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ABSTRACT

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. We present evidence that 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. The evidence we present suggests that the cuts negatively affected degree attainment at the undergraduate and graduate levels. While the evidence on research is mixed, there are indications that the impact of spending declines on research outcomes may become evident over a longer time period

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Public colleges and universities have been major drivers of growth in collegiate attainment over the past century (Goldin and Katz, 1999); today, these institutions enroll 77% of all undergraduate students (67% of students at the four-year level) and award 64% of all bachelor's degrees. Public research universities award 72% 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.a).

The overall amount of subsidy per student 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% since 1990, with the bulk of this decline in the last decade (SHEEO, 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 paper, 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. And, 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 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 which contributes to economic growth.

Section 1: 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 20th century brought about the transformation in American higher education at 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 Goldin and 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 U.S. entered the post-war 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% 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, it is the dissemination of knowledge, not the production of knowledge via research, that is the primary mission. With 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, while the number of two-year community colleges increased by nearly a factor of 3, from 297 to 846 (Table 317.10, Digest of Education Statistics).

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 which are afforded by appropriations from the state governments. Historically, the gap between tuition paid and cost of instruction was greater at the 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, while comprehensive universities may draw from a regional area encompassing a quadrant of a state and, in some cases, these universities 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, with these out-of-state students paying much higher tuition levels that are far closer

to the "market" levels charged by private institutions. In Section 2, 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. There is a continuum of research intensity 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 which 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 62 universities that form the American Association of Universities, 34 are American public universities.

The second and third categories depend on the taxonomy employed by the Carnegie Foundation for the Advancement of Education (2010), 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 which have high or very high research activity according to the 2010 Carnegie definition. Non-research 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 non-research schools as "broad access" universities, even as the sample excludes institutions that only grant bachelor's degrees and other specialized four-year institutions.

[1] With U.S. doctoral education in its infancy at the dawn of the 20th century, the presidents of a set of leading institutions initiated an effort to reduce disarray and develop uniformity of 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, there are three categories: (1) very high research activity, (2) high research activity, and (3) doctoral universities. The combination of (1) and (2) form the basis of our "high research activity" group and (3) along with the "master's institutions" for the "non-research" category of four-year-degree-granting colleges and universities.

Both research and doctorate education became less concentrated in a few institutions over the course of the 20th century. While the original 14 AAU members awarded 90 percent of doctorates in 1900, AAU members awarded about 50 percent of U.S. doctorates in 2000. Over the century, the number of institutions awarding doctorates grew to nearly 400, and the annual number of doctorates awarded grew to more than 40,000. 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 (National Science Foundation, 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 enroll 250% more students at the undergraduate level. The top 24 largest AAUs by undergraduate enrollment are all public, and in the top 30, 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. 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. 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

[3] In terms of the quality of undergraduate education, five public universities typically appear among the top 30 undergraduate colleges and universities in the U.S. 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 are in the top 30 universities ranked by *U.S. News and World Report* (2018).

private universities. In the next section, we turn to the examination of changing public support for public universities across states.

Section 2: Declines in State Support and Implications for Public Universities

We start by documenting trends in the aggregate state expenditures on public colleges and universities. Figure 1 plots appropriations per full-time equivalent enrollment (FTE) and local and state revenue from 1980 through 2017.[4] Since the early 1990s, there has been a substantial decline in appropriations per student, from about $9,000 per FTE in 1990 to about $7,600 per FTE 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 in the U.S. and in part, the increase in the relative costs of higher education. In other words, the increase in college enrollment during the period imply more students per taxpayer, which could lead to less higher education funding per student. That said, as also noticeable in Figure 1, an important contributor to this decline was the drop in the share of state general fund expenditures devoted to higher education. Indeed, based on our calculations, if this share had remained constant at its early 1990s level, appropriations per FTE at public universities would have remained essentially constant over the past 25 years.[5]

<Include Figure 1>

It is worth emphasizing that there is substantial variation among states in the changes over time in state appropriations per FTE. Figure 2 illustrates this for a subset of states between 1989 and 2017.[6]

[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% more than the CPI (3.6% per year versus 2.8% per year, 1980–2015).
[5] Between 1980 and 2016, appropriations as a share of state general revenue fell from 0.042 to 0.027. *Ceteris paribus*, had the share remained at 0.042, appropriation in 2016 would have been over 58% higher than they were, at a little bellow $12,000 per FTE.
[6] Appendix Figure A1 shows changes between 2001 and 2017 for all states.

States like 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, while the non-research universities receive on average just under $9,000 per undergraduate. Over the next two decades, cuts would be approximately proportional, narrowing the difference in support measured in levels (Figure A2).

<Include Figure 2>

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). Past research has suggested that the variation in higher education budgets is derived from the interplay between a state's revenue cycle and spending obligations, like Medicaid (Kane, Orszag, and Apostolov, 2005). 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% of the decline in state appropriations for higher education. While 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 there must be other important forces at work.

Beyond fiscal pressure on state budgets, there are several factors that could plausibly lead to a decline in the willingness of state legislature to support public universities. The national integration of the market for higher education (Hoxby, 2009) has meant that high-achieving students increasingly go out of state for their education. 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 in terms of the economic returns to research activity. These factors are likely to have decreased the political will of state legislators to support higher education. While these factors may reduce the political will to support higher education, it is difficult to find credible statistical support for these hypotheses with only 50 states in interdependent economies.

Section 3: Adapting Revenues of Public Universities

How do public universities accommodate changes in state appropriations? As a basic accounting identity, either 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.

With 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 non-mutually exclusive groups of public universities, as described in section 1: AAU universities (34), research (136), and non-research (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 are not dependent 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 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:

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

[7] This strategy has been used by us in previously published work (Bound, Braga, Khanna, and Turner, 2019), as well as by other authors (Deming and Walters, 2017; Chakrabarti et al., 2018). Authors often use total state appropriations net of an institution's own appropriations. Estimating using such instruments produces results similar to the ones we report here.

