Less Funding, More Lecturers, and Fewer Professors: Stagnating State Funding for Higher Education and its Effect on Faculty

Senan Hogan-Hennessy*
Economics Department, Cornell University†

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Abstract

Public universities employ more lecturers and fewer professors today than at any other point in the last thirty years, relative to student enrolment. At the same time, state funding for higher education has stagnated. This paper shows that the decline in state funding led to a substitution away from professors toward lecturers at US public universities. Using a shift-share approach to instrument for state funding, I find that universities employ 4.4% more lecturers per student following a 10% funding cut. This shift is accompanied by a reduction in assistant and full professors by 1.4% and 1.2% per student, respectively. Incumbent professors' salaries, promotion rates, and quit rates at Illinois universities remain unaffected by funding cuts, indicating that the substitution arose from limiting the hiring of new tenure-track/tenured professors. Stagnating state funding impacts public universities and faculty, likely contributing to deteriorating student outcomes at public universities seen since the 1990s.

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†Address: Uris Hall #447, Economics Department, Cornell University NY 14853 USA.

1 Introduction

States fund their public universities with roughly the same amount today as they did in the 1990s, despite enrolment rising by over 50%. At the same time, public universities have systematically substituted away from professors towards lecturers, who often work on contingent and lower-salaried contracts. Previous research shows state funding cuts led to worsening student outcomes (Deming & Walters 2017, Chakrabarti, Gorton & Lovenheim 2020), but there is little evidence on whether these funding cuts impacted faculty. In this paper I show that falling state funding caused a change in the composition of faculty at US public universities, substituting professors for more lecturers.

Per-student state funding for higher education has stagnated the last thirty years. The average public university received around \$11,600 of state funding per-student in 1990 and \$8,300 in 2021, while the number of lecturers per-student increased by 109% and professors per-student decreased by 23% over 1990–2021. I use a shift-share instrumental variables (IV) approach to estimate how faculty are affected by these funding cuts. Universities employ 4.4% more lecturers per-student following a 10% funding cut, and correspondingly rely less on tenure-track faculty by employing 1.4% fewer tenure-track professors and 1.2% fewer tenured professors per-student. In a secondary analysis of all public university faculty in the state of Illinois, I show that incumbent faculty were unaffected, in terms of wages, promotion and quit rates. This implies that the faculty substitution arose by disrupting hiring of new tenure-track/tenured professors, which is supported supplementary data on professor hiring at US public universities over 2010–2021. This paper shows the institutional effects of stagnating state funding for higher education, and offers one possible mechanism for how funding cuts affected student outcomes.

I use two different analyses to explore the causal effects of state funding on faculty composition and salaries. My first analysis uses data from the *US Department of Education Integrated Postsecondary Education Data System* (2021, IPEDS) to study the impact of changes in state funding for all US public universities 1990–2021. My second analysis uses panel data for every faculty member at Illinois public universities for 2010–2021 *Illinois Board of Higher Education* (2021, IBHED), to measure how incumbent faculty (i.e., those already employed at the university) are affected by changes in state funding. These data allow me to answer the following research question: if a US public university has its funding cut by $1,000 per-student (or a 10% cut), do they change how many faculty members they employ? If so, which positions do universities substitute towards, and do these funding cuts affect the faculty themselves?

It is a priori unclear how faculty may be affected, as there are various margins that universities may to respond to funding cuts. On one hand, faculty may be negatively affected by universities cutting salaries or laying-off incumbent faculty. This happened in 2010 when the University of Illinois System furloughed university staff following budget cuts after the Great Recession (Employee Relations and Human Resources at the University of Illinois 2010). Similarly, faculty hiring committees are often cancelled or disrupted in response to funding cuts, meaning there are fewer faculty entering a department to replace those leaving. On the other hand, lecturers could be hired to fill in teaching duties, on shorter and cheaper contracts with fewer employment protections. But it is not certain that universities would hire more lecturers in the face of budget cuts. Public university administrators, motivated by increased competition (Hoxby 2009, Urquiola 2020), may notice that their rankings are negatively affected by falling professor-lecturer ratios, and so limit departments from hiring more lecturers to replace leaving/retiring professors. Administrators could even start courting private funding or increase tuition prices to fill funding gaps (Bound, Braga, Khanna & Turner 2019), possibly leaving faculty unaffected by state funding cuts. These are some ways that the long-run stagnation in state funding would not guarantee a substitution towards lecturers at US public universities.

State funding for higher education is not decided randomly; universities that rely more on state funding may also be institutions that find it difficult to attract new faculty thanks to location, or other factors. This means that correlations between state funding and faculty outcomes do not necessarily represent causal relationships. As such, it would be naïve to think of state higher education funding as independent of public university faculty, so I employ a shift-share IV approach to identify causal effects of state funding cuts. The shift-share instrument identifies exogenous changes in state funding by exploiting differences in universities' reliance on state funding, interacted with state-wide shifts in higher education funding — following the methods of Deming & Walters (2017), Chakrabarti et al. (2020). Yearly state government budgets are decided without targetting individual universities for funding cuts, so more reliant universities will be more affected by state-wide funding cuts, so the shift-share approach estimates causal effects among more reliant universities. Additionally, I estimate effect of state funding on faculty multiple years after the initial funding cuts, using the local projections method.[1] This approach allows me to test whether the effects of funding cuts are persistent or universities recover quickly e.g., by quickly resuming faculty hiring in years after funding cuts.

In my university-level analysis (IPEDS), I find that state funding cuts cause public universities to substitute away from tenured and tenure-track professors towards lecturers. A funding cut of 10% per-student leads to a fall of 1.4% in the number of assistant professors per-student at a university, a fall of 1.2% for tenured professors, and an increase in 4.4% the number of lecturers per-student. Local projection estimates show that these effects linger for up to ten years after the initial funding cut, showing that effects are persistent and not transitory. Over the same time period, state funding per-student fell by around 35%, professors per-student fell by 9%, and lecturers per-student increased by 99%. These results show that falls in state funding explain around 53% of the fall in professors per-student, and 15.5% of the rise in lecturers per-student. In my analysis of all Illinois faculty

[1] To the best of my knowledge, this is also the first paper to use the local projections method for a shift-share instrument, and to acknowledge the time-series confounding for shift-share IV models when the outcome is in future time periods.

