Public Universities: The Supply Side of Building a Skilled Workforce

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Over the past few decades, public universities have faced significant declines in state funding per student. We investigate whether these declines affected the educational and research outcomes of these schools. Declining funding induced public universities to shift toward tuition as their primary source of revenue. Selective research universities enrolled more out-of-state and international students who pay full fare and increased in-state tuitions, moderating impacts on expenditures. Public universities outside the research sector had fewer options to replace stagnating state appropriations, requiring diminished expenditures and increased in-state tuitions. We find suggestive evidence that cuts have negatively affected research, and more definitive evidence that they adversely affected degree attainment at both the undergraduate and graduate levels.

Keywords: public universities, state appropriations, research outputs

Public colleges and universities have been major drivers of growth in college education over the past century (Goldin and Katz 1999); today, these institutions enroll 77 percent of all undergraduate students (67 percent of those at the four-year level) and award 64 percent of all bachelor's degrees. Public research universities award 72 percent of doctorate degrees in science and engineering fields and receive roughly half of the federal research funds devoted to academic institutions. Thus, public universities serve a central role in producing college-educated workers and scientific innovations. Yet an increasingly common refrain over the past decade from knowledgeable experts is that "public higher education appears to be in a state of crisis" (Ehrenberg 2006).

The overall amount of subsidy per student

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enrolled in higher education from states has eroded over the past quarter century, and the financial health and educational quality of these institutions would appear challenged by reductions in state appropriations. On a per student basis, constant dollar appropriations from state governments to higher education have decreased by 16 percent since 1990, with the bulk of this decline in the last decade (SHEEO 1980–2018). It seems natural to imagine that the reduction in state support for public research universities would manifest itself in a decline in both the educational effectiveness and the research capacity of these institutions. Declining subsidies might be projected to impact a host of activities that are part of universities' portfolios that are not fee-for-service or revenue generating, including: doctorate education, need-based financial aid, and research.

In this article, we use available data to examine the impact of declining state support for public research universities on both their educational and research functions. Heterogeneity across states in the decline gives us econometric leverage for studying the impact of these declines. We find evidence that the more highly ranked research universities have been able to adapt to declining subsidies by raising tuition, attracting out-of-state students and international students, and, to some extent, raising funding from philanthropic sources. Outside the top tier of research universities, our evidence suggests that public universities—particularly those that do not emphasize research and doctorate education as part of their missions—have not been able to replace lost dollars. The evidence suggests that budget cuts have affected the quantity of undergraduate and graduate degrees awarded. As has been widely demonstrated, it is degrees at the bachelor's level and above that have garnered the greatest increases in labor-market returns over the past three decades (Autor 2014). Evidence on the impact of budget cuts on research output from these universities is somewhat mixed, though many public universities remain to this day some of the most highly ranked research universities in the world (Shanghai Ranking 2018). Going forward, there is reason for concern that continued stagnation of state support for public universities will adversely impact the supply of skilled workers with undergraduate and graduate degrees to the workforce, along with the long-term research capacity that contributes to economic growth.

PUBLIC UNIVERSITIES IN THE CONTEXT OF U.S. HIGHER EDUCATION

Significant public subsidies for colleges and universities from state sources in the first three-quarters of the twentieth century brought about the transformation in American higher education on two margins. The first was a dramatic expansion in the scale and breadth of higher education—the shift to "mass higher education"—which encompassed not only the growth of existing public universities but also the expansion and upgrading of a large network of community colleges and broad-access institutions. In addition, states invested in "research universities" to engage in the production of knowledge and scientific excellence. The investments in public research universities could be viewed as a way for states to not only grow the stock of college-educated labor but to also build scientific expertise complementary to local industry (Goldin and Katz 1999).

Some public universities received greater support from states than others. As Claudia Goldin and Lawrence Katz (1999) document, those states with the strongest public university sectors were those without established private universities and those with a broad potential middle class and industries dependent on agriculture and mining likely to benefit from scientific innovation. States in the Midwest and western United States entered the postwar era with the strongest research universities.

Resources for higher education were especially plentiful in the two decades following World War II, a period sometimes referred to as the Golden Years of higher education. One study cites an average annual growth rate of 8 percent in education and general expenditures per student during the 1960s (Cheit 1971). The post–World War II era not only defines the period of a massive increase in access to U.S. higher education in terms of increased enrollment rates, but it also captures a rise to preeminence in graduate education and research innovation.

Within-State Markets

The overall public sector of higher education includes a much broader range of institutions that provide mass higher education and often offer courses of study with strongly vocational or professional orientations. For these institutions, the primary mission is the dissemination of knowledge, not the production of knowledge via research. Given the massive increase in demand for higher education and the public commitment to increasing collegiate opportunities in the post–World War II era, states added new four-year colleges and community colleges. Between 1950 and 1980, the number of public four-year institutions increased from 344 to 464, and the number of two-year community colleges by a factor of nearly three, from 297 to 846 (table 317.10, *Digest of Education Statistics* [Snyder, de Brey, and Dillow 2019]).

At public colleges and universities, the tuition price for in-state students is often appreciably less than the cost of instruction, implying substantial across-the-board subsidies that are afforded by appropriations from the state government. Historically, the gap between tuition paid and cost of instruction was greater at research universities than at the community colleges or broad-access four-year institutions (Winston 2000).

Community colleges tend to focus on local markets, essentially within commuting distance, whereas comprehensive universities may draw from a regional area encompassing a quadrant of a state and, in some cases, may have particular subject-level expertise. The research universities generally draw students from across the state and, in some cases, may draw students from the national and international market, these out-of-state students paying much higher tuition levels that are far closer to the market levels that private institutions charge. Later in this article, we present empirical evidence on the changing stratification within states in tuition levels and appropriations from the state.

Public Research Universities in a Mixed Market

The categorization of institutions as research universities is neither discrete nor static. Research intensity spans a continuum among universities in both the public and private sectors and, to the extent that higher education competes along the margins of quality and prestige, some institutions face incentives to become research universities (Labaree 2017). In this analysis of public research universities, we focus attention on three categorizations that distinguish public universities: the first is membership in the American Association of Universities (AAU), representing the most resource-intensive and selective public research universities.[1] Today, of the sixty-two universities that form the AAU, thirty-four are public universities.

The second and third categories depend on the taxonomy used by the Carnegie Foundation for the Advancement of Education, which classifies institutions based on sponsored research funding, doctorates awarded, and other metrics.[2] Research universities (which include the AAU schools) are the 136 public, doctorate-granting universities with high or very high research activity according to the 2010 Carnegie definition. Nonresearch universities are 292 broad-access public institutions, which are a combination of those that grant master's degrees as their highest degree and those that grant doctorate degrees but are not classified by the 2010 Carnegie definition as having high or very high research activity. We refer to nonresearch schools as broad-access universities,

1. At the start of the twentieth century, with U.S. doctoral education still in its infancy, the presidents of leading institutions moved to reduce disarray and develop uniform standards for doctorate education and founded the American Association of Universities.

2. The Carnegie Classification taxonomy classifies institutions by the highest level of degrees awarded and research intensity, measured by factors such as research expenditures, doctorates awarded, and number of research-focused faculty. Among institutions awarding doctorate degrees are three categories: very high research activity, high research activity, and doctoral universities. The combination of the first two form the basis of our high research activity group. The third, along with master's institutions, make up the nonresearch category of four-year colleges and universities.

even though the sample excludes institutions that grant only bachelor's degrees and other specialized four-year institutions.

Both research and doctorate education became less concentrated in a few institutions over the course of the twentieth century. In 1900, AAU members awarded 90 percent of doctorates. By 2000, that proportion had slipped to 50 percent. Over the century, the number of institutions awarding doctorates grew to nearly four hundred, and the annual number of doctorates to more than forty thousand. This growth tended to favor public universities. Public doctorate-granting institutions outnumbered private institutions by 1952, and by the 1970s, public universities accounted for about two-thirds of doctorates awarded (Thurgood, Golladay, and Hill 2006).