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 state population at age 18, 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. While 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. There is a higher, but statistically indistinguishable from zero, elasticity of 0.156 for the sample of all research universities. 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, non-research universities display a meaningful relationship between instructional expenditures and appropriations, whereas there is no detectable relationship for AAUs.

<Include Table 1>

In turn, three functional categories capture most university expenditures: instruction, research, and institutional support, with the latter capturing many of the centralized operational components of

[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."

university activities. It is only in the "institutional support" category where there is a consistent and positive link to appropriations across all types of public universities. 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 there is some evidence (Ehrenberg, Rizzo, and Jakubson 2007) that some startup and faculty support costs are shouldered from institutional funds, and it would appear that these expenditures are largely insulated from appropriations changes.

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

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, while the expenditures at the non-research 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.

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

Because state appropriations are broadly unrestricted, it is more difficult to employ 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, tuition 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. While universities are not perfect substitutes, there is ample evidence 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. As modeled by Bound, Braga, Khanna, and Turner (2018), a public university weighs added tuition revenue against the potentially endogenous legislative response of reduced funding. Because the outside option for many in-state students is a non-profit 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.

In addition to tuition price changes, public universities can adjust total tuition revenues by changing the quantity and composition of students. Note that 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

[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.
[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.

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 and Bound, Braga, Khanna, and Turner 2018), generates 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. As 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 non-research universities.

<Include Figure 3>

The quantitative link between total tuition revenues and appropriations changes is strong at all public research universities, ranging from an elasticity of -3.1 at the AAU institutions to the more modest -1.8 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.

<Include Table 2>

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

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

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 -0.265 for the AAU institutions, -0.164 for research universities, and -0.187 for non-research universities.[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 places produce greater changes in the absolute level of in-state tuition at the research universities. A 10% 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 non-research institution.[14] Note that these differences in price responses may well reflect differences in the price elasticity of demand in the respective student markets, as the research universities draw more affluent students who are likely to be less price elastic than students at the broad-access non-research institutions.

Yet, even as in-state charges adjust markedly, out-of-state charges do not move to a significant degree 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 which 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 some adjustments in the composition of students. In the most recent decade, there has been a strong shift to foreign students, particularly among those institutions that are nationally strong but not ranked among the most competitive, while a small number of nationally ranked universities are able to attract domestic out-of-state students. Indeed, this is the focus of Bound, Braga, Khanna, and Turner (2018), who show that public research universities that were disproportionately hurt by state funding declines were more likely to turn to full-fee paying students from abroad. Leveraging

[13] Bound, Braga, Khanna and Turner (2018) 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] Webber (2017) also finds evidence that declining public funding leads to increases in attendance costs to students.

variation in state budgetary cycles, the paper examines the sharp rise in undergraduate enrollment, mostly from China, over the period between 1996 and 2012. Instrumental variable estimates highlight that a 10% decrease in state funding was associated with a 16% rise in foreign enrollment at public research universities, with little change in the enrollment mix outside the research sector.

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 Cook and 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 (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 (NPSAS) show that unmet need increased by about $6,800 for dependent students from families in the $48,000–$75,000 income range, with increases of about $5,000 for those with lower incomes. The net effect in the short run is increased

[15] With little change in net price, it should be unsurprising that there is little link between the changes in posted tuition and the level of enrollment of in-state, low-income students. For public research universities, these discounts are generally regarded as institutional investments, as they represent forgone expenditures in other areas. Note that, in addition to expanding need-based aid, there is some indication 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).

borrowing, while recent evidence from Chakrabarti, Gorton, and Lovenheim (2018) suggests that declines in state appropriations have longer-term effects on student debt, car ownership, and homeownership.

Other Sources of Financial Support

Beyond tuition revenues and state appropriations, other sources of support for colleges and universities are 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. While a meaningful source of funds for AAU institutions, such funding is largely unavailable to universities outside the research sector. Resourceful university administrators may instead be able to raise private funding when faced with decline subsidies.

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, there is a strong relationship indicating that a 10% reduction in appropriations is associated with a 12% increase in private funds. Even among other research universities, the elasticity is a meaningful -0.64, but outside the research sector, there is no detectable relationship, highlighting the limited capacity of non-research colleges in raising such funds.

<Include Table 3>

Section 4: Educational Outcomes

Changes in state appropriations potentially impact enrollment and attainment on a number of margins. Declining appropriations could induce universities to admit fewer students, or, as discussed above, 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. In Table 4, we report estimates of the effect of

appropriations on in-state undergraduate enrollment.[16] Both our OLS and IV estimates suggest modest and statistically insignificant effects of appropriation in first-year enrollment, but with somewhat larger and statistically significant effects on total undergraduate enrollment, with IV estimates suggesting a 10% drop in appropriation would reduce in-state undergraduate enrollment by about 1.7% at research universities.

<Include Table 4>

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). Since 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% drop in state appropriations would induce a 3.6% drop in bachelor's degree attainment at both research universities. Estimated effects on doctorate degrees are somewhat larger, suggesting that a 10% drop in state appropriations would induce a 7.2% 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% reduction in appropriations would reduce STEM master's granted by 5.0% (2.1) and STEM PhDs by 10.2% (3.3).[17] Deming and Walters (2018), using somewhat different samples and specifications than us, also find significant effects of appropriations on enrollment and degree completion at both two- and four-

[16] The OLS specification used in Table 4 for first-year in-state enrollment is replicates Bound, Braga, Khanna, and Turner (2018). The IV speciation diverges somewhat from this study because we use total state appropriation rather than total state appropriations net of an institution's own appropriations as the instrumental variable.
[17] We do not report these results in the table, but they are available under request.

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.

