The Impact of International Students on US Colleges: Higher Education as a Service Export*

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Abstract

Between 2005 and 2016, international enrollment in US higher education nearly doubled. I examine how trade shocks in education affect public universities' decision-making. I construct a shift-share instrument to exploit institutions' historical networks with different origins of international students, income growth, and exchange-rate fluctuations. Contrary to claims that US-born students are crowded out, I find that international students increase schools' funding via tuition payments, which leads to increased in-state enrollment and lower tuition prices. Schools also keep steady per-student spending and recruit more students with high math scores. Lastly, states allocate more appropriations to universities that attract fewer international students.

Keywords: Higher education, international student, university objective, service trade, education export
JEL Codes: I21, I23, F14, F22, J61

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1 Introduction

Education is one of the most vital comparative advantages in trade for the US. During the 2017-18 academic year, over one million international students studied in the US and contributed $45.3 billion to the economy.[1] The trade surplus in education accounts for about 14 percent of total US services trade surplus in 2018. Whereas recent immigration restrictions, the COVID-19 pandemic, and the trade war with China have cast doubt on the future of education exports (Lorin, 2019; Barros, 2020; Fischer, 2020), the impact of such service trade on the US remains unclear. On the one hand, tuition revenue from international students is crucial to many US public universities in order to cushion a loss in state funding (Bound et al., 2019; 2020). However, critics argue that international students crowd out in-state students and some have advocated for caps on nonresident enrollment (Belkin, 2017).

This paper studies the impact of education exports on the US higher education sector and sheds light on objectives of public universities in the face of changing revenue sources. I focus on the period between 2005 and 2016, during which the inflow of new international students doubled (IIE, 2019). This staggering influx of international students is due to both demand factors, such as the rising ability to pay for US education in developing countries, and supply factors, such as increased incentives to raise tuition revenue following the Great Recession (Bound et al., 2021). The listed tuition and fees for nonresidents are 2.6 times the amounts for in-state students (see Appendix Figure A.1), and the absolute difference has increased over time and is larger among research institutions.

Using administrative data on student visas, I first document the fiscal impact of international students by estimating their financial contributions by geographic region, institution, and degree program.[2] I find that on average, international students' tuition revenue accounts for 12 percent of the total tuition revenue (net of institutional aid) across public universities in 2016, exceeding 30 percent for some institutions. Undergraduates' revenue constitutes more than half of the international tuition revenue from degree programs.

Next, with tuition revenue from international students increasing and state funding decreasing, I test whether US public universities choose to expand in-state enrollment or raise quality by increasing per-student spending, which leads to the displacement of

[1] Source: US Department of Commerce, 2016.export.gov/industry/education

[2] Through Project ADVISE (Analytics and Data Visualization for International Student and Education), I build a data visualization tool to make estimates of international students' financial contributions available to the general public (ers.princeton.edu/project-advise-about).

in-state students. Public universities historically rely heavily on state appropriations and are mandated to educate in-state students (Groen and White, 2004). The changing composition of universities' revenue sources provides an opportunity to study their optimizing behaviors.

To do so, I estimate the causal effect of international undergraduate enrollment on various public university outcomes. I focus on the case of undergraduates as it is where international students experienced the most increase (Bound et al., 2021) and public institutions face clear trade-offs. I combine three national surveys of colleges to assemble a panel dataset with rich school information on enrollment by place of origin (PO) and state residency, completions, peer quality, prices, school expenditures, and state funding.[3] I employ a shift-share design to exploit the variation in international student enrollment that is driven by changes in foreign demand for US education. I measure the foreign demand based on family's ability to pay for US services, which consists of PO-specific economic growth and exchange-rate fluctuations. My design leverages institutions' differential exposure to foreign demand shocks based on their networks with foreign countries years prior to the recent expansion of international undergraduate students. My results are robust to tests suggested by recent developments in the shift-share literature (Jaeger et al., 2018; Adão et al., 2019; Goldsmith-Pinkham et al., 2020; Borusyak et al., 2021).

I find that the increase in international students at US public universities does not crowd out local students. Instead, schools create additional seats for in-state students and graduate more domestic students. On average, for every one additional international undergraduate enrolled, the in-state freshman enrollment increases by two, and the number of domestic students who graduate in six years increases by 1.4. I show that schools provide more access to in-state students by decreasing the listed tuition and fees. Meanwhile, the increase in international students leads universities to raise total expenditures on students but keep per-student spending constant. The increase in total expenditures is mainly attributed to instructional costs.

Furthermore, given the large increase in foreign demand for US education, public universities do not recruit international students under lower admission standards for SAT scores compared with their domestic peers. In fact, I find that enrolling more international students increases overall class academic credentials in terms of the top SAT math quartile and does not change the bottom SAT quartiles for both math and verbal. This is consistent

[3] I avoid using "country" to report geographic units identified in the data because not all are countries (e.g., Hong Kong).

with the fact that international students enrolled in the US have higher SAT scores on average, especially in math, compared with their US peers (Chen et al., 2020).

Lastly, I find that the allocation of state appropriations can depend on institutions' ability to generate tuition revenue from international students. Enrolling more international students decreases the state appropriations received by public research universities, which attract over 70 percent of international undergraduates at public institutions. Furthermore, state allocate more state appropriations when there is an international enrollment increase at peer institutions in the same state.

Whereas a large volume of research has focused on the demand (student) side of the higher education market, this paper contributes to our limited understanding of the supply (school) side.[4] Because universities are multi-product organizations with a complicated set of goals, it is difficult to discern their priorities. I leverage revenue shocks from international students to shed light on how public universities make trade-offs between educating in-state students and school quality or prestige, measured by per-student spending. My results provide empirical justification for the modeling choice of a university's objective function, whereas prior literature usually takes an explicit stance on ex-ante (e.g., Epple et al., 2013; Hoxby and Stange, 2020). Relatedly, studies have examined the impact of revenue shocks from state appropriation cuts on US public institutions and found declines in enrollment and college attainment (Deming and Walters, 2017; Bound and Turner, 2007). Given that public research universities increase international student enrollment in response to state funding cuts (Bound et al., 2020), my results suggest that in the absence of international students, in-state student enrollment and degree attainment would decline at such institutions.

This paper also contributes to the empirical literature on the impact of trade on the US and has important implications for policymakers when considering trade deals. Thus far, the literature has focused on the effect of manufacturing goods imports on the US labor market and generally finds employment losses in directly competing sectors (e.g., Autor et al., 2013; Acemoglu et al., 2016; Pierce and Schott, 2016; Bloom et al., 2019). In contrast, this paper examines the impact of education service exports on the US higher education market and finds benefits for US students and institutions. In 2018, education service ranked fifth for service exports and was the third-largest contributor to the services trade

[4]Some examples of the demand side with respect to the cost of and access to higher education include Bound and Turner (2002); Dynarski (2003); Deming and Dynarski (2010); Sargent et al. (2011); Hoxby and Avery (2012); Stange (2012); Hoxby and Turner (2013); Pallais (2015); Becker et al. (2016), and Jacob et al. (2018).

surplus (see Appendix Table A.1).

Last, this paper adds to the immigration literature on international students—a population that influences US education markets, high-skilled labor markets, and local economies. Shih (2017) is perhaps the most related paper; it finds that international graduate students cross-subsidize domestic graduate students in 1995-2005, which is broadly consistent with the cross-subsidization result at the undergraduate level in this paper.[5] My paper differs from Shih (2017) in important ways. Shih (2017) is limited by the data to only consider domestic enrollment stock as the outcome and cannot distinguish university-funded doctoral students from self-paying master's students. Shih (2017) studies graduate students in a time period with modest boom of international students. In contrast, I study undergraduates in a time period with a large-scale expansion of international students that is driven by undergraduates. My paper exploits rich data to examine the impact of international student inflow on various institutional outcomes, such as enrollment inflow by state residency, degree attainment, and SAT scores. My setting and data allow me to test how public universities make trade-offs between in-state enrollment and other university interests during a period of large declines in state appropriation.

The rest of the paper proceeds as follows. Section 2 describes the data and context. Section 3 presents the conceptual framework and empirical strategy, and Section 4 reports the main results. Section 5 presents discussion and extensions. Section 6 concludes.

2 Background and Data

2.1 Data

To estimate the financial contributions of international students, I use the universe of F-1 visa SEVIS records between 2001 and 2017 obtained from US Immigration and Customs Enforcement (ICE) via several Freedom of Information Act requests. The data contain student-level information on PO, dates of study, program of study, cost of attendance, and funding amount and source. I match this dataset with the Department of Education's Integrated Postsecondary Education Data System (IPEDS) using school name and address to obtain additional information on institutions.

