A Passage to America

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A Passage to America: University Funding and International Students[†]

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The number of international undergraduate students at US public research universities increased dramatically over the past two decades, alongside concurrent reductions in state support for universities. We show that these trends are closely connected as public research universities relied on foreign students to cushion the effects of falling appropriations. The growing capacity in emerging economies to pay for a US education provided opportunities for universities to recover revenues from full-fare-paying foreign students. We estimate that between 1996 and 2012, a 10 percent reduction in state appropriations led to an increase in foreign enrollment of 16 percent at public research universities. (*JEL* H75, I22, I23)

There have been substantial declines in state support for public higher education over the past few decades, with particularly dramatic declines occurring in the wake of recessions. Universities may choose to respond to such declines along a few margins, such as raising tuitions, reducing spending, or changing the mix of enrolled students toward those paying out-of-state tuition. At the same time, income growth in countries like China dramatically increased the pool of families with the capacity to pay out-of-state tuition at US universities. Since the beginning of the twenty-first century, the number of international undergraduate students in the United States increased markedly, rising by 98 percent from 288,000 students in 2000 to 570,300 in 2016 (Snyder, de Brey, and Dillow 2018). Indeed, students from China account for much of this increase, and they are disproportionately concentrated at public research universities. In this paper, we argue that public research universities cushioned the declines in state funding by markedly increasing the number of foreign students enrolled.

Public universities typically receive substantial state subsidies and have a mandate to provide collegiate opportunities to in-state students, which is usually fulfilled via below-cost tuition rates and preferential treatment in admissions. Domestic out-of-state and foreign students pay substantially higher tuitions at public universities than in-state students do. While the supply of domestic students willing to pay out-of-state tuitions is plausibly limited, the supply of foreign students, especially from China, is large and was growing over this period.

The broad hypothesis presented in this paper is that declines in state appropriations, in an environment of increasing demand from abroad, have driven the dramatic growth in full-fare-paying students from abroad at public research universities. We show that public research universities relied on foreign students to mitigate the effects of declining state appropriations. Increased demand for undergraduate positions at US universities driven by improvements in secondary educational attainment in China, and the increasing ability of Chinese families to pay for a US education, allowed research universities to enroll increasing numbers of qualified full-fare-paying students from abroad.

To support our argument, we present a model that illustrates how universities may balance educational objectives with the constraints of state funding and leverage the availability of out-of-state and foreign students to subsidize the education of in-state students. In the model, universities benefit from increases in the availability of talented students willing to pay out-of-state tuition, while declining state subsidies induce universities to increase their reliance on foreign students.

To measure the impact of changes in state appropriations on foreign enrollment, we leverage the considerable cross-state variation in the timing and the extent to which funding for higher education changed since the late 1990s. We use the aggregate of higher education appropriations within a state to address concerns that a university's funding may be an endogenous outcome of a complex bargaining process with the legislature.[1] The variation in a state's appropriations to other institutions often depends on fluctuations in the state's revenue cycles and spending priorities, like Medicaid (Bell 2008), and is plausibly exogenous to foreign enrollment at a particular university. We find strong evidence that appropriation cuts induced public research universities to increase reliance on foreign students. In our preferred estimates we find that a 10 percent drop in state appropriations induced a 16 percent increase in foreign student enrollment at public research universities.

In falsification tests, we find no indication of a greater increase in foreign enrollment at private universities in states experiencing declines in appropriations. As such, declines in appropriations provide an explanation for the greater increase in foreign enrollment at public research universities relative to comparable private institutions. In addition, we do not find effects at nonresearch public universities. Within states, there is often substantial stratification among institutions in resources, with research universities being more resource intensive. This variation is reflected in the extent to which student enrollment encompasses a local, regional, or national market. Thus, it seems reasonable to assume that research universities were in a

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[1] To be precise, we use appropriations to all *other* institutions in a state as an instrument for observed institutional appropriations.

position to attract out-of-state or foreign students, while nonresearch public universities were not.

We show how increases in the enrollment of foreign students generate substantial gains in tuition revenues for public research universities, which partially offset the loss in appropriations and mitigate the need to raise in-state tuition rates or cut expenditures. The response of foreign enrollment to declines in appropriations is larger than the response of out-of-state domestic enrollment, which is consistent with the interpretation that the pool of qualified students with the capacity to pay nonresident tuition levels from abroad is substantially larger than the pool of comparably prepared domestic out-of-state students. Our evidence suggests that the demand by foreign undergraduate students for places at US public research universities has helped these institutions adjust to declines in state funding.

In Section I, we review trends in international participation in US higher education at the undergraduate level and present evidence on the role of students from China in the recent expansion. In Section II, we outline the institutional features of the US market for higher education. In Section III, we present a conceptual framework of the enrollment and pricing decisions for public universities given their resource constraints and the availability of well-qualified students from different domiciles. Section IV outlines the empirical strategy. Section V presents empirical evidence that declines in appropriations induced research universities to increase their enrollment of foreign students. The final section concludes.

I. The Demand from Abroad and the Role of China

There is a long history of foreign participation in US higher education at both the undergraduate and graduate levels, though the cross-country patterns of flows have changed markedly over time.[2] Data from the International Institute of Education track enrollment at US colleges and universities by country of origin over time. In 1993, Japan (with 31,960 students enrolled in the United States), Canada (13,149), and South Korea (12,521) were the three largest source countries for enrollment among foreign students at US colleges and universities, but by 2013, the landscape changed appreciably, with Canada falling to fifth, Saudi Arabia[3] jumping to second (26,865), and China leapfrogging ahead of the others (110,550). In fact, the growth in undergraduate students from China accounts for most of the total increase in foreign undergraduates over this decade—from slightly fewer than 9,000 students in 2000 to more than 110,000 in 2013. Figure 1 illustrates the dramatic increase in students from China, with a sharp shift that begins around 2006.

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[2]The predominant visa permitting study in the United States is the F visa, which is a nonimmigrant visa requiring prospective students to receive and accept an offer of admission from a US college or university. Unlike work visas, such as the H-1B, F visas are not numerically constrained. Information on the enrollment of students from abroad comes from multiple sources, including the Department of Education's Integrated Postsecondary Education Data System (IPEDS) survey, the College Board's Annual Survey of Colleges (ASC), administrative data from the Department of Homeland Security on F visa recipients, and the Open Doors resource assembled by the International Institute of Education. The Data Appendix provides details on the strengths and weaknesses of these resources.

[3]The introduction of an explicit government fellowship for study abroad is clearly a contributing factor to the observed increase in enrollments among students from Saudi Arabia (Kurtz 2012).
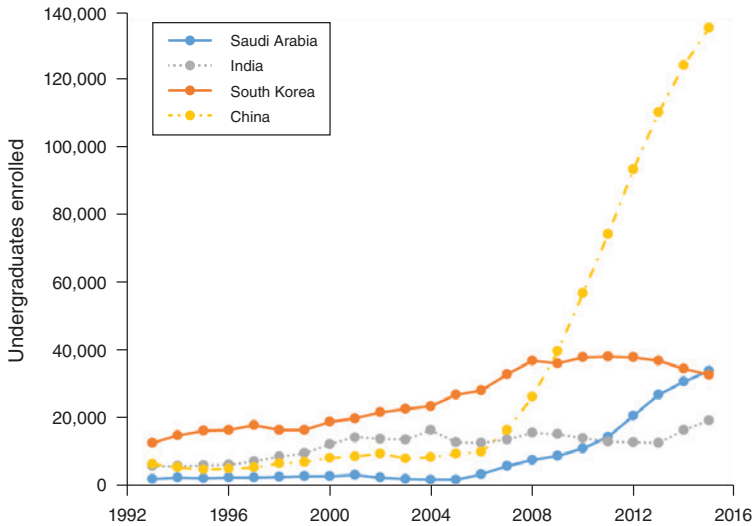
FIGURE 1. COUNTRY TRENDS IN FOREIGN UNDERGRADUATE ENROLLMENT
AT US HIGHER EDUCATION INSTITUTIONS, 1992–2015

Source: Open Doors (Institute for International Education), various years

The supply of students from abroad is a function of home- and destination-country education and labor markets (Rosenzweig, Irwin, and Williamson 2006). Plausibly, four broad factors affect this supply: the number of students who can afford the cost of pursuing a college degree abroad, the number of students completing secondary education and prepared for postsecondary study, the extent to which home countries are "constrained" in the availability of comparable-quality higher education, and the extent to which study in the United States provides an "option value" to the US labor market.

The capacity to pay for higher education is a potent factor in the flow of students to the United States at the undergraduate level. Unlike foreign doctoral students, who commonly receive full support in the form of fellowships, teaching assistantships, and research awards, foreign undergraduates are generally expected to make full tuition payments. Administrative data on F-1 visa recipients from China illustrate this point: for the 2010–2015 period, only 6.6 percent of undergraduate students from China at research universities received funding from the universities they attended (see online Appendix Table A1, panel B). A very small number of households in the Chinese population could afford undergraduate education in the United States until the late 1990s, when China began to experience rapid economic growth. With a fourfold increase in China's GDP per capita between 1996 and 2012 and an appreciation of the yuan starting in 2005, the percentage of Chinese families with incomes greater than the average amount charged by US public universities for out-of-state tuition and room and board grew from 0.005 percent in the year 2000 to approximately 0.032 percent by 2009. This growth continued exponentially such that by 2013 more than 2 percent of families were predicted to have such

incomes (online Appendix Figure A1).[4] These fractions closely track the fraction of college-age Chinese students studying in the United States. Other factors also led to an increase in the demand of Chinese students for a US college education. The Chinese government implemented a number of policies that made it easier for students using their own sources of funds to study abroad (Li and Zhang 2010), and in June 2005, Chinese and US authorities extended the terms of student visas to allow for multiple-entry 12-month visas, which reduced the administrative hurdles for Chinese students studying in the United States. For more details on the visa policy change, see US Department of State (2005).