(IBHED), I find that incumbent professors were not meaningfully affected, in terms of total salary, promotion rate, or rate of leaving the Illinois public university system. This implies that faculty substitution arose by limiting the hiring of new professors, and is supported by suggestive evidence on professor hiring counts.

I provide the first causal evidence on the impact of state funding on faculty composition and wages. In a contemporaneous working paper, Hinrichs (2022) use the same national-level variation in university funding to analyse effects on faculty and wages, coming to different conclusions.[2] The closest related research on higher education funding examined how university spending affected graduation rates and levels of student debt (Deming & Walters 2017, Chakrabarti et al. 2020), and university finances (Miller & Park 2022, Bound et al. 2019, Webber 2017). For faculty outcomes, descriptive work measures how US faculty salaries are correlated with other factors (Hilmer & Hilmer 2020), and applied theory work models university decision-making and faculty hiring (see e.g., Abe & Watanabe 2015, Johnson & Turner 2009, Courant & Turner 2019). Other papers measure university decision–making after endowment shocks (Brown, Dimmock, Kang & Weisbenner 2014), and trends in the academic job market following the 2008 recession (Turner 2014). These papers measure changes in state funding and university revenues, but do not measure effects of state funding cuts on faculty composition or salaries, or other outcomes related to university instruction. My results provide evidence that the long term trends in higher education funding and faculty outcomes are causally related, contributing to the literature on faculty outcomes (Ehrenberg 2003) and trends in US higher education and funding (Hoxby 2009, Ehrenberg 2012).

Another contribution of my paper is to provide evidence on possible mechanisms connecting state funding cuts for higher education and worsening student outcomes. In 2021, around 65% of lecturers at US public universities are employed part-time (IPEDS); this arrangement is often arranged as an adjunct contract, where faculty are paid based on how

[2] Hinrichs (2022) considers a shorter time-period than this paper (2010–2021), uses only national variation in IPEDS data, relies on IPEDS data for faculty salaries, and has no individual-level analysis of faculty or their salaries. See ?? for an elaboration on these issues.

many courses they teach, without employment benefits (Monks 2009). While funding cuts force universities to substitute towards lecturers, there is consistent evidence that students are worse off being taught by part-time lecturers than full-time faculty. Universities that rely on more lecturers have lower student retention and graduation rates (Jaeger & Eagan 2011, Ehrenberg & Zhang 2005). Similarly, students at a large public university have consistently worse education outcomes if taught by adjunct lecturers than those taught by full-time faculty, largely thanks to the worse working conditions adjunct lecturers face (Zhu 2021). Alternatively, Bettinger & Long (2010), Figlio, Schapiro & Soter (2015) study lecturers at a highly selective universities, finding that adjunct lecturers improve subject retention for undergraduates compared to professors. This paper studies faculty at public universities, which are by-majority not selective, and where lecturers are more often employed part-time with less institutional support. Combining the evidence that adjunct lecturers lead to worse student outcomes with the trends in education finances and performance (Deming & Walters 2017, Chakrabarti et al. 2020), implies that substituting towards lecturers contributed to deteriorating student outcomes at public universities.

This paper proceeds as follows. Section 2 describes the data for university funding, data on faculty in Illinois, and recent trends in higher education funding. Section 3 gives the conceptual framework for how state funding may affect faculty. Section 4 draws the empirical framework for isolating the causal effects of state funding on faculty, with Section 5 presenting the empirical results. Section 6 concludes.

2 Data and Institutional Context

2.1 Data Description

The data used in this paper come from two primary sources: *US Department of Education Integrated Postsecondary Education Data System* (2021, IPEDS) for data on university funding, finances, and enrolment, and *Illinois Board of Higher Education* (2021, IBHED) for data on every faculty member in the Illinois public university system.

IPEDS is a survey of higher educational institutions in the US, and legally requires institutions to participate in order to receive Federal Title IV student aid.[3] Data are consistent for 1990–2021,[4] and provide information on university funding, enrolment, and numerous other characteristics.[5] I restrict analysis to public, four-year, degree-granting institutions, as these institutions have the largest majority of faculty employed and students enrolled. For-profit institutions employ and enrol a negligible share of professors and students respectively, while students at two-year institutions by majority intend to eventually enrol at a four-year institution (Mountjoy 2022), so that these institutions are not considered. IPEDS reports the count of professors employed by position; IPEDS data on average faculty salaries are inconsistent with trends in faculty salaries from other sources, so I do not consider these data reliable and conduct no analysis involving them.[6][7] This gives a resulting panel data-set,

[3]IPEDS does not necessarily cover the universe of US higher education institutions, yet in practice every public university and not for-profit four-year institution is represented.

[4]The years 1987-1989 are represented in these data in an incompletion fashion, so I focus on the years 1990 onwards. Year refers to the calendar year of the spring term — i.e., 1990 refers to the academic year that ran August 1989 to July 1990.

[5]I combine the Urban Institute's 2018 compilation of IPEDS data for the years 1990–2017, and manually combine raw National Center for Education Statistics (NCES) data on 2018–2021 for all relevant variables. Figures for enrolment and faculty counts come from the raw NCES version of IPEDS for all years, addressing inconsistencies in the Urban Institute's data formulation for these variables. I also integrate Barron's selectivity index, from the 2009 rankings, to analyse effects for different levels of selectivity (Barron's 2009).