[5] A contemporaneous study to my paper (Shen, 2017) uses time dummies relative to 2005 as instruments and finds a negative but statistically insignificant impact of international undergraduates on domestic enrollment at public universities. These instruments are problematic because they pick up supply-side drivers of international students (Bound et al., 2020) and violates the exclusion restriction. The lack of enrollment data by state residency also makes the dependent variable harder to interpret.

I combine three national surveys of US colleges for my causal analysis. First, information on listed tuition, expenditures, state appropriations, SAT scores, degree completion and enrollment of first-time degree-seeking undergraduates are mainly from IPEDS; institutions that receive federal financial aid via Title IV programs are required to fill out IPEDS' annual surveys. My enrollment data are from the Fall Enrollment Survey, and an international student is defined as "any person who is not a citizen or national of the United States and who is in this country on a visa or temporary basis and does not have the right to remain indefinitely." I use data for the period between the 2005-06 and 2016-17 academic years. All monetary variables are adjusted for inflation using the Higher Education Price Index. Second, following Bound et al. (2020), I use the Annual Survey of Colleges (ASC) to supplement missing data on enrollment by state residency and SAT scores. The missing data in IPEDS are due to high non-response rates on SAT scores in early years and the fact that schools are only required to report enrollment by state residency every 2 years. My results are qualitatively the same when not using or only using data from ASC.

Third, I obtain information on schools' historical enrollment stock by PO from the restricted-access part of the 1997 Open Doors survey. The Institute of International Education administers the Open Doors survey annually to approximately 3,000 accredited US institutions, with support from the US Department of State. The survey focuses entirely on international students. Chen et al. (2020) show that data from IPEDS and Open Doors match closely on the aggregate trend in foreign enrollment. The Open Doors provides data for the "share" part of the shift-share IV, and information on GDP per capita and exchange rates for the "shift" part are from the Penn World Table 9.1.

Unless otherwise stated, the analysis in this paper focuses on four-year, Title-VI, degree-granting, public institutions in 50 US states and the District of Columbia. I exclude schools that switched from private to public during my sample period. I also exclude military schools and schools identified as primarily granting associate degrees, exclusively graduate programs, medical centers, law schools, or tribal colleges by the Carnegie Classification. Schools are required to be active throughout 2005-06 to 2016-17 and present in the 1997 Open Doors survey. This results in 359 public institutions with 140 research universities. Research institutions are classified as high or very high research activity by Carnegie.

Appendix Table A.2 presents the mean of key variables in selected years by institutional type. Freshman enrollment of all resident types and expenditures on instruction increased

over the sample period. Whereas state appropriations decreased, the increased listed tuition for all students suggests that the increase in student expenditure came at the cost of increased tuition revenue. Furthermore, research institutions are much larger than non-research institutions, attract more international and out-of-state students, and fall into higher SAT percentiles. While research institutions spend close to 90 percent more per student than non-research institutions, they also receive more per-student state funding and charge out-of-state students much higher tuition. However, the in-state tuition difference between research and non-research institutions is much smaller.

2.2 Trends in education exports

Driven by middle-income regions, trade in education service (measured by the number of students studied abroad) underwent a staggering increase of 160 percent in the last two decades. In 2016, about 5 million students pursued higher education in places other than their PO (Appendix Figure A.2). A distinctive feature of trade in education is that it entails the sharing of cultural and political values and transfers of skills and labor, in addition to monetary transfers.

The US has a comparative advantage in education service over any other country in the world. It is the most popular destination country for international students seeking higher education, hosting 24 percent of all students studying abroad in 2016, followed by the UK (11 percent) and China (10 percent).[6] For 2016-17, the size of the international student body is similar to the size of degree-granting for-profit institutions, or four times the size of the University of California system. Using administrative data on F-1 visas, I estimate conservatively that international students in US higher education spent over $38 billion on tuition, fees, and living expenses after netting out financial support from US institutions, up 164 percent from 2005-06.[7] Among public universities, Appendix Figure A.3 shows that the share of tuition revenue from international students of total tuition revenue increased from less than 5 percent on average in 2005 to 12 percent in 2016, and by more than 30 percent for some institutions (e.g., University of Illinois at Urbana-Champaign).

International undergraduates account for more than half of all international students in the US, with an increase of 86 percent between 2005-06 and 2016-17 (51 percent for

[6]Source: Project Atlas, www.iie.org/Research-and-Insights/Project-Atlas.

[7]This estimate is conservative, since I do not have data on other student visa types such as J-1 and M visas. Living expenses exclude spending beyond regular on-campus needs, such as traveling within the US.

graduate students). Panel (a) of Figure 1 shows that students from China contributed to the majority of the increase in international students, though developing countries, such as South Korea, Saudi Arabia, and India, also contributed to the growth. Chinese undergraduates alone spent over $7.4 billion on net tuition and expenses in 2016-17.

The expansion of international students is unequal across institutions. As panel (b) of Figure 1 shows, while the inflow of international undergraduates at public four-year universities started to expand in 2005-06, the subsequent expansion was concentrated in research institutions. Tuition and fees paid by international undergraduates to public four-year institutions increased 300 percent to over $6.2 billion in 2016-17, or $9.5 billion when living expenses are included. The vast majority of tuition revenue went to research universities.

2.3 Factors in international student mobility

Recent literature finds that both the demand- and supply- side factors of the US higher education market for international students are important in explaining the recent expansion of US education exports. On the demand side, in addition to an increase in the need for high-quality higher education from developing countries that is unmatched by local supply, rapid economic growth has rendered US higher education more affordable (Bound et al., 2021). Taking China as an example, between 2005 and 2016, real GDP per capita increased 150 percent. Furthermore, a regime switch to a flexible exchange rate in 2005 caused Chinese currency to appreciate by 19 percent against the USD during the same period.

Studies have demonstrated the importance of the ability to pay for US goods and services in explaining US education exports. Khanna et al. (2020) argue that a major driver of income growth in China is its accession to the World Trade Organization in 2001; they find that trade-liberalization-driven wealth can explain a quarter of Chinese enrollment in the following decade. They also show that trade liberalization first had an impact on Chinese students' inflow to the US in 2005-06, since it takes time for income gains and college decisions to materialize. In addition, Chen et al. (2020) analyze data on over 100 PO between 2004 and 2015 and show that a PO's real GDP per capita is positively correlated with its number of SAT takers and enrollment in the US.

US immigration policies can also influence the demand side by changing international students' expected return of investing in US college applications and access to the US labor market after graduation. Increase in the perceived chance of obtaining an F-1

student visa, the chance of winning an H-1b work visa lottery, and the time allowed to work under the Optional Practical Training program all increase international students' applications and enrollment in the US (Kato and Sparber, 2013; Shih, 2016; Chen et al., 2020; Amuedo-Dorantes et al., 2020).

On the supply side, public universities in the US have had an increasing financial incentive to recruit international students. On one hand, international undergraduates typically receive little institutional aid and pay out-of-state tuition that is 2.6 times higher than the listed in-state price (Appendix Figure A.1). Only 3 percent of all funding for tuition and living expenses comes from hosting US institutions for Chinese students seeking bachelor's degrees (Chen, 2019). Moreover, international students can often pay more than domestic out-of-state students. At least 45 states have some form of tuition reciprocity agreement that largely reduces tuition for students from surrounding states.[8] Lastly, according to the American Survey of Colleges, in 2017, 21 public universities charged foreign students an average additional tuition of $3,120 on top of the listed out-of-state price, and 70 public universities charged an average additional fee of $1,610.

On the other hand, while public universities historically depend on state appropriations to operate, they have had to rely more heavily on tuition revenue following each of the last three recessions. For example, the share of tuition revenue in total revenue increased permanently from 36 percent before the Great Recession to more than 47 percent after 2012 (SHEEO, 2019). In this vein, Bound et al. (2020) find that reductions in state appropriations led to an increase in international student enrollment at public research universities.

3 Conceptual framework and empirical strategy

3.1 Objectives of public universities

Although the interests of public universities are diverse and heterogeneous, I focus on two objectives that are common to most institutions and testable with my research design. In my conceptual framework, a public university optimizes over a combination of in-state enrollment and school quality, subject to capacity constraint and budget constraint. School quality is measured by per-student spending for now and is later extended to include the academic ability of the students in Section 5.1. The budget constraint consists of tuition revenue and state appropriation, in which state funding is determined by state

[8]Source: www.instateangels.com/tuition-reciprocity-agreements-explained

legislatures whose goal is to maximize in-state enrollment in the entire state. Since a state's total funding for higher education is usually fixed, a school's state appropriation depends on its alternative source of revenue and its peer institutions' budget constraints.