The expansion of secondary education at a rate much greater than the growth of university supply in China also affects demand for collegiate study abroad. Between 1996 and 2012, secondary enrollment in China increased by 48.9 percent, from 63.8 million students to 95 million (UNESCO Institute for Statistics 2016). While China has roughly four times the population of the United States, it has less than half the number of higher education institutions listed in the World Higher Education Database. Figure 2 uses administrative data on F-1 visa recipients enrolled as undergraduates at US institutions by different levels of academic selectivity. We show the number of freshmen from China in panel A, and freshmen from China as a share of first-time undergraduate enrollment in panel B. With a few exceptions, Chinese enrollment was concentrated in strong public research universities, which tend to be somewhat less selective than the very top private research universities in the United States. The concentration of Chinese students at these public universities reflects their scale and capacity (panel A), and that there are few institutions in China of comparable quality.[5] While the more modest representation of Chinese students at the very strongest US private universities likely reflects limited admission opportunities, the lack of Chinese students at low-selectivity institutions likely reflects limited demand from abroad.

Between 2007 and 2012, public research universities experienced a 133 percent increase in freshman foreign undergraduate enrollment, while private research universities experienced a 61 percent increase. The observation that students from China have chosen to enroll at public universities in large numbers motivates our consideration of why these institutions have accommodated the growth in demand from foreign students.

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[4] These are the authors' calculations, based on income distribution data from the World Bank (2017) and average tuition and room and board charges for out-of-state students at public universities recorded in IPEDS; see online Appendix Figure A1 for details.

[5] Since the late 1990s there has been an expansion in the supply side of nonselective universities in China, during which enrollment increased from 3.1 to 20 million in approximately 10 years. Since Chinese students would have opportunities to enroll in comprehensive-level institutions in their home countries at a fraction of the cost, we see almost no Chinese enrollment in nonresearch US universities. Even as postsecondary options have increased somewhat in China and other Asian countries, expansion in enrollment among their top-tier universities has been very limited. Indeed, the selectivity of top universities in India and China—measured by applicants relative to admissions opportunities—is greater than that of the most elite private universities in the United States (LaFraniere 2009).

Panel A. Chinese F-1 visa recipients for
bachelor's degrees by university selectivity
(average 2010–2015)
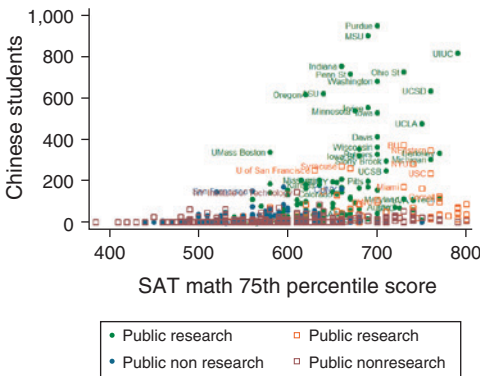
Panel B. Chinese F-1 visa recipients for
bachelor's degrees as share of first-time
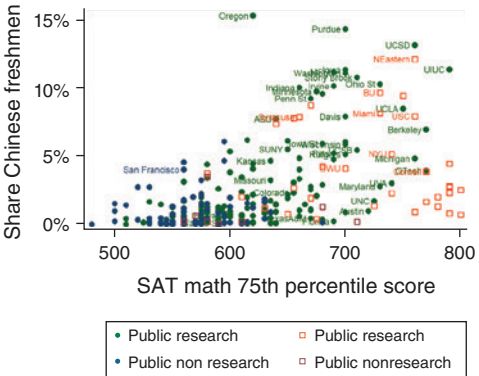undergraduate enrollment by university selectivity
(average 2010–2015)

FIGURE 2. CHINESE UNDERGRADUATE ENROLLMENT BY UNIVERSITY SELECTIVITY

Notes: Source is F-1 visa administrative data from US Citizenship and Immigration Services and first-time undergraduate enrollment from ASC and IPEDS. Panel B is restricted to universities with undergraduate enrollment greater than 1,500 in 2012. Research universities are those classified as having high or very high research activity by the 2010 Carnegie classifications. Nonresearch includes both doctoral universities with low research activity and master's universities. Panel A plots the number of Chinese students obtaining a student visa between 2010 and 2015 for the university. Panel B is the share (as a ratio of first-time undergraduate enrollment) obtaining a visa between 2010 and 2015.

II. Market Structure and Resources for Higher Education in the United States

Colleges and universities in the United States vary widely in terms of their resources and the extent to which they compete in national (or international) markets for students and faculty. Sources of support differ with institutional control. While private institutions rely on tuition revenues and (among the elite) endowment returns, public universities draw on state subsidies and tuition revenues with a more modest role for endowment returns. Of the 60 US universities that form the Association of American Universities (AAU), a long-standing organization of leading research universities, 34 are public universities. In exchange for funds provided by the state government, public universities have a mandate to provide collegiate opportunities to in-state students, which are usually manifested in below-cost tuition rates and preferential treatment in admissions.[6] Within states, there is significant stratification and specialization among the public institutions.

Trends in US Higher Education.—Over the past three decades, there has been a substantial decline in appropriations per student, from about $12,000 per full-time

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[6]Examples of the tuition for in-state versus out-of-state students at three selective public institutions in the 2014–2015 academic year include $13,208 (in-state) versus $42,394 (out-of-state) at the University of Virginia, $13,486 versus $41,906 at the University of Michigan, and $12,972 versus $35,852 at the University of California, Berkeley. Notably, the out-of-state tuition charges at these institutions approach those of similarly selective private institutions.
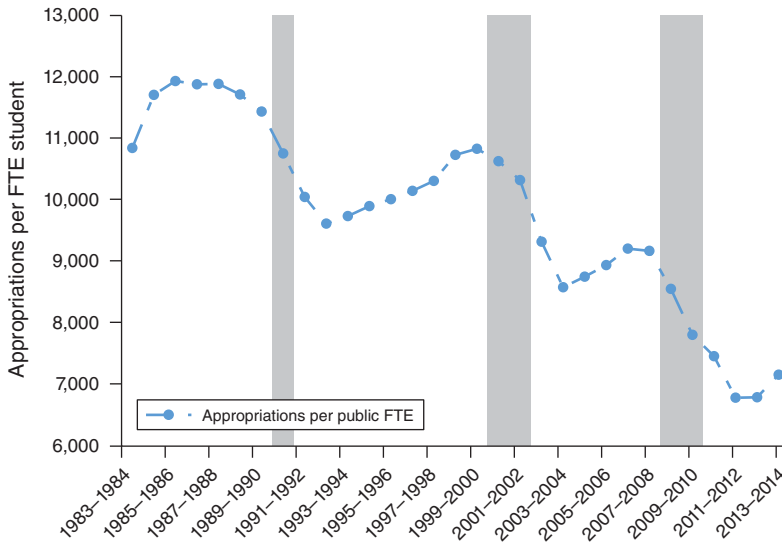
FIGURE 3. APPROPRIATIONS PER FTE STUDENT OVER TIME, 1983–2013

Notes: Gray bars show US recessions as enumerated by NBER. All figures are deflated by the Higher Education Price Index.

Source: College Board (2015) and Snyder, de Brey, and Dillow (2018), various years

equivalent (FTE) student in the mid-1980s to less than $7,000 per FTE student in the most recent year. The secular decline is punctuated by clear downward cycles following recessions in 1990, 2001, and 2008. For public universities, the balance between state appropriations and tuition revenues has shifted markedly over time toward greater reliance on tuition revenues. While this shift began in the 1990s, it accelerated with the Great Recession in 2008 (Figure 3).

The decline in constant dollar state appropriations led to a marked increase in the share of public universities' total educational revenues covered by net tuition revenue, a share that rose from 29.2 percent in 2001 to 47.8 percent in 2012 (State Higher Education Executive Officers Association 2017). Tuition and fees have risen at a much greater rate in recent years for in-state students at public universities than for students at private institutions. For example, between 2008–2009 and 2015–2016, inflation-adjusted tuition and fees increased by about 20 percent at private four-year institutions and about 31 percent at public four-year institutions (College Board 2015). States with the most severe economic downturns in the 2008 recession were among those in which public institutions raised tuition the most; in-state tuition increases were greatest at more selective institutions within each state (Barr and Turner 2013).