[6]IPEDS gives a mean salary measure for faculty by rank, but these figures have many missing values and disagree with calculated values from other reputable sources. Over 40% of university–year observations are missing in the IPEDS panel data-set, representing an average of 55% undergraduate enrolment in each year. Yearly averages of faculty salaries by the non-missing values do not agree with trends in average professor salary over the sample time period compared to summary statistics provided in AAUP (2021). IPEDS values consistently report that public university professors are paid on average 20% more than private sector faculty, which disagrees with other sources on the salary gap direction, and IPEDS figures are consistently higher than averages calculated from individual-level IBHED data. For these reasons I do not further analyse IPEDS salary data, and use salary data from IBHED (which do closely agree with trends in other sources) to analyse faculty salaries. Notably, IPEDS data on faculty counts do not suffer from these problems.

[7]In a contemporaneous working paper, Hinrichs (2022) analyses the effect of state funding cuts on university faculty, using the same shift-share variation. Hinrichs (2022) bases the shift–share instrument in the year 2011, despite major upheavals in the level of state funding for state funding for higher education around the 2008 Great Recession, and years following (see Subsection 2.2); Hinrichs (2022) also does not mention the data inconsistencies in IPEDS data for average faculty salaries. These two major differences explain the different conclusions that our contemporary papers come to; Subsection A.5 replicates the Hinrichs (2022) empirical findings with my primary specification, and further discuses the differences in findings.

where each row represents a university-year, and includes columns for university funding and tuition revenue, plus total count for each faculty position (lecturer, assistant professor, tenured professor, and total faculty), and other university characteristics. Table 1 presents summary statistics for these variables in IPEDS data.

IPEDS provides information at the university level, but only provides aggregated information within a university. To investigate outcomes for individual faculty members, I integrate individual-level data for all faculty members at all Illinois public universities 2010–2021. These data allow me to investigate how individual faculty members are affected by funding cuts to their university, investigating individual-level professor outcomes unavailable in IPEDS data. IBHED freely provides this information, as the state of Illinois is required to publicly report base salary and benefits[8] for all administrators, faculty members, and instructors employed by each public college or university.[9] These data provide the basis to build a panel of Illinois public university faculty across years 2010–2021; I define a faculty member as an individual by their first plus last name and university pairing,[10] and link this database to IPEDS for data on their university employer. The Illinois sample represents 16,932 professors in the year 2010 and 15,352 in the year 2021, with summary statistics presented in Table 2. Analysis of professors' in their first year on the job focuses on the subset of professors with observed year of hiring 2011–2021 (i.e., after the panel's first year), representing 1,778 professors in 2011, and 9,099 in 2021.

[8]Real salary is computed by scaling nominal salary and benefits to 2021 dollars by the CPI-U.

[9]Public Act 96-0266, effective 1 January 2010, is the relevant Illinois law that requires publicly publishing salary data for all public university faculty salary and benefits (Illinois General Assembly 2010). A pdf copy of Public Act 096-0266 is included in the supplmentary data of this paper. This law applies to all nine Illinois public universities: Chicago State University, Eastern Illinois University, Governors State University, Illinois State University, Northeastern Illinois University, Northern Illinois University, Southern Illinois University (all five campuses), University of Illinois (all four campuses), Western Illinois University.

[10]Some faculty are listed multiple times in these panel data. For example, Professor Alberto Agustin Lopez-Scala of the University of Illinois Chicago has two appointments in each year 2013–2021, one as an adjunct faculty and one as a department director. For this observation I take the highest paid position (department director) as the primary appointment and drop the secondary appointment (adjunct faculty). In analysis of faculty exit rate, I collapse the appointments into one and only consider faculty exits as having a faculty appointment versus no appointment.

2.2 Trends in Funding, Enrolment, and Faculty Counts

States vary largely in how much they fund their public university systems, thanks in part to the state-wide budgeting process (Deming & Walters 2017). Planning for an annual budget begins two years ahead of the fiscal year, and the legislature votes to approve or reject the governor office's budget request a number of months before the fiscal year begins.[11] US state governments, by majority, are legally obliged to run a balanced-budget, so that yearly variation in tax revenues (e.g., caused by changing economic conditions) necessarily led to state government spending cuts. Public universities have lower lobbying power than other state institutions, so often bear the brunt of these funding cuts (Delaney & Doyle 2011).[12] Additionally, the number of higher education students in each state varies thanks to the size of each birth cohort. For example, the birth cohort of 1971 was larger than that of 1970 or 1972, leading to more student demand for limited public university places for students turning 18 in 1989 (Bound & Turner 2007). These features lead to yearly variation in state funding not seen in other revenues sources, such as federal funding.

State funding for public universities stagnated over the last thirty years. Figure 1 show the trends in revenues for the mean public university for the years 1990–2021. We see a rise in total revenues received by public universities (from all sources), and a notable increase in mean tuition revenues from \$48 million per year-university to \$150 million per year-university. At the same time, total state funding stagnated at around \$100 million per year-university for 1990–2008, falling around 2008 and have not recovered ever since. While public universities experienced a stagnation in state support, private universities were not exposed to the same constraints, receiving \$37,000 per student in 1990 and \$49,000 in 2021, experiencing no

[11] Deming & Walters (2017) present a full discussion of the decision-making process for state funding, drawing on administrative records originally analysed by Parmley, Bell, L'Orange & Lingenfelter (2009).

[12] Delaney & Doyle (2011) fully describe the financial environment of state expenditures, and what makes spending on higher education an attractive area for state governments to expand funding during years of higher tax revenues, and retract funding in leaner years. An analysis of state expenditures for the years 1980-2004 (overlapping with the sample for this analysis) provides solid evidence for these trends, and Figure 1 observes these same trends.

corresponding decline in any specific component.

At the same time, student enrolment at public universities rose precipitously. 6.2 million students were enrolled in public universities in 1990, and this number rose by 47% to 9.1 million in 2021, with most of the increase occurring after the year 2000. Figure 2 shows that total enrolment at private universities has also risen over the same time period, but not as drastic in either relative or absolute terms; the mean private university grew from 9,800 students in 1990 to 11,800 in 2021. This means that funding per student has stagnated for all sources (seen in Figure 1b), falling from $11,000 per student on average in 1990 to less than $8,000 per student in 2021.