An increase in international student enrollment at public universities brings additional tuition revenue and affects the two objectives under my conceptual framework. If public universities are strictly constrained in physical space, an increase in international students will displace domestic students on campus mechanically. If there is room for enrollment expansion, universities can either use the new revenue to expand seats for in-state students or increase per-student spending to improve school quality. They can also choose a mix of these two options. Hence, examining the impact of the increase in international students provides an opportunity to test which objective universities decide to optimize.

3.2 Shift-share design

To estimate the causal impact of international student enrollment on institutional outcomes, I employ the following model specification:

$$\Delta Y_{jt} = \beta \Delta E^{f}_{jt} + \Delta W_{jt}\alpha + \lambda_t + \epsilon_{jt} \tag{1}$$

where Y_{jt} is school j's outcome in the academic year t, such as in-state freshman enrollment in the fall and expenditures on students. The independent variable of interest, E^{f}_{jt}, is international freshman enrollment in the fall. W_{jt} is a vector of state-level time-varying controls and λ_t are year fixed effects. Δ represents that I take the first difference instead of using levels, which controls for any school-specific time-invariant characteristics. Year fixed effects control for aggregate trends such as overall demand for college education and immigration policies. Among W_{jt}, I control for state-level college-age populations (age-18 population) and labor market conditions (unemployment rate), since they are drivers of college enrollment (Bound and Turner, 2007). Institution-year observations are weighted by the undergraduate enrollment at baseline (2005).[9] Standard errors are clustered at the institutional level.

Estimating equation (1) with an ordinary least squares (OLS) regression may not capture the causal impact of international enrollment for several reasons. First, increases in in-state enrollment reduce available seats and induce a reverse causality on international enrollment, which would bias OLS estimates downward. Second, there may be

[9] Appendix Table A.4 shows my results are robust when not using weights.

time-varying unobserved institutional characteristics that affect in-state enrollment and international enrollment. For instance, a change in the school's recruiting strategy or investment in a school amenity can attract students of all residencies.

To address these potential identification challenges, I construct a shift-share instrumental variable (SSIV), Z_{jt}, to measure institutions' exposure to foreign demand shocks for US education. Specifically, I interact a measure of families' ability to pay for US colleges in a PO with institutions' historical network with students from that PO:

$$\Delta Z_{jt} = \sum_{c} \frac{E^{s}_{cjt=1997}}{E^{s}_{jt=1997}} \Delta M_{ct} \tag{2}$$

where the fraction $\frac{E^{s}_{cjt=1997}}{E^{s}_{jt=1997}}$ is the share of international enrollment stock from PO c at school j in 1997. M_{ct} is a measure of families' ability to pay for US education from c in the period before academic year t. In practice, I use real GDP per capita in USD (PPP adjusted), which contains variation from real GDP per capita and exchange rates adjusted for the cost of living. The summation is over the top 30 PO with the highest enrollment stock in 1997, covering over 80 percent of total international enrollment in the US.[10]

My SSIV design requires two key assumptions for causal inference. First, the instrument Z_{jt} must have predictive power for international enrollment E^{f}_{jt}, conditional on the controls. In my SSIV, institutional exposure to foreign demand shock from a particular PO depends on the PO's enrollment share in the initial year (1997). Like the formation of immigration enclaves, prior graduates are an essential channel for establishing an international reputation and through which prospective students can obtain information. There is, in fact, a strong positive correlation between E^{f}_{jt} and Z_{jt} (see Appendix Figure A.4): Institutions with larger exposure to foreign demand shock for US education enroll more international students.

Second, initial shares of international students in 1997 must be exogenous to *changes* in other determinants of the outcome variable, conditional on observables (Goldsmith-Pinkham et al., 2020). In addition to using initial shares 8 years before the sample period to mitigate this concern, I test whether initial shares correlate with pre-trends in in-state enrollment, per-student spending, and other determinants of the outcomes (population at age 18, unemployment rate, and state appropriations). Appendix Figure A.5 shows no clear correlation between initial shares for PO with the highest Rotemberg weights

[10] Appendix Table A.4 shows that my results are robust when using the top 80 PO, which cover 99 percent of international enrollment.

and changes in outcomes between 2000 and 2005. Appendix Table A.3 provides formal statistical tests and includes determinants of outcomes.

The thought experiment of my SSIV design is similar to a difference-in-differences, which compares the change in outcomes for institutions with high exposure to foreign demand shock with low-exposure institutions. The test for pre-trends suggests that effects on outcomes are unlikely to be explained by unobserved differences between institutions with high and low foreign demand exposure. Note that despite the shocks' being viewed as weights in Goldsmith-Pinkham et al. (2020) and not needing be exogenous, using shocks for foreign demand isolates my SSIV from time-varying supply-side factors.[11]

4 Results

4.1 The impact of education exports on university objectives

This section presents empirical results for the causal impact of the increase in international students on the two objectives of public universities laid out in Section 3.1. Table 1 reports OLS and 2SLS estimates of equation (1) for the impact on domestic enrollment by state residency. The first-stage estimates in columns 2 and 3 suggest that the SSIV is positively correlated with international student inflow. This is consistent with my hypothesis that foreign demand shocks induced by a rise in the ability to pay for US education lead to increased education exports.

Column 1 of Table 1 shows that the OLS estimate for the impact of education exports on in-state enrollment is small and statistically insignificant, while column 2 shows that the 2SLS estimate using the SSIV is statistically significant and positive. This difference is consistent with the downward bias induced by the reverse causality discussed in Section 3. Column 3 of Table 1 shows that the 2SLS estimate is robust after controlling for the statewide population at age 18 and the unemployment rate. On average, for every additional international freshman enrolled, the in-state freshman enrollment increases by 2.2 at US public universities. In contrast, columns 4-6 show a small and statistically insignificant impact of education exports on out-of-state enrollment. Lastly, column 7 shows that the enrollment increase for in-state students translates into graduates: Every additional international student leads to an increase of 1.4 domestic college graduates in

[11] Borusyak et al. (2021) show that we can alternatively view shares as weights and require shocks to be exogenous. However, one key assumption is to not have many correlated shocks. Since shocks are correlated overtime in my panel setting, I choose to focus on the shares view.

6 years.

Table 2 presents 2SLS estimates for the impact of education exports on various measures of student spending (in logs).[12] Columns 1 and 2 suggest that while an increase in international student enrollment leads to an increase in total expenditures on students, the effect on per-student spending is very small and not statistically significant. Columns 3 to 5 break down student expenditures by type and show that the increase in total spending is mainly attributed to instruction. On average, for every 10 additional international students, schools increase instructional spending by 0.5 log points. The increase in instructional spending is consistent with an increase in new faculty hires. Column 6 shows that for every 10 additional international students, schools increase new faculty hires by one.

4.2 SSIV robustness checks

In light of recent literature on the identification challenges of SSIVs, I perform a series of sensitivity checks and show that my results are robust when suggested tests are feasible. As stated in Section 3, Goldsmith-Pinkham et al. (2020) show that a key identifying assumption is the exogeneity of shares to changes in unobserved determinants of the outcomes, especially for shares carrying high weights. I have shown that top-weighted PO are uncorrelated with pre-trends of the outcomes and their observed determinants in Appendix Figure A.5 and Appendix Table A.3. In addition, column 1 of Appendix Table A.4 shows that despite a decline in first-stage power, the 2SLS estimate is statistically indistinguishable when excluding the top-weighted PO.[13] Given the prevalence of Chinese students, column 2 also shows that my results are robust when excluding China.

Furthermore, in column 3, I include log state appropriations as a control and find no effect on my results. This is broadly consistent with Bound et al. (2020), who find that state appropriations only affect international enrollment but not in-state and out-of-state enrollment during a similar time window. Finally, following Adão et al. (2019), column 6 reports standard errors accounting for the correlation across institutions in PO shares, and my results remain the same.

[12] For the rest of the paper, I focus my discussions on 2SLS estimates with controls. Parallel OLS estimates are included in the Appendix.

[13] I compute Rotemberg weights following Goldsmith-Pinkham et al. (2020) to measure the weight of each PO (see the full list in Appendix Table A.7).

5 Discussion and extensions

5.1 What do public universities value?

Results from Section 4.1 suggest that when public universities receive additional tuition revenue from international students, they choose to expand seats for in-state students rather than increase quality by raising per-student spending. This rejects the hypothesis that international students crowd out in-state students.