The institutions distinguished as research universities for their production of doctorate education and research output exist in a mixed market in which public and private institutions compete directly for students, faculty, and research support. The two most salient distinctions between research universities in the public and private sectors are scale and funding structures. Not only do the AAU public universities award more doctorate degrees than their private counterparts, but, on average, they also enroll 250 percent more students at the undergraduate level. The top twenty-four largest AAUs by undergraduate enrollment are all public, and in the top thirty, the only private university is NYU. This greater scale generally follows with lower per student resource intensity. The typical disciplinary department is generally not much larger in terms of tenure-track faculty size in a public university than in a private university.[3]

Sources of revenue support also differ with institutional control. Whereas 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. In exchange for funds provided by the state government, public universities have a mandate to provide collegiate opportunities to in-state students, which is usually manifested in below-cost tuition rates and preferential treatment in admissions. Public research universities face constraints and incentives tied directly to state funding, while they also compete at the national (and international) levels for faculty and research innovation with marquee-name private universities. In the next section, we turn to the examination of changing public support for public universities across states.

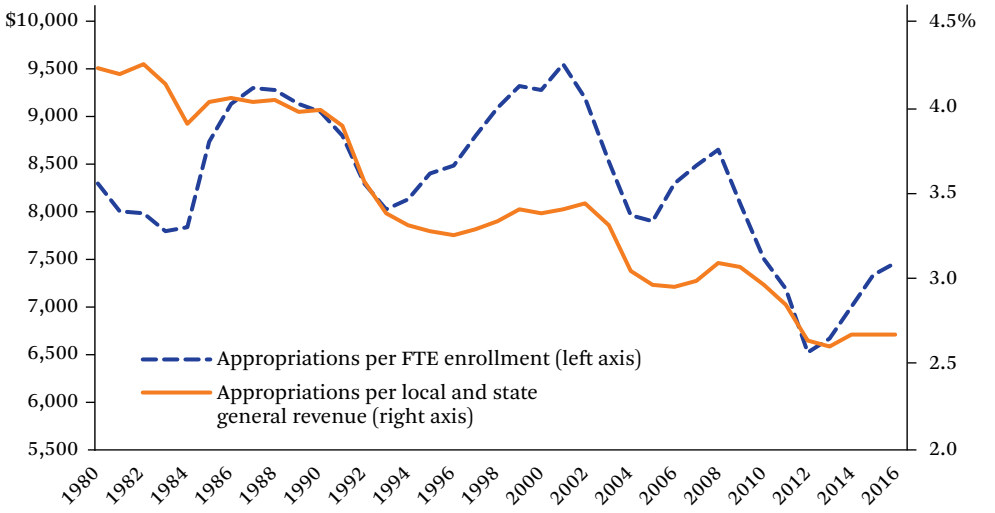
DECLINES IN STATE SUPPORT AND IMPLICATIONS FOR PUBLIC UNIVERSITIES

We start by documenting trends in aggregate state expenditures on public colleges and universities in the United States. Figure 1 plots appropriations per full-time equivalent enrollment (FTE) and local and state revenue from 1980 through 2017.[4] Since the early 1990s, the decline in appropriations per student has been substantial, from about $9,000 per FTE in 1990 to about $7,600 in 2017. The secular decline is punctuated by clear downward cycles following recessions in 1990, 2001, and 2008. This downward trend reflects, in part, a growth in FTE enrollment relative to the size of the working-age population and in part, the increase in the relative costs of higher education. In other words, the increase in college enrollment during the period implies more students per taxpayer, which could lead to less higher education funding per student. That said, as also clear in figure 1, an important contributor to this decline was the drop in the share of state

3. In terms of the quality of undergraduate education, five public universities typically appear among the top thirty in the United States: the University of California, Berkeley, UCLA, the University of Michigan–Ann Arbor, the University of Virginia, and the University of North Carolina at Chapel Hill (*U.S. News and World Report* 2018).

4. We use the Higher Education Cost Adjustment (HECA) index, which was designed to reflect changes in the cost of higher education. Primarily because the higher education sector is dependent on college-educated labor, the HECA has risen roughly 30 percent more than the CPI (3.6 percent per year versus 2.8 percent per year between 1980 and 2015).

Figure 1. Constant Dollar Higher Education Appropriations



Source: Authors' compilation based on State Higher Education Finance reports (SHEEO 1980–2016) and Tax Policy Center (1980–2016).

Note: Higher education appropriations are local and state appropriations net of special-purpose, research, and medical appropriations measured in 2017 dollars. We use HECA (Higher Education Cost Adjustment) deflator. FTE is the full-time equivalent enrollment net of medical students. Years in the x-axis are fiscal years.

general fund expenditures devoted to higher education. Indeed, based on our calculations, had this share remained constant at its early 1990s level, appropriations per FTE at public universities would have remained essentially constant over the past twenty-five years.[5]

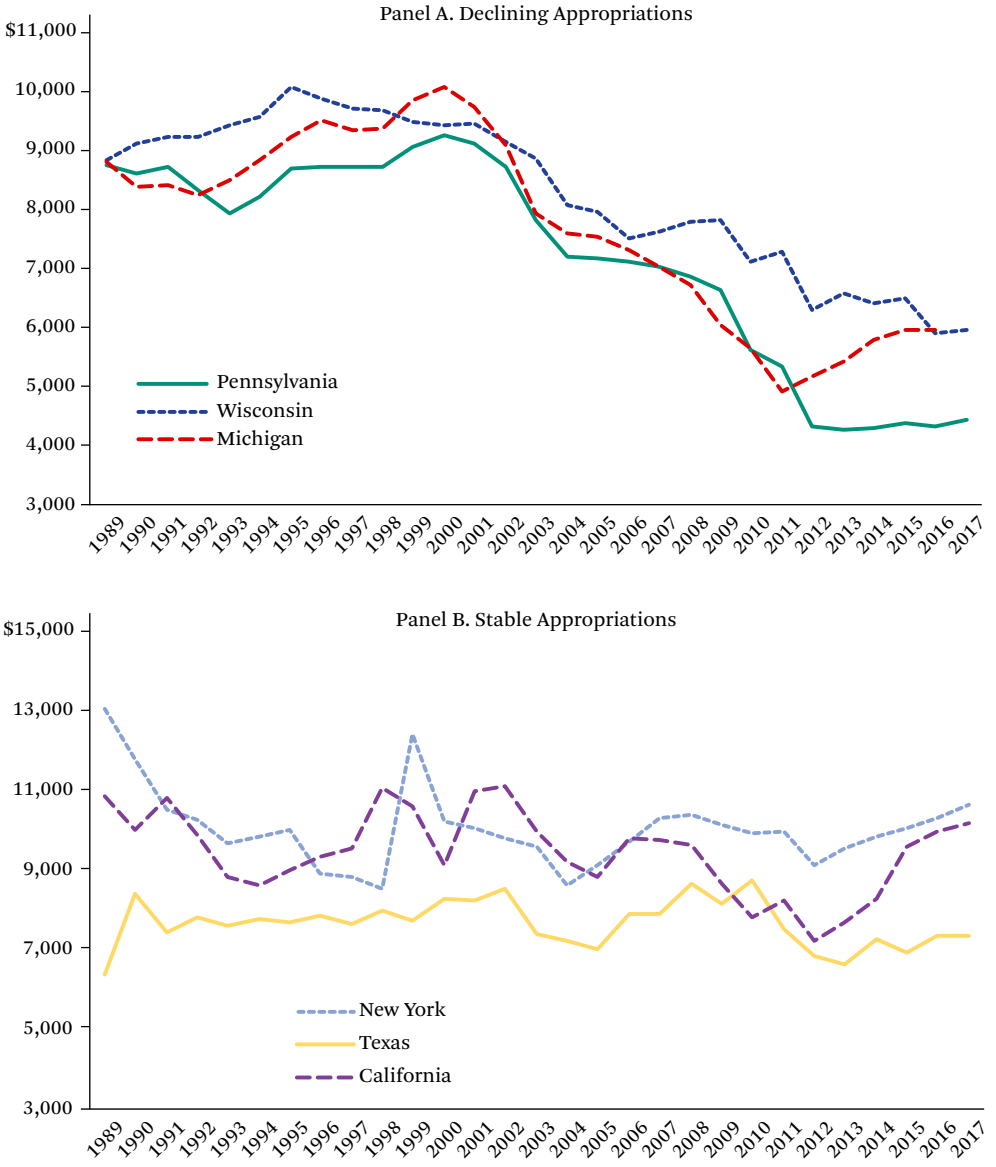
It is worth emphasizing that variation among states is substantial in the changes over time in state appropriations per FTE. Figure 2 illustrates this for a subset of states between 1989 and 2017.[6] States such as New York are among the relative winners, even as traditionally well-funded systems of higher education in Michigan and Wisconsin continue to lose funds. Historically, the more research-intensive universities have received more generous funding from states. In 1997, the public research universities received on average a bit over $16,000 per undergraduate student in state appropriations; the nonresearch institutions received on average just under $9,000. Over the next two decades, cuts would be approximately proportional, narrowing the difference in support measured in levels (figure A2).