<Include Table 5>

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), and some evidence 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 impact institutional quality, capacity, and tuition price might be expected to impact college choice on different margins for different groups of students. First, for non-traditional 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 institution, 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). While selectivity among public universities has increased among the small number of colleges and universities that compete for students in the national market, overall selectivity has been stagnant or declining in much of the public sector (Hoxby, 2009, Bound, Hershbein, and Long, 2009).[18]

[19] Because of the potential spillover effects that research universities have on local economies, state legislatures have some incentive to subsidize research. Golden and Katz (1999) emphasize this was true historically, Aghion et al. (2009) find evidence that this is still true.

Section 5. Research Productivity

Declines in state appropriations may affect the research output of public research universities. While we have seen evidence that the top public research universities have been able to replace much of their lost revenue, 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 inputs to research are talented researchers themselves. With 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 (1973–94), Zoghi (2003) finds substantial declines in the salaries of public university professors relative to their private university counterparts. Using IPEDS data, Kane, Orszag, and Apostolov (2005) find a similar pattern for research universities. Stratifying by rank, they find 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 6). Since 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

[19] Because of the potential spillover effects that research universities have on local economies, state legislatures have some incentive to subsidize research. Golden and Katz (1999) emphasize this was true historically, Aghion et al. (2009) find evidence that this is still true.

faculty salaries. Overall, we find that appropriation cuts are related to lower salaries for professors in all levels at research and non-research 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, there are limits on the extent to which universities can shield research faculties from budgetary pressures. Budgets are limited, and, with salaries typically in the public domain at public universities, there are plausible limits in the degree to which universities can engage in compensation practices that produce substantial discrimination in salaries (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.

<Include Table 6>

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 500 universities in the world. Universities are ranked by an academic score 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 investigate the relationship between appropriations and the aggregate score used by 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 21 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% decrease in appropriations lowers the overall score by only 0.8 points, off of 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. While 14 of the top 30 U.S. universities were public in 2003, 13 public universities were among the top 30 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 (USPTO) 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 going to public universities fell from a bit over 60% to just under 50%.

<Include Table 7>

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

[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).

period of time. 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 researchers 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 which suggests reason for concern, though, again, these are measures on expenditures on inputs, not output. While the direct evidence we have is quite mixed, and it would be difficult, if not impossible, to estimate long run 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.

Section 6: 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 also 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 while the benefits from research infrastructure may be concentrated in the university communities while also benefiting broader markets.

Writing a bit over a decade ago in an article titled “The Perfect Storm and the Privatization of Public Higher Education,” Ehrenberg (2006a) raised concerns that the decline in state support for public higher education would increase the stratification between the research universities and the broad access public institutions, ultimately eroding the research capacity at the former and educational resources for students at the latter. The evidence we have assembled in this paper 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 which have long-term implications for economic productivity and the supply of high-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 bachelors and post-baccalaureate levels. Secondly, our results, together with results reported in Aghion et al. (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–paying 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 universities in the world and can still provide a substantial amount of aid to their students. On the other hand, public universities outside the research sector had fewer options to replace lost or stagnating state appropriations, requiring moderated expenditures, increased in-state tuition, and decreases in grant aid. The evidence we have compiled in this paper suggest that such actions might have effects on education attainment and on the quality of education students receive.

While our work does not find support for 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–paying international students. Second, non-research universities are not successful at insulating lower and moderate-income students from tuition increases, which may represent a change in the population that can be served by these public institutions.

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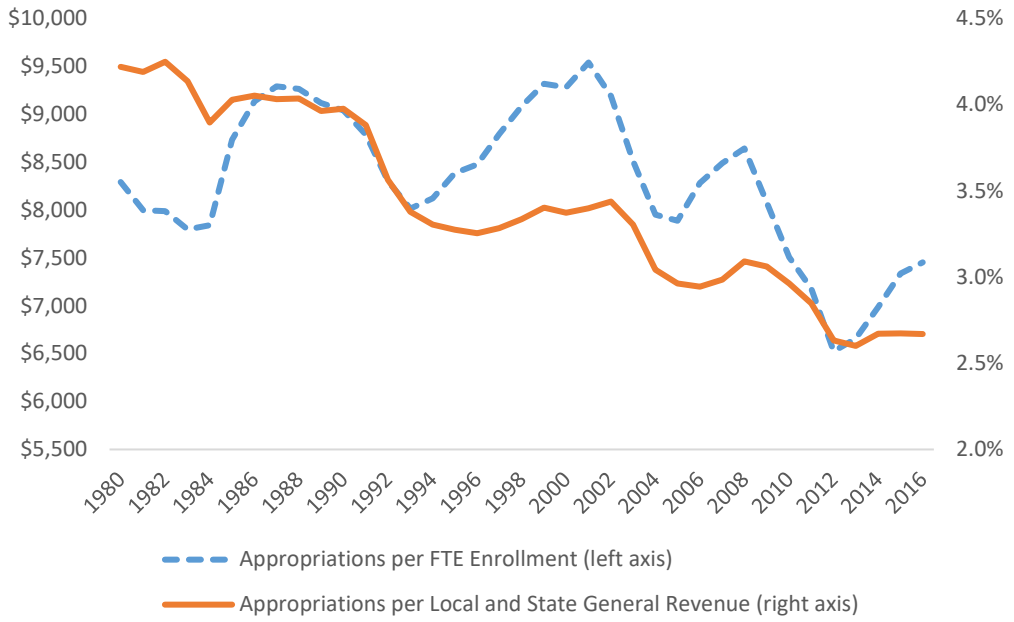
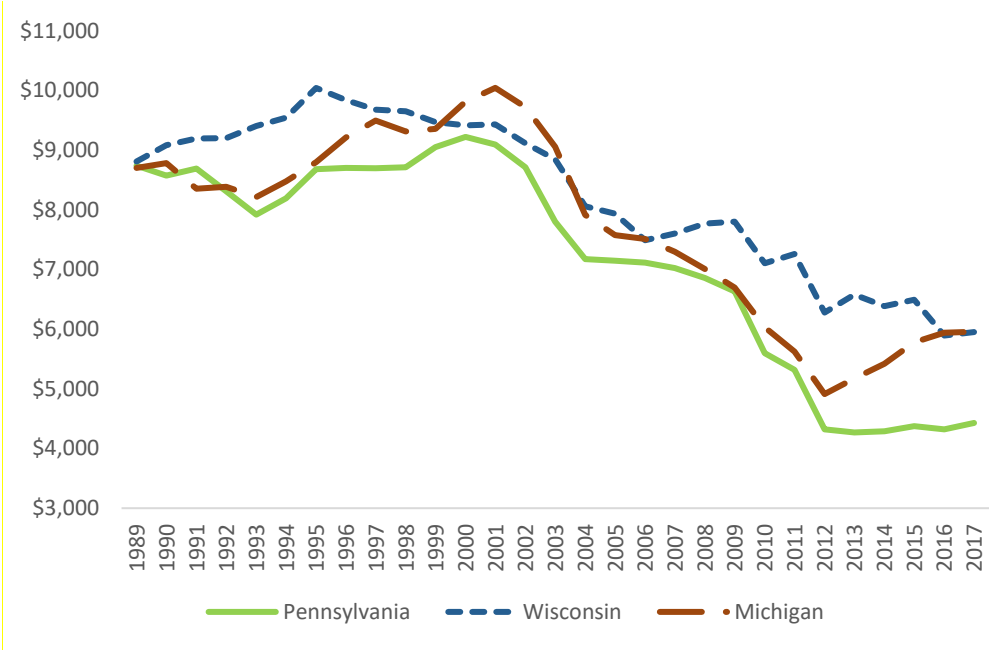
Figure 1: Constant Dollar Higher Education Appropriations relative to Enrollment and State and Local Tax General Revenues 1980-2016