My results also suggest that schools are unlikely to be capacity constrained in physical space, but they are in monetary resources. I test further whether international students displace in-state students at more capacity-constrained schools. Columns 1-2 of Appendix Table A.5 show the impact of education exports on main outcomes of interest by whether a university requires first-year students to live on campus in the baseline year (2005). While the effects of education exports are concentrated in schools that do not require freshmen to live on campus, there is no detectable crowding-out effect at schools with a live-on-campus requirement. This result strengthens the finding that in-state enrollment is a key optimizing objective for public universities.

One dimension of school quality that has not been considered is the academic ability of students. The increased monetary incentive to recruit international students during the Great Recession may lead schools to lower admission standards for international students. Since international students also lead to higher in-state enrollment, the academic ability distribution of freshman can also be influenced by the marginal in-state student. Table 3 reports the impact of education exports on SAT quartiles of the freshman class by math and verbal. The 25^{th} percentile can be viewed as a proxy for admission threshold, and the 75^{th} percentile can be considered a measure of academic ability for highachievers.

Columns 1 and 3 of Table 3 show that international enrollment increase has a positive and statistically significant effect on the 75^{th} percentile of SAT math scores but has no significant effect on verbal. For every 10 additional international students enrolled, the top quartile of SAT math scores for the freshman class increases by 0.63 points. Despite a small magnitude, this result suggests that schools benefit from admitting more high-scoring students. Given that on average, international students score 105 points higher than their US peers on SAT math (Chen et al., 2020), the increase in the SAT math quartile is likely attributed to the rise in international students. An important observation is that the average share of international students in the freshman class is very small (4 percent in 2016). Hence, for the marginal international student to move the SAT percentiles of the

entire freshman class, the SAT scores of the marginal student must be considerably high.

In addition, columns 2 and 4 of Table 3 show that education exports have no statistically significant impact on the 25th percentile of SAT math and verbal scores. This suggests that institutions did not systematically lower admission standards for marginal international and in-state students. A potential way schools attracted more qualified in-state students was by decreasing tuition and fees for local students. Columns 1-3 of Appendix Table A.6 show that every 10 additional international students lead to a decrease of the listed price for in-state students by 0.4 log points. In contrast, education exports have no impact on the listed price for out-of-state students or institutional aid.

Thus far, I have presented evidence to support that in-state enrollment is one of public universities' core interests. My results do not rule out that school quality is an important objective, but is, less prioritized than in-state enrollment. Institutions with high exposure to foreign demand shocks kept per-student spending constant and did not lower admission standards.

Whereas maximizing over in-state enrollment may be surprising when state appropriations decreased, there are several reasons why expanding seats for local residents is beneficial to public universities. First, the market for recruiting in-state students is competitive, especially with demographics shifting towards the declining college-aged population. Since local residents are the major supply of students on campus, maximizing in-state enrollment can help universities maintain a healthy enrollment level in the long run. Second, since in-state students are more likely to stay in the state after graduation (e.g., Mountjoy, 2018), they may be particularly valuable for schools seeking to build stronger local networks, attract donations, and even gain political bargaining power for higher education funding. For example, Chatterji et al. (2018) find that state legislatures with more in-state public college alumni spend more on education.

5.2 Treatment effect heterogeneity

Panel (b) of Figure 1 shows that the expansion of education exports is concentrated in research institutions, which are typically more attractive to international students. Columns 3 and 4 of Appendix Table A.5 show that the impact of education exports is more pronounced at public research universities. Furthermore, columns 5 and 6 show that the effects are larger at institutions with a higher profit margin for international students than in-state students. The profit margin is measured by the ratio of net tuition and fees for international students to that for in-state students. Data for institutional aid is from F-1

visa administrative data for international students and IPEDS for domestic students.

5.3 The impact of education exports on state appropriations allocation

The allocation of state appropriations to individual institutions is a complicated process. The funding proposal is often developed by a state education board.[14] Given the limited amount of state budget for higher education funding, institutions with higher ability to generate tuition revenue from international students may receive less state funding appropriations.

I examine the effect of education exports on state funding received in Panel A of Table 4. Column 1 shows that an increase in international student enrollment leads to a decrease in state appropriations. Columns 2 and 3 break the sample into research and non-research institutions. Public research universities enroll over 70 percent of international undergraduates at public institutions and hence have a higher ability to generate tuition revenue from education exports. Results from columns 2 and 3 indicate that the effect of foreign enrollment on state funding is pronounced at research institutions. For every 10 additional international students enrolled, the state funding received by research institutions reduces by 1.1 log point. The effect for non-research institutions is statistically insignificant, and the instrument is weak in this subsample.

In Panel B of Table 4, I examine whether the allocation of state appropriations within a state can depend on peer institutions' ability to attract international students. Columns 2 and 3 show that for both research and non-research universities, every 10 additional international students enrolled at peer institutions in the same state is associated with a 0.1 log point increase in state appropriations. These results suggest that education exports also have an impact on the allocation of state appropriations across institutions.

6 Conclusion

This paper leverages the impact of education exports on the US higher education market to better understand public universities' objectives and how schools respond to financial incentives. Without changing school quality, maximizing in-state enrollment subject to budget and capacity constraints is a core interest of public universities.

[14] See Deming and Walters (2017) and Chatterji et al. (2018) for more detailed descriptions of the state funding determination process.

Contrary to criticism that international students crowd out domestic students, I find that the public sector of the US higher education market benefited greatly from international students' increase. Universities with higher increases in international students were able to expand in-state enrollment by keeping the price low, graduated more domestic students in 6 years, and enrolled more students with higher SAT math scores. Khanna et al. (2020) demonstrate that the trade deficit in goods cycles back as a surplus in US exports of education services, and this paper shows that exports in education service have a large positive impact on the US higher education market.

Note that international undergraduates have value beyond what is captured in this paper. For example, college presidents have advocated for the importance of international students by arguing that global diversity is valuable for college campuses and US students (Wong, 2018). They are also more likely to be in STEM majors and hence contribute to the STEM workforce; however, Anelli et al. (2020) find that they can shift domestic students to non-STEM majors with higher expected income.

A policy implication of this paper is that keeping foreign demand for US education high is important for US students and universities, especially given the recent revenue shortfalls due to the COVID-19 pandemic. However, the task is difficult due to recent events such as the trade war and immigration restrictions. For example, the recent political tension between the US and China may have driven some Chinese students to the UK (Bennett et al., 2019). Furthermore, China has increased its investment in providing high-quality education, and Chinese universities have increasingly been included in to top university rankings (Bound et al., 2021). One way to increase foreign demand is by relaxing immigration policies. Studies have shown that making student visas less restrictive and work visas more accessible have positive impacts on international student inflow to the US, especially for those with high SAT scores (Kato and Sparber, 2013; Shih, 2016; Chen et al., 2020).