There are large differences in the average number of professors per student between the private and public sector. Figure 3 shows that private universities start with an average of 40 students for every one full professor, and little change thereafter. Public universities start with 40 students per professor, and by 2021 there are 52.4 students professors for every full professor — with the largest rise coming in the 2008–2011 time period. The general trend is similar for the number of assistant professors at both public and private universities. Private and public universities have similar numbers of associate and full professors before the year 2000. After 2000, the number of professors at public univeristies fell drastically, with the average public university has 6 fewer full professors per hundred students than the average private university by 2021. Over the same time period, we see the rise in use of lecturers; lecturers were employed at similar rates in private and public sectors in 1990. Since 1990, both sectors began employing more lecturers on a per-student basis. In sum, this means public universities have begun relying on lecturers, because they decreased their professor counts, compared to private unviersities who started employing more lecturers and professors.

2.3 Trends in Illinois

Illinois funding for higher education has stagnated, experiencing serious declines in the decade 2010–2021 — similar in magnitude to the nation-wide decline over 1990–2021. State funding Illinois public universities fell by over 50% over 2010–2021, in both absolute and per-student terms (see Figure 4).

There was not only a stagnation in state funding in this time period, but also large annual rises and falls, particularly around 2016. In the calendar year 2015, partisan disagreements between the democratic legislature and republican governor led to the 2016 fiscal year starting with no state budget. State agencies, and higher education institutions, employed accounting techniques to continue operating without any resources provided by the state government.[13] While most public universities were able to stay open, there were drastic revenue and spending cuts in response to the budget impasse, as it continued through fiscal year 2017, and ended with a new budget restoring funding to state institutions for 2018. This means that Illinois public universities exhibit sizable changes in their state funding over 2010–2021, of similar order to those for the rest of the country over 1990–2021. Additionally, the 2016 episode stemmed entirely from political disagreements, and not from state decisions regarding higher education and its finances, exhibiting how state-level changes in funding affect public universities thanks to unrelated issues (Young, Wiley & Searing 2020).

3 Conceptual Framework

University administrations can respond in multiple ways to state funding cuts. Deming & Walters (2017) established that public universities experiencing state funding cuts did not fully off-set by raising tuition, and instead cut spending. It is not clear how these funding or spending cuts went on to affect faculty — or whether they affected faculty at all.

[13]Fiscal year 2016 refers to June 2015 to June 2016, so is the same as the academic year definition.

Wider changes in American higher education could concurrently explain the national trends in state funding and faculty substitution. College selectivity changed drastically over the 21st century, where the top universities have become more selective while the average university less selective (Hoxby 2009). While the average public university is becoming less selective, it is possible that their most productive or research-focused faculty more often move to more selective and prestigious (and often private) institutions, leaving public universities substituting toward lecturers over time. This is one way in which the trends may be concurrent, but not causally related. I address this issue by using shift-share IV approach to isolate funding cuts that affected more funding-intensive universities, measuring the rate of substitution between lecturers and professors in response to yearly changes in state-wide funding.

Similarly, institution-specific factors could explain correlations between state funding cuts and individual-faculty outcomes, such as salaries or rates of tenure. FOr example, an administration could respond to funding cuts by cutting faculty salaries, leading to more faculty leaving for jobs at other universities. Multiple universities passed a university-wide pay-cut for their faculty in response to state budget cuts around the 2008 recession, and Cornell University implemented a professor salary cut in 2020 at the onset of the Covid-19 pandemic.[14] Funding cuts could also limit the salaries public universities can offer to new faculty hires, leading to fewer or less accomplished faculty accepting offers at public universities.[15] This effect may not be the same across faculty seniority; most universities hire more junior faculty each year, so that yearly hiring disruptions may disrupt the looser market for established full professors more than tighter market for assistant professors or lecturers. While these factors make it unclear who will be affected most by funding cuts,

[14]The Cornell University administration expected large fiscal squeezes in mid-2020, so imposed a faculty salary cut, and then returned the amount cut later in 2020 when the financial squeeze did not materialise.

[15]Faculty often consider their outside options in job decisions, considering offers for employment and/or promotion from multiple universities at the same time — see Blackaby, Booth & Frank (2005) for an overview of faculty outside options. If public universities can only make low salary offers thanks to funding cuts, then they are less likely to land professors with multiple offers.

there is one empirical fact worth noting: lecturers have substantially lower annual salaries than professors. The average Illinois assistant professor's annual salary is $\$76,897$, tenured professors' is $\$109,283$, while lecturers' is $\$31,449$ (annual salary for 2010–2021 in 2021 USD, see Table 2). If a public university's primary obligation is to teach, and they must fulfil this objective with less funding, then substituting away from tenure-track and tenured professors towards lecturers is rationalisable purely on this basis.

If faculty are affected by state funding cuts, then it is still not clear whether effects are persistent or merely transitory. Universities employ professors on multiple-year contracts (e.g., the tenure contract), and professors' decisions to retire, move university, or leave academia are multiple-year commitments, so that it may take multiple years for effects to trickle down to faculty. On the other hand, university departments hire in annual cycles, so that a funding cut in one year may immediately impact faculty hiring in the same year, and thus faculty counts in the next academic year. As such, this paper investigates the dynamics of state funding cuts, and their effects on faculty, by employing local projections methods to measure the persistence of effects for multiple years after a state funding cut.

4 Empirical Framework

This paper identifies the effects of changes in state funding on faculty. However, a university's state funding is not exogenous to state decisions for support of higher education. Instead, the state government undertakes a complex process of budgeting funding across many priorities, while higher education and faculty outcomes may not be independent in this process. This means that faculty outcomes would not be conditionally independent of faculty outcomes, and correlations between the two are not causal relationships. Shifts in state for higher education, however, provide opportunity to address such endogeneity.