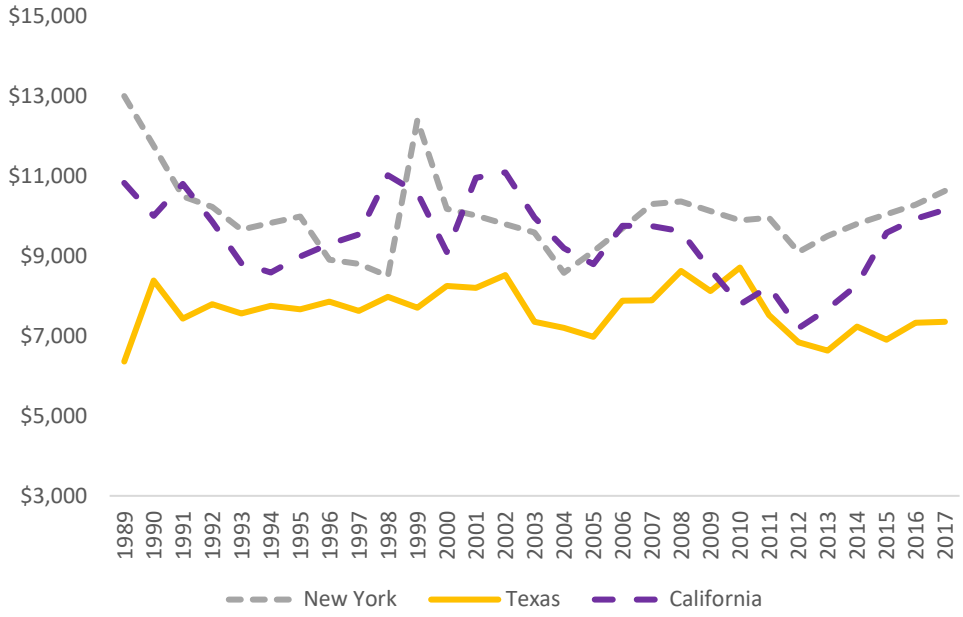
Note: Higher education appropriations are local and state appropriations net of special-purpose, research, and medical (RAM) appropriations measured in 2017 dollars. We use HECA (Higher Education Cost Adjustment) deflator. FTE is the full-time equivalent enrollment net of medical students. Years in the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

Figure 2 – Constant Dollar Appropriations per FTE 1989-2017 – Selected States

Panel A – States with Declining Appropriations

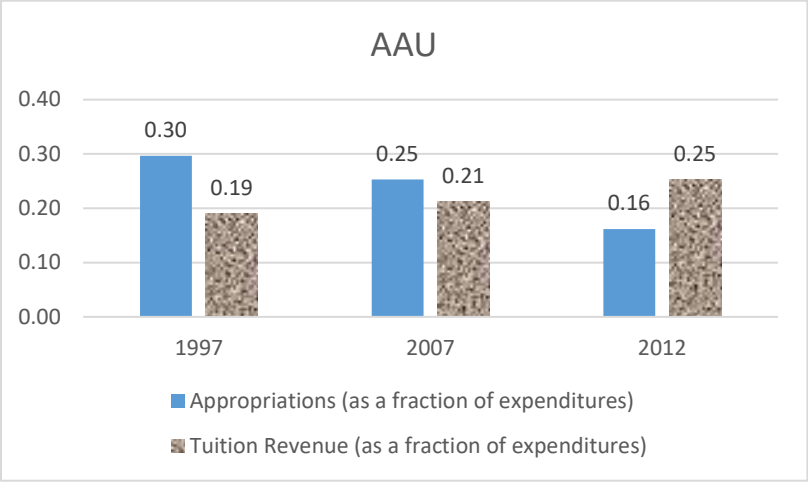


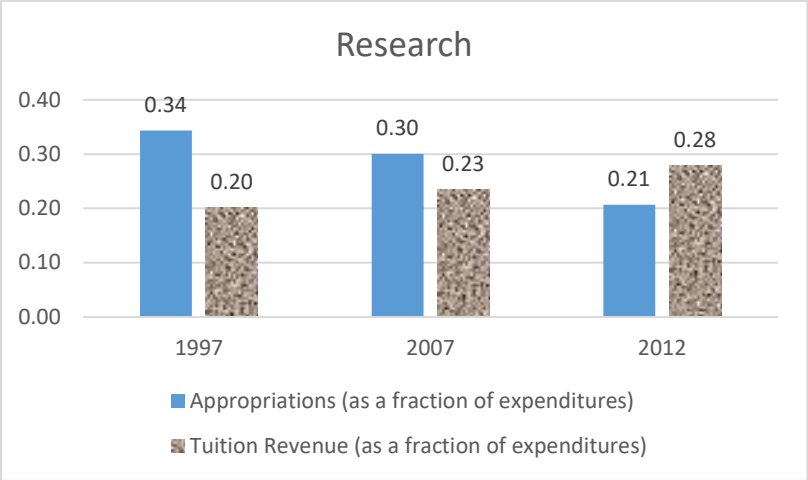
Panel B – States with Stable Appropriations

