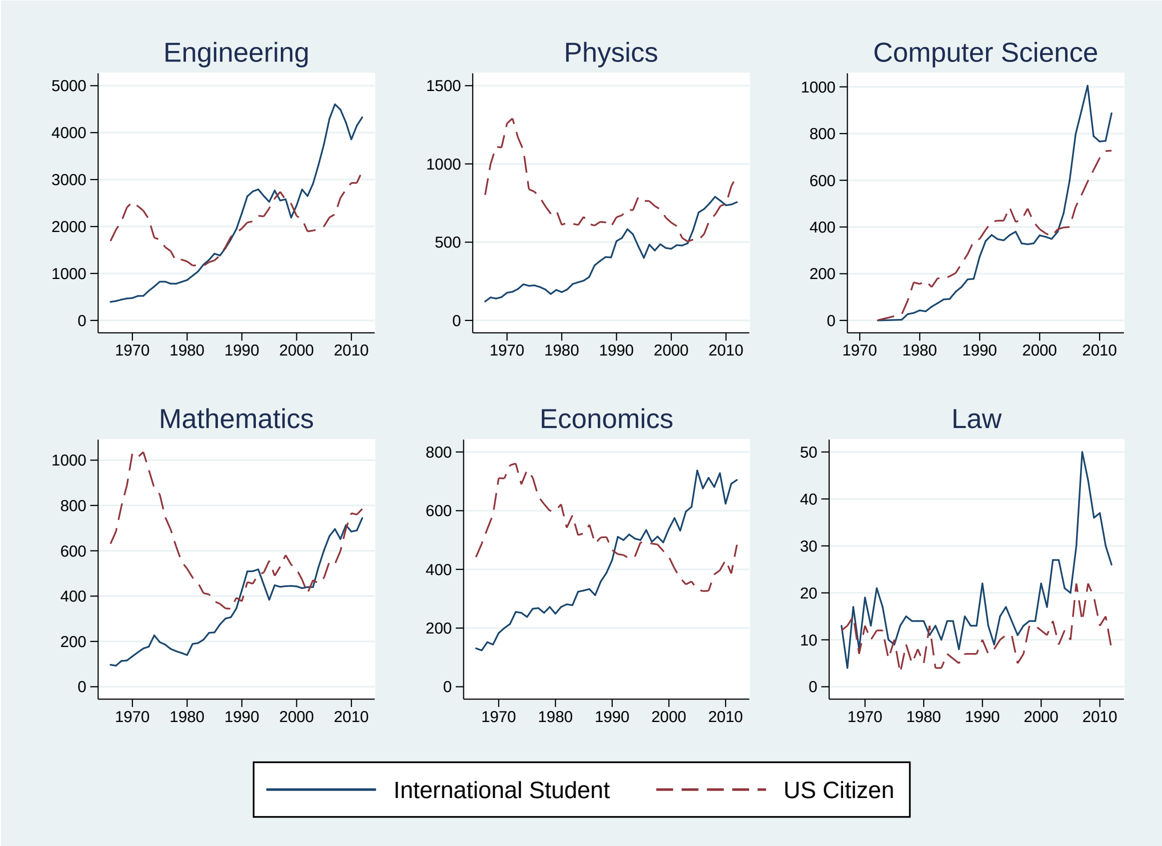
Note: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. All specifications include university fixed effects and time period dummies. Standard errors are clustered at the university level.

Table VIII: Effects on Domestic Enrollment in Academic vs. Professional Programs

	Boom: 1995-2001		Bust: 2002-2005	
	(1)	(2)	(3)	(4)
	Main	No Imputed Data	Main	No Imputed Data
Academic				
ΔF	0.77**	0.95**	0.66*	0.41
	(0.36)	(0.40)	(0.35)	(0.36)
1st Stage F-Statistic	97.9	83.9	53.4	44.7
# of Universities	258	193	258	193
Professional				
ΔF	-0.12	-0.21	0.11	0.13
	(0.21)	(0.25)	(0.17)	(0.18)
1st Stage F-Statistic	43.7	33.6	25.9	25.7
# of Universities	115	89	115	89

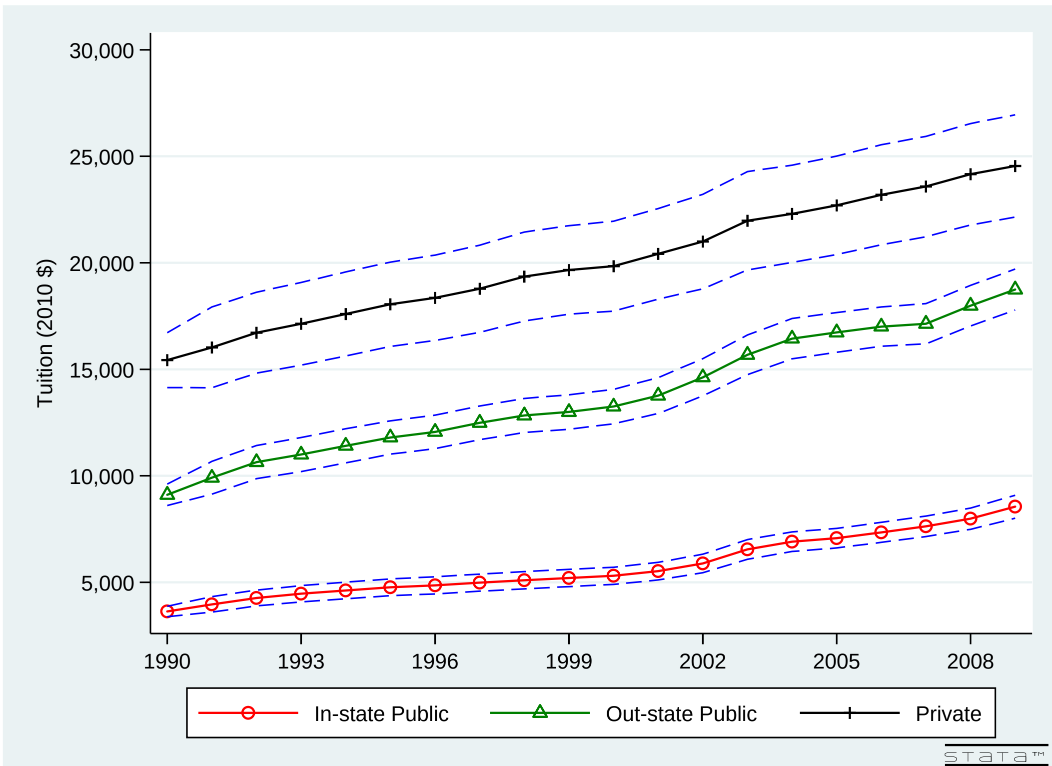
Note: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. All specifications include university fixed effects and time period dummies. Standard errors are clustered at the university level.