Various factors have plausibly contributed to the decline in appropriations as a share of state budgets. 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). Research suggests that the variation in higher education budgets is derived from the interplay between a state's revenue cycle and spending obligations, such as Medicaid (Kane, Orszag, and Apostolov 2005).

5. Between 1980 and 2016, appropriations as a share of state general revenue fell from 0.042 to 0.027. All else equal, had the share remained at 0.042, appropriation in 2016 would have been over 58 percent higher than they were, at a little bellow $12,000 per FTE.

6. Figure A1 shows changes between 2001 and 2017 for all states. Additional tables and figures, designated in text with a leading A, are available via the online appendix at https://www.rsfjournal.org/content/5/5/43/tab-supplemental.

Figure 2. Constant Dollar Appropriations per FTE, Selected States



Source: Authors' compilation based on State Higher Education Finance reports (SHEEO 1980–2018), years 1989 to 2017.

Note: Appropriations by FTE is total appropriations to higher education in the state divided by full-time equivalent enrollment net of medical students. All measures are in 2017 dollars using the HECA index. Years are fiscal years.

Indeed, in the aggregate, the increase in the share of state spending on Medicaid closely matches the decline in the share devoted to tertiary education. Other factors broadly associated with the decline in state funding for higher education include increased expenditures on elementary to secondary education, often mandated by school finance litigation (Labaree 2017), and increased expenditures for corrections.

However, despite the fact that Medicaid put fiscal pressure on state budgets, the empirical

evidence using more recent data does not support the centrality of Medicaid in explaining the decline in higher education expenditures. Using data from 1980 to 2014, we regress state-level appropriations per capita on Medicaid expenditures per capita (table A1). The coefficient on per capita Medicaid expenditures is –0.026 (0.014), which suggests that the increase in Medicaid expenditures accounts for a bit less than 20 percent of the decline in state appropriations for higher education. Although point estimates are not precise, we find that changes in expenditures on Medicaid can account for only a modest fraction of the total decline in state appropriations, suggesting other important forces must be at work.

Beyond fiscal pressure on state budgets, several factors could plausibly lead to a decline in the willingness of state legislatures to support public universities. The national integration of the market for higher education has meant that high-achieving students increasingly go out of state for their education (Hoxby 2009). Historically, many of the states that provided significant public support for higher education were in the Midwest, such as Michigan, Wisconsin, Indiana, Minnesota, and Iowa, and these states have been losing college graduates (Bound and Holzer 2000; Bound et al. 2004; Moretti 2013). In addition, it seems likely that states enjoy a smaller share than they used to of the economic returns to research activity. These factors are likely to have decreased the political will of state legislators to support higher education. Although these factors may reduce the political will to support higher education, it is difficult to find credible statistical support for these hypotheses with only fifty states in interdependent economies.

ADAPTING REVENUES OF PUBLIC UNIVERSITIES

How do public universities accommodate changes in state appropriations? As a basic accounting identity, expenditures must fall with a decline in appropriations or other sources of support must increase. We examine the link between expenditures, revenue sources, and appropriations, both graphically and in a regression context, comparing research universities with other four-year institutions.

Given the unit of analysis at the level of the university and academic year, our main data are drawn from the Department of Education's Integrated Postsecondary Data System (IPEDS) survey modules and the American Survey of Colleges assembled by the College Board, which are surveys of institutions that record information on finances, student characteristics, and institutional outcomes. In providing an empirical characterization of outcomes, we focus on three groups of public universities that are not mutually exclusive, as described earlier: AAU universities (34), research (136), and nonresearch (292). In the analysis that follows, we distinguish expenditures by type (excluding auxiliary enterprises like university hospitals) and revenues by source, with particular attention to tuition levels and total tuition revenues.

Our primary interest is in the impact of budget cuts on educational and research outcomes, which is inherently a question of causal inference. Related to the study of the effect of budget changes on educational outcomes are accounting relationships illustrating the financial adjustments and choices made in response to declines in state appropriations. We present the accounting relations as descriptive regressions using ordinary least squares (OLS). In measuring the effect of appropriation changes on educational outcomes, we recognize that the state appropriations to specific universities may reflect some endogeneity, and we emphasize an instrumental variable (IV) strategy based on plausibly exogenous state-level aggregate variation. As long as a state's aggregate appropriations do not depend on a specific institution's enrollment decisions or research output, our instrumental variable estimates should represent consistent estimates of the causal effect of appropriations on student outcomes.[7] To be precise, we use appropriations to all institutions in a state as an

7. We have used this strategy (Bound et al., forthcoming), as have other authors (Deming and Walters 2018; Chakrabarti, Gorton, and Lovenheim 2018). Authors often use total state appropriations net of an institution's appropriations. Estimating using such instruments produces results similar to the ones we report here.

instrument for observed institutional appropriations.

Expenditure Adjustments

We regress university-level expenditures (and, later, revenues, endowments, tuition rates, and patenting output) on appropriations, cohort size, and state economic conditions such as the unemployment rate in some specifications. With observations at the level of the university (i) and the year (t), we follow the specification

$$Ln\, y_{it} = \beta_0 + \beta_1 Ln\, App_{it} + X_{it}\lambda + \gamma_t + \delta_i + \varepsilon_{it}, \quad (1)$$

where the outcome of interest (y_{it}) and institution-level appropriations (App_{it}) are specified in logs. The vector X_{it} includes state-level controls such as state population at age eighteen, and unemployment rate in some specifications, which capture some of the in-state demand for higher education. With year and institution fixed effects (γ_t and δ_i), we abstract from 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.

In table 1, we study the relationship between appropriations and expenditures. Although certain types of expenditures, like institutional support—which includes expenses for general administrative services and management—are more responsive to changes in appropriations across the board, research expenditures are less sensitive to such changes.[8] For the resource-intensive AAU institutions, there is essentially no systematic relationship between overall university academic expenditures (E&G) and state appropriations. The elasticity for the sample of all research universities is higher, but statistically indistinguishable from zero, at 0.156. The public colleges and universities outside of this research-intensive sector provide strong contrast, with a positive association between appropriations changes and total expenditures [0.301 (0.031)]. Similarly, nonresearch universities display a meaningful relationship between instructional expenditures and appropriations, whereas for AAUs no relationship is detectable.

In turn, three functional categories capture most university expenditures: instruction, research, and institutional support, the last capturing many of the centralized operational components of university activities. It is only in the institutional support category that a link to appropriations across all types of public universities is consistent and positive. Presumably, university-wide infrastructure projects and investments are sensitive to the availability of general support from the state. On the other hand, research expenditures show little sensitivity to state appropriations. To the extent that these are funded by the federal government and private sponsors, this may be unsurprising. Yet some evidence indicates that some start-up and faculty support costs are shouldered from institutional funds (Ehrenberg, Rizzo, and Jakubson 2007). It would appear that these expenditures are largely insulated from appropriations changes.

The AAU universities show essentially no link between appropriations and instructional expenditures, of which the number of faculty and their salaries is the largest expense, suggesting that few adjustments are made in class size or faculty hiring in response to changes in appropriations. At the other extreme of nonresearch universities is a significant and positive elasticity for instructional expenditures: a 10 percent decrease in state support ties to a 2.93 percent decrease in instructional expenditures, implying that the quantity and quality of instruction offered to students varies directly with state appropriations.