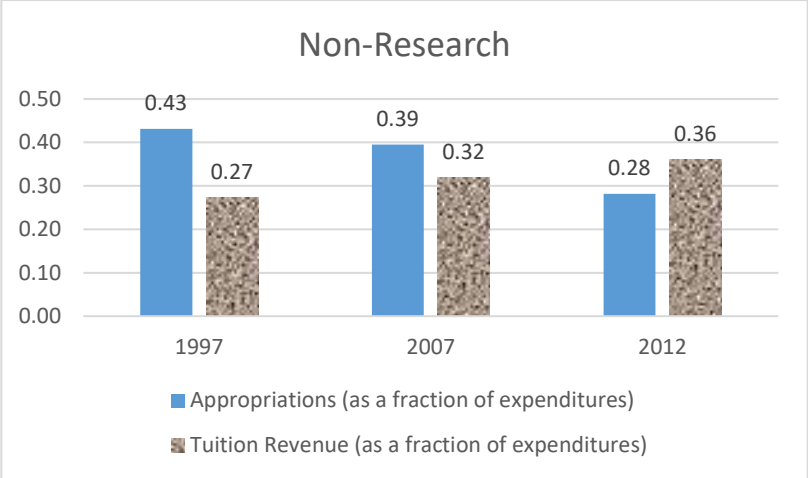


Note: Appropirations by FTE is total appropriations to higher education in the a state divided by full-time equivalent enrollment net of medical students. All measures are in 2017 dollars using the HECA index. Years are fiscal years. Source: State Higher Education Finance (SHEF)

Figure 3: Changes in Appropriations and Tuition Revenue Relative to Expenditures 1997-2012







Notes: Sample of Public 4+ 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). Non-Research is sample of master's universities or Doctoral universities with low research activity. Source: Appropriations, total educational expenditures and tuition revenue data from IPEDS (1997 to 2012)

Table 1. Effects of Appropriations on Expenditures per FTE, by Type of Public University 1996-2012

Panel A, Dep. Variable: Log(Total ed & general exp)	AAU	Research	Non-Research
Log(State Appropriations)	0.014	0.156	0.301
	(0.051)	(0.095)	(0.031)
Panel B, Dep. Variable: Log(Institutional support exp.)	AAU	Research	Non-Research
Log(State Appropriations)	0.239	0.338	0.392
	(0.121)	(0.101)	(0.064)
Panel C, Dep. Variable: Log(Exp for research)	AAU	Research	Non-Research
Log(State Appropriations)	-0.015	0.012	0.050
	(0.135)	(0.170)	(0.181)
Panel D, Dep. Variable: Log(Exp. for instruction)	AAU	Research	Non-Research
Log(State Appropriations)	-0.008	0.142	0.293
	(0.068)	(0.091)	(0.035)
Observations	505	1,969	4,036
Universities	32	126	262

Notes: All models are estimated using linear least squares. All regressions include year and university fixed effects, a control for the size of the cohort aged 18, and the unemployment rate. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level. Source: Enrollment data from IPEDS includes both graduate and undergraduate students (1996 to 2012).

Table 2: Effects of Appropriations on Total Tuition Revenues, by Type of Public University 1996-2012

Dependent Variable	Log Tuition Revenue		
	AAU	Research	Non-Research
Log(State Appropriations)	-0.311	-0.190	-0.117
	(0.075)	(0.047)	(0.046)
Log(FTE Undergrad)	0.457	0.557	0.685
	(0.190)	(0.092)	(0.084)
Log(FTE Grad)	0.230	0.216	0.059
	(0.081)	(0.047)	(0.020)
Observations	538	2,221	4,763
Number of Universities	34	137	293

Notes: 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 aged 18. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level. Source: Enrollment data from IPEDS includes both graduate and undergraduate students. Revenue data from IPEDS (1996 to 2012).

Table 3 - Effects of Appropriations on Log (Private gifts and Endowment) 1996-2012

Dependent Variable	Log (Private gifts and Endowment)		
	Research	AAU	Non-Research
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

Notes: All regressions include year and university fixed effects, and a control for the size of the cohort aged 18. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level. Source: Gifts and Endowments data from IPEDS (1996 to 2012)

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

Panel A

Dependent Variable	Log(In-State UG Freshmen Enrollment)					
	AAU		Research		Non-Research	
	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	2835
Partial R-squared		0.284		0.270		0.283
F- Statistic		26.66		65.59		65.99

Panel B

Dependent Variable	Log(In-State UG Total Enrollment)					
	AAU		Research		Non-Research	
	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-squared		0.309		0.283		0.271
F- Statistic		32.18		66.30		55.88

Notes: 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 aged 18. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level. Source: Enrollment data from IPEDS (1996 to 2012).