Beyond increasing revenues through raising tuition rates, some public universities may be able to increase the proportion of their student body that pays the full out-of-state tuition rate. Yet higher education policy experts have recognized that the "demand" from well-qualified domestic out-of-state students is modest, particularly

TABLE 1—SUMMARY STATISTICS, SAMPLE MEANS—SELECTED YEARS

	Type of public four-year university		
	Research	AAU	Nonresearch
Number of universities	137	34	294
2007			
First-year undergraduate enrollment (average)			
Number of foreign students	72	154	25
Number of in-state students	2,757	3,973	1,323
Number of out-of-state students	658	1,014	165
Revenues, 2013 constant dollar			
State appropriations	$241,331,146	$397,742,472	$58,255,327
Tuition revenue	$188,362,238	$338,900,270	$76,791,389
Share of own appropriations in total state appropriations (percent)	17.6	16.6	3.7
Tuition level, 2013 constant dollar			
Out-of-state tuition	$21,239	$26,329	$14,758
In-state tuition	$7,318	$8,555	$5,556
SAT I verbal: twenty-fifth percentile	502	538	445
SAT I math: twenty-fifth percentile	522	570	451
2012			
First-year undergraduate enrollment (average)			
Number of foreign students	168	441	30
Number of in-state students	2,754	3,900	1,353
Number of out-of-state students	798	1,158	164
Revenues, 2013 constant dollar			
State appropriations	$189,866,578	$298,381,649	$47,237,423
Tuition revenue	$256,562,687	$467,993,348	$101,000,567
Share of own appropriations in total state appropriations (percent)	16.2	14.8	3.4
Tuition level, 2013 constant dollar			
Out-of-state tuition	$24,375	$29,576	$16,596
In-state tuition	$8,875	$10,236	$6,656
SAT I verbal: twenty-fifth percentile	504	532	444
SAT I math: twenty-fifth percentile	527	579	457

Notes: Data are for four-year public universities. Monetary variables are deflated by the Higher Education Price Index and presented in 2013 dollars. Research universities are those classified as having high or very high research activity by the 2010 Carnegie classifications. AAU institutions are also research universities. Nonresearch universities include both doctoral low-research-activity universities and master's universities. Enrollment, test score, and tuition rate data are from the ASC.

Source: Tuition revenue and state appropriations data from IPEDS

for those public institutions that do not compete with top private universities.[7] At the same time, the growing pool of well-qualified students from abroad who are able to afford a US education would allow some public universities to use foreign enrollment as an important tool in recovering lost state appropriations while maintaining admissions criteria.

Indeed, our descriptive evidence, presented in Table 1, underscores these basic points about revenue sources and the flow of students from different geographies.

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[7]See Hoover and Keller (2011). There is considerable variation in the extent to which public universities draw domestic students from other states. For example, domestic out-of-state students constitute less than 5 percent of total domestic enrollment at the University of California, Davis, at the University of California, Irvine, and at Texas A&M, while they constitute more than 35 percent of domestic enrollment at the University of Michigan–Ann Arbor, at the University of Colorado Boulder, and at the University of Iowa.

We distinguish public universities by the scope and scale of their activities, including doctorate education and sponsored research. The columns of the table present different public university categorizations (research, AAU, and nonresearch)—the AAU set represents the most resource-intensive and selective public research universities[8]—while the top and bottom panels show measures for 2007 and 2012, respectively.[9] Across all institutional categories we see a rise in tuition revenue and a decline in state appropriations, and change is largest among the AAU universities. For research universities, the ratio of appropriations to tuition revenue declined from 1.28 to 0.75 over the period; at nonresearch universities, the ratio fell from 0.76 to 0.47. It is also the case that tuition levels increased, with the greatest percentage change for in-state students. Concurrently, we see dramatic changes in the representation of students from abroad (outside the nonresearch universities) and largely insignificant changes in the number of domestic out-of-state students. On the other hand, nonresearch four-year institutions enrolled a small number of foreign students in 2007, with little growth by 2012, even as overall enrollment increased modestly.

In online Appendix Figure A2, the states of California and Michigan illustrate a simple point. Across the California State University campuses, nonresident enrollment is low, perhaps as the quality of marginal out-of-state applicants is low. At the other extreme, the University of Michigan and the University of California, Berkeley, have access to a substantial pool of high-quality out-of-state domestic students. Other research universities, such as Michigan State University or the University of California, Davis, have access to a large pool of high-quality foreign applicants but face a rapid decrease in out-of-state applicant quality as they expand enrollment. As a result, declines in appropriations in the state of Michigan were associated with little change in foreign enrollment for the University of Michigan but a sharp increase at Michigan State.

III. A Conceptual Framework for Public University Decisions

A simple model illustrates the responses of public universities to changes in the state funding and the availability of students from abroad. Our model shows how the enrollment of well-qualified foreign students can subsidize the education of in-state students while declines in state appropriations magnify the value of enrolling foreign students.

In our model, the behavior of public universities and state legislators, each with a different objective function, reflects a principal-agent problem. Universities maximize the quality of education provided,[10] while legislators focus on the enrollment of in-state students and the provision of other government services subject to a budget constraint. Universities can respond to funding declines by changing the

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[8] Specifically, "research" includes the 136 public doctorate-granting universities that have high or very high research activity according to the 2010 Carnegie definition. AAU universities are a subset of research universities. There are 60 US-based AAU universities (34 are public), and these institutions award more than half of all US doctoral degrees.

[9] We focus on 2007 and 2012 to capture the period that coincided with state budget contractions over the recession.

[10] Alternatively, we could have modeled university administrators as caring only for the educational attainment of in-state students and would have come to similar conclusions.

composition of students to include more students paying the out-of-state rate (both foreign students and those from other states), increasing the in-state tuition charge, or decreasing educational resources, with the impact of each path of adjustment depending on the availability of well-qualified students of each type.[11] In the online Appendix, we present the detailed derivation of the model.

A. *Optimization Problem of a Public University*

In this section, we provide the model outline and key comparative statics in the context of a parametric setup; full details of the model are in the online Appendix. University administrators have an objective function focused on the quality of the education provided by the public university, defined as $q = q(I, \theta) = \alpha I + \theta$, where I is the per student educational resources, including infrastructure and staffing. The variable θ is a measure of the academic ability of the undergraduate student body, and $\alpha > 0$ reflects the association between per student resources and the quality of education provided by the university.[12]

The university administration determines student quality (θ) through the admission of undergraduate students and the setting of in-state tuition, where K_s, K_o, and K_f are the number of enrolled in-state, out-of-state domestic, and foreign undergraduate students and p_s is the in-state tuition. The quality of the student body (θ) depends on the supply of college applicants to the university. We assume that θ declines with increases in student enrollment, but the rate of decline depends on the quality of applicants from in state, out of state, and abroad.

Consistent with the large pool of foreign applicants, we assume that their quality does not decline as quickly with additional enrollment as the quality of domestic applicants. To represent the rapid decrease in quality of domestic applicants compared with foreign applicants, we assume that student body quality (θ) declines linearly as a university expands foreign enrollment but declines quadratically as it expands in-state and out-of-state enrollment. Thus, the derivatives of θ with respect to enrollment of different student types can be expressed as

$$(1) \qquad \frac{\partial \theta}{\partial K_f} = -\mu_f, \quad \text{and} \quad \frac{\partial \theta}{\partial K_j} = -\mu_j K_j \text{ for } j = s, o,$$

where the parameters μ_s, μ_o, and μ_f reflect the decline in the quality of students associated with the expansion of enrollment from each respective type. For foreign students the decline in quality is constant, and for domestic students it increases with enrollment, reflecting the assumption that declines in quality are increasing in quantity. Increases in the supply of highly qualified foreign students seeking admis-

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[11] In this paper and in the model, we focus on the role universities play in educating undergraduate students. We do not model graduate students. Doctoral students commonly receive financial support from universities, and universities face different trade-offs when enrolling PhD students. Master's programs are another means by which universities could increase revenues, but they are not the focus of our paper. See online Appendix Table A1 for results by degree level.

[12] Epple et al. (2017) presents a general equilibrium model of the market for undergraduate higher education, modeling both public and private colleges, which uses a similar framework. Unlike the existing literature, we describe the relationship between the university and state legislature as a principal-agent problem and incorporate foreign enrollment decisions into the university's set of choices.

sion to US schools (as more Chinese families can afford a US education) over this period would serve to decrease μ_f.

Finally, increases in in-state tuition levels are associated with a lower quality of in-state students; if the tuition is high, the best in-state students might seek alternatives either in private colleges or in higher-ranked state universities, thus decreasing the overall quality of the university. These assumptions produce the following partial derivatives:

$$(2) \qquad \frac{\partial \theta}{\partial p_s} = \pi(p_s - c) < 0,$$

where π is a positive constant, c is the marginal cost of enrollment, and $c > p_s$ for any p_s.

University Budget Constraint.—Public university revenue comes from tuition revenue—the in-state tuition and the out-of-state tuition (p_o), the latter of which is paid by both foreign and out-of-state domestic students—and from nontuition sources like appropriations. We assume that public universities take out-of-state tuition as given but do set the in-state tuition price p_s.[13] The university's revenue is

$$(3) \qquad Rev(K_s, K_o, K_f) = R(K_s) + p_s K_s + p_o(K_o + K_f),$$

where $R(\cdot)$ denotes the nontuition income of the public university. In our framework, it corresponds to state appropriations $R(K_s)$, which represent a contract set by the state legislature as a function of the enrollment of in-state students. This transfer from the state is an increasing function of the number of in-state students the university enrolls. We focus on contracts in which the state appropriation is a fixed piece-rate of in-state enrollment: $R(K_s) = \gamma K_s$. Piece-rate contracts are simple to analyze, create uniform incentives, and are observed in many real-world settings.