8. *Institutional support* is defined by IPEDS as a functional expense category that includes expenses for the day-to-day operational support of the institution such as "general administrative services, central executive-level activities concerned with management and long-range planning, legal and fiscal operations, space management, employee personnel and records, logistical services such as purchasing and printing, and public relations and development. Also includes information technology expenses related to institutional support activities."

Table 1. Effects of Appropriations on Expenditures, 1996–2012

	AAU	Research	Nonresearch
Panel A Dependent Variable	Log(Total Ed. and General Expenditure)		
Log(state appropriations)	0.014 (0.051)	0.156 (0.095)	0.301 (0.031)
Panel B Dependent Variable	Log(Institutional Support Expenditure)		
Log(state appropriations)	0.239 (0.121)	0.338 (0.101)	0.392 (0.064)
Panel C Dependent Variable	Log(Expenditure for Research)		
Log(state appropriations)	−0.015 (0.135)	0.012 (0.170)	0.050 (0.181)
Panel D Dependent Variable	Log(Expenditure for Instruction)		
Log(state appropriations)	−0.008 (0.068)	0.142 (0.091)	0.293 (0.035)
Observations	505	1,969	4,036
Universities	32	126	262

Source: Authors' compilation based on IPEDS (U.S. Department of Education 1996–2012).
Note: All models are estimated using linear least squares. All regressions include year and university fixed effects, a control for the size of the cohort age eighteen, and the unemployment rate. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level.

What the expenditure changes show are striking differences within the public university sector: the top public research universities have demonstrated resilience to changes in state funding, and the expenditures at the nonresearch universities are strongly tied to state-level fortunes. How, then, have these research institutions adjusted revenues?

Potential Sources of Revenue

Alternative sources of revenue to state appropriations include tuition flows, private gifts, and federal (and private) funds for research.[9] The capacity to tap these sources to replace lost state appropriations depends on market conditions and the fungibility of funds from alternative sources. Because state appropriations are broadly unrestricted, it is more difficult to use either federal research funding or private philanthropy to replace state funds, as these sources are often—though not always—restricted to specific purposes.

Tuition revenue has been the primary source of funds to replace lost state appropriations. The main dimension of differentiated pricing occurs at the undergraduate level, with in-state students paying a lower tuition than out-of-state students.[10] As an accounting matter, tu-

9. In addition, a typical university will have some auxiliary services lines on its income statement, which represent flows from activities such as hospitals or athletic facilities.

10. Also, institutions typically charge different tuitions among program areas, with graduate programs in professional fields generally priced most closely to the rates charged by peers in the private sector.

ition revenues can increase by changing either increasing tuition levels or changing the relative quantities of students paying high and low tuition levels.

As an economics matter, the capacity of institutions to raise tuition revenue by adjusting price or quantities is determined within a market context. Universities are not perfect substitutes, but evidence is ample that many public research universities operate in a national market where students are choosing among public and private options.[11] In this sense, universities will have only limited scope to adjust the prices charged to out-of-state students in response to changes or stagnation in state funding. On the other hand, universities have much more scope to raise in-state tuition charges, subject to constraints imposed by state political actions. A public university weighs added tuition revenue against the potentially endogenous legislative response of reduced funding (see Bound et al., forthcoming). Because the outside option for many in-state students is a nonprofit private institution of comparable (or greater) quality but at a much higher price, public universities have the capacity to increase prices for these students without a significant impact on demand.

Public universities can adjust total tuition revenues as well as price changes by changing the quantity and composition of students. To increase revenue, an institution must add (or substitute) a student for whom the net revenue will exceed marginal cost, leading to an emphasis on recruiting out-of-state domestic and foreign students. The ease (or difficulty) of drawing revenue generating students depends in large part on institutional quality and the overall supply pool. Expansion in demand from abroad, particularly the increased capacity of families in China to pay for a college education, and growth in the college-age population in states where in-state options are limited (Bound, Hershbein, and Long 2009; Bound et al., forthcoming) generate a potential pool from which universities can expand on the extensive margin.

Tuition Revenue Response

Figure 3 shows the coincident changes in appropriations and tuition shares as a fraction of expenditures between 1997 and 2012. Because total expenditures are larger in magnitude than revenues from appropriations and tuition, these fractions together are less than 1.[12] Figure 3 highlights the sharp increase in tuition shares relative to decreases in appropriations shares across the sample of AAU, research, and nonresearch universities.

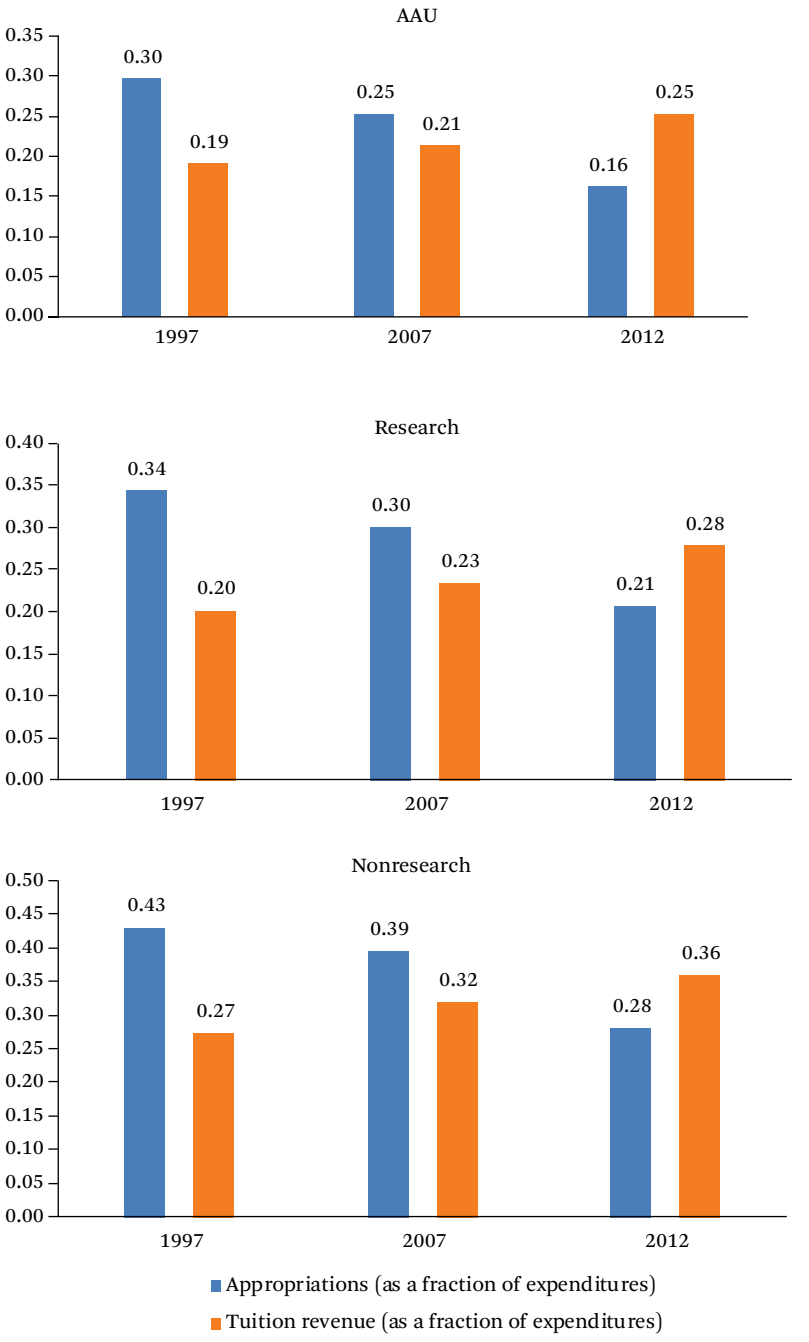
The quantitative link between total tuition revenues and appropriations changes is strong at all public research universities, with a 10 percent decrease in appropriations producing an increase of 3.1 percent at the AAU institutions, and a more modest 1.8 percent increase at the general set of research universities, when estimated in a regression with year fixed effects and controls for enrollment and cohort size (table 2). Outside the research sector, however, public colleges and universities display an elasticity that is less than half the size than that at AAUs, showing somewhat limited capacity in replacing lost funding with higher tuition revenues.