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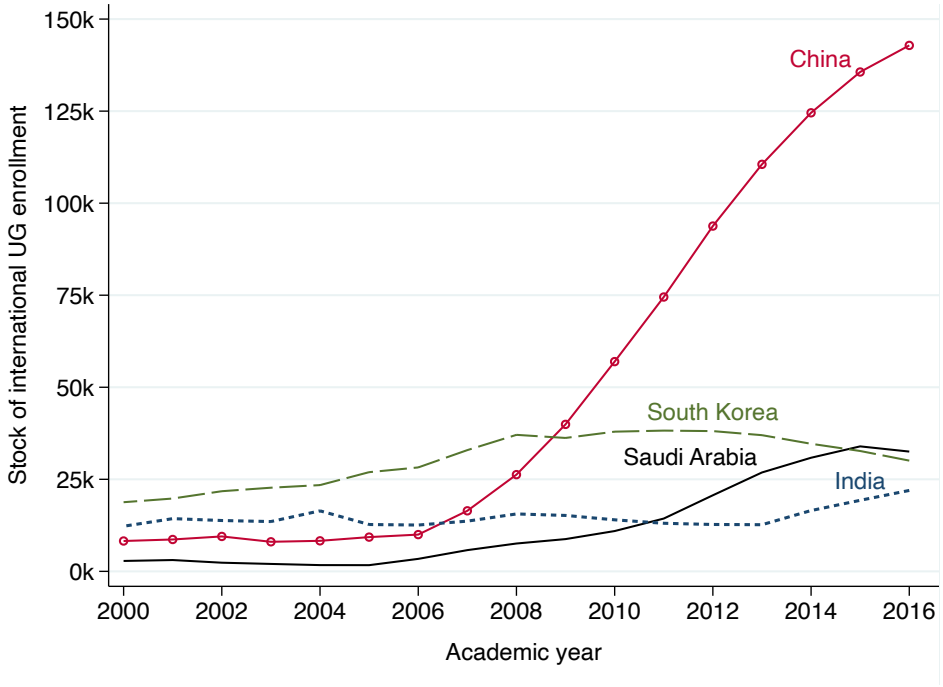
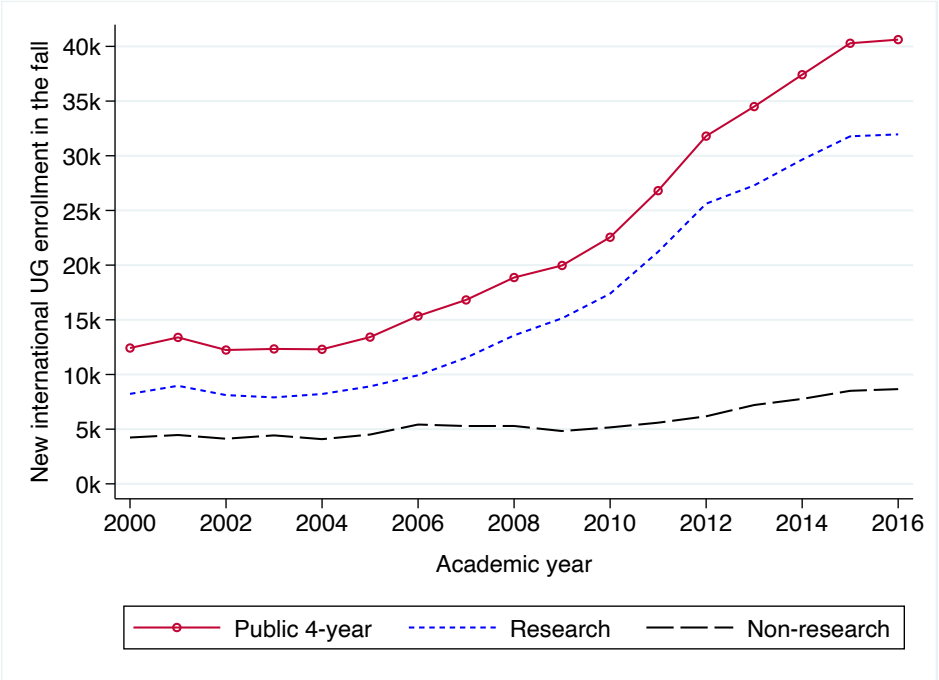
Figures and tables

Figure 1: International undergraduate enrollment in the US



(a) By top place of origin, enrollment stock



(b) By public four-year university type, new enrollment in fall

Note: Data for (a) include all undergraduate degree-granting institutions and are from the Institute of International Education, and data for (b) include public four-year universities only and are from IPEDS, both for the 2000/01 to 2016/17 academic years.

Table 1: The impact of education exports on domestic enrollment

	In-state			Out-of-state			Domestic graduates in 6 years
	OLS (1)	2SLS (2)	2SLS (3)	OLS (4)	2SLS (5)	2SLS (6)	2SLS (7)
New intl. student enrollment	−0.108	2.032**	2.248**	0.057	0.529	0.502	1.396**
	(0.101)	(0.912)	(0.953)	(0.068)	(0.378)	(0.386)	(0.704)
First-stage estimates							
SSIV		0.025***	0.024***		0.025***	0.024***	0.028***
		(0.005)	(0.005)		(0.005)	(0.005)	(0.008)
1^{st}-stage F-stat		30.78	28.08		30.78	28.08	36.93
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	No	Yes	No	No	Yes	Yes
Observations	3,817	3,817	3,817	3,817	3,817	3,817	2,030
No. of schools	358	358	358	358	358	358	358

Notes: Dependent variables are institutions' yearly change in the number of degree-seeking first-time in-state and out-of-state undergraduates entered in the fall semester. The independent variable of interest is the yearly change in the number of degree-seeking first-time international undergraduates entered in the fall. The SSIV, defined by equation (2), reflects an institution's exposure to yearly change in foreign purchasing power of US colleges based on historical networks. Controls include lagged population at age 18 and unemployment at the state-year level. Data include four-year, Title-VI, degree-granting, public institutions in 2005/06-2016/17 academic years. Regressions are weighted by total full-time enrollment in 2005. See Section 2.1 for more details on data. Standard errors, clustered at school level, are in parentheses. *** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level.

Table 2: 2SLS estimates for the impact of education exports on student spending

	Log expenditures on students					
	Per pupil (1)	Total (2)	Instruction (3)	Academic support (4)	Student services (5)	No. of new faculty hires (6)
New intl. student enrollment (×10)	−0.001 (0.002)	0.004* (0.002)	0.005** (0.002)	0.001 (0.003)	−0.002 (0.003)	1.011* (0.560)
1st-stage F-stat	27.46	27.46	27.46	27.46	27.46	21.11
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,737	3,737	3,737	3,737	3,737	3,125
No. of schools	358	358	358	358	358	352

Notes: Dependent variables are institutions' yearly change in total expenditures on students (broken down by instruction, academic support, and student services), per pupil total expenditures, and the number of new tenure-track faculty hires. All monetary dependent variables are in logs and are adjusted for inflation using the Higher Education Price Index. The independent variable of interest is the yearly change in the number of degree-seeking first-time international undergraduates entered in the fall. The SSIV, defined by equation (2), reflects an institution's exposure to yearly change in foreign purchasing power of US colleges based on historical networks. Controls include lagged population at age 18 and unemployment at the state-year level. The Cragg-Donald F-statistic on the SSIV in the first-stage is reported. Data include four-year, Title-VI, degree-granting, public institutions in 2005/06-2016/17. Regressions are weighted by total full-time enrollment in 2005. See Section 2.1 for more details on data. Standard errors, clustered at school level, are in parentheses. *** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level.

Table 3: 2SLS estimates for the impact of education exports on freshman SAT scores

	SAT Math		SAT Verbal	
	75^{th} pctl	25^{th} pctl	75^{th} pctl	25^{th} pctl
	(1)	(2)	(3)	(4)
New intl. student enrollment (×10)	0.629**	0.176	0.052	−0.123
	(0.298)	(0.282)	(0.269)	(0.248)
1^{st}-stage F-stat	24.30	24.30	24.30	24.30
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	2,639	2,639	2,639	2,639
No. of schools	320	320	320	320

Notes: Dependent variables are SAT quartiles of the freshman class in the fall by math and verbal. The independent variable of interest is the yearly change in the number of degree-seeking first-time international undergraduates entered in the fall. The SSIV, defined by equation (2), reflects an institution's exposure to yearly change in foreign purchasing power of US colleges based on historical networks. Controls include lagged population at age 18 and unemployment at the state-year level. The Cragg-Donald F-statistic on the SSIV in the first-stage is reported. Data include four-year, Title-VI, degree-granting, public institutions in 2005/06-2016/17. Regressions are weighted by total full-time enrollment in 2005. See Section 2.1 for more details on data. Standard errors, clustered at the school-level, are in parentheses. *** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level.

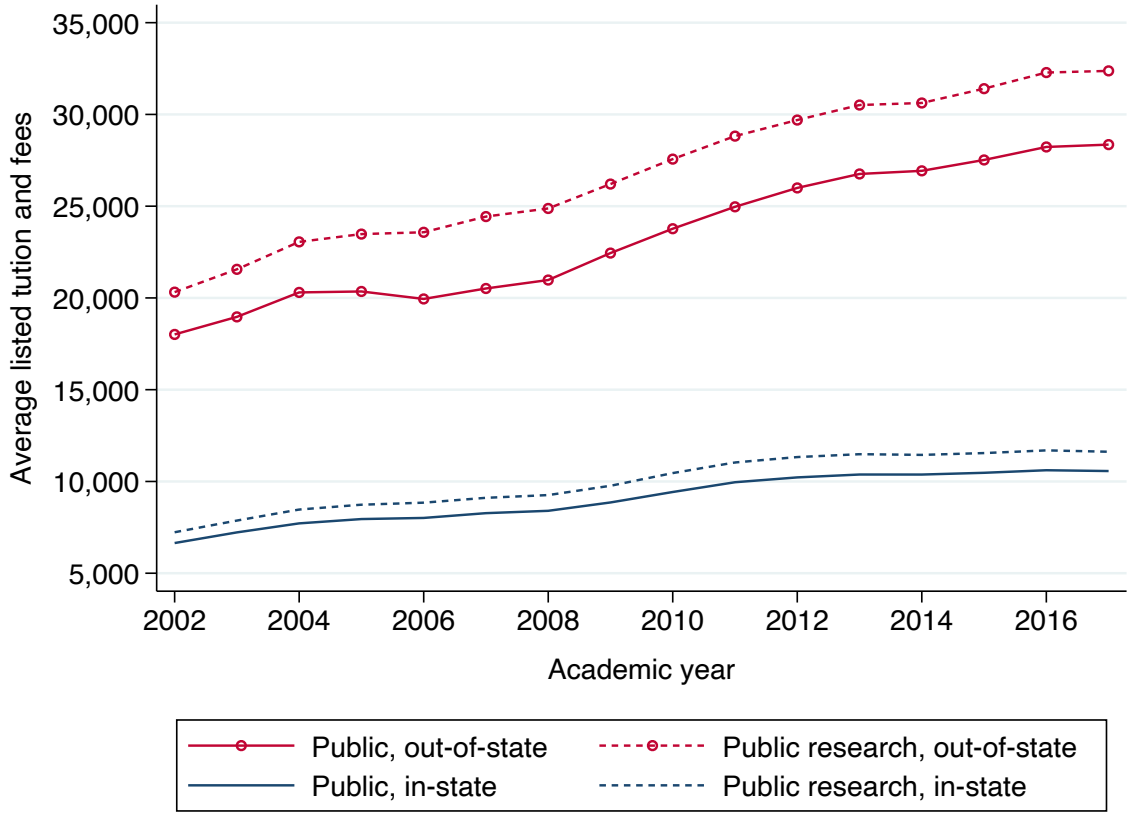
Table 4: The impact of education exports on state appropriations allocation