Table 5 – The Effect of Appropriations on Degrees Awarded 1996-2012

Dependent Variable: Log(Bachelor Degrees)

	AAU		Research		Non-Research	
	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	0.385	0.089	0.262	0.361	0.205	0.060
	(0.118)	(0.226)	(0.060)	(0.092)	(0.044)	(0.138)
Observations	546	546	2,177	2,177	4,742	4,742
Number of Universities	34	34	136	136	292	292

Dependent Variable: Log(Master Degrees)

	AAU		Research		Non-Research	
	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	0.428	0.575	0.248	0.301	0.157	0.296
	(0.140)	(0.182)	(0.065)	(0.152)	(0.086)	(0.189)
Observations	558	558	2,219	2,219	4,775	4,775
Number of Universities	34	34	136	136	294	294

Dependent Variable: Log(PhD Degrees)

	AAU		Research		Non-Research	
	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	0.386	0.590	0.532	0.719	1.088	2.306
	(0.126)	(0.226)	(0.117)	(0.223)	(0.483)	(0.725)
Observations	546	546	2,176	2,176	1,313	1,313
Number of Universities	34	34	136	136	116	116
Partial R-squared		0.218		0.249		0.264
F- Statistic		9.197		35.78		34.95

Notes: 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 Bachelors and Doctorate degrees and over the previous three years for Masters degrees. All regressions include year and university fixed effects, and a control for the size of the cohort aged 18. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level. Source: Degree data from IPEDS (1996 to 2012) via the Urban Institute Data Portal.

Table 6- Effect of Appropriations on Faculty Salaries 1996-2012

Dependent Variable: Log(Assist Prof Salary)

	AAU		Research		Non-Research	
	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		Non-Research	
	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		Non-Research	
	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-squared		0.262		0.325		0.249
F- Statistic		12.97		46.72		42.85

Notes: 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 aged 18, and the unemployment rate. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level. Source: Salary data from IPEDS includes both graduate and undergraduate students (1996 to 2012).

Table 7 - Effect of Appropriations on Patents 1996-2012

Dependent Variable	Log(Patents)			
	AAU		Research	
	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-squared		0.319		0.301
F- Statistic		50.40		17.18

Notes: 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 aged 18. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level. Source: Patenting data from National Science Foundation (1996 to 2012), United States Patent and Trademark Office, University Patent Count & Expenditures.

Appendix

Data Sources and Preparation

Sources

The data assembled for this project are organized at the university and academic year and draw on multiple sources including the Department of Education's IPEDS survey modules, the American Survey of Colleges assembled by the College Board, the National Science Foundation, the United States 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, there are three categories: (1) Very high research activity, (2) High research activity, and (3) 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" defined as the combination of (1) and (2) and create a comparison group of "Non-Research" institutions as the aggregate of (3) and the Master's institutions.

1- University Level 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 employ 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' 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]

[21] In 2004, the 78th Legislature passed House Bill (HB) 3015, amending Texas Education Code §54.0513 to allow governing boards of public universities to set different designated tuition rates. Tuition deregulation became

Private gifts, grants and contracts (from IPEDS) includes revenues from private (non-governmental) 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, etc.), and by contract length. We use data on the equated 9-month contract. We use data on non-medical full time instructional staff only. Instruction/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, this 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 (HEPI). Since most of our regression formulations 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.

Test Scores

Test score data are from the American Survey of Colleges. ASC report the 25th and 75th percentile of tests scores for the incoming freshmen class. These data are available for SAT and ACT tests separately, and by each component of the test: we report the SAT Verbal 75th percentile of incoming freshmen, SAT Math 75th percentile of incoming freshmen, and the ACT Comprehensive score's 75th percentile of incoming freshmen.

Academic Outcomes

Academic score data (2003 to 2018) comes from the Academic Ranking of World Universities 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 3 specific components of the score: HiCi score is based on the number of highly cited researchers in 21 broad subject categories; N&S score

effective September 1, 2003, and universities began increasing designated tuition in spring 2004. More information can be found at the Overview: Tuition Deregulation and Tuition Set Asides Report.

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.

Patents

Patenting data are from the National Science Foundation (1996 to 2012), and the University Patent Count & Expenditures. These sources compile patenting information from the United States Patent and Trademark Office (USPTO). (see this website for an easy to access version of the data). We harmonize university names in the data and match it to the rest of our data.