These changes in tuition revenue are—by construction—the combination of price changes and changes in relative quantities. Focusing on the undergraduate level, the relative importance of price and quantity changes differs for in-state and out-of-state students. For in-state students, price effects dominate, with in-state charges responding markedly to changes in appropriations. As shown in table A2, the elasticity of in-state price response is –0.289 for the AAU institutions, –0.203 for research universities, and –0.166 for nonresearch universi-

11. For any student, the demand for an out-of-state university will likely depend on the quality, price, and admission probability at his in-state option and the net price and quality of the private options where he is likely to receive offers of admission.

12. Other sources of revenue not shown in this figure, but which we examine later, include private gifts, grants, and earnings from investments or endowments

Figure 3. Changes in Appropriations and Tuition Revenue as a Fraction of Expenditures



Source: Appropriations, total educational expenditures, and tuition revenue data from IPEDS (U.S. Department of Education 1996–2012), years 1997 to 2012.
Note: Sample of public four-year degree granting universities. AAU represents members of the American Association of Universities. Research sample is of doctoral universities with high or very high research activity (Carnegie classification). Nonresearch is sample of master's universities or doctoral universities with low research activity.

Table 2. Effects of Appropriations on Tuition Revenues, 1996–2012

	Log(Tuition Revenue)		
Dependent Variable	AAU	Research	Nonresearch
Log(state appropriations)	−0.311	−0.190	−0.117
	(0.075)	(0.047)	(0.046)
Log(FTE undergraduate)	0.457	0.557	0.685
	(0.190)	(0.092)	(0.084)
Log(FTE graduate)	0.230	0.216	0.059
	(0.081)	(0.047)	(0.020)
Observations	538	2,221	4,763
Number of universities	34	137	293

Source: Authors' compilation based on IPEDS (U.S. Department of Education 1996–2012).
Note: Enrollment data from IPEDS includes both graduate and undergraduate students. Revenue data from IPEDS (1996 to 2012). All models are estimated using linear least squares. All regressions include year and university fixed effects, and a control for the size of the cohort age eighteen. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level.

ties.[13] This result is consistent with much of the literature that indicates that appropriation changes have a significant impact on tuition decisions (Baum et al. 2018). Not only is the elasticity somewhat larger at the AAU universities, but the greater baseline levels of in-state tuition for the research-oriented institutions also yield greater changes in the absolute level of in-state tuition. A 10 percent decrease in state appropriations is associated with an $840 increase in tuition at an AAU research university, relative to an increase of about $340 at a broad-access nonresearch institution.[14] These differences in price responses may well reflect differences in the price elasticity of demand in the respective student markets, given that the research universities draw more affluent students who are likely to be less price elastic than students at the broad-access nonresearch institutions.

Yet, even as in-state charges adjust markedly, out-of-state charges do not move significantly in response to changes in tuition. We interpret this as consistent with a greater price elasticity of demand of out-of-state students, who typically have choices that include other out-of-state options of similar quality (both public and private), along with a discounted home-state university option. For public research universities, we also see adjustments in the composition of students. In the most recent decade, a strong shift to foreign students is evident, particularly among institutions that are nationally strong but not among the highest ranked universities. In contrast, the highest ranked universities are able to attract domestic out-of-state students. This is in fact the focus of a study showing that public research universities disproportionately hurt by state funding declines were more likely to turn to full-fee paying students from abroad (Bound et al., forthcoming). Leveraging variation in state budgetary cycles, that article examines the sharp rise in undergraduate enrollment, mostly from China, between 1996 and 2012. Instrumental variable estimates highlight that a 10 percent decrease in state funding was associated with a 16 percent rise in foreign enrollment at public research universities, with little change in the enrollment mix outside the research sector.

13. Bound and his colleagues (forthcoming) also go to considerable lengths to investigate the timing of the changes in tuition relative to appropriations and are able to demonstrate that the timing aligns with appropriations changes impacting tuition levels, rather than the reverse.

14. Douglas Webber (2017) also finds evidence that declining public funding leads to increases in attendance costs to students.

Table 3. Effects of Appropriations on Private Gifts and Endowment, 1996–2012

	Log(Private Gifts and Endowment)		
Dependent Variable	Research	AAU	Nonresearch
Log(state appropriations)	−0.641	−1.229	0.068
	(0.202)	(0.345)	(0.165)
Observations	1,919	488	3,399
Number of universities	126	32	266

Source: Authors' compilation based on IPEDS (U.S. Department of Education 1996–2012).
Note: Gifts and endowments data from IPEDS (1996 to 2012). All regressions include year and university fixed effects and a control for the size of the cohort age eighteen. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level.

A natural question that follows from the large increases in in-state tuition at the public research universities is whether these institutions have become less affordable to low-income students, particularly from within the state. Evidence from Emily Cook and Sarah Turner (2018) points to a substantial response in institutional financial aid, which is concentrated among the more research- (and resource-) intensive universities. Indeed, by 2015, the average net tuition defined as "tuition and fees less grant aid" was lower at the flagship than at broad-access public colleges for the lowest-income students, that is, from families with income less than $30,000. Moreover, changes in sticker price translate about dollar for dollar to increases in net price for low-income students at broad-access institutions, but changes in net price are small, if not zero, at many research universities for such students.[15]

The overall increase in in-state tuition levels and the increased stratification in pricing structures among public colleges and universities has increased unmet need—that is, cost of attendance not covered by grants or expected family resources—markedly among moderate-income students as well as low-income students. Comparing students entering public four-year colleges and universities between 2004 and 2016, data from the National Postsecondary Student Aid Study show that unmet need increased by about $6,800 for dependent students from families in the $48,000 to $75,000 income range, with increases of about $5,000 for those with lower incomes. The net effect in the short run is increased borrowing, though recent evidence suggests that declines in state appropriations have longer-term effects on student debt, car ownership, and homeownership (Chakrabarti, Gorton, and Lovenheim 2018).

Other Sources of Financial Support

Beyond tuition revenues and state appropriations, other sources of support for colleges and universities include local grants, federal support for research activities, earnings from investments and endowments, and private philanthropic support, which may include current spendable gifts or endowment funds. Although a meaningful source of funds for AAU institutions, such funding is largely unavailable to universities outside the research sector.

In table 3, we examine the impact of appropriations on the revenues from private gifts, grants, contracts, and earnings from investments and endowments. At AAU universities, a strong relationship indicates that a 10 percent reduction in appropriations is associated with

15. Given little change in net price, the minimal link between the changes in posted tuition and the level of enrollment of in-state, low-income students should not be a surprise. For public research universities, these discounts are generally regarded as institutional investments, as they represent forgone expenditures in other areas. In addition to expanding need-based aid, some indications are that public research universities are also increasing merit aid awards in order to keep the highest achieving students, many of whom would be eligible for need or merit awards from private universities (Bowen and McPherson 2016; Cook and Turner 2018).

Table 4. Effect of Appropriations on In-State Enrollment, 1996–2012

	Panel A Log(In-State UG Freshmen Enrollment)					
	AAU		Research		Nonresearch	
Dependent Variable	OLS	IV	OLS	IV	OLS	IV
Log(state appropriations)	0.053	−0.074	0.098	0.139	0.116	0.058
	(0.059)	(0.085)	(0.052)	(0.091)	(0.050)	(0.092)
Observations	547	547	2,121	2,121	3,162	3,162
Number of universities	34	34	136	136	285	285
Partial R^2		0.284		0.270		0.283
F-statistic		26.66		65.59		65.99
	Panel B Log(In-State UG Total Enrollment)					
	AAU		Research		Nonresearch	
Dependent Variable	OLS	IV	OLS	IV	OLS	IV
Log(state appropriations)	0.136	0.151	0.147	0.172	0.157	0.151
	(0.069)	(0.129)	(0.042)	(0.061)	(0.043)	(0.052)
Observations	495	495	1,929	1,929	3,174	3,171
Number of universities	34	34	136	136	288	285
Partial R^2		0.309		0.283		0.271
F-statistic		32.18		66.30		55.88

Source: Authors' compilation based on ASC (College Board 1996–2012).
Note: Enrollment data from ASC (1996 to 2012). Overall state appropriations to higher education used as an instrument are used as an instrument for institution-level state appropriations in the IV regressions. All regressions include year and university fixed effects, and a control for the size of the cohort age eighteen. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level.

a 12 percent increase in private funds. Even among other research universities, the elasticity is a meaningful −0.64, but outside the research sector, no relationship is detectable, highlighting the limited capacity of nonresearch colleges in raising such funds.