4.1 State Funding Shift-Share

I use a shift-share instrument variables (IV) approach to address endogeneity concerns for state governments' higher education funding decisions. Deming & Walters (2017), Chakrabarti et al. (2020) first developed the shift-share approach for public university funding by exploiting shifts in yearly state-wide higher eduction funding, interacted with universities' reliance on state funding in a base period. $Z_{i,t}$ is the shift-share instrument for institution i in year t:

$$Z_{i,t} := -\left[\left(\frac{\text{Total State Funding}_{s(i),t}}{\text{Student Population}_{s(i),t}}\right)\sum_{k=0}^{3}\frac{1}{4}\left(\frac{\text{State Funding}_{i,1990+k}}{\text{Total Revenues}_{i,1990+k}}\right)\right]. \tag{1}$$

The system exploits the fact that institutions who rely more on state funding will be affected by follow-on state-wide funding cuts. It is constructed by interacting the average funding for universities in state $s(i)$ with reliance on state funding relative to total revenues, averaged across the base years 1990–1993.[16] $Z_{i,t}$ is negative to reflect the fact that the long term trend in, and most of the short-run shifts in, state funding for higher education have been negative.[17] State funding has been falling, so that the instrument describes shocks to university revenues, mostly in a negative direction.[18]

The first-stage is then as follows, including institution and year fixed effects, where $X_{i,t}$ represents the amount of state funding divided by the number of full-time students attending

[16] 1990–1993 are defined as data for public university finance data are most comparable (i.e., without many missing values) beginning in 1990. Deming & Walters (2017) use the single year 1990 as the base year, though I use the four years to ameliorate missing values in the single year of 1990. Results are similar in either specification.

[17] When used in log terms, the instrument is the negative of the logged shock — i.e., $-\log(-Z_{i,t})$ as opposed to log of the negative shock $\log Z_{i,t}$ directly.

[18] Chakrabarti et al. (2020), Webber (2017) note the tendency for public universities to respond to state funding cuts by increasing reliance on tuition, where Deming & Walters (2017) specifically instruments for tuition revenues with collected information on legislative tuition price controls. It may be argued that tuition revenues are confounder between the causal effect of changes in state funding on a university's total revenues, so that this analysis focuses on state support for higher education (not total revenue), as do Chakrabarti et al. (2020). On the other hand, rises in tuition revenues (per-student) may arise as result of tuition hikes thanks declining state support, which would mean controlling for tuition would constitute a bad control. Nonetheless, estimates including tuition revenues (per-student) as a control in the second stage of the IV estimates produce results of very similar magnitude and direction, and so are omitted.

the university.

$$X_{i,t} = \eta_i + \zeta_t + \delta Z_{i,t} + \epsilon_{i,t} \tag{2}$$

The instrument must be conditionally independent of faculty outcomes for the IV results to be valid causal estimates. The instrument is conditionally independent if state policy decisions for funding of public universities are uncorrelated with unobserved institutional changes of any specific college or university in the state. This assumption is plausible given that the majority of states have multiple (i.e., more than five) public universities, without any single university campus receiving the majority of state funding within any single state. Secondly, the shift-share identification strategy requires exogeneity in either the base-share or shift component of the instrument (Borusyak, Hull & Jaravel 2022). We satisfy the second: faculty or university institutional-level decisions are not correlated with contemporaneous (or upcoming shocks) to state funding, so that the shift-share approach yields causal estimates by IV (Chakrabarti et al. 2020).[19] Additionally, the shift-share approach assumes that shift-share instruments affect faculty outcomes only via affecting university funding (exclusion restriction). This means that state-wide changes in higher education funding are assumed to affect faculty at universities only by changing how much their university is funded.

The conditional independence assumption for the shift-share instrument makes sense in theory for state funding, but is fundamentally untestable with data. However, the assumption is bolstered by the fact that universities with higher values of the shift-share instrument differ little in observed characteristics compared to those with lower values (Pei, Pischke & Schwandt 2019). Universities are by and large smaller (in terms of enrolment, total revenues, and professor count) at the top of the shift-share instrument distribution (see Table A1). Though on a per-student basis, there is little difference across the distribution (except in the outcomes under consideration). The shift-share instrument is positively associated with

[19] It would be plausible to consider the case that universities make institutional-level decisions in a consistently different manner to those with differing reliance on state funding in 1990, so that exogeneity by the base-share is not plausible here.

the total enrolment and total amount of state funding for each university, in both \$ and log/percentage change terms, while other the other sources of university finances are not associated with the funding shift-share. So that the other sources of finances are not clear confounders for the IV strategy, as they exhibit balance with respect to the funding shift-share. Nonetheless, yearly and institution fixed effects are included in regressions throughout to implicitly control for differences between universities and years.

4.2 Instrumental Variables (IV) Model

I use the instrument defined in Equation (1) to overcome the endogeneity concerns for state funding to each public university, for an IV approach. Equation (2) is the first-stage for exogenous variation in the state funding for university i in year t, and Equation (3) the second stage for the effect of state funding on faculty outcomes.[20]

$$Y_{i,t} = \alpha_i + \gamma_t + \beta \widehat{X}_{i,t} + \varepsilon_{i,t} \tag{3}$$

I estimate the system by two stage least squares, including institution and year fixed effects.[21] $Y_{i,t}$ represents faculty outcomes for university i in year t, α_i, γ_t university and year fixed effects, and $\widehat{X}_{i,t}$ state funding for university i estimated in first-stage (2).

Additionally, I investigate the effect of state funding cuts on professors using the Illinois data (IBHED). State funding cuts may affect faculty in years after they join the university, so I base the instrument in the year that the professor was hired, and include fixed effects

[20]The IV approach identifies the local average treatment effect, weighted towards larger values of the instrument in the continuous case. So we interpret this treatment effect as a weighted average of causal effects on faculty at public universities to state funding changes, specific to shift-share instruments, among compliers — i.e., among universities who respond to funding cut and would not have made faculty-outcome changes absent the funding cut. Also, we assume that no universities state funding increased in response to the negative shift-share instrument (monotonicity).