2- State Level data

Higher Education Appropriations

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

State-Level Demographic and Labor Market Variables

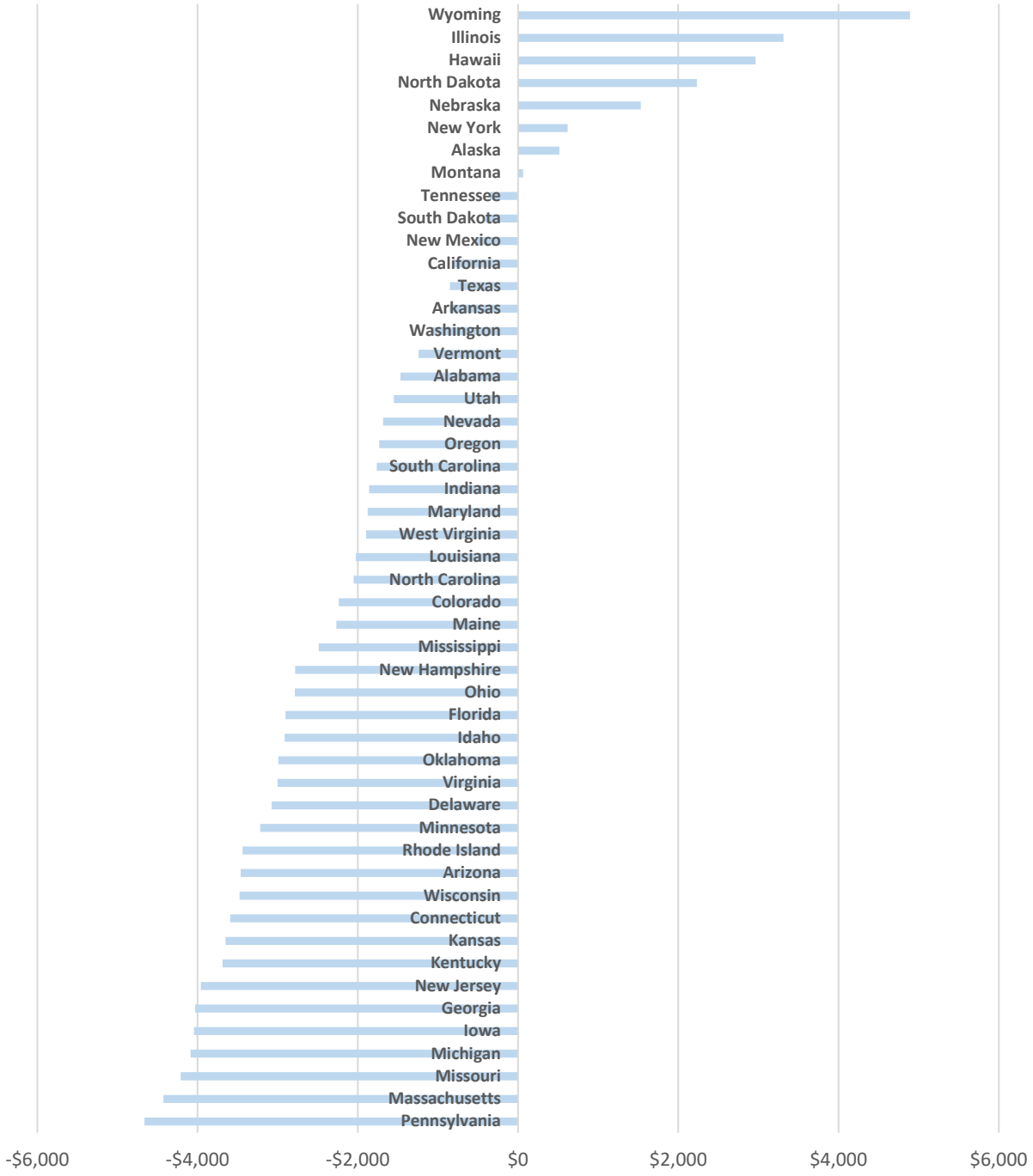
In order to control for changes to the local economy, we compile historical Census estimates of the population at age 18 by state, and Bureau of Labor Statistics (BLS) data on the state unemployment rate. State General Revenue is from the Tax Policy Center. Medicaid Expenditure from the Center for Medicare and Medicaid Services. State population, personal income, and indicator whether the governor is Democrat is from the University of Kentucky Poverty Center.

3- 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 (CDS) available on their Institutional Research webpages and the University of California System available at <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, 84 to the Flagship, 49 to the AAU and 4 to the Non-Research. Our main results are robust to excluding the hand-coded data.

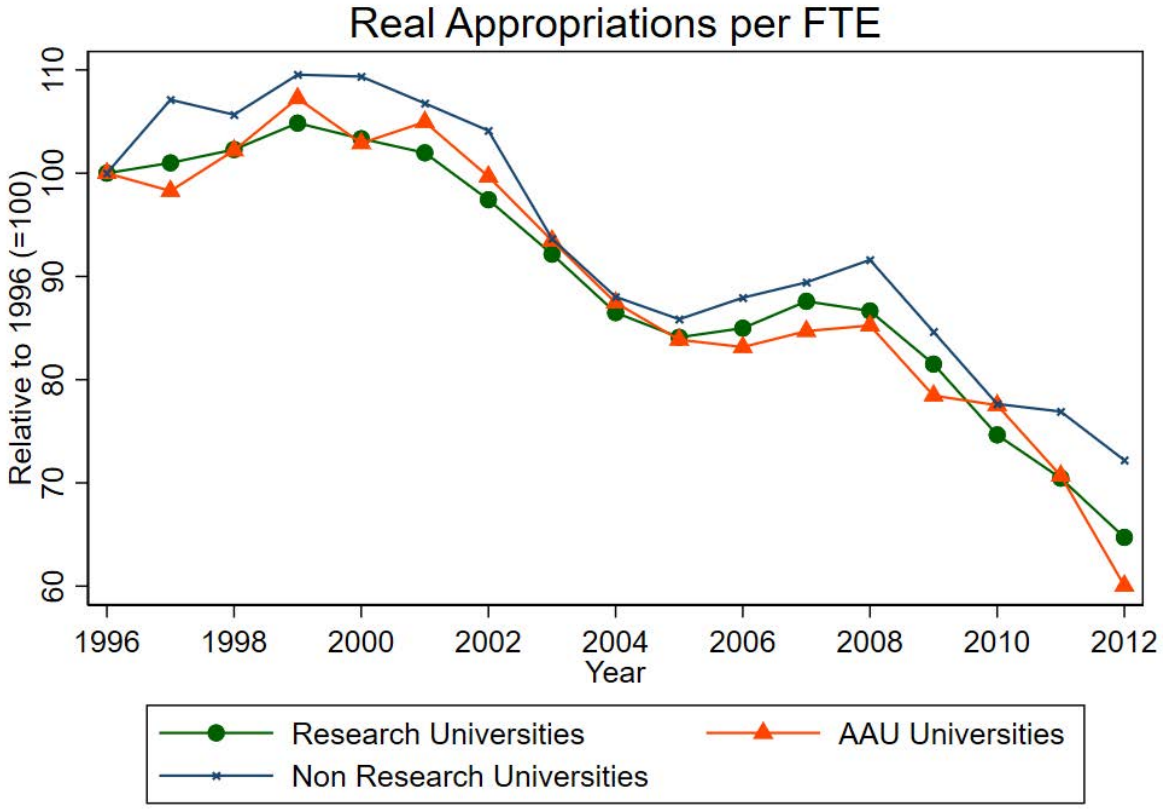
Additional Figures and Tables

Figure A1. Changes in Higher Education Appropriations per FTE between 2001 and 2017 by State



Note: Appropirations by FTE is total appropriations in the a 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. For Illinois, a $1.25 billion back payment in FY 17 to their historically underfunded higher education pension program resulted in past legacy pension funds accounting for 37.8 percent of all educational appropriations. Source: State Higher Education Finance (SHEF).