	Institutional type		
	All	Research	Non-research
	(1)	(2)	(3)
Panel A: 2SLS estimates			
New intl. student	−0.011***	−0.009**	−0.061
enrollment (×10)	(0.004)	(0.004)	(0.047)
1st-stage F-stat	30.21	11.68	3.21
Controls	Yes	Yes	Yes
Panel B: OLS estimates			
New intl. student enrollment (×10)		0.001**	0.001***
at peer institutions in the same state		(0.000)	(0.000)
Year FE	Yes	Yes	Yes
Observations	3,670	1,463	2,207
No. of schools	350	138	212

Notes: The dependent variable is state appropriations received by an institution. All monetary dependent variables are in logs and adjusted for inflation using the Higher Education Price Index. For Panel A, the independent variable of interest is the yearly change in the number of degree-seeking first-time international undergraduates entered in the fall. The SSIV, defined by equation (2), reflects an institution's exposure to yearly change in foreign purchasing power of US colleges based on historical networks. The Cragg-Donald F-statistic on the SSIV in the first-stage is reported. For Panel B, the indepdent variable of interest is the yearly change in new international undergraduates at peer institutions in the same state. Research institutions are classified based on Carnegie 2015 definitions of high or very high research activity. Controls include lagged population at age 18 and unemployment at the state-year level. Data include four-year, Title-VI, degree-granting, public institutions in 2005/06-2016/17. Regressions are weighted by total full-time enrollment in 2005. See Section 2.1 for more details on data. Standard errors, clustered at school level, are in parentheses. *** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level.

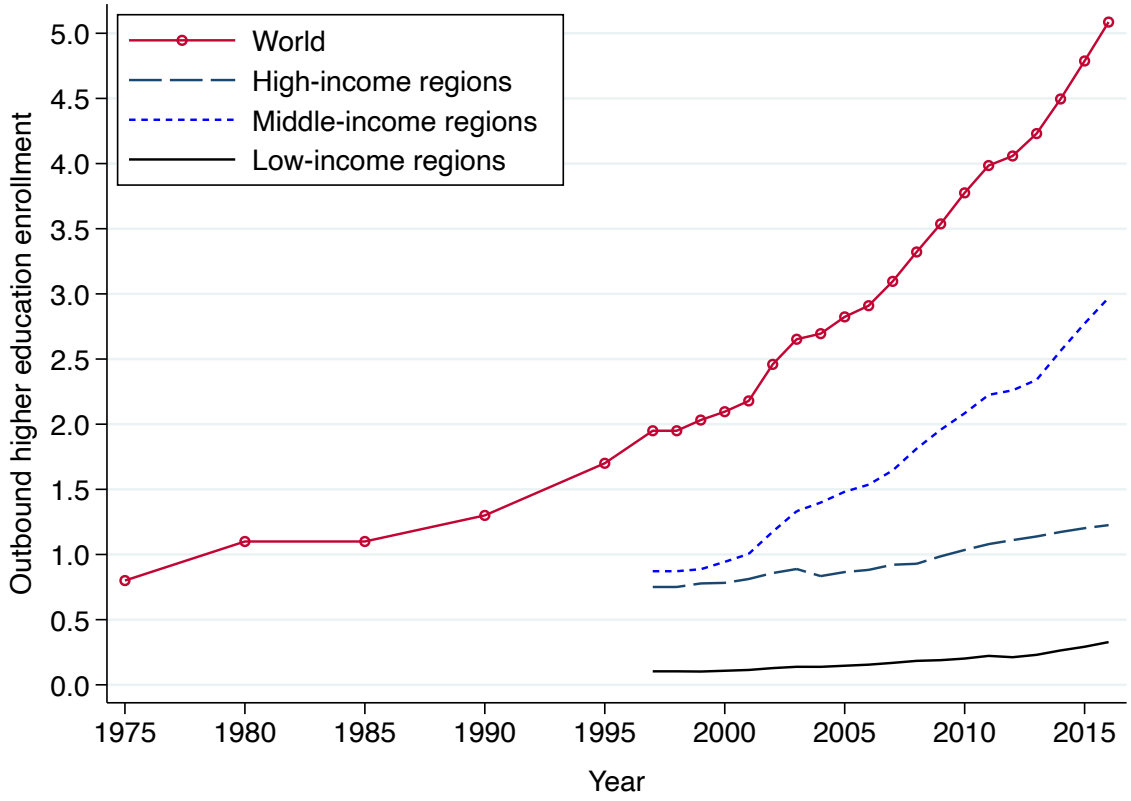
A Appendix figures and tables

Figure A.1: Listed undergraduate tuition and fees at public four-year institutions



Note: The figure shows the average published tuition and fees weighted by FTE reported in IPEDS at four-year year, Title-VI, degree-granting, non-online, and public four-year US institutions between 2002/03 and 2017/18 academic years. Prices are adjusted for inflation using the Higher Education Price Index in 2019 USD. Research institutions are classified based on Carnegie's 2015 definitions of high or very high research activity.

Figure A.2: Worldwide outbound tertiary education enrollment (millions)

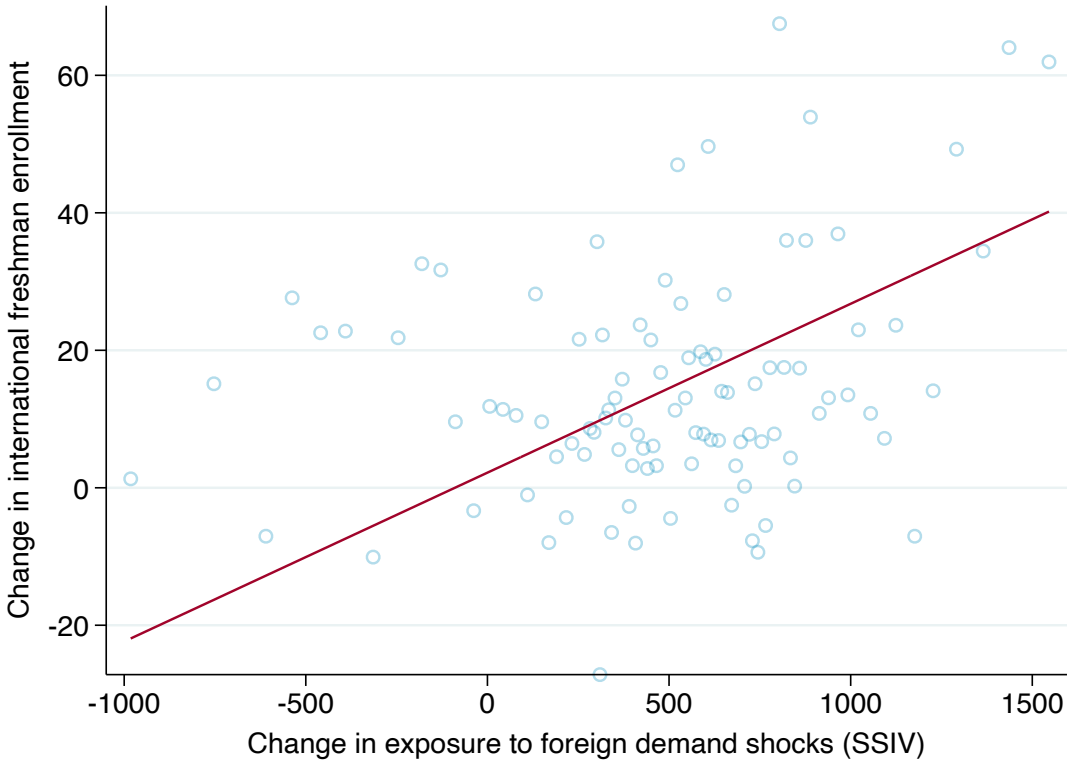


Data Source: The United Nations Educational, Scientific and Cultural Organization, and the Institute of International Education's Project Atlas for outbound enrollment data prior to 1997.