[21]Note that dividing by student count also implicitly controls for the size of the university, so that this model implicitly accounts for yearly variation in professor count and university revenues arising from a university's size of growth/decline.

for the hiring year.[22] The instrument exogeneity and exclusion follows the same argument as above, where no single Illinois campus takes the majority of state funding, and so the Illinois state government's funding cuts are not majority aimed at any single campus.

It is not a priori clear which units are appropriate for this analysis; does it make sense to consider state funding in purely dollar amounts per-student, or in percent change rate? The funding shift-share is a strong predictor for the average university's level of state funding in either unit; a funding shift-share of \$1,000 per-student in the entire state leads to around \$1,176 per-student at the university, while a funding shift-share of -10% leads to around 9.77% less state funding per year. Yet, the level of state funding (and the outcome variables) vary greatly between states for the unit of analysis. For example, the average Illinois public university receives \$10,709 in state funding per-student in 1990 and \$6,713 in 2021 (a fall of over 30%), while California went from \$19,224 per-student to \$12,915 in the same time span (a fall of 37%). While most states are not exactly the same as California or Illinois, this is example is telling for the phenomenon of stagnating state funding: states vary in their absolute funding for higher education in 1990, but most have experienced a decline of around 30% in per-student funding, so that the trend is a common phenomenon in percentage terms across the US. As such, I include regression specifications where the explanatory and outcome variables are log transformed, and refer to these when stating results in percent change terms.

4.3 Effects in Years After the Initial Funding Cut

Faculty outcomes could be only affected in a transitory manner, where effects are limited to the short-run and fade away quickly, or persistently, where the effects of state funding cuts linger for many years. I employ a Local Projections (LP) approach to answer the following

[22] This formulation follows that presented by Chakrabarti et al. (2020), where individual student outcomes are analysed via variation in state funding after a student's freshman-year. This contrasts with Subsection 4.2 and Deming & Walters (2017), where the unit of analysis is the university-year, where base year 1990 is more appropriate. See Subsection A.2 for the instrument and second-stage specification.

question: are university faculty affected multiple years after a state funding cut to their university? The LP method is an empirical model used to estimate dynamic treatment effects when time-series confounding is present, and accommodates an instrument (Jordá 2005, Olea, Stock & Watson 2021).

$$X_{i,t} = \eta_i + \zeta_t + \delta Z_{i,t} + \epsilon_{i,t} \tag{4}$$

$$Y_{i,t+k} = \alpha_i + \gamma_t + \beta_k \widehat{X}_{i,t} + \varepsilon_{i,t+k} \tag{5}$$

The approach estimates the first-stage (4) by ordinary least squares; here this approach is the same as in conventional IV analysis, instrumenting for a university's state funding in year t with state-wide funding shifts in year t. The second-stage (5) is estimated by a regression of faculty outcomes in future years $t+k$ on (predicted) state funding cuts in year t. Fixed effects, and two-way standard error clustering are maintained throughout, as before.

The LP method estimates the cumulative effect of a state funding cut in year t, and its cumulative follow-on funding cuts in intermediate years, on faculty outcomes in year $t+k$.[23] This is because the funding shift-share instrument is significantly auto-correlated year-on-year, as shown in Figure A1. If Vermont cuts state funding for higher education in 1993, the LP method uses this observation's predicted state funding in year 1993 to calculate the effect of the funding cut in 1993, combined with the correlated funding cut in 1994, on faculty outcomes in 1995. The LP method then averages estimates across all years and all universities by two-stage least squares, calculating an estimate $\widehat{\beta}_k$. This is an estimate of the effect of a funding cut in year t, and the average of accumulated funding cuts in intermediate years, on faculty outcomes in year $t+k$.[24]

[23] See Jordá (2023, Section 8.3) for a technical definition, and discussion of the differences in estimands when accounting (or not) for the intermediate values.

[24] The funding shift-share has a persistent effect on state funding, multiple years after the initial shift-share instrument, so that estimates in this setting represent both the effect of the initial funding cut and cumulative funding cuts in intermediate years. See Subsection A.1 for this demonstrated by estimating the first-stage by the LP method.

5 Results

5.1 First-Stage Estimates

The shift-share instrument has a strong first-stage for universities' yearly state funding. Table 3 show results of the first-stage regression among IPEDS data, separately with and without a control for tuition revenue per student. Table 3 Panel A shows estimates of a state funding shift-share of \$1 per student on state funding per student at the university, and Panel B the effects of a 1% increase in the state funding shift-share on state funding per student. Column (1) shows that a state funding shift-share of \$10 per student is associated with \$11.76 less state funding per student at the university; -10% state funding shift-share leads to -9.77% state funding per student at the average university. Estimates are presented for specifications with and without fixed effects. Column (2) shows estimates of the first-stage without including fixed effects, and gives less precise estimates for the funding shift-share — this may be due to systematic differences in universities, which are not accounted for when omitting fixed effects. Columns (3) and (4) include the tuition revenue as a control (explained in footnote 18) to exhibit estimates with or without this control variable. Column (3) shows similar estimates to column (1) in both Panels A and B thanks to inclusion of fixed effects, so whether tuition revenue is a bad control does not affect empirical estimates. Column (1) represents the estimates for Equation (2) with fixed effects (not including tuition revenue as a control variable), and is the preferred specification that I proceed with; all specifications (except column 4 in both panels) have a large F statistic on the excluded instrument.[25] I use the same empirical strategy in the analysis of Illinois faculty, and Table A3 presents first-stage estimates among the IBHED data; results are similar to those calculated in IPEDS data. These results show the funding shift-share instrument strongly predicts a university's state funding in the first-stage estimation.