The cost function $c(K_s + K_o + K_f) + (\rho/2)I^2$ captures the cost of expanding enrollment and is strictly increasing in all arguments, with marginal cost c of enrollment being the same for all students. A constant $\rho > 0$ is associated with costs of per student resources. We assume that $p_o - c > 0$, as out-of-state and foreign students are net revenue generators for the university.

The Optimization Problem.—To maximize its objective function, the public university makes choices on in-state tuition, on the number of in-state, out-of-state, and foreign students to enroll, and, correspondingly, on how much to invest in educational resources. The choices must satisfy a budget constraint and a condition of nonnegativity of its inputs. The university's problem is defined as

$$\max_{I, p_s, K_s, K_o, K_f} q(I, \theta),$$

[13] It is reasonable to think that out-of-state tuition is set by the market because state universities have to set these tuitions to be competitive with the private sector. In contrast, it is natural to assume that state universities have some market power and, as such, have an incentive to raise in-state tuition in response to declining appropriations.

subject to the budget constraint

$$\gamma K_s + p_s K_s + p_o K_o + p_o K_f = c\left(K_s + K_o + K_f\right) + \frac{\rho}{2}I^2$$

and nonnegativity constraints

$$K_s, K_o, K_f, I, p_s \geq 0.$$

The first-order conditions are shown in detail in the online Appendix, and they provide some intuition regarding the decision of the public university. The marginal benefit of in-state students is the tuition they pay, p_s, as well as the increase in state appropriations associated with higher in-state enrollment γ, whereas the marginal benefit of foreign and out-of-state students is the tuition they pay, p_o, which is higher than the tuition paid by in-state students. The marginal cost of each type of student is the expense of enrolling an additional student as well as the monetized cost of the decrease in the quality of the current student body associated with expanding enrollment. The marginal benefit of investments I is the monetized benefit of an increase in the quality of education provided by the university.

B. *State Legislature's Decision Problem*

The determination of the appropriations rule from the state $R(K_s) = \gamma K_s$ follows from the legislature's maximization of its objective function, which weighs the number of in-state students enrolled in a public university against the provision of other public goods (g). We assume that a state legislature has a Cobb–Douglas preference over these two goods: $K_s^\beta g^{1-\beta}$, where $0 < \beta < 1$ is the state preference for higher education.

The state budget constraint is $Y = \gamma K_s + p_g g$, where Y is the exogenous state (disposable) revenue, p_g is the price of the public good provided by the state, and γK_s is the level of state appropriations to public universities. The state legislature chooses a state appropriation contract γ and a provision of a public good g:

$$\max_{\gamma, g} K_s^\beta g^{1-\beta}.$$

When making their appropriation decisions, state legislatures must consider the optimal strategy of university administrators and the university's budget constraint.

Solution, Comparative Statics, and Heterogeneity.—We demonstrate that the optimal enrollment of out-of-state students is $K_o^* = \mu_f / \mu_o$, which decreases with the quality of marginal foreign students applying to the university and increases with the quality of marginal out-of-state students applying to the university (see online Appendix 3 for the derivation). The intuition is that universities turn to domestic out-of-state students if they are relatively more qualified than foreign students.

Further, using the optimization conditions for the state legislature, we can predict equilibrium state appropriations as a function of the parameters of the model:

$$(4) \qquad R^* = \frac{\beta}{2-\beta} Y,$$

where university revenue from state appropriations is an increasing function of exogenous state (disposable) revenue and the legislature's preference for higher education.

Finally, we derive equilibrium foreign enrollment as a function of model parameters:

$$(5) \qquad K_f^* = \frac{p_o - c}{2\rho}\left(\frac{\alpha}{\mu_f}\right)^2 - \frac{\mu_f}{\mu_0} - \frac{\pi\mu_s(p_o - c)}{\mu_f^2 + \pi\mu_s(p_o - c)^2}\frac{\beta}{2-\beta}Y.$$

Equation (5) is consistent with our empirical specifications used in Section IV:

- *The number of foreign students rises as state appropriations fall*: a fall in state revenue Y is associated with a decline in appropriations (equation (4)), which consequentially leads to a rise in foreign enrollment. This result follows from the fact that additional tuition revenue provided by foreign students to finance operations works as a substitute for the subsidies from the state government. Drops in appropriations will increase the relative value of foreign students.
- *Universities respond to appropriations cuts with higher foreign enrollment when they have access to qualified students from abroad*: an increase in the supply of highly qualified foreign students to a university is characterized by a fall in μ_f (from equation (1)). Our model predicts that the response of foreign enrollment to appropriation shocks is bigger when μ_f is small (i.e., the magnitude of dK_f^*/dY is larger). In the same way, we expect that nonresearch universities, which have limited access to foreign student applicants (high μ_f), do not increase foreign enrollment much when faced with budget shocks.

Other predictions of the model align with the empirical specifications, including the determination of the in-state tuition charged by the public university p_s^* as

$$(6) \qquad p_s^* = c - \left(\frac{\mu_f}{\pi(p_o - c)\left[1 + (\mu_s/\mu_f^2)\pi(p_o - c)^2\right]}\frac{\beta}{2-\beta}Y\right)^{\frac{1}{2}}.$$

Equation (6) is also consistent with our empirical specifications used in Section IV:

- *Universities increase in-state tuition as state appropriations fall:* a fall in state revenue Y is associated with declines in appropriations (equation (4)), which consequentially lead to a rise in in-state tuition p_s^*.
- *Adjustments to in-state tuition are smaller when universities have access to qualified students from abroad*: dp_s^*/dY is attenuated when universities have

significant access to foreign students, with a relatively unconstrained flow of foreign students represented by a smaller μ_f. Thus, an expanding pool of foreign students serves to lessen the increase in in-state tuition in response to appropriation declines.

IV. Empirical Framework

Our empirical approach focuses, first, on regressions that show the link between changes in state appropriations and enrollment by domicile. If public universities are using out-of-state and foreign students to cushion the effects of appropriation cuts, then we should see that universities suffering the largest budget cuts are the ones most likely to adjust enrollment composition, disproportionately enrolling foreign students. But the capacity to adjust on this margin will be limited to those universities that are able to offer an educational product recognized on a national and international market. Examination of how institutional adjustments in finances, including tuition revenues and expenditure categories, adjust to changes in state appropriations illustrates the mechanism, demonstrating how expenditure categories and tuition prices respond differently to changes in appropriations. In our setup, we address the concern that institution-level changes in appropriations are endogenous by using an instrumental variables (IV) strategy that draws on state budget mechanics.

Estimation Model.—We use a panel of institutional observations for public universities and regress university-level outcomes on appropriations, cohort size, and state economic conditions. Observations are at the level of the university (i) and the year (t), and our preferred specification is

$$(7) \qquad y_{it} = \beta_0 + \beta_1 App_{it} + X_{it}\lambda + \gamma_t + \delta_i + \varepsilon_{it},$$

where y_{it} is the outcome of interest, App_{it} represents institutional-level appropriations, X_{it} are state-level time-varying controls, and γ_t and δ_i are year- and institution-specific fixed effects. The variation we use is therefore unaffected by secular changes in the entire economy and institution-specific time-invariant characteristics. The year fixed effects control for the overall increase in the demand for a college education from domestic and foreign applicants, with year fixed effects in specifications for each group of universities accounting for overall changes in demand for universities in the group. Among the state-level controls is a measure of the population at age 18, which may capture institutional capacity.[14] Evidence indicates that college-age populations strongly drive in-state enrollment patterns

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[14] State trends in the number of high school graduates and potential college-age students vary widely. For example, from 1970 to 2004, college-age populations declined in Iowa (-22 percent) and Ohio (-18 percent), while they increased substantially in Texas ($+56$ percent) and California ($+42$ percent). States that experienced declines in the number of potential in-state students over time have particularly strong incentives to draw students from out of state. On the other hand, states like Texas and California, which have experienced large-scale population growth since the middle of the twentieth century (when many investments in public higher education were made), are less likely to have excess capacity.

(Bound and Turner 2007). We use the basic specification to study the effects of state appropriations on enrollment by domicile and on finance variables, such as instructional expenditures and tuition levels. Our institution-year observations are weighted by the undergraduate population at baseline (1996).[15]

There are a few reasons why an ordinary least squares (OLS) regression might not capture the causal effect of state appropriations on foreign enrollment. First, there may be unobserved university characteristics correlated with foreign enrollment and state funding. For instance, a successful university administrator might make qualitative changes (such as a curricular reorganization) that affect both the university's desirability to foreign students and state legislators' willingness to provide state funding to the university. Second, state legislators may punish schools that enroll more foreigners by cutting their funding, inducing some reverse causality. Last, growing universities may see concurrent increases in both funding and the number of foreign students.

In order to address these potential endogeneity issues, we use variation in appropriations at the *state level* assigned to all other universities in the state (total state-level appropriations minus a university's own appropriations). The higher education budget is often described as a "balance wheel" of state budgets, as many states determine the amount of appropriations to colleges and universities by what is left over after other spending priorities (Bell 2008). The variation in higher education budgets is derived from the interplay between a state's revenue cycle and spending obligations. This interpretation is consistent with the literature, which indicates that a major determinant of state appropriations is the cyclical pressures from federal programs with state-level matching features, like Medicaid (Kane, Orszag, and Apostolov 2005). Excluding a university's own appropriations from the aggregate addresses the concern that big universities might represent a substantial share of state-level appropriations in smaller states.