Figure 1: Doctoral Degree Awards to US Citizens and International Students, 1966-2012



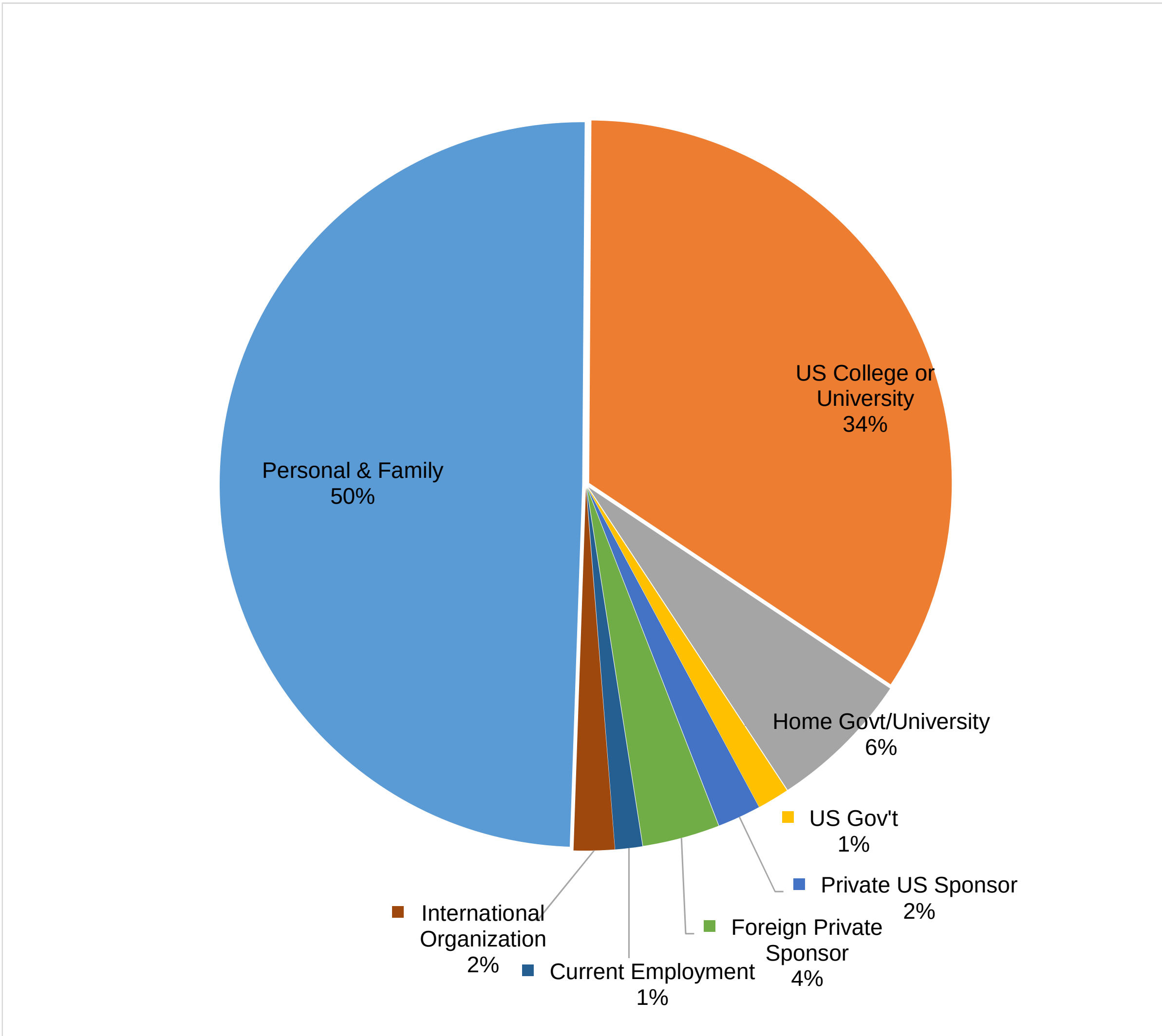
Note: Data taken from the Survey of Earned Doctorates public-use data, available from the National Science Foundation's WebCASPAR, see: https://ncsesdata.nsf.gov/webcaspar/.