EDUCATIONAL OUTCOMES

Changes in state appropriations potentially affect enrollment and attainment on a number of margins. Declining appropriations could induce universities to admit fewer students, or, as discussed, change the composition of the students they admit. Rising tuition and declining resources per student could affect student demand, though this is complicated by the fact that resource-rich universities are increasingly offering both need-based and merit aid.[16] In table 4, we report estimates of the effect of appropriations on in-state undergraduate enroll-

16. The accommodation of cyclical student demand and the enrollment response to changes in appropriations differs markedly across postsecondary institutions, with open access public institutions including community colleges demonstrating a greater supply-side elasticity in enrollment than research universities (Bound and Turner 2007; Barr and Turner 2013).

ment.[17] Both our OLS and IV estimates suggest modest and statistically insignificant effects of appropriations in first-year enrollment, but with somewhat larger and statistically significant effects on total undergraduate enrollment. IV estimates suggest a 10 percent drop in appropriations would reduce in-state undergraduate enrollment by about 1.7 percent at research universities.

In table 5, we turn our attention to degree attainment, distinguishing between undergraduate and graduate degrees, which may respond to funding not just via the margin of enrollment but also given the ease of completion when resources are high (Bound, Lovenheim, and Turner 2010). Because degree attainment will likely be affected by appropriations over previous years, we average log appropriations over the previous six years for bachelor's and doctorate degrees and over the previous three years for master's degrees. Our results are not sensitive to the choice of years or to simply not averaging across years as in earlier specifications. Focusing on the IV results, our estimates suggest quite a substantial effect of appropriations on degree attainment. These estimates suggest that a 10 percent drop in state appropriations would induce a 3.6 percent drop in bachelor's degree attainment at both types of research universities. Estimated effects on doctorate degrees are somewhat larger, suggesting that a 10 percent drop in state appropriations would induce a 7.2 percent drop in PhD degrees at research universities. We redid this analysis restricting ourselves to master's and PhDs in STEM fields. If anything, these results suggest somewhat larger effects. Focusing on the results for research universities, our IV estimates suggest that a 10 percent reduction in appropriations would reduce STEM master's granted by 5.0 percent (2.1) and STEM PhDs by 10.2 percent (3.3).[18] David Deming and Christopher Walters (2018), using somewhat different samples and specifications than ours, also find significant effects of appropriations on enrollment and degree completion at both two- and four-year institutions. Interestingly, they present evidence suggesting that the effect of appropriations on enrollments is primarily not being mediated by the effect of appropriations in tuitions.

We have little evidence of the quality of education college students receive. One way universities can accommodate declines in appropriations per FTE is to substitute lecturers for tenure-track professors; however, it is unclear what effects this might have on academic achievement. The little available evidence we have suggests that the increased use of instructors has negatively affected graduation rates (Ehrenberg and Zang 2005); some evidence even suggests that instructors are less likely to motivate students to continue in a field, though these effects are small and may vary across fields (Bettinger and Long 2004).

Declines in state appropriations that affect institutional quality, capacity, and tuition price might be expected to affect college choice on different margins for different groups of students. First, for nontraditional students, and for those who are likely to have close attachments to local markets, one might expect to see shifts from the public four-year sector to the community college sector. Some of these students may be on the extensive margin, forgoing enrollment altogether. For students from relatively affluent families and those with high levels of academic preparation, loss of resources and increased prices in the public sector may shift student enrollment decisions to the private sector. The hypothesis that declines in state appropriations, and thus declines in subsidies going to students at four-year public institutions, induce students to attend private institutions is supported by evidence that the quality of public colleges in a state affects student application behavior (McDuff 2007). Although selectivity among public universities has increased among the few colleges and universities that compete for students in the national market, overall selectivity has been stagnant or declining in much of the public sec-

17. The OLS specification used in table 4 for first-year in-state enrollment is used in an earlier study (Bound et al., forthcoming). The IV speciation diverges somewhat from this study because we use total state appropriations rather than total state appropriations net of an institution's own appropriations as the instrumental variable.

18. We do not report these results in the table, but they are available on request.

Table 5. Effect of Appropriations on Degrees Awarded, 1996–2012

	Panel A Dependent Variable: Log(Bachelor's Degrees)					
	AAU		Research		Nonresearch	
	OLS	IV	OLS	IV	OLS	IV
Log(state appropriations)	0.385 (0.118)	0.089 (0.226)	0.262 (0.060)	0.361 (0.092)	0.205 (0.044)	0.060 (0.138)
Observations	546	546	2,177	2,177	4,742	4,742
Number of universities	34	34	136	136	292	292
	Panel B Dependent Variable: Log(Master's Degrees)					
	AAU		Research		Nonresearch	
	OLS	IV	OLS	IV	OLS	IV
Log(state appropriations)	0.428 (0.140)	0.575 (0.182)	0.248 (0.065)	0.301 (0.152)	0.157 (0.086)	0.296 (0.189)
Observations	558	558	2,219	2,219	4,775	4,775
Number of universities	34	34	136	136	294	294
	Panel C Dependent Variable: Log(PhD Degrees)					
	AAU		Research		Nonresearch	
	OLS	IV	OLS	IV	OLS	IV
Log(state appropriations)	0.386 (0.126)	0.590 (0.226)	0.532 (0.117)	0.719 (0.223)	1.088 (0.483)	2.306 (0.725)
Observations	546	546	2,176	2,176	1,313	1,313
Number of universities	34	34	136	136	116	116
Partial R^2		0.218		0.249		0.264
F-statistic		9.197		35.78		34.95

Source: Authors' compilation based on IPEDS (U.S. Department of Education 1996–2012).
Note: Degree data from IPEDS (1996 to 2012) via the Urban Institute Data Portal. Overall state appropriations to higher education used as an instrument are used as an instrument for institution-level state appropriations in the IV regressions. We average log appropriation over the previous six years bachelor's and doctorate degrees and over the previous three years for master's degrees. All regressions include year and university fixed effects and a control for the size of the cohort age eighteen. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level.

tor (Hoxby 2009; Bound, Hershbein, and Long 2009).

RESEARCH PRODUCTIVITY

Declines in state appropriations may affect the research output of public research universities. We have seen evidence that the top public research universities have been able to replace much of their lost revenue, but the source of this revenue is largely in terms of tuition, and those paying this tuition might want to see their dollars spent on the educational, rather

than the research mission of the university.[19] At the same time, the impact of budget cuts on research output is likely to work with long lags.

Faculty Salaries Between Public and Private Universities

Presumably the most important input to research are talented researchers. Given tight budgets, it is hard for public research universities to offer competitive salaries or, perhaps more importantly in the sciences, generous start-up packages. Previous researchers have found evidence that salaries for tenure-track faculty at public universities have not kept pace with those at private universities and that recessionary forces have long-lasting effects on faculty hiring at public universities (Turner 2014). Using data from the American Association of University Professors (1973–1994), Cindy Zoghi (2003) finds substantial declines in the salaries of public university professors relative to their private university counterparts. Using IPEDS data, Thomas Kane, Peter Orszag, and Emil Apostolov (2005) find a similar pattern for research universities. Stratifying by rank, they determine that as of the mid-1970s, salaries at public and private research universities were roughly comparable. By 1998, full professors at public research universities were, on average, being paid 82 percent of what their counterparts at private research universities were being paid.