State-level appropriations might be problematic if, for example, employment growth in a state both boosts state budgets and affects enrollment decisions of domestic in-state or out-of-state students, which might feed back into less need or room for foreign students.[16] We provide evidence that this is not an issue in our empirical framework. We demonstrate that our main results are unaffected, and are often stronger, with the inclusion of a rich set of controls: the state unemployment rate, the share of the population below the poverty line, whether the governor is a Democrat, the nonfarm employment growth rate, the population at age 18 for neighboring states, the state-level personal income per capita, and median wages of employed workers with at least a bachelor's degree by age group. While it is natural to worry about the possibility that unobserved factors might be biasing our estimates, adding controls tends to have little effect on estimated effects.[17]

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[15] We show in online Appendix Table A4 that our results are robust to not weighting the regressions. The table also shows the reduced-form regression of our proposed instrument on foreign enrollment.

[16] McHugh and Morgan (1984) and Kennan (2015) document the migration of domestic students across US states according to employment growth and expected lifetime income, and these time-varying controls may help account for changes in state-level economies.

[17] Here it is worth noting that the bias in IV estimates due to specification error will be inversely proportional to the strength of the first stage (Bound, Jaeger, and Baker 1995; Conley, Hansen, and Rossi 2012). Budgetary

We show that these trends are not driven by international student preferences: foreign students are *not* more likely to attend private universities in states suffering economic-downturn-driven state appropriation cuts. Our results are stronger when we exclude the state of California, which has historically had a disproportionately high Asian population. In alternative specifications we explore a distributed lead-lag model and additional instruments, such as a state's disposable revenue and a university's baseline dependence on appropriations interacted with a state's higher education budget.

Even though we do not model the dynamic response of universities to changes in state appropriations, some lag in the enrollment response is expected as it takes admissions offices time to gear up to evaluate foreign applicants. At the same time, most of the variation in the state appropriations measure we use as an instrument is of low frequency, and our fixed-effect estimators are designed to reflect this variation.[18] As such, our estimates should be interpreted as reflecting the behavior of state universities in the presence of persistent appropriation changes.

V. Empirical Results

A. *Effects of State Appropriations on Foreign Enrollment*

The questions motivating our analysis concern how declines in state appropriations are accommodated by changes in the composition of undergraduate enrollment across the public sector given the expansion of the pool of foreign students in recent decades. Institution-level regressions of total first-time foreign enrollment on appropriations, including additional institutional and time-varying effects, are shown in Table 2 for the period 1996–2012. We present these results for two main groupings of institutions: public research universities and public universities outside the research sector. We also report results for the subset of AAU research universities, which generally produce more pronounced adjustments than the broader aggregate. Enrollment measures are derived from institution-level surveys from the Department of Education's IPEDS survey and the ASC. Recognizing the concern that appropriations changes may be endogenously related to other institution-level adjustments affecting the composition of enrollment, we focus on the estimates using state higher education appropriations minus the own-institution value as an instrument for the institution-level measure (with the first-stage estimates in the bottom panel). We include the OLS estimates for comparison.

There is a strong, consistent, and negative link between appropriations changes and the enrollment of foreign students at public research universities but no such link outside this sector during this interval. With a specification in logs, we find that a 10 percent decline in state appropriations corresponds to a 16 percent increase in the representation of foreign students at the undergraduate level across all research

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shortfalls experienced by states over the period of our study produce substantial variation within states over time in the overall state appropriations variable used as an instrument.

[18] We employ Fourier decomposition methods following Baker, Benjamin, and Stanger (1999) to analyze the time series properties of our state-level appropriation measure. We find that over 70 percent of the variance occurs at the lowest two frequencies identified in the data.

TABLE 2—EFFECTS OF LN(STATE APPROPRIATIONS) ON LN(FIRST-YEAR FOREIGN ENROLLMENT), 1996–2012

| | Dependent variable: ln(foreign first-year enrollment) | | | | | |
| | Research | | AAU | | Nonresearch | |
Explanatory variable	OLS	IV	OLS	IV	OLS	IV
Panel A. OLS and Second Stage						
ln(state appropriations)	−0.617	−1.596	−0.720	−2.180	0.088	0.608
	(0.180)	(0.642)	(0.286)	(0.908)	(0.156)	(0.403)
ln(population 18)	0.128	0.484	−1.167	−0.665	0.437	0.292
	(0.323)	(0.424)	(0.716)	(0.693)	(0.422)	(0.710)
R^2	0.350		0.634		0.063	

| | Dependent variable: ln(state appropriations) | | |
Explanatory variable	Research	AAU	Nonresearch
Panel B. First stage			
ln(appropriations of other universities in the state)	0.303	0.415	0.710
	(0.072)	(0.097)	(0.093)
R^2	0.571	0.623	0.625
Partial R^2	0.0953	0.159	0.250
F-statistic	17.69	18.35	58.60
Observations	2,121	547	3,162
Number of universities	136	34	285

Notes: Overall state appropriations to higher education minus own appropriation is used as an instrument for institution-level state appropriations in the IV regressions. A levels-log version of this regression is in the online Appendix. All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors, reported in parentheses, are clustered at the university level in the OLS and at the state level in the IV. Enrollment data are from the ASC. University-level appropriations are from IPEDS. State-level appropriations are from the State Higher Education Executive Officers Association (2017). Population data are from the Census in 1991, 2001, and 2011. Research universities are those classified as having high or very high research activity by the 2010 Carnegie classifications. AAU institutions are also research universities. Nonresearch institutions include both doctoral low-research-activity universities and master's universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau.

universities. As a point of reference, the OLS results tell a similar story with somewhat attenuated point estimates (the difference between OLS and IV is never close to statistically significant). These estimates imply that the drop in appropriations that state universities experienced over the 2007–2012 period can explain just over 60 percent of the increase in representation for foreign students at research universities and the subset of AAU universities.[19]

The graphic presentation over the period from 2005 to 2012 in Figure 4 helps to anchor the negative relationship between total appropriations at the state level and foreign enrollment among public research universities, with a focus on the AAU institutions. While the basic negative relationship for public universities is clear, there is also a significant amount of heterogeneity. For instance, for the same state-level budgetary shock, Michigan State significantly increased foreign enrollment, while the University of Michigan did not. One plausible reason is that the University of Michigan consistently attracts well-qualified domestic out-of-state students (around

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[19] To calculate the fraction explained for each university subgroup over the period, we take the product of the estimated IV–two-stage least squares coefficient and the average change in appropriations and divide this predicted change in foreign enrollment by the total actual change in foreign enrollment.
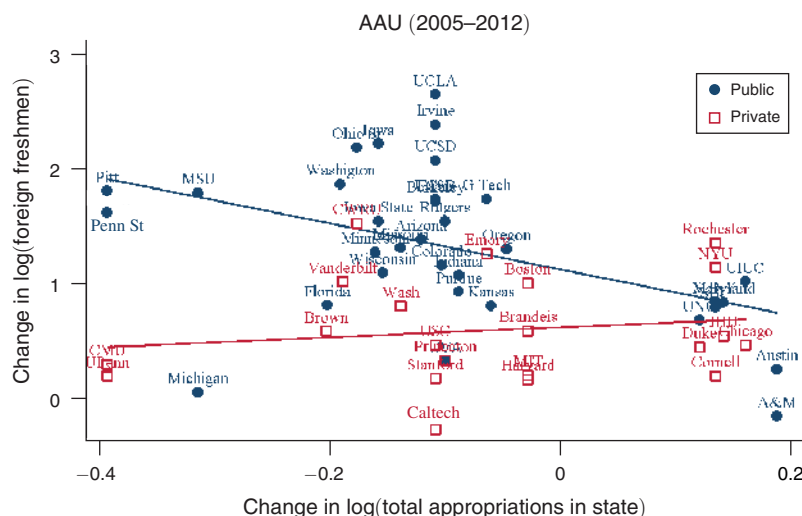
FIGURE 4. FOREIGN ENROLLMENT AND STATE-LEVEL APPROPRIATIONS TO HIGHER EDUCATION: AAU UNIVERSITIES, 2005–2012

Notes: Sample comprises the 60 research universities that are part of the AAU. Changes in log(foreign freshmen) are university-level changes in first-year students from abroad. Changes in log(total appropriations in state) are state-level measures for changes in total appropriations to all public universities in the state between the financial years 2005–2006 and 2012–2013.

Source: Foreign freshmen data are from the ASC; total appropriations in a state are from the State Higher Education Executive Officers Association (2017)

30 percent of total freshmen), whereas Michigan State does not (only 10 percent of total freshmen).

If foreign students had state-specific preferences, one might expect to see a parallel response in private peer institutions. Regression results using state-level appropriation on foreign enrollment at private universities show no negative link between state appropriations and foreign enrollment (online Appendix Table A3). The contrast between public and private responses is evident in Figure 4.