Figure 2: Sticker Price Tuition Rates at Research Universities , 1990-2009



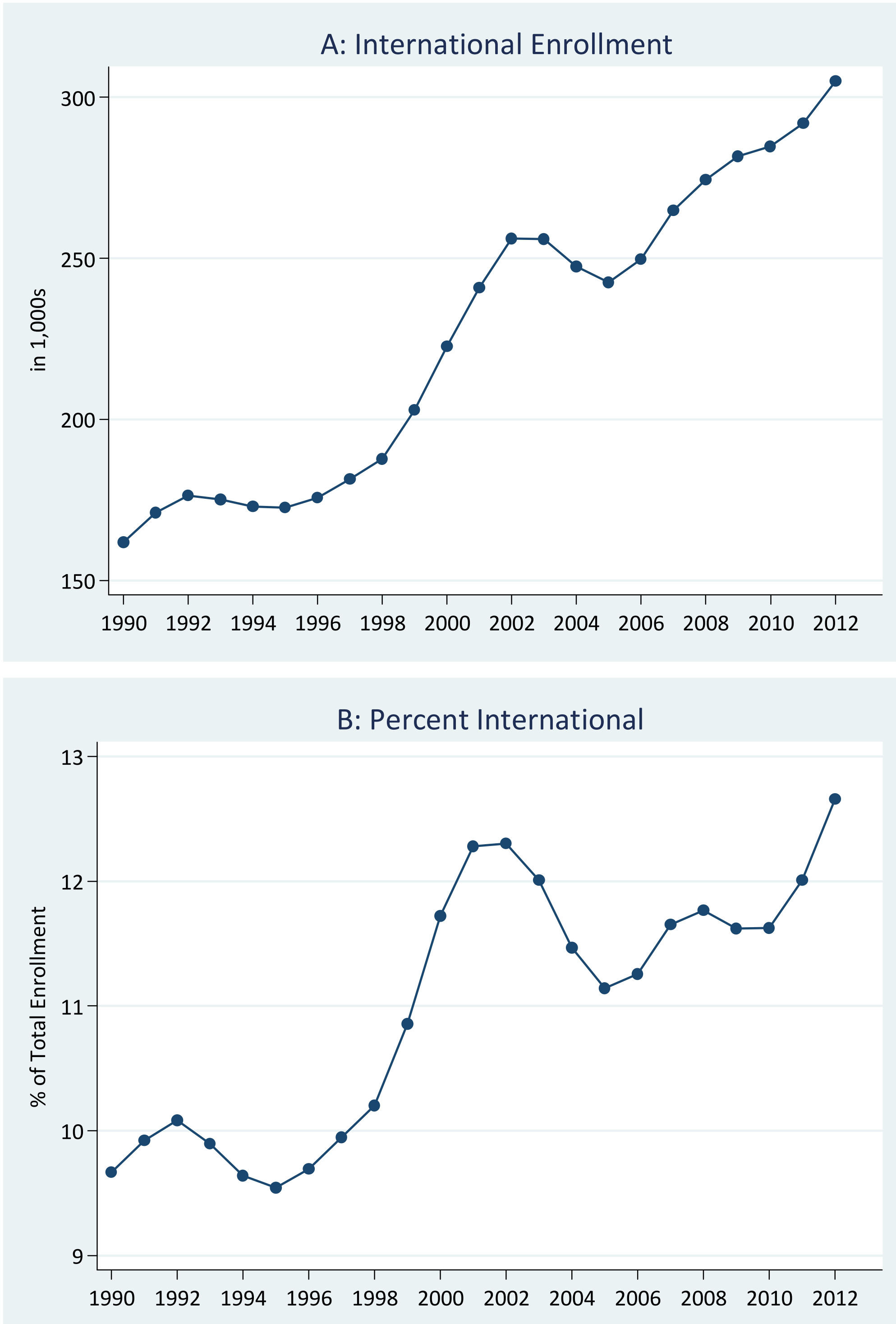
Note: Above series show average in-state and out-of-state tuition at public universities, and average private university tuition. Dashed lines represent 95% confidence intervals. Sample consists of research universities. Data comes from the IPEDS Delta Cost Project (Lenihan 2012). Dollar amounts have been converted to constant 2010 $.