[25]I calculate the F statistic on the excluded instrument, while also accounting for fixed effects and two-way standard error clustering, by the methods provided in Olea & Pflueger (2013).

The first-stage is strong in both IPEDS and IBHED data, and the argument for exogeneity comes from independence of the state funding mechanism to any individual public university campus (as in Section 4). The IV approach also assumes that shifts in state-wide funding for higher education (the instrument) affect outcomes only via affecting state funding for the university (exclusion restriction). This assumption is fundamentally untestable, but is bolstered by the lack of relationship with university characteristics. Table A1 shows the mean of various university variables, across the instrument distribution.[26] The university–years in the bottom 20% of the instrument distribution have more research spending than those in the next 20%; this is to be expected, as university spending is heavily related to state–wide shifts in funding. On the other hand, the measures of selectivity (acceptance rate, 6–year graduation rate) are noticeably different across the distribution of the instrument. While the shift–share instrument exhibits balance for many relevant university characteristics (except tuition revenues and selectivity), I include institution and year fixed effects throughout my analysis, effectively controlling for any possible confounding effects of differences between universities.

Do state funding cuts meaningfully affect universities? While the shift-share performs well in predicting state funding (i.e., a strong instrument), it could be the case that the day-to-day operations of a university are not affected. University could have responded to state funding cuts by cutting areas of spending unrelated to research or instruction, or fully off-set the cuts by charging higher tuition fees, leading to no effects on the university or faculty. To allay this concern, I estimate the IV model on IPEDS data for areas of university spending (Table A2). This exercise gauges the effects of state funding cuts on areas of university spending to gauge whether the first-stage is economically meaningful, and to see which areas of higher education operations are affected by state funding cuts. Following a state funding cut, universities

[26]The shift-share instrument is correlated with tuition revenues (and thus the sum of non-institutional revenues), so could be a presenting a threat to endogeneity. As mentioned above, including tuition revenue as a control (even though it could also be a bad control) does not meaningfully change first- and second-stage results in any specification, rendering this plausible threat to identification moot. See footnote 18 and Table 3.

spend less on instruction, student services, operations, and grant aid. Additionally, they charge higher tuition fees, though this rise is at most a quarter of the state funding cut, so does not come close to fully off-setting state funding cuts. These results are in line with previous work showing state funding cuts (or tuition price limits) reduce student-focused spending (Deming & Walters 2017), financial aid (Miller & Park 2022), and lead to increased tuition fees (Bound et al. 2019).

5.2 University Level, IPEDS

State funding cuts lead to measurable changes in the number of faculty at US public universities. Table 4 presents OLS and IV estimates for the effect of state funding cuts on the number of faculty at public universities, separately for each faculty position (lecturer, assistant and full professors, total). The results are presented in two different units: Panel A shows how a $1 increase in state funding changed the count of faculty per students, while Panel B shows how a 1% increase in state funding led to a percent change in the number of faculty per students.

An extra $1,000 in state funding per student leads to the average university employing 6 fewer lecturers, while effects for the other positions are not discernible from zero (Table 4, Panel A). A 10% state funding cut lead to a 4.4% increase in the number of lecturers per student, and a decrease of 1.35% and 1.37% for assistant and full professors, respectively. A state funding cut of 10% leads to a 0.65% decrease in the total number of faculty per student (Table 4, Panel B). These are large substitution effects, and explain roughly 40% of the trend in substitution towards lecturers over the same time period. The average public university has roughly 36% less state funding per student in 2021 than they did in 1990, while employing over double the number of lecturers and 20% fewer professors (relative to enrolment, seen in Figure 1b, 3).

Universities do not re-adjust by hiring more professors to make up for last year's funding cut, and so the substitution towards lecturers becomes persistent. Figure 5 shows LP estimates, showing the elasticity for professor count per student in year $t + k$ with respect to state funding in year t (and cumulative intermediate cuts). State funding cuts affect the number of lecturers and professors at universities up to 9 years after the initial funding cut. A 10% state funding cut leads to 4.2% (2.9–5.5 in a 95 percent confidence interval) more lecturers per student the following year, and around 3.1% (0.6–5.5 confidence interval) more lecturers nine years later. A 10% state funding cut leads to 1.5% (0.6–2.2 in a 95 percent confidence interval) fewer assistant professors per student the following year, and around 1.1% (0.2–2.0 confidence interval) fewer nine years later; the same cut leads to 1.2% (0.6–1.8 in a 95 percent confidence interval) fewer full professors per student the following year, and around 0.9% (0.1–1.7 confidence interval) fewer nine years later.

These effects are a substitution of professors for lecturers at public universities, as the total number of faculty per students are relatively unrelated to funding cuts, but the lecturer count increases and professor count decreases. This agrees with a model for universities departments having fixed teaching requirements making human-resources decisions under constrained resources (e.g., Abe & Watanabe 2015), lending credibility to this type of model for understanding recent human resources decisions of public universities. Furthermore, if a university must teach more students, but cannot afford to hire a full-time professor who teaches 2–3 classes a year, then it makes sense that they hire 2–3 additional lecturers on part-time contracts for each class as a replacement. This provides simple intuition for why the lecturers' elasticity is 2–3 times larger than that for assistant/full professors in Table 4. While no previous research causally connects funding cuts to substituting professors for lecturers, the phenomenon has been alluded to in popular media (University Communications at Western Illinois University 2016) and university rankings (where more lecturers hurts a university's ranking, Morse & Brooks 2023). The results provided here give the first real evidence for such popular claims.

5.3 Illinois Faculty, IBHED

Incumbent professors at Illinois universities are relatively unaffected by state funding cuts at their university. Table 5 show estimates of a 10% change in state funding per student on faculty salaries, rate of exiting the Illinois public university system, and rate of promotion. The estimates are not discernible from zero in any specification, including the shift-share IV estimates, so that faculty seem to have little or no state funding cuts passed on to them for these outcomes.