We are able to use the student-level data from the F visa issuances to reproduce these specifications. The F visa data have the advantage of distinction by country of origin and the measurement of graduate enrollment distinguished at the master's and doctoral levels, though there is the disadvantage of a shorter interval, limited to 2004 to 2012. Our results are not only consistent with the baseline results presented in Table 2 but also provide strong confirmation that the role of the expanding pool of Chinese students is central to this adjustment mechanism. The estimated enrollment elasticity for Chinese students is about -2.6 at all research universities and is indistinguishable from zero at the nonresearch institutions (online Appendix Table A1, panel A).[20] Significantly, enrollment of foreign master's students, who

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[20] Online appendix Table A1 is based on F-1 visa data from the US Citizenship and Immigration Services, and these data are available only from 2004.

generally pay full fare, has an elasticity of -1.4, while the result is insignificant at the doctoral level.

B. *Alternative Specifications*

A number of specification alternatives confirm the tenor of these results and, in the interest of parsimony, are presented in the online Appendix. First, consideration of the dependent variable either as a level (number of students) or as the foreign share among all first-time students also yields the negative relationship between appropriations and enrollment at the research institutions and little measured effect outside this sector (online Appendix Table A2). Second, we demonstrate that our results are robust to the inclusion of the long list of additional state-level controls, which are correlated with state economic activity (online Appendix Table A4).[21]

Finally, we explore alternative IV strategies to solidify our approach. The first strategy reflects differential dependence on state appropriations among universities within the same state. For instance, in 1996, state appropriations reflected more than 50 percent of the educational expenditures budget for each of the University of California campuses, while appropriations provided 13 percent of education expenditures at the University of Virginia and 17 percent at the University of Michigan. Following the analysis in Deming and Walters (2017) of attainment at broad-access postsecondary institutions, we also construct an instrument using the product of the baseline budget share of appropriations (in 1996) and the aggregate state-level appropriations for higher education (online Appendix Table A5, panel A). These results are consistent with the main findings of the paper presented in Table 2.

Second, we use a state's disposable revenue (general revenue net of entitlements) as an instrument for university-level appropriations (online Appendix Table A5, panel B), consistent with the notion that state budgetary cycles are driving the variation in question. State disposable revenues are likely orthogonal to political pressure for increasing higher education funding. While this instrument displays a weaker first stage, the results are consistent with our main specification. Again, all the results are in accordance with the finding that research universities increase foreign enrollment as a response to declines in appropriations. In online Appendix Table A5, panel C, we show that our results are robust to using the entire higher education budget (including a university's own appropriations).

Online Appendix Figure A3 plots estimates from a regression of log(foreign first-year enrollment) on lags and leads of log(state appropriations) to universities using the IV approach described in Section IV. Consistent with our identifying assumptions, future appropriation cuts cannot predict current increase in enrollment of foreigners. In fact, research and AAU universities take on average one year to react to appropriation cuts.

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[21] Our results from Table 2 are unaffected when we drop California schools. California is the state with the biggest East Asian and Chinese population in the United States, and these schools may benefit the most from the increase in family incomes in China. We estimate an even stronger relationship between state appropriations and foreign enrollment for research universities when we exclude California schools from our sample.

Overall, these findings are consistent with our underlying hypothesis and conceptual framework: when state appropriations decline, public research universities are more likely to admit foreign students because the marginal benefit of adding foreign students (and associated tuition revenues) increases. For those public colleges and universities outside the research sector, the absence of a link between changes in state appropriations and foreign student enrollment persists, which is consistent with the interpretation that nonresearch universities tend to be more locally focused than the research universities and have limited capacity to attract foreign students.

Given the increases in demand from foreign students for positions in US research universities, it seems likely that foreign enrollment rates at US universities—both public and private—would have increased significantly even were it not for the drop in state appropriations that has occurred over the past two decades. However, the evidence we have presented is consistent with the expectation that the growth at public universities would have been substantially less dramatic and less concentrated at the research universities experiencing declining state appropriations had state funding remained unchanged.

C. *Effects on Domestic In-State and Out-of-State Enrollment*

In addition to increasing the representation of students from abroad, universities might respond to appropriations changes with other adjustments to undergraduate enrollment on the margins of in-state and out-of-state enrollment. Table 3 considers these specifications in format parallel to that of Table 2. The overall story line is that there is little adjustment on these margins, with coefficients on appropriations that are statistically indistinguishable from zero and, overall, small in magnitude. The absence of an effect on out-of-state domestic students, another source of revenue from out-of-state tuition, is consistent with the proposition that the supply of academically qualified domestic full-pay students at the enrollment margin for most public universities is modest.[22] Also, given these results, we have no reason to expect that any changes in foreign enrollment are driven by changes in domestic enrollment in the wake of falling appropriations.

It is important to emphasize that our results focus on initial undergraduate enrollment at four-year universities, which represent a subset of all public postsecondary institutions.[23] Deming and Walters (2017) present estimates of a negative effect of changes in state appropriations on total enrollment, with the measure of total enrollment defined for all levels of enrollment and the estimates presented for all postsecondary institutions (including community colleges). Results in other

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[22] There were increases in out-of-state enrollment at the University of California, Los Angeles, and the University of California, Berkeley, which are two of the best public universities in the country. While historically restricted by state policy to be committed to California residents, these schools reevaluated their admission decisions, likely due to budget considerations. Other top public universities, like the University of Michigan and the University of Virginia, had consistently enrolled out-of-state domestic students.

[23] Using the 2010 Carnegie classification, we define research universities as belonging to the categories "very high research activity" and "high research activity," while nonresearch universities include those classified as "doctoral universities" and "master's universities." Not included in our analysis are specialized institutions or local degree-granting institutions classified as "baccalaureate." Our aim in choosing the institutional types for analysis is to group institutions that might be expected to follow broadly similar production functions.

TABLE 3—EFFECTS OF LN(STATE APPROPRIATIONS) ON LN(IN-STATE FIRST-YEAR ENROLLMENT) AND LN(OUT-OF-STATE FIRST-YEAR ENROLLMENT) OF UNDERGRADUATES, 1996–2012

| | Dependent variable: ln(out-of-state first-year enrollment) | | | | | |
| | Research | | AAU | | Nonresearch | |
Explanatory variable	OLS	IV	OLS	IV	OLS	IV
Panel A						
ln(state appropriations)	0.045	0.064	0.095	−0.715	−0.018	−0.492
	(0.135)	(0.327)	(0.256)	(0.518)	(0.134)	(0.266)
ln(population 18)	−0.678	−0.685	−0.580	−0.302	−0.541	−0.409
	(0.233)	(0.295)	(0.521)	(0.529)	(0.319)	(0.267)
R^2	0.248		0.231		0.041	

| | Dependent variable: ln(in-state first-year enrollment) | | | | | |
| | Research | | AAU | | Nonresearch | |
Explanatory variable	OLS	IV	OLS	IV	OLS	IV
Panel B						
ln(state appropriations)	0.098	0.226	0.053	−0.148	0.116	0.031
	(0.052)	(0.173)	(0.059)	(0.111)	(0.050)	(0.096)
ln(population 18)	0.626	0.580	0.509	0.577	1.051	1.075
	(0.096)	(0.139)	(0.103)	(0.080)	(0.151)	(0.230)
R^2	0.397		0.376		0.336	
Observations	2,121		547		3,162	
Number of universities	136		34		285	

Notes: For the first stage of the IV regression, see Table 2. Overall state appropriations to higher education minus own appropriation is used as an instrument for institution-level state appropriations in the IV regressions. All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors, reported in parentheses, are clustered at the university level in the OLS and at the state level in the IV. Enrollment data are from the ASC. University-level appropriations are from IPEDS. State-level appropriations are from the State Higher Education Executive Officers Association (2017). Research universities are those classified as having high or very high research activity by the 2010 Carnegie classifications. AAU institutions are also research universities. Nonresearch universities include both doctoral low-research-activity universities and master's universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau.

work (Bound and Turner 2007, Barr and Turner 2013) show that the accommodation of resource changes and cyclical student demand differs markedly across postsecondary institutions, with open-access public institutions such as community colleges demonstrating greater supply-side elasticity in enrollment than research universities.[24] To this end, economic theory and available empirical evidence suggest that changes in state appropriations for higher education may have impacts on domestic enrollment in other contexts, including for community colleges and among older students.

Focusing on public research universities, we find that within this group there is heterogeneity in the response in foreign enrollment to appropriations changes that is related to institutional selectivity, research intensity, and scope of the domestic market (Table 4).[25] First, public research universities with higher baseline math

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[24] Barr and Turner (2013) shows that local economic conditions (such as the unemployment rate) have a substantial impact on enrollment at community colleges, including substantial increases in the participation of older students.

[25] We also report Chernozhukov and Hansen (2008) reduced-form *p*-values for the instrument in this table to address concerns when the first stage is limited in strength.