Using IPEDS data, we investigate the relationship between state appropriations and average salaries of professors at public universities (table A3). Because we expect effects to work with some lags, we average appropriations over the three previous years. Point estimates using longer lags are similar, though estimated with less precision. The estimates in table 6 suggest significant effects of appropriations on faculty salaries. Overall, we find that appropriation cuts are related to lower salaries for professors in all levels at research and nonresearch universities, with elasticities varying from 0.08 to 0.16.

It is challenging to translate these impacts on wages into estimates of potential research productivity. Faculty are not that mobile, and universities will typically try to hold on to star researchers by matching outside offers. Still, the extent to which universities can shield research faculties from budgetary pressures is constrained. Budgets are limited, and, because salaries are typically in the public domain at public universities, the degree to which universities can engage in compensation practices that produce substantial discrimination in salaries is as well (Card et al. 2012). It seems likely that a more sustained loss in compensation packages to faculty at public colleges and universities would contribute to a flight of talent to private colleges and universities.

It seems natural to also imagine that tight budgets would affect the size of the research faculty at public universities, and, indeed, as we alluded to before (Ehrenberg and Zhang 2005) a trend toward the use of non-tenure-track faculty is evident. In the same vein, postdoctoral scholars are an increasingly important component of university research. With this in mind, we estimated equations similar to those reported in table 6, using the number of postdoctoral scholars, and size of faculty, by rank, as the dependent variable. We find suggestive evidence that falls in appropriations adversely affect both the number of faculty and postdoctoral scholars at research universities.

Changes in Academic Rankings

Since 2003, the Shanghai Ranking Consultancy has been annually presenting the Academic Ranking of World Universities (ARWU), which is a list of the top five hundred universities worldwide. Universities are ranked by an academic score based on several indicators of research performance (including alumni and staff Nobel Prizes and Fields Medals), highly cited researchers, papers published in *Nature* and *Science*, papers indexed in major citation indices, and the per capita academic performance of an institution.

We investigate the relationship between appropriations and the aggregate score used by

19. Because of the potential spillover effects that research universities have on local economies, state legislatures have some incentive to subsidize research. Claudia Goldin and Lawrence Katz (1999) emphasize this was true historically. Philippe Aghion and his colleagues (2009) find evidence that this is still true.

Table 6. Effect of Appropriations on Faculty Salaries, 1996–2012

	Dependent Variable: Log(Assist Prof Salary)					
	AAU		Research		Nonresearch	
	OLS	IV	OLS	IV	OLS	IV
Log(state appropriations)	0.017	0.138	0.025	0.081	0.047	0.103
	(0.041)	(0.067)	(0.020)	(0.031)	(0.018)	(0.044)
Observations	390	390	1,714	1,714	3,528	3,528
Number of universities	32	32	131	131	273	273
	Dependent Variable: Log(Associate Prof Salary)					
	AAU		Research		Nonresearch	
	OLS	IV	OLS	IV	OLS	IV
Log(state appropriations)	0.056	0.191	0.060	0.109	0.062	0.115
	(0.037)	(0.071)	(0.019)	(0.033)	(0.015)	(0.048)
Observations	390	390	1,714	1,714	3,528	3,528
Number of universities	32	32	131	131	273	273
	Dependent Variable: Log(Full Prof Salary)					
	AAU		Research		Nonresearch	
	OLS	IV	OLS	IV	OLS	IV
Log(state appropriations)	0.033	0.156	0.075	0.135	0.086	0.113
	(0.034)	(0.079)	(0.021)	(0.036)	(0.017)	(0.053)
Observations	390	390	1,714	1,714	3,528	3,528
Number of universities	32	32	131	131	273	273
Partial R^2		0.262		0.325		0.249
F-statistic		12.97		46.72		42.85

Source: Authors' compilation based on IPEDS (U.S. Department of Education 1996–2012).
Note: Salary data from IPEDS includes both graduate and undergraduate students (1996 to 2012). Overall state appropriations to higher education used as an instrument are used as an instrument for institution-level state appropriations in the IV regressions. We average log appropriation over the previous three years. All regressions include year and university fixed effects, a control for the size of the cohort age eighteen, and the unemployment rate. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level.

the Shanghai Ranking Consultancy to rank universities (table A4). We also look at the three specific components of the score: HiCi score is based on the number of highly cited researchers in twenty-one broad subject categories, N&S score is based on the number of papers published in *Nature* and *Science*, and PUB score depends on the number of papers indexed in the Science Citation Index and Social Science Citation Index.

Overall, regressions of aggregate scores and components on the log of appropriations show positive effects, but with modest magnitudes. Even at its largest, seen in the IV specification for the AAU sample, a 10 percent decrease in appropriations lowers the overall score by only

Table 7. Effect of Appropriations on Patents, 1996–2012

	Log(Patents)			
	AAU		Research	
Dependent Variable	OLS	IV	OLS	IV
Log(state appropriations)	0.437	0.841	0.367	0.910
	(0.335)	(0.383)	(0.236)	(0.585)
Observations	559	559	2,228	2,228
Number of universities	34	34	136	136
Partial R^2		0.319		0.301
F-statistic		50.40		17.18

Source: Authors' compilation based on U.S. Patent and Trademark Office (1996–2012).
Note: Patenting data from National Science Foundation (1996 to 2012), United States Patent and Trademark Office, University Patent Count & Expenditures. Dependent variable is inverse hyperbolic sine of number of patents granted to a university in a year. Overall state appropriations to higher education used as an instrument are used as an instrument for institution-level state appropriations in the IV regressions. We average log appropriation over the previous three years. All regressions include year and university fixed effects and a control for the size of the cohort age eighteen. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level.

0.8 points, off a baseline mean of 30 points.[20] Indeed, comparisons of the distribution of scores and ranks for both public and private research universities show little movement between 2003 and 2018. Although fourteen of the top thirty U.S. universities were public in 2003, thirteen public universities were among the top thirty in 2018.

Federal Support for Science and Patenting

To examine whether federal support responds to state funding, we obtain university-by-year level data on federal support for science from the NSF Survey of Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions. We find little association between state appropriations and federal funding support for research. Indeed, the share of federal dollars received by public research universities has remained virtually constant since 1970.

Last, we obtain data from the U.S. Patent and Trademark Office to examine how funding declines are associated with patenting activity. Regressions of the log of the number of patents on log appropriations show sizable, though imprecise, effects: 0.8 for AAU universities and 0.9 for research universities (table 7). Between the late 1990s and the most recent period, the share of patents taken out by universities that went to public universities fell from a bit over 60 percent to just under 50 percent.

Summary of Impacts on Research Productivity

The direct evidence we have assembled on the effect of the decline in state appropriations to public research universities on research output is mixed. Perhaps our most comprehensive measure involves the Shanghai Rankings, which show only modest effects; however, these rankings span a short period. Data on federal research dollars cover a substantially longer time series and show no effects, though this measure reflects expenditures on inputs, not outputs, and one can imagine some endogenous response to budget cuts, with budget cuts at public research universities inducing re-

20. To put these numbers into context: an effect of 0.8 points is small relative to the difference in scores between University of California, Berkeley (70 points), San Diego (48 points), and Davis (31 points).

searchers to increase efforts to secure federal funding. In contrast to the federal dollars awarded for research, the patent data suggest negative effects of appropriation cuts, but not all fields file patents. Last, we have seen evidence of an effect of appropriations on salaries that suggests reason for concern, though, again, these are measures of expenditures on inputs, not output. Although the direct evidence we have is quite mixed, and it would be difficult, if not impossible, to estimate long-term effects of the decline in state appropriations on research output, it seems very likely that such effects exist. Declining resources will make it harder for universities to attract talented researchers or to provide them with the resources to conduct research. In addition, as tuition makes up an increasing share of public university budgets, it seems likely that public universities, including research universities, will put more emphasis on their teaching missions.

DISCUSSION

The long-standing state-based system for funding public higher education is coming under real strain and may be poorly positioned to respond to changes in the nature of the U.S. economy to increase the supply of college-educated workers. Economic forces are working against the old model of higher education funding in which state appropriations covered the majority of instructional expenses across all public institutions and provided subsidies to cover research infrastructure at flagship universities. The economic return to investments in higher education may be less likely to accrue to the state as a whole than in prior decades: college graduates are mobile in a national market, and though the benefits from research infrastructure may be concentrated in the university communities, they also benefit broader markets.