Figure 3: Primary Source of Funding for International Graduate Students, 1995



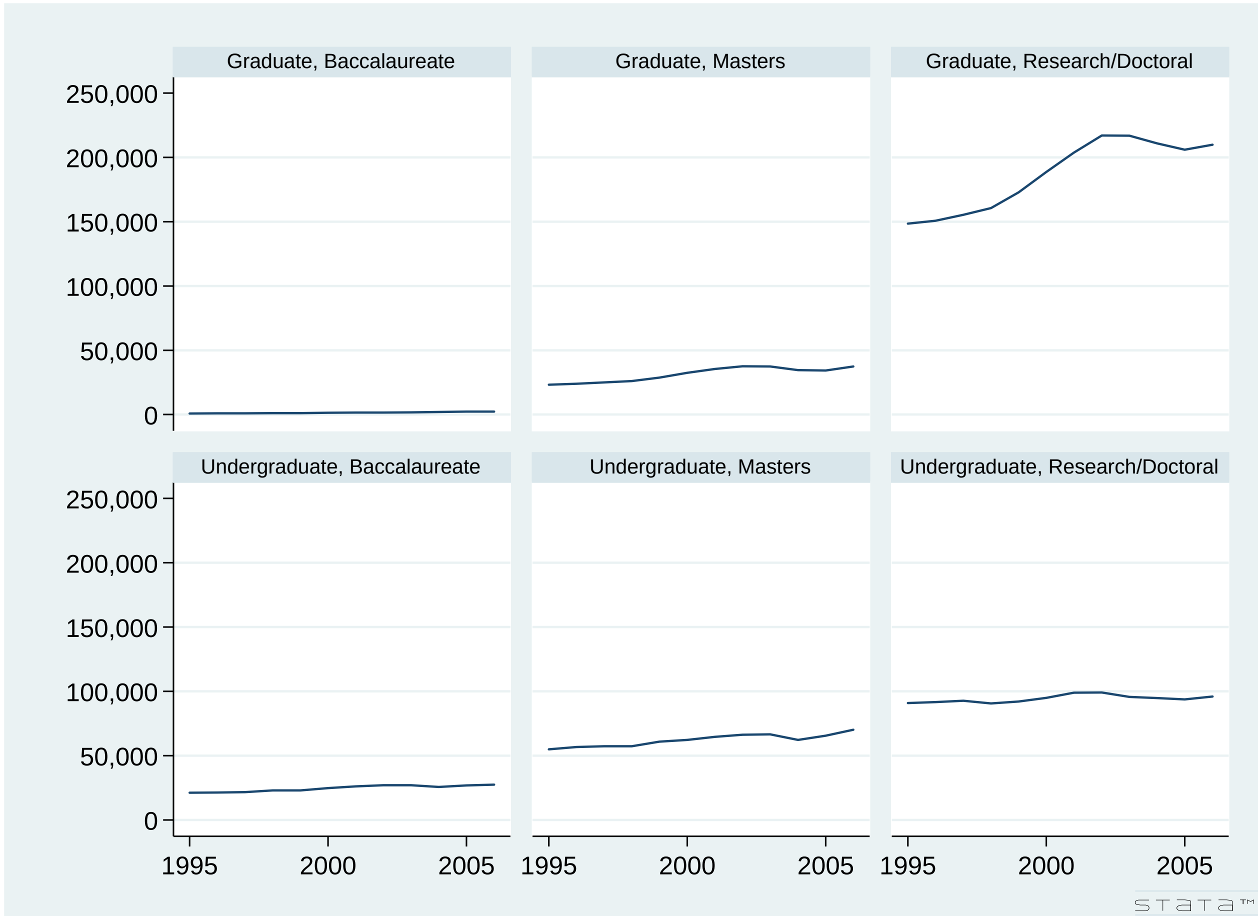
Note: Above shows the primary source of funding for foreign graduate students. Figures reflect the fraction of students reporting each category as the main source of financial support to finance their education. Data from IIE Open Doors report for the 1995-1996 academic year (Davis 1996).

Figure 4: Trends in International Graduate Enrollment in the US, 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).

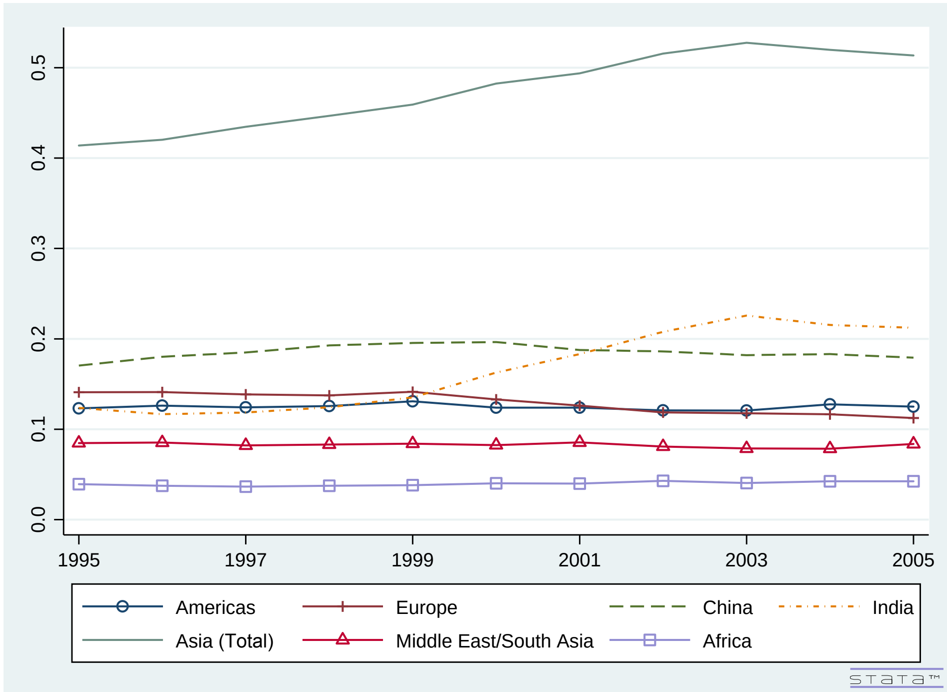
Figure 5: International Enrollment by Academic Level and University Type, 1995-2005