Table 4—Effects of ln(State Appropriations) on ln(Foreign First-Year Enrollment) of Undergraduates, 1996–2012, Research Universities, Heterogeneous Effects—IV Specification

	Dependent variable: ln(foreign first-year enrollment)						
	Math SAT 75th percentile		Fraction of expenditure for research		Fraction of students from out of state		
Explanatory variable	High	Low	High	Low	Low	Medium	High
ln(state appropriations)	−2.542	−0.047	−3.164	0.710	−1.276	−2.242	−1.543
	(0.874)	(0.512)	(0.891)	(0.728)	(1.382)	(0.702)	(1.009)
ln(population 18)	0.306	−0.103	0.184	−0.476	1.125	0.454	0.396
	(0.886)	(0.468)	(0.542)	(0.603)	(1.062)	(0.826)	(0.332)
C&H p-value	0.000	0.931	0.000	0.357	0.326	0.008	0.169
Observations	867	906	1,014	958	691	692	718
Number of universities	55	57	63	63	44	45	45
Partial R^2	0.173	0.055	0.138	0.067	0.094	0.129	0.070
F-test of IV	23.96	6.598	22.570	6.942	15.76	12.00	5.603

Notes: Overall state appropriations to higher education minus own appropriation is used as an instrument for institution-level state appropriations in the IV regressions. Samples are defined on the basis of baseline (1996) characteristics. High and low are defined as above or below median when the sample is split in half. Low, medium, and high are defined by thirty-third percentile when sample is split in thirds. All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors, reported in parentheses, are clustered at the state level. C&H p-values are the Chernozhukov and Hansen (2008) p-values from reduced-form regressions. Data on test scores and enrollment are from the ASC. University-level appropriations and expenditures data are from IPEDS. State-level appropriations are from the State Higher Education Executive Officers Association (2017). Research universities are those classified as having high or very high research activity by the 2010 Carnegie classifications. AAU institutions are also research universities. Nonresearch universities include both doctoral low-research-activity universities and master's universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau.

SAT scores have the ability to attract qualified students from abroad. Second, universities that spend a larger fraction of their total expenditures on research-related activities, at baseline, also do a better job of accommodating a fall in funds by enrolling more foreign students. Both of these findings are consistent with the interpretation that demand from foreign students is limited to those institutions that would clearly dominate most home-country options. Last, we explore heterogeneity along the baseline ability to attract domestic out-of-state students. Here we expect that the universities that most aggressively pursue foreign students will be those that are outside the very top tier but are capable of attracting a substantial number of domestic out-of-state students. While the contrasts in this last set of columns are not precisely estimated, this is exactly the pattern that emerges. Our interpretation of these results is that universities that have a very low baseline attraction for domestic out-of-state students find it difficult to recruit students from abroad. Consistent with the conceptual framework discussed in Section III, those with a very high baseline ability to enroll full-paying domestic students find it less necessary to look abroad when they can recruit these students from other states. It is, therefore, in the universities that lie in between that we see the strongest associations between declining appropriations and rising foreign enrollment.

While a common question that follows from observation of the growth in the enrollment of foreign students is whether these students "crowd out" domestic students (Machin and Murphy 2017), the declines in the appropriations that are the

focus of this analysis affect in-state tuition charges. Thus, any correlational relationship between foreign enrollment and in-state enrollment represents the net effect of changes in tuition charges, institutional resources, and other unobserved factors, as well as the direct effect of foreign students. With these limitations in mind, in online Appendix Table A6, we show a negative association between the number of foreign students enrolled and the number of in-state students enrolled in research and AAU universities. Two additional foreign students are associated with one less in-state student. While these estimates should not be interpreted as causal, our model suggests that crowd-out effects can occur even when university administrators care about the quality of the education in-state residents obtain.[26]

D. *State Appropriations and University Finances*

Changes in state appropriations directly affect university budget constraints. Absent other channels of adjustment in university revenues, declines in state appropriations would have a negative effect on measures of expenditures—particularly those related to undergraduate education. Our interest is in understanding how such effects may be moderated by other channels of adjustment—either changing the composition of student enrollment by expanding the matriculation of foreign students or increasing the tuition charged.

Consider the basic accounting relationship between changes in appropriations and changes in expenditures, which is reflected in regressions of expenditures (by category) on appropriations (Table 5). Focusing first on the instructional categories, the link between appropriations and expenditures on instructional activities (panel A1) is much stronger at nonresearch universities (with an elasticity of 0.2) than at research universities, where 0 is well within the confidence interval. As expected, there is no link between appropriations and research expenditures, whereas support services are sensitive to appropriations at all types of institutions, with elasticities ranging from 0.22 at AAU universities to 0.40 at nonresearch universities (online Appendix Table A7, panel A2).

Revenue-side adjustments to changes in appropriations are limited by market forces: the capacity and willingness of students to pay the price of attendance. Across research and nonresearch institutions, declines in appropriations are tied to increases in in-state tuition charges, with elasticities ranging from -0.327 among AAU universities to -0.261 among the nonresearch universities (Table 5, panel B1). Because universities have considerably more market power with in-state students than with out-of-state students, it is not surprising that there is no clear statistical connection between out-of-state charges and state appropriations, reflecting the constraints of the market (Table 5, panel B2).[27] Changes in tuition revenues represent the aggregation

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[26] Because the representation of in-state students affects the subsidies received by public universities, the number of in-state students affects the administrators' allocative choices, as does the impact of resources on the overall quality of education for all students.

[27] The greater changes in in-state relative to out-of-state tuition levels likely reflect the observation that universities have more "market power" with in-state students than out-of-state students, who are comparing public universities with private universities across geographic markets. Increases in in-state tuition are likely muted by strong political forces and by the economic consideration that the net tuition revenue generated by a tuition increase will be less than dollar-for-dollar as financial aid obligations increase with higher tuition levels.

TABLE 5—EFFECTS OF ln(STATE APPROPRIATIONS) ON UNIVERSITY FINANCIAL VARIABLES, 1996–2012

Expenditure variables	Research	AAU	Nonresearch
Panel A1. ln(expenditures for instruction)			
ln(state appropriations)	0.088	−0.017	0.226
	(0.082)	(0.058)	(0.035)
ln(population)	0.036	0.010	−0.094
	(0.077)	(0.168)	(0.073)
ln(FTE)	0.342	0.105	0.287
	(0.094)	(0.132)	(0.052)
R^2	0.874	0.918	0.894
Panel A2. ln(expenditures for research)			
ln(state appropriations)	−0.012	0.026	−0.013
	(0.175)	(0.127)	(0.192)
ln(population)	−0.066	0.057	−0.799
	(0.131)	(0.186)	(0.498)
ln(FTE)	0.279	−0.175	0.367
	(0.181)	(0.186)	(0.196)
R^2	0.523	0.908	0.165
Observations	1,904	492	3,853
Number of universities	126	32	262

Revenue variables	Research	AAU	Nonresearch
Panel B1. ln(in-state tuition)			
ln(state appropriations)	−0.264	−0.327	−0.261
	(0.047)	(0.087)	(0.034)
ln(population)	0.334	0.376	0.134
	(0.089)	(0.234)	(0.087)
ln(FTE)	−0.006	−0.189	0.058
	(0.078)	(0.081)	(0.036)
R^2	0.935	0.955	0.923
Panel B2. ln(out-of-state tuition)			
ln(state appropriations)	−0.075	−0.114	−0.052
	(0.052)	(0.079)	(0.033)
ln(population)	0.134	0.513	−0.236
	(0.084)	(0.187)	(0.085)
ln(FTE)	−0.044	−0.075	0.014
	(0.082)	(0.128)	(0.034)
R^2	0.903	0.933	0.827
Observations	2,103	532	4,438
Number of universities	136	34	293

Notes: OLS regressions, including institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors, reported in parentheses, are clustered at the state level. Data on expenditures and appropriations are from IPEDS. Data on tuition rates and enrollment are from the ASC. Research universities are those classified as having high or very high research activity by the 2010 Carnegie classifications. AAU institutions are also research universities. Nonresearch universities include both doctoral low-research-activity universities and master's universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau. Expenditures for instruction include compensation for academic instruction, while expenditures for research include operating expenses associated with research activities, research centers, and individual and project research.

of price changes and changes in numbers of students paying different prices. There is a clear negative relationship between appropriations and tuition revenues (online

Appendix Table A7, panel B1) at the research universities (-0.185 for research and -0.269 for AAU). There is a common pattern of substantial increases in in-state tuition levels, more modest increases in out-of-state tuition charges, and growth in foreign enrollment; for the 2007–2012 interval, these patterns are evident graphically (online Appendix Figure A4). A different framework for viewing these results is with tuition revenues as the dependent variable and enrollment as the key explanatory variable. We find a positive relationship between foreign first-year enrollment and tuition revenues (online Appendix Table A8), with elasticities varying from 0.02 at research universities to 0.07 at selective AAU institutions. Importantly, having access to a ready pool of foreign students may mute increases in in-state tuition rates or cuts to expenditures.[28] In times when there were more foreign students who were able to afford tuitions charged by US institutions (2005 onward), the responsiveness of tuition rates and expenditures to appropriations is smaller (online Appendix Table A9). However, since there may be other differences across the two time periods, these cross-period comparisons should be taken to be suggestive.

E. *Heterogeneity and Adjustment Channels to Appropriation Changes*

Our results demonstrate that changes in the flow of students from abroad and increases in the price charged to in-state students are the primary channels through which universities moderate declines in state appropriations. The capacity to reduce the impact of appropriation declines varies with an institution's market position: public universities with national and international recognition have the capacity to increase the intake of foreign (and, potentially, out-of-state) students while also potentially increasing tuition charges. Local and regional institutions likely have fewer options to the extent that there is little foreign (or out-of-state) demand, while the capacity to raise in-state tuition to increase revenue is limited by the presence of comparable options and the capacity of students to pay, as students attending these colleges are more likely to be from low- to moderate-income families than their peers attending flagships.