Figure A.3: Share of net tuition revenue from international students in total tuition revenue

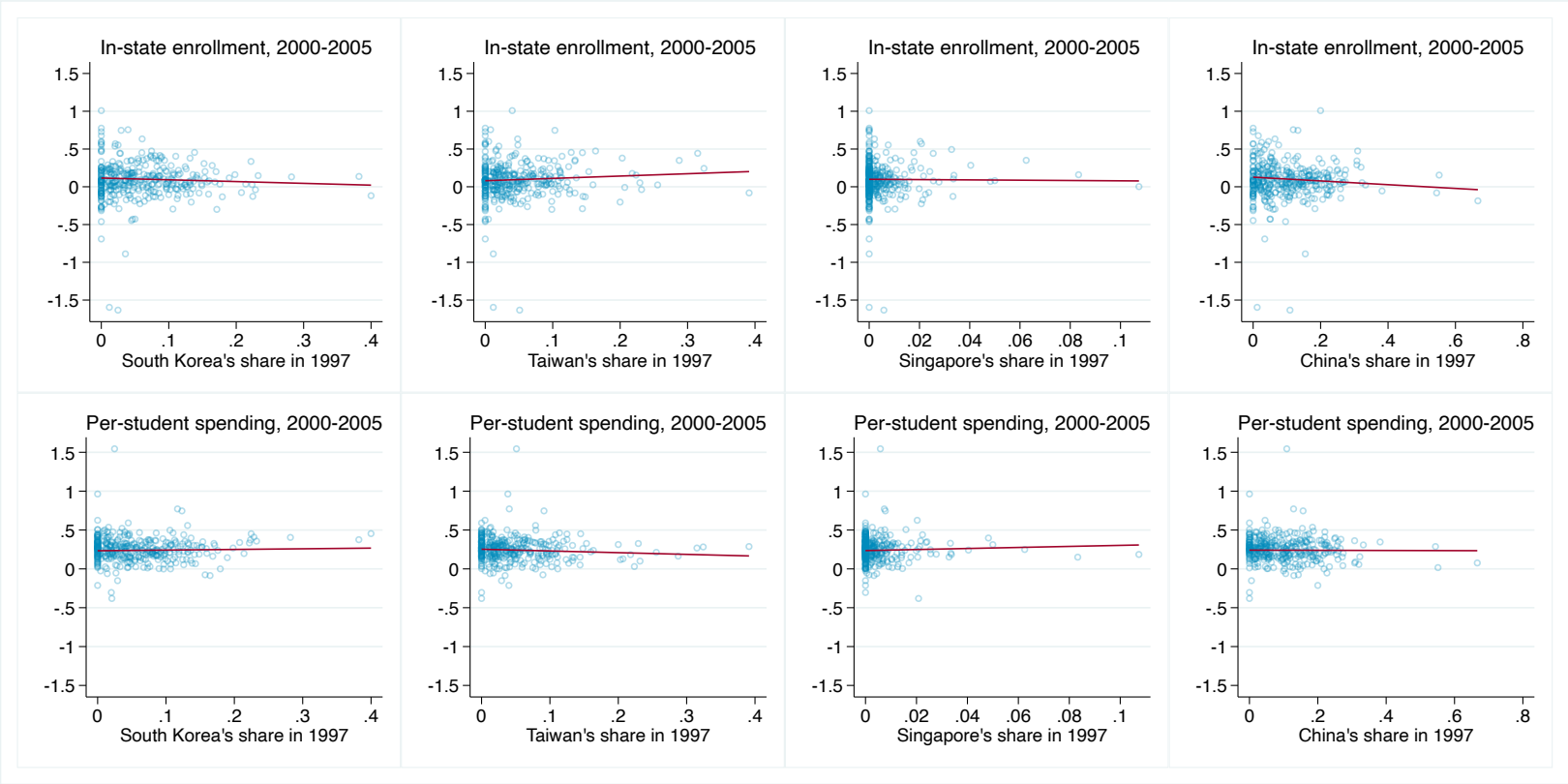
Note: Data on international students' tuition revenue net of institutional aid are from administrative data on F-1 visas obtained from ICE. Data on total tuition revenue are from IPEDS. The box plot shows percentiles of the revenue share distribution across public four-year universities weighted by FTE.

Figure A.4: Graphic presentation of the first-stage regression



Note: The figure shows a binned scatter plot of data on the change in international freshman enrollment, change in foreign demand shock IV, and the fitted line using the estimate from the first-stage regression in column 3 of Table 1.

Figure A.5: Correlation between initial shares of top PO and pre-trends in outcomes



Note: Changes in outcomes are measured in log change.

Table A.1: US trade in services by type in 2018

Service category	Exports (millions $)	Share in surplus	Rank in surplus %
Personal travel–Other	127,054	0.040	12
Professional & Mngmt consulting svc	86,828	0.151	2
Financial Mngmt, advisory, & custody svc	53,335	0.157	1
Use of IP–Industrial processes	45,287	0.078	7
Personal travel–Education	44,715	0.139	3
Research & development svc	42,555	0.031	13
Air transport–Passenger	41,465	-0.002	23
Business travel	38,813	0.086	5
Use of IP–Computer software	37,643	0.105	4
Technical, trade-related, & other business svc	36,438	0.026	15
Maintenance & repair svc	30,967	0.086	6
Credit card & other credit-related svc	25,766	0.063	10
Computer svc	24,455	-0.032	26
Use of IP–Trademarks & franchise fees	23,997	0.076	8
Use of IP–Audio-visual & related products	21,749	0.021	18
Secty lending, elec funds xsfer, & other fin svc	21,425	0.067	9
Government goods & svc	21,235	-0.007	24
Insurance svc	17,465	-0.096	27
Sea transport–Port	15,610	0.049	11
Air transport–Freight	15,333	0.024	16
Secty brokerage, underwriting, & related svc	11,489	0.024	17
Air transport–Port	11,390	-0.011	25
Information svc	9,386	0.026	14
Telecommunications svc	9,355	0.014	19
Other modes of transport	5,149	0.005	21
Personal travel–Health	4,097	0.006	20
Sea transport–Freight	3,903	-0.124	28
Use of IP–Other	72	0.000	22
Total service exports		826,981	
Total surplus in trade svc		259,660	

Source: Bureau of Economic Analysis.

Table A.2: Summary statistics (mean) by public institutional type in selected years

	All			Research			Non-research		
	2005 (1)	2011 (2)	2016 (3)	2005 (4)	2011 (5)	2016 (6)	2005 (7)	2011 (8)	2016 (9)
New undergraduate enrollment									
International	32	68	103	55	138	208	18	23	36
In-state	1,706	1,821	1,883	2,652	2,790	2,930	1,101	1,201	1,213
Out-of-state	312	381	453	593	738	904	132	152	164
Outcome of domestic cohort in 6 years									
Graduate	1,142	1,316	.	2,072	2,355	.	548	651	.
SAT of the freshman class									
Math 75th pctl	593	592	589	627	634	638	567	561	556
Math 25th pctl	483	481	478	517	520	521	456	454	448
Verbal 75th pctl	583	577	576	613	613	617	561	551	547
Verbal 25th pctl	473	466	466	503	498	504	451	444	440
Listed tuition and fees (2019 USD)									
In-state	7,688	9,387	10,085	8,689	10,828	11,522	7,049	8,467	9,166
Out-of-state	19,254	21,955	23,426	23,059	26,926	29,078	16,822	18,777	19,813
State appropriations (2019 USD, millions)									
State funding	133	112	116	254	212	218	57	47	50
Expenditures on students (2019 USD, millions)									
Instrutional	142	183	199	279	359	393	54	71	74
Accademic supp.	37	52	60	76	107	126	13	17	18
Student service	20	28	32	34	47	55	12	17	18
Total	200	264	291	389	512	574	79	105	110
No. of schools		359			140			219	

Notes: Data include four-year, Title-VI, degree-granting, public institutions observed in both IPEDS and IIE data. Monetary variables are adjusted for inflation in 2019 dollars using the Higher Education Price Index. Research institutions are classified based on Carnegie 2015 definitions of high or very high research activity. See Section 2.1 for more details on data.