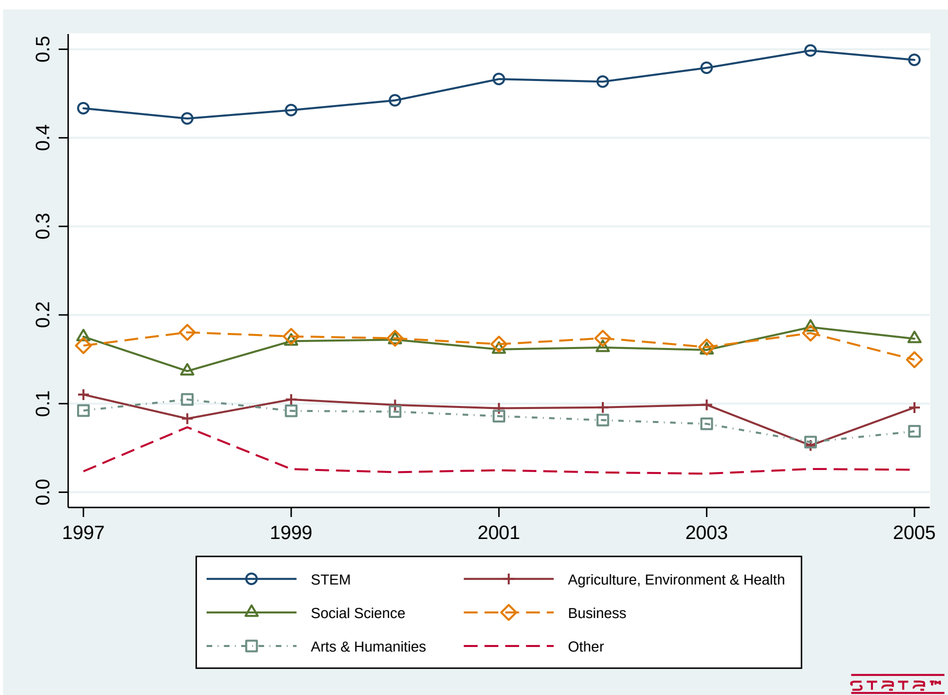
Note: Series constructed from IPEDS Fall Enrollment Surveys, 1995-2006. Figures above include total international undergraduate and graduate enrollment in baccalaureate, master's, and research/doctoral universities as defined by the 2000 Carnegie Classification.