Just how quantitatively important are these channels of adjustment to different universities? Looking at the period from the pre–Great Recession academic year 2007–2008 to 2012–2013, we consider the change in tuition revenues per student generated from the following sources: (i) the change in the share of foreign undergraduates, (ii) the change in the share of out-of-state undergraduates, (iii) the change in the tuition charged to foreign and domestic out-of-state students, and (iv) the change in tuition charged to in-state students. This decomposition is

$$(8) \qquad \Delta \frac{Tuition\,Revenue}{Students} \; = \; \left(\Delta s_o \times \bar{D}_t \right) + \left(\Delta s_f \times \bar{D}_t \right) + \left(\bar{s}_o \times \Delta D_t \right)$$
$$+ \left(\bar{s}_f \times \Delta D_t \right) + \Delta T_i,$$

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[28] Shih (2017) finds evidence suggesting that the expansion in enrollment of *graduate* students from abroad contributes to growth in domestic student enrollment, with these effects being largest at institutions with high relative tuition paid by students from abroad.

where D_t is the difference between in-state and out-of-state tuition, s_o is the domestic out-of-state share of total undergraduate enrollment, s_f is the foreign share of enrollment, $1 - s_o - s_f$ is the in-state share of enrollment, and T_i is in-state tuition. Overbar notation represents an average over two years, while delta indicates the change over time. We deflate all monetary variables by the Higher Education Price Index.

Table 6 shows this decomposition for two research and two nonresearch universities in five states: California, Wisconsin, Indiana, Michigan, and New York. The first five columns show each right-hand-side term divided by the total change in tuition revenue per student to show the percent of the tuition revenue change accounted for by each component. The final two columns show the change in (potential) tuition revenue per undergraduate student and the change in appropriations per undergraduate student. Changes in total tuition revenues make up a sizable share of the loss in state appropriations and, in a few cases—such as Purdue University, Michigan State University, and the University of Michigan—changes in total tuition revenue actually exceeded the negative shock in appropriations.

This accounting exercise shows the sources of change in tuition revenues: research universities have a diversity of revenue sources, including changing the composition of undergraduate students to include more students from abroad, while nonresearch universities rely on the in-state price to affect tuition revenues. What is striking are the within-state differences in the extent to which changes in the price charged to in-state students are the primary source of revenue generation. Outside the research sector, the change in the in-state price dominates. The factor represents more than 99 percent of the tuition revenue increase at California State University, Fullerton, and Northern Michigan University while more than accounting for the total change at University of Wisconsin–La Crosse and Central Michigan University. The picture differs at the research universities, particularly those in the AAU level, where the increased price charged to domestic students is a more modest share of the total increase in revenues. At Purdue University and Indiana University, this share is less than 40 percent, while an appreciable share of tuition revenue gains comes from increases in the share of foreign students.

While we do not wish to underplay the importance of in-state tuition changes for nearly all universities, the research universities are distinguished by their capacity to draw revenue from increased foreign enrollment. In effect, this source of revenue lessened the need to raise resources from in-state charges.

VI. Conclusion

Concurrent with the erosion of state support for public higher education (which has occurred to different degrees across the United States), there has been a substantial increase in the pool of students from abroad who are academically college ready and have the financial capacity to enroll. In many developing countries, and most notably in China, home-country options for postsecondary study at the research university level are far more limited than student demand. In the aggregate, there is no question that US colleges and universities have absorbed some of this increase in demand with the evident growth in foreign undergraduate enrollment.

TABLE 6—DECOMPOSING PER STUDENT CHANGES IN TUITION REVENUES, 2007–2012—SELECTED UNIVERSITIES

Institution name	Type	$\Delta s_f \times D_t$ (percent)	$\Delta s_o \times D_t$ (percent)	$s_f \times \Delta D_t$ (percent)	$s_o \times \Delta D_t$ (percent)	ΔT (percent)	$\Delta\left(\frac{Rev}{Ugrad}\right)$	$\Delta\left(\frac{App}{Ugrad}\right)$
California universities								
California Polytechnic State University	Nonresearch	1	17	0	0	81	4,158	−3,993
California State University, Fullerton	Nonresearch	1	0	0	0	100	3,079	−3,378
University of California, Berkeley	Research	22	3	1	1	73	6,863	−11,864
University of California, Los Angeles	Research	18	14	1	1	67	7,191	−13,315
Indiana universities								
Indiana University Northwest	Nonresearch	−2	12	1	8	81	708	−2,363
Purdue University Fort Wayne	Nonresearch	6	−36	3	19	107	464	29
Indiana University Bloomington	Research	29	−26	8	49	39	3,223	−1,878
Purdue University	Research	35	14	4	13	35	4,656	−364
Michigan universities								
Central Michigan University	Nonresearch	5	−25	5	12	104	−422	−943
Northern Michigan University	Nonresearch	3	−4	0	6	94	1,285	−793
Michigan State University	Research	26	4	5	10	55	3,871	−3,666
University of Michigan–Ann Arbor	Research	7	9	6	36	42	5,108	−3,085
New York universities								
SUNY Buffalo State College	Nonresearch	4	0	8	12	76	880	−1,052
SUNY College at Cortland	Nonresearch	2	0	1	5	92	926	−1,125
SUNY University at Albany	Research	16	0	2	4	79	989	−771
SUNY University at Buffalo	Research	27	0	16	5	52	1,978	−5,790
Wisconsin universities								
University of Wisconsin–La Crosse	Nonresearch	3	0	−1	−8	105	2,158	−2,939
University of Wisconsin–Oshkosh	Nonresearch	1	10	−1	−3	92	1,067	−1,322
University of Wisconsin–Madison	Research	15	10	0	2	73	3,283	−2,076
University of Wisconsin–Milwaukee	Research	7	16	5	12	60	2,368	−783

Notes: All changes are 2007 to 2012. Variables are as follows: s_f is the share of the undergraduate population that is nonresident alien, s_0 is the share of the undergraduate population that is out-of-state domestic students, ΔT is the change in in-state tuition rates, D_t is the tuition differential between out-of-state and in-state tuitions, $\Delta(App/Ugrad)$ is the change in appropriations per undergraduate between 2007 and 2012, and $\Delta(Rev/Ugrad)$ is the change in tuition revenues per undergraduate between 2007 and 2012. Enrollment and tuition data are from the ASC. Appropriations and revenue data are from IPEDS. Research universities are those classified as having high or very high research activity by the 2010 Carnegie classifications. Nonresearch universities include both doctoral low-research-activity universities and master's universities. Values in the first four numerical columns add up to 100 percent.

This analysis demonstrates that within-state declines in appropriations have disproportionately affected the accommodation of the expanding pool of foreign students by US colleges and universities. We estimate that a 10 percent reduction in state appropriations leads to a 16 percent increase in the enrollment of students from abroad at public research universities and a slightly larger increase of about 22 percent at the more resource-intensive AAU universities. There is no systematic accommodation at public colleges and universities outside the research university sector. Evidence presented in this analysis suggests that expanding foreign enrollment at the undergraduate level is an important channel through which public research universities buffer changes in state appropriations. While additional revenue from in-state tuition increases appears to recoup a large fraction of the fall in appropriations, research universities would have had to navigate reductions in resources per

student or yet larger increases in in-state tuition in the absence of the large pool of foreign students.

Not only are the results in this analysis consistent with straightforward economic theory, but they also align with the comments of public university administrators. In a public letter to California State Auditor Elaine M. Howle on March 8, 2016, University of California president Janet Napolitano writes (emphasis in original),[29]

> California's situation is not unique. Nearly every state in the nation has faced this Hobson's choice, and they have all reached the same decision: *open doors to out-of-state students in order to keep the doors open for in-state students*.

The capacity of public universities to use foreign enrollment as a margin of adjustment depends critically on demand from well-qualified potential undergraduates from abroad with the capacity to pay the tuition charged by US universities. While this demand has been plentiful in the past decade, owing primarily to demographic and economic changes in countries like China, this reservoir of talent and resources did not emerge in full force until the new millennium. What is more, the demand from such students to US universities is not likely to remain constant in future decades. Growth in home-country institutions of similar quality, negative shocks to home-country economies, or changes in US immigration policy would likely drain this pool of students from abroad. Indeed, the US Department of State (2018, table XVIB) estimates that the number of student F-1 visas awarded fell from about 644,000 in 2015 to about 362,000 in 2018.

The dramatic increase in the number foreign undergraduates on US campuses over the past decade raises questions about the impact of this influx. For example, the concentration of foreign students in majors such as business, engineering, and economics may dilute per student instructional resources in these majors or lead domestic students to concentrate in other areas. Also, some suggest that the rapid expansion in the number of foreign students has generated institution-level administrative challenges, while others have questioned how well foreign students are integrated in US universities (Jordan 2015, Redden 2014, Gareis 2012). Nonetheless, our research suggests that in order to provide quality education to in-state students, public research universities have turned to high-paying foreign students in times of systematic declines in state funding. Finally, the substantial increase in the number of foreign undergraduate students in the United States may affect both domestic and home-country economies. While beyond the scope of this paper, these issues are worthy of future investigation.

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[29] See http://universityofcalifornia.edu/sites/default/files/Howle-Elaine-030816.pdf.

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