Figure A2. Changes Appropriations per FTE between 1998 and 2012 by University type



Note: We create real appropriations (IPEDS data) per full-time equivalent student for each university after deflating by the higher education price index (HEPI) and dividing by the number of undergraduates enrolled. We then create the mean value by type of university, and normalize the values to the 1996 level.

Table A1 – Determinates of State Appropriations 1996-2012

Dependent Variable	State Appropriations per capita	
State General Revenue per Capita	0.013	0.014
	(0.002)	(0.002)
Medicaid Expenditure per Capita	-0.026	-0.026
	(0.014)	(0.014)
Personal Income (Thousands) per Capita	2.596	1.963
	(1.058)	(1.092)
Governor is Democrat	-1.326	-1.842
	(3.132)	(3.040)
Lag Unemployment Rate		-4.922
		(1.399)
Observations	1,750	1,750

Notes: All regressions include year and state fixed effects. Standard errors clustered at the state level. Source: State Appropriations is from State Higher Education Finance (1980-2014). State General Revenue is from the Tax Policy Center. Medicaid Expenditure from the Center for Medicare and Medicaid Services. State population, personal income, and indicator whether the governor is Democrat is from the University of Kentucky Poverty Center. State unemployment rate is from the Bureau of Labor Statistics.

Table A2. Effects of Appropriations on Log (Tuition and Fees Rate) by category and Type of Public University 1996-2012

Dependent Variable: Log (In State Tuition and Fees Rate)

	AAU		Research		Non-Research	
	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	-0.265	-0.338	-0.164	-0.157	-0.187	-0.124
	(0.087)	(0.156)	(0.052)	(0.100)	(0.047)	(0.172)
Observations	541	548	2,151	2,172	4,602	4,630
Number of Universities	34	34	136	136	293	293

Dependent Variable: Log (Out of State Tuition and Fees Rate)

	AAU		Research		Non-Research	
	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	-0.014	0.405	-0.027	0.193	0.018	0.130
	(0.069)	(0.227)	(0.043)	(0.134)	(0.033)	(0.141)
Observations	548	548	2,172	2,172	4,599	4,630
Number of Universities	34	34	136	136	293	293
Partial R-squared		0.267		0.227		0.185
F- Statistic		46.16		76.16		50.64

Notes: 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, a control for the size of the cohort aged 18, and the unemployment rate. Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level. Source: Tuition and fee charges from American Survey of Colleges (ASC) 1996-2012.

Table A3 - Effects of Appropriations on Test Scores 1996-2012

Dependent Variable: Log(SAT Verb 75)

	AAU		Research		Non-Research	
	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	0.029	0.032	0.003	0.008	-0.002	0.001
	(0.014)	(0.047)	(0.007)	(0.019)	(0.011)	(0.021)
Log(FTE)	0.056	0.055	-0.002	-0.004	-0.011	-0.014
	(0.036)	(0.035)	(0.010)	(0.011)	(0.019)	(0.028)

Dependent Variable: Log(SAT Math 75)

	AAU		Research		Non-Research	
	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	-0.011	-0.045	-0.011	-0.012	0.007	0.023
	(0.015)	(0.052)	(0.008)	(0.023)	(0.010)	(0.015)
Log(FTE)	0.053	0.059	-0.000	0.000	0.002	-0.007
	(0.045)	(0.040)	(0.011)	(0.009)	(0.017)	(0.017)

Dependent Variable: Log(ACT Comp 75)

Log(Full Prof Salary)	AAU		Research		Non-Research	
	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	0.029	0.042	0.008	0.024	0.015	0.021
	(0.021)	(0.061)	(0.011)	(0.026)	(0.011)	(0.020)
Log(FTE)	0.020	0.018	-0.005	-0.011	0.015	0.012
	(0.061)	(0.053)	(0.017)	(0.023)	(0.019)	(0.031)
Observations	419	418	1,634	1,630	2,154	2,141
Number of Universities	29	28	122	118	227	213
Partial R-squared		0.335		0.303		0.275
F- Statistic		39.93		59.98		56.76

Notes: 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 control for Log(population at age 18). Regressions weighted by baseline (1996) enrollment. Standard errors clustered at the university level. Source: Test score data from ASC (1996 to 2012).

Table A3 - Effects of Appropriations on Academic Rankings 2003-2017

Sample: AAU			Components of the Score					
Dependent Variable	Aggregate Score		HiCi		N&S		PUB	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	2.916	8.051	5.797	5.833	0.399	9.192	1.871	6.971
	(2.831)	(2.621)	(2.821)	(2.510)	(4.341)	(6.067)	(2.196)	(4.901)
Observations	336	336	336	336	336	336	336	336
Number of Universities	34	34	34	34	34	34	34	34
Partial R-squared		0.355		0.355		0.355		0.355
F- Statistic		26.24		26.24		26.24		26.24

Sample: Research Universities			Components of the Score					
Dependent Variable	Aggregate Score		HiCi		N&S		PUB	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	1.564	2.125	1.907	2.261	3.159	5.767	1.596	4.797
	(1.483)	(1.342)	(1.597)	(1.791)	(2.541)	(2.868)	(1.933)	(2.178)
Observations	892	892	892	892	892	892	892	892
Number of Universities	104	104	104	104	104	104	104	104
Partial R-squared		0.401		0.401		0.401		0.401
F- Statistic		90.31		90.31		90.31		90.31

Notes: 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, a control for the size of the cohort aged 18, and the unemployment rate. Source: Academic score data from Shanghai Ranking (2003 to 2017). Aggregated score is used to create the Academic Ranking of World Universities. HiCi score is based on the number of highly cited researchers in 21 broad subject categories; N&S score is based on the number of papers published in Nature and Science; and PUB score is based number of papers indexed in Science Citation Index-expanded and Social Science Citation Index.