Figure 6: Composition of International Students, 1995-2005

A: Country of Origin

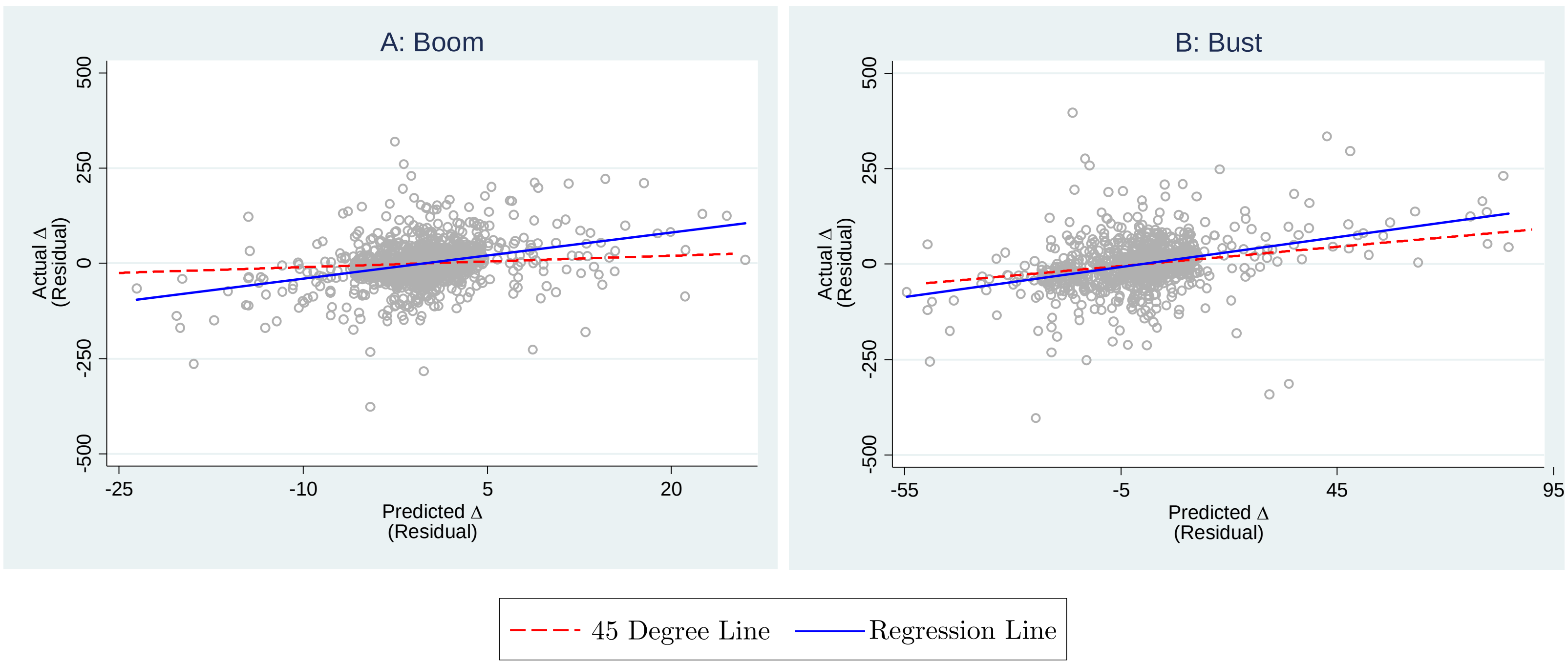


B: Field of Study



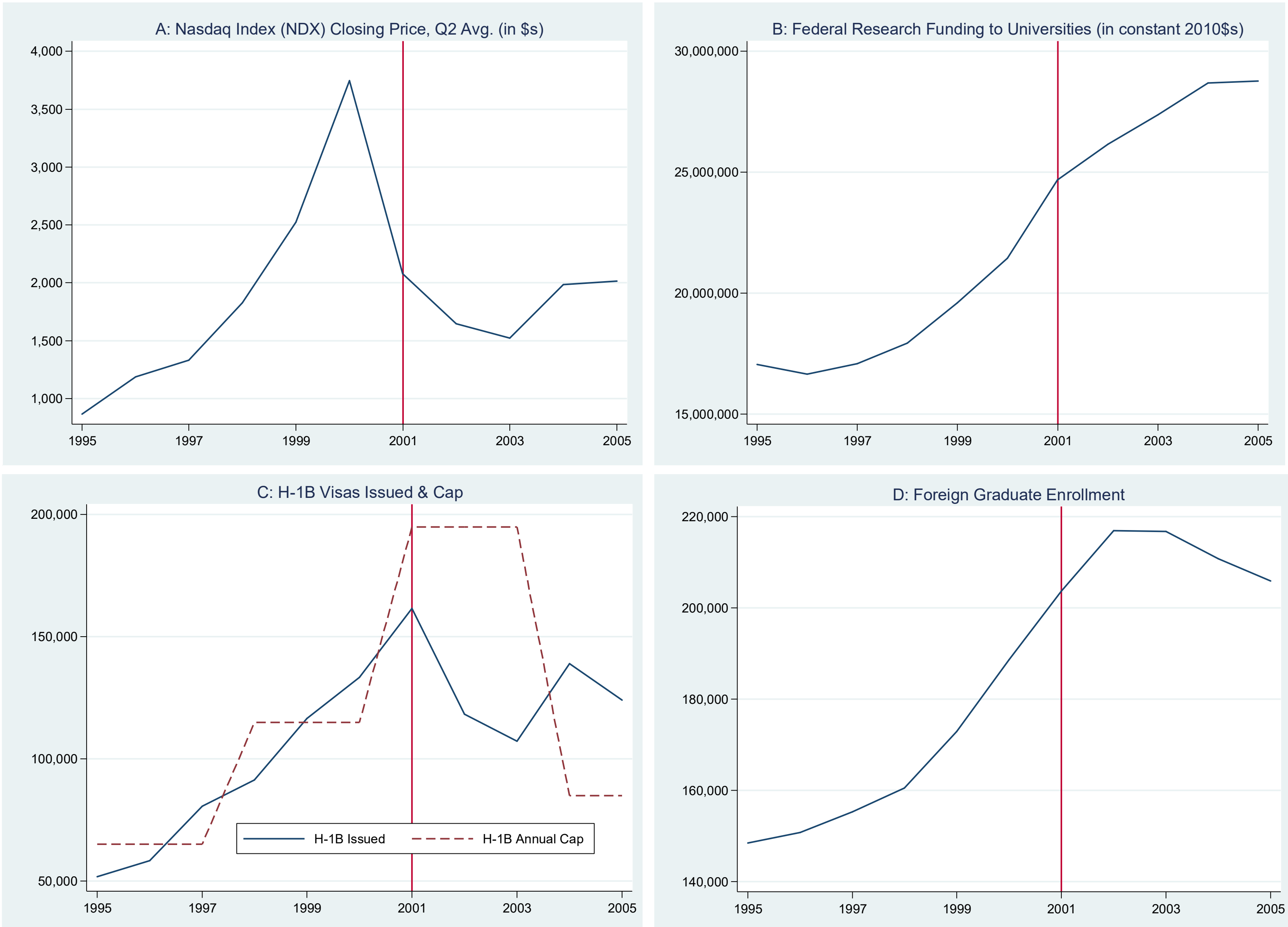
Note: Series constructed from IIE International Student Census restricted-use data from 1995-2005. Graduate enrollment by field of study was available only from 1997 on.

Figure 7: Visual First Stage Estimates



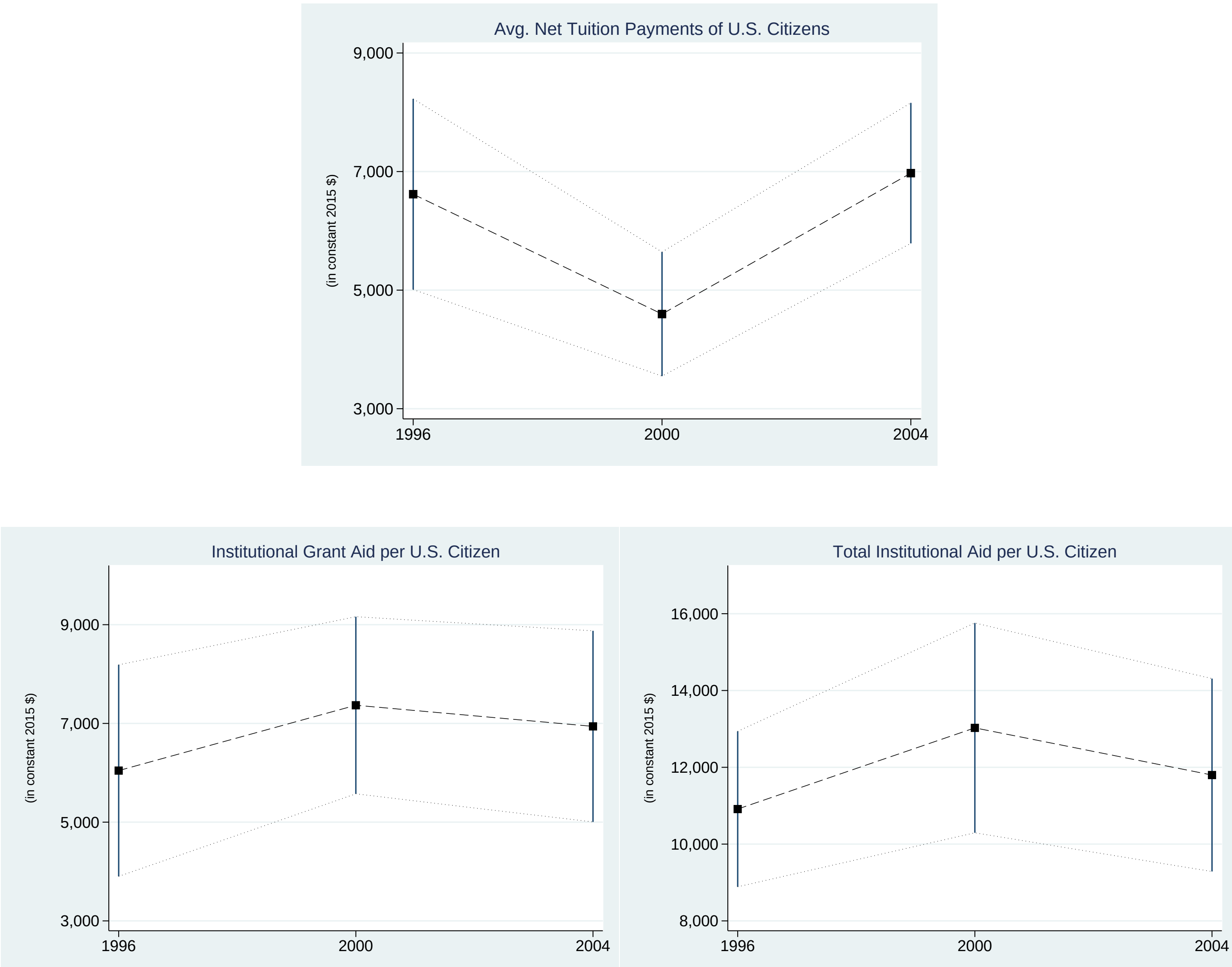
Note: Figure plots the actual change in foreign enrollment over the boom (left) and bust (right) against the change predicted by the instrument for each university in the main sample. For reference, the 45-degree line is represented by the dashed line. The regression line is represented by the solid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