Writing a bit over a decade ago in an article titled "The Perfect Storm and the Privatization of Public Higher Education," Ronald Ehrenberg (2006) raised concerns that the decline in state support for public higher education would increase the stratification between research universities and broad-access public institutions, ultimately eroding the research capacity at the former and educational resources for students at the latter. The evidence assembled in this article suggests that high-research public universities have started to resemble their private counterparts, as they increasingly depend on tuition revenues and private grants and gifts, while state funding now accounts for a minority share of resources. Our evidence suggests that declining state support for higher education has real effects that have long-term implications for economic productivity and the supply of highly skilled workers in the labor market. First, our estimates, consistent with the evidence in Deming and Walters (2018), indicate that declines in state support have had substantial effects on degree attainment at the bachelor's and postbaccalaureate levels. Second, our results, together with those reported by Aghion and his colleagues (2009), suggest that declining state support for higher education is also likely to have an effect on the research output of public universities.

Our current and past work suggests that expanding full-fee student enrollment at the undergraduate level is an important channel through which selective public research universities buffer changes in state appropriations. Research universities also have the capacity to raise gift and endowment funding to complement tuition revenues. Despite the decline in appropriations, public research universities remain some of the most highly ranked research institutions in the world and can still provide substantial aid to their students. On the other hand, public universities outside the research sector have fewer options to replace lost or stagnating state appropriations, requiring moderated expenditures, increased in-state tuition, and decreases in grant aid. The evidence compiled in this article suggests that such actions might have effects on education attainment and on the quality of education students receive.

Although our work does not support the notion that declining public support for higher education has overwhelmed the public higher education sector, there is reason for some concern. First, public research universities may be unable to continue to replace lost revenue, especially if states continue to cut appropriations, and U.S. education becomes less attractive to full-fee international students. Second, nonresearch universities are not successful at insulat-

ing lower and moderate-income students from tuition increases, which may represent a change in the population that can be served by these public institutions.

APPENDIX: DATA SOURCES AND PREPARATION

The data assembled for this project are organized at the university and academic year and draw on multiple sources including the U.S. Department of Education's IPEDS survey modules, the American Survey of Colleges assembled by the College Board, the National Science Foundation, the U.S. Patent and Trademark Office, and the Shanghai Ranking. In addition, we assembled annual state-level data on state revenues, higher education appropriations, demographics and economic conditions from many sources.

We use the 2010 Carnegie Classification to form groups of public universities. The Carnegie Classification taxonomy classifies institutions by the highest level of degrees awarded and research intensity, measured by factors such as research expenditures, doctorates awarded, and number of research-focused faculty. Among institutions awarding doctorate degrees are three categories: very high research activity, high research activity, and doctoral universities. In all, there are 177 public doctorate-granting universities across eighteen years (1997 to 2014) of which 138 universities are in the first two categories. There are an additional 265 master's institutions. We focus our analysis on research universities, which are defined as the combination of very high and high research activity and create a comparison group of nonresearch institutions as the aggregate of doctoral universities and master's institutions.

University Data: Finance Variables and University Characteristics

The finance module of the IPEDS data collection contains detailed financial information on revenues and expenditures by source and use. These data are the source of our measures of total tuition revenue, expenditures by purpose and state appropriations measures. For 2010 and prior, we use the harmonized files assembled as part of the Delta Cost Project and add the subsequent years from the annual IPEDS files. The institutional characteristics module contains data on in-state and out-of-state tuition charges. We do not use data on University of Texas's tuition prior to 2004 because the Texas legislature had the regulatory authority to set tuition rates, generally mandating that the same statutory and designated tuition rate be charged across the state.[21]

Private gifts, grants, and contracts (from IPEDS) includes revenues from private (nongovernmental) entities including revenue from research or training projects and similar activities and all contributions (including contributed services) except those from affiliated entities, which are included in contributions from affiliated entities. We use the sum of the restricted (subject to limitations by a donor-imposed restriction) and unrestricted amounts.

Salary data are from IPEDS. IPEDS distinguishes salary by academic rank (assistant professor, associate professor, full professor, lecturer, instructor, and so on), and by contract length. We use data on the equated nine-month contract. We use data on nonmedical full-time instructional staff only. Instruction or research staff employed full time (as defined by the institution) whose major regular assignment is instruction, including those with released time for research. For the faculty salaries survey, the group includes faculty designated as primarily instruction and instruction combined with research and public service. We use the average across all workers (men and women).

All the monetary variables (including state appropriations, tuitions and expenditures) are deflated by the Higher Education Price Index. Because most of our regression formulations

21. In 2004, the 78th Legislature passed House Bill 3015, amending Texas Education Code §54.0513 to allow governing boards of public universities to set different designated tuition rates. Tuition deregulation became effective September 1, 2003, and universities began increasing designated tuition in spring 2004 (for more information, see Texas Higher Education Coordinating Board, "Overview: Tuition Deregulation and Tuition Set Asides Report," April 2016, http://www.thecb.state.tx.us/reports/PDF/8035.PDF?CFID=52037689&CFTOKEN=47878139, accessed July 17, 2019).

include the logged monetary variable and fixed effects, the method of deflation for these regressions is inconsequential, and the deflation only affects the figures and levels regressions.

University Data: Enrollment Measures

The enrollment measure we employ is first-time undergraduate enrollment; fall enrollment is recorded in both the IPEDS "Fall Enrollment" module and the Annual Survey of Colleges (ASC), which is assembled by the College Board.

To distinguish domestic students by in- or out-of-state status, we use first-time undergraduate enrollment data from the ASC. The ASC has more detail on the characteristics of admitted and matriculating students than IPEDS measures. When this information is missing in the ASC, we complement the data set with institutional sources (see Missing Data section). In addition to total enrollment, the ASC reports the number of foreign freshmen and the fraction of domestic first year students who are from out of state on an annual basis. Given the fraction of out of state, the number of foreign students, and the total enrollment, we compute in-state enrollment for first-year students. We have verified this approach with the examination of independent reporting at the university level.

University Data: Academic Outcomes

Academic score data (2003 to 2018) comes from the ARWU provided by the Shanghai Ranking in the website. The academic score is based on several indicators of research performance (including alumni and staff winning Nobel Prizes and Fields Medals), highly cited researchers, papers published in *Nature* and *Science*, papers indexed in major citation indices, and the per capita academic performance of an institution. We also look at the three specific components of the score: HiCi score is based on the number of highly cited researchers in twenty-one broad subject categories; N&S score is based on the number of papers published in Nature and Science; and PUB score depends on the number of papers indexed in the Science Citation Index and Social Science Citation Index.

University Data: Patents

Patenting data are from the National Science Foundation (1996 to 2012), and the University Patent Count and Expenditures. These sources compile patenting information from the U.S. Patent and Trademark Office. We harmonize university names in the data and match it to the rest of our data.

State Data: Higher Education Appropriations

State-level data on total appropriations comes from the State Higher Education Finance report provided by the State Higher Education Executive Officers. We use appropriations net of special purpose research dollars and full time equivalent enrollment net of medical students.

State Data: Demographic and Labor-Market Variables

In order to control for changes to the local economy, we compile historical census estimates of the population at age eighteen by state, and Bureau of Labor Statistics data on the state unemployment rate. State General Revenue is from the Tax Policy Center. Medicaid Expenditure from the Center for Medicare and Medicaid Services. State population, personal income, and the indicator on whether the governor is a Democrat is from the University of Kentucky Poverty Center.

State Data: Missing Data

When data elements related to tuition and finances were missing from standard institutional surveys, we attempted to locate the missing elements from the universities' Common Data Sets available on their institutional research webpages and the University of California System (http://universityofcalifornia.edu/uc-system). In addition, we consulted the annual university financial statements (annual financial reports) to locate institutional data on appropriations and revenues when missing from IPEDS. By using the complementary data on enrollment and state appropriations, we add 139 observations (at the level of the year-university) to the research university sample, eighty-four to the flagship sample, forty-nine to the AAU sample, and four to the nonresearch

sample. Our main results are robust to excluding the hand-coded data.

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