Table A.3: Pre-trends test

	South Korea (1)	Taiwan (2)	Singapore (3)	China (4)
In-state	−0.237	0.309	−0.202	−0.248
	(0.211)	(0.235)	(0.849)	(0.167)
Per-student spending	0.084	−0.220	0.671	−0.010
	(0.175)	(0.247)	(0.789)	(0.137)
State pop 18	−0.043	0.006	−0.142	−0.069*
	(0.065)	(0.078)	(0.318)	(0.039)
Unemployment rate	1.074	−1.108	9.833	0.176
	(1.407)	(1.853)	(10.545)	(0.823)
State appropriations	−0.011	−0.095	−0.985	0.009
	(0.159)	(0.197)	(0.852)	(0.118)
Observations	361	361	361	361

Dependent variables are log change in in-state enrollment, per-student spending, population 18, unemployment rate and state appropriations for public institutions between 2000 and 2005. Standard errors, clustered at school level, are in parentheses. *** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level.

Table A.4: SSIV robustness checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				A. In-state freshman enrollment			
Exclude top 1 Rotemberg weight	3.654*						
	(1.892)						
Exclude China		2.340**					
		(1.013)					
Add state app. as a control			2.165**				
			(0.928)				
AKM SE test				2.248***			
				(0.607)			
Lagged SSIV					1.828		
					(1.630)		
					0.743		
					(1.772)		
Include 80 PO in share						2.603**	
						(1.235)	
Not weighted							2.780***
							(1.022)
1st-stage F-stat	8.46	23.98	28.88	28.08	3.22	16.20	18.75
Observations	3,745	3,817	3,711	3,817	3,745	3,827	3,711
				B. Log of per-student spending			
Exclude top 1 Rotemberg weight	−0.000						
	(0.000)						
Exclude China		−0.000					
		(0.000)					
Add state app. as a control			0.000				
			(0.000)				
AKM SE test				−0.000			
				(0.000)			
Lagged SSIV					0.000		
					(0.000)		
					−0.000		
					(0.000)		
Include 80 PO in share						−0.000	
						(0.000)	
Not weighted							0.000
							(0.000)
1st-stage F-stat	8.60	23.15	17.99	27.46	3.16	15.69	18.75
Observations	3,737	3,738	3,658	3,737	3,665	3,747	3,711
No. of schools	358	358	350	358	358	359	350

Notes: All columns include year fixed effects and controls. Clustered standard errors at school level are in parentheses. *** = p<0.01, ** = p<0.05, and * = p<0.1.

Table A.5: 2SLS estimates heterogeneity for the impact of education exports

	Live on campus		Research		Net tuition ratio	
	Yes	No	Yes	No	Above p50	Below p50
	(1)	(2)	(3)	(4)	(5)	(6)
	A. In-state undergraduate enrollment					
New intl. student enrollment	1.136	2.862**	2.997**	2.335	3.274**	1.806
	(0.935)	(1.333)	(1.445)	(3.231)	(1.570)	(1.532)
1st-stage F-stat	14.01	15.49	10.74	7.17	11.29	9.71
Observations	1,201	2,616	1,774	2,043	1,653	1,874
No. of schools	111	247	166	193	154	177
	B. Log of per-student spending					
New intl. student enrollment (×10)	0.001	−0.002	−0.001	0.008	−0.002	0.003
	(0.003)	(0.002)	(0.002)	(0.020)	(0.003)	(0.004)
1st-stage F-stat	14.20	15.47	12.06	2.07	12.11	8.82
Observations	1,169	2,568	1,758	1,979	1,620	1,846
No. of schools	111	247	166	193	154	177
	C. SAT math 75th pctl					
New intl. student enrollment (×10)	0.463	0.745*	0.828**	−1.590	1.382**	−0.047
	(0.438)	(0.379)	(0.386)	(1.547)	(0.542)	(0.519)
1st-stage F-stat	19.51	15.34	14.70	0.86	15.05	8.84
Observations	746	1,893	1,457	1,182	1,131	1,289
No. of schools	97	223	158	163	141	154
	D. Log of state appropriations					
New intl. student enrollment (×10)	−0.001	−0.019***	−0.012***	−0.071	−0.014***	−0.012
	(0.004)	(0.005)	(0.004)	(0.109)	(0.004)	(0.008)
1st-stage F-stat	19.51	15.34	14.70	0.86	15.05	8.84
Observations	1,140	2,528	1,735	1,933	1,583	1,835
No. of schools	108	242	164	187	149	176
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The net tuition ratio is the net tuition and fees for international students divided by net tuition and fees for in-state students, where net is defined as taking out institutional aid. The independent variable of interest is the yearly change in the number of degree-seeking first-time international undergraduates entered in the fall. Controls include lagged population at age 18 and unemployment at the state-year level. Data include four-year, Title-VI, degree-granting, public institutions in 2005/06-2016/17. Regressions are weighted by total full-time enrollment in 2005. Standard errors, clustered at school level, are in parentheses. *** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level.

Table A.6: 2SLS estimates for the impact of education exports on other outcomes

	Tuition and fees		
	In-state	Out-of-state	Institutional aid
	(1)	(2)	(3)
New intl. student enrollment (×10)	−0.004***	−0.001	−0.009
	(0.001)	(0.002)	(0.007)
1st-stage F-stat	22.57	22.57	28.27
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	3,684	3,684	3,795
No. of schools	358	358	358

Notes: Dependent variables are listed tuition and fees for in-state students, out-of-state students, and institutional aid. All monetary dependent variables are in logs and adjusted for inflation using the Higher Education Price Index. The independent variable of interest is yearly change in the number of degree-seeking first-time international undergraduates entered in the fall. The SSIV, defined by equation (2), reflects an institution's exposure to yearly change in foreign purchasing power of US colleges based on historical networks. Controls include lagged population at age 18 and unemployment at the state-year level. The Cragg-Donald F-statistic on the SSIV in the first-stage is reported. Data include four-year, Title-VI, degree-granting, public institutions in 2005/06-2016/17. Regressions are weighted by total full-time enrollment in 2005. See Section 2.1 for more details on data. Standard errors, clustered at school level, are in parentheses. *** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level.

Table A.7: Rotemberg weights by top 30 places of origin

	Rotemberg weights	
Country	In-state	Per student spending
South Korea	0.472	0.442
Taiwan	0.331	0.344
Singapore	0.159	0.154
Hong Kong	0.113	0.102
Indonesia	0.102	0.096
Kuwait	0.077	0.122
China	0.043	0.042
Germany	0.043	0.021
Turkey	0.016	0.014
United Kingdom	0.015	0.006
Saudi Arabia	0.012	0.021
Italy	0.009	0.011
Brazil	0.009	0.009
Israel	0.004	0.004
India	0.001	0.010
France	−0.006	−0.004
Columbia	−0.006	−0.007
Kenya	−0.006	−0.006
Greece	−0.006	−0.005
Spain	−0.007	−0.008
Pakistan	−0.007	−0.006
Bangladesh	−0.009	−0.008
Mexico	−0.010	−0.028
Japan	−0.012	−0.029
Thailand	−0.022	−0.023
Canada	−0.040	−0.024
Russia	−0.048	−0.045
Sweden	−0.054	−0.056
Venezuela	−0.060	−0.059
Malaysia	−0.114	−0.089

Table A.8: OLS estimates of the impact of education exports on student spending

	Log expenditures on students					
	Per pupil (1)	Total (2)	Instruction (3)	Academic support (4)	Student services (5)	No. of new faculty hires (6)
New intl. student enrollment (×10)	0.000 (0.000)	0.000* (0.000)	0.000 (0.000)	0.001 (0.001)	0.001 (0.000)	−0.068 (0.052)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,737	3,737	3,737	3,737	3,737	3,125
No. of schools	358	358	358	358	358	352

Notes: Dependent variables are institutions' yearly change in total expenditures on students (broken down by instruction, academic support, and student services), per-pupil total expenditures, and the number of new tenure-track faculty hires. All monetary dependent variables are in logs and adjusted for inflation using the Higher Education Price Index. The independent variable of interest is yearly change in the number of degree-seeking first-time international undergraduates entered in the fall. Controls include lagged population at age 18 and unemployment at the state-year level. Data include four-year, Title-VI, degree-granting, public institutions in 2005/06-2016/17. Regressions are weighted by total full-time enrollment in 2005. See Section 2.1 for more details on data. Standard errors, clustered at school level, are in parentheses. *** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level.