Figure 8: Coincident Shocks During the Boom and Bust



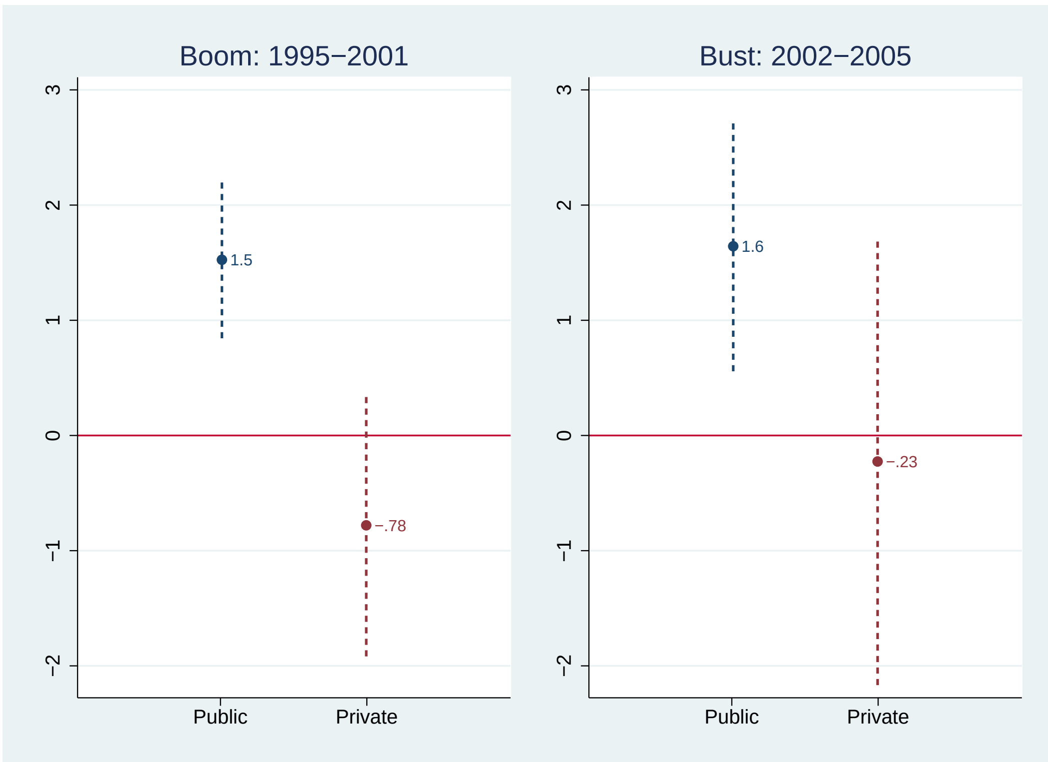
Note: Panel A: Nasdaq Composite Index stock prices are from Yahoo Finance Historical Prices and reflect the average daily closing price over the 2nd quarter, when students generally make enrollment decisions. Panel B shows data from the NSF on total federal research and development obligations to universities 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 9: Net Tuition and Institutional Aid, US Citizens in the NPSAS Sample



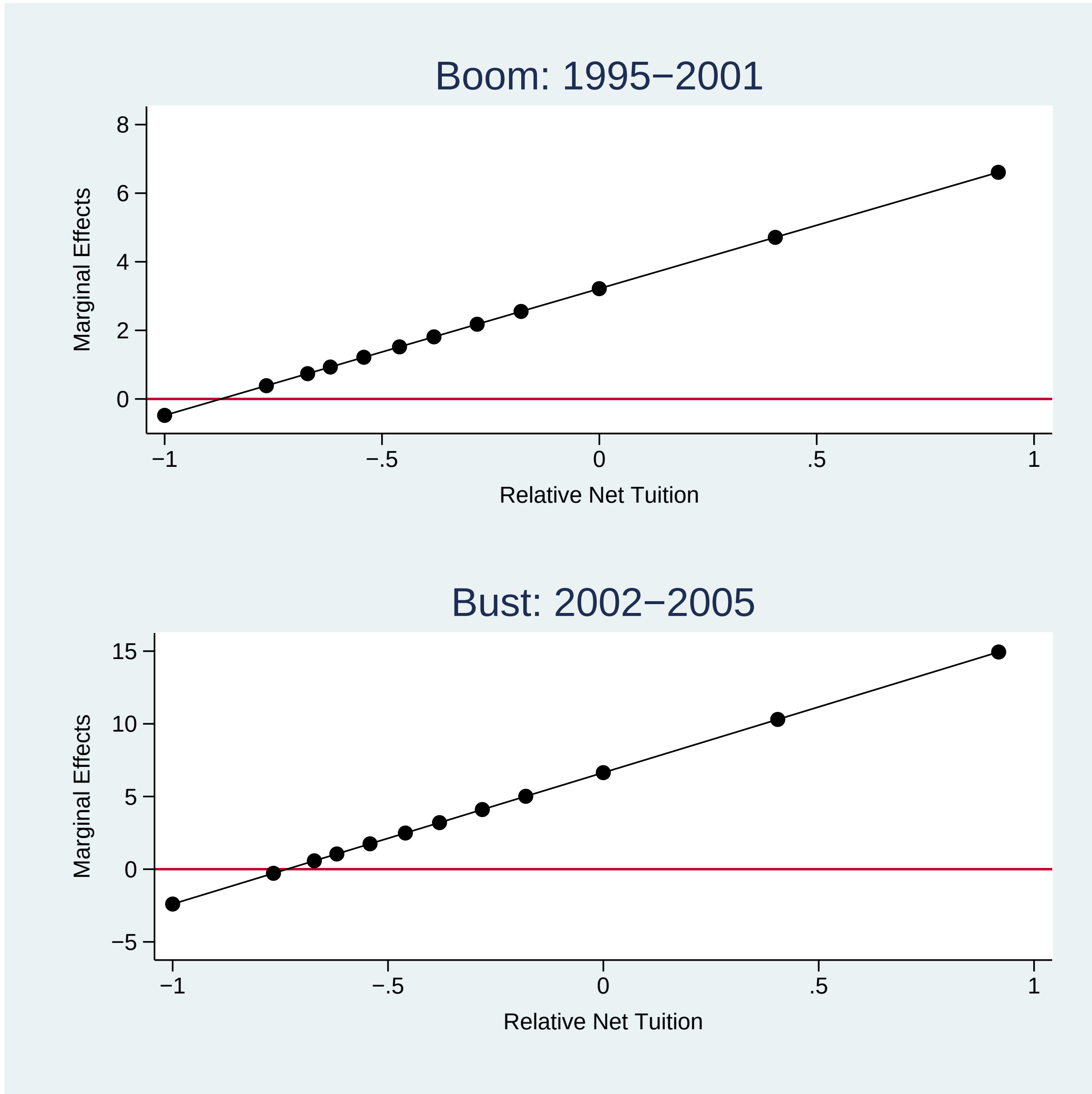
Note: Figure reflects average net tuition, institutional aid, and institutional grant aid in constant 2015 dollars for US citizens enrolled in graduate programs at research universities from the 1996, 2000, and 2004 NPSAS surveys. Data retrieved from the National Center for Education Statistic's Data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

Figure 10: Impacts on Domestic Enrollment at Public vs. Private Universities



Note: Figure displays point estimates and 90% confidence intervals from regressions of equation 1 when stratifying on public and private universities. Coefficient values are measured on the vertical axis.

Figure 11: Heterogeneous Effects by Relative Net Tuition



Note: Figure displays the marginal effects, plotted over ventiles (i.e. every 5th percentile) of relative net tuition measures. Note that the 0-40th percentiles have relative net tuition equal to -1, and are represented by the left-most point of the figure. The vertical axis measures the marginal effect size.

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 for each state total enrollment by country of origin in non-research universities. 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 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 US 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.[22] 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:

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

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

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

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

[22] 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.

Similar to 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:

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

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),

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

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,

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

Endowment per student values are constructed for each university by dividing ending market value of endowment assets ($endowment_{u93}$) by total enrollment (E^{total}_{u93}), 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.[23] I adjust these values for inflation by transforming all data into constant 2010$.

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

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,

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

A.3 Derivation of Theoretical Model

The following model adapts the theory from James (1979) to incorporate university decisions over foreign and domestic students. Universities choose D, F, and q to maximize $U(D, F, q)$ subject to the non-profit constraint,

$$FC + c(q)D + c(q)F - t_D D - t_F F - FR = 0$$

With $E = D + F$ and $c = c(q)$, the first-order conditions are:

$$U_D - \lambda\,(c - t_D) = 0 \tag{A.2}$$

$$U_F - \lambda\,(c - t_F) = 0 \tag{A.3}$$

$$U_q - \lambda c' \cdot E = 0 \tag{A.4}$$

How would domestic enrollment change after an exogenous shock to foreign student supply, holding all else constant? Substituting equation 7 in 6 and 5, and using the implicit function theorem yields:

$$\frac{\partial D}{\partial F} = -\frac{U_F}{U_D} = \frac{t_F - c}{c - t_D} \tag{A.5}$$