It could be the case that effects on faculty do not materialise until multiple years after a funding cut, though the data do not support this possibility. LP estimates show that professors' salaries, including salaries, are not significantly affected in years following funding cuts (Figure 6) — they do not receive lower rates of pay raises, or delayed salary cuts, in response to state funding cuts. Similarly, promotion rate and rate of exit from the Illinois public university system are also unaffected in later years (Figure A3, A4). Lecturers receive a 0.75% increase in salary in the second and third year after a 10% increase in state funding (Figure 6a), though they are they only faculty who saw any effect of state funding cuts in terms of salaries.

These results show that faculty — both lecturers and professors — are relatively unaffected by state funding cuts, in the Illinois public university system. Illinois is a state with a large public university system, relative to student enrolment, with trends in state funding for education similar to national trends, and with both selective and non-selective universities. If faculty are unaffected in Illinois, then it is unlikely that faculty in the rest of the nation are affected on average. Note, however, that this analysis studies faculty who are already faculty. The IBHED data do not measure the entire pool of academics applying for faculty jobs at Illinois universities, but only those who applied to, were accepted, and then started a job as a lecturer or professor. These are incumbent faculty, and the data show they are unaffected by state funding cuts. This raises a question: how can funding cuts lead to a large substitution of professors for lecturers, when incumbent faculty are not affected?

5.4 Impacts on Faculty Hiring

Turn-over is the primary channel that changes in faculty composition happen, where faculty exit their jobs and new faculty are hired to replace those leaving — or no more are hired to replace those who left. Figure A4 shows that Illinois faculty are no more likely to exit the Illinois system (either retire or take a new job elsewhere) following state funding cuts, so there is one remaining channel for the substitution of professors for lecturers: increased hiring of lecturers and reduced hiring of new professors.

To investigate reduced hiring of new professors, I first investigate faculty hiring rates among Illinois universities from the IBHED data. To do so, I count the number of faculty new in the panel of all Illinois public university faculty for years 2011–2021, where the panel first year is 2010. I then use this as the outcome in OLS and shift-share IV regressions, where each observation is an Illinois university–year and data for state funding come from IPEDS.[27] To study whether these effects hold true nation-wide, I use public on the number of professors at all US public universities for the entire decade 2011–2021, provided by (Wapman, Zhang, Clauset & Larremore 2022*b*), and perform the same analysis to see if state funding affected the number of professors hired. See Subsection A.3 for further details on this data source.

Table A5 shows these estimates for Illinois public universities. In general, faculty counts are relatively unrelated to state funding among Illinois universities; though the point estimates line up with analysis in IPEDS, the smaller number of observations mean that the precision of estimates are small and indistinguishable from zero, in both raw counts and in log units. In the national-level Wapman et al. (2022*b*) data, universities with more state funding hire more professors across 2011–2021. An extra 10% in state funding is associated with 8.5% more

[27] This is the same specification as the IPEDS analysis restricted to Illinois universities. The IPEDS data have yearly faculty counts, but not discern between faculty promotions, quits, and hires; the Illinois data can do so thanks to the panel structure of the data.

professors hired per students, as seen in Figure 7. I use these data as part of a shift-share analysis, showing that a 10% state funding cut per student leads to 13% fewer professor hires (relative to enrolment), and that these hires are roughly equal for gender of professor hired.

State funding cuts lead to lower professor hiring, and the persistent funding cuts to public universities led to lower professor hiring across the last three decades. The channels for faculty turn-over were unaffected by state funding cuts in the analysis of Illinois faculty, while professor hiring is related to funding cuts in both correlational terms and in a shift-share analysis. Combining these pieces of evidence means that reduced professor hiring was likely the main mechanism for how state funding cuts led to a substitution of professors for lecturers at public universities.

5.5 Robustness Checks and Heterogeneity Analysis

It is possible that the identification strategy is not robust to some confounding issues or trends. For example, selective institutions may have received funding cuts for other reasons, or states with lower performing institutions or declining populations strategically cut funding for only less selective universities. Additionally, the effect of state funding cuts may affect faculty at different universities to different extents I investigate these issues with three different analyses.

First, I re-estimate the primary results from Subsection 5.2 with additional controls for university selectivity. Specifically, I estimate Equation (3) with controls added for the base share of state funding, average acceptance rate and 6-year completion rate in 2004–2006, tuition revenue, total enrolment, size of state enrolment, size of university enrolment relative to the rest of the state. Measures of selectivity are only available in certain years, so I use these values across the entire panel. This means that institution fixed effects would over-identify the system, so I estimate with state + year fixed effects (not institution + year fixed effects). In this way, this model also works as an alternative specification test.

Additionally, this analysis uses the enrolment measure of full-time equivalent (FTE), and not reported enrolment as in the original analysis. The first-stage is strong of the same order as the original analysis (Table A8). The relationship between state funding, in both raw count terms and log units, are roughly the same as for the main analysis (Table A9, A10), despite the multiple specification changes, additional controls, and different measures for enrolment.

Second, I return to the primary specification in Equation (3), and estimate effect of state funding cuts on faculty counts separately among universities of different selectivity rates. This investigates whether substitution rates are different across different levels of selectivity; Table A7 collects these results together, separated by the Barron's (2009) selectivity rankings. Barrons rank 1-2 are the most selective (including e.g., UC Berkeley and SUNY Binghamton), 3-4 selective (including e.g., Clemson University and University of Dallas), and rank 5 for the rest of universities. The first-stage is strong in every group of universities, even among the small sample size of the 12 universities in the most selective group, and the 28 universities in the next selective group. Faculty substitution rates are not very strong among the most selective universities, but are very similar between selective universities and unranked universities. One might expect that the effect is driven entirely by the least selective universities, as they are the most resource-constrained; this heterogeneity analysis shows that even selective (if not top) universities substitute towards lecturers following state funding cuts.

The final robustness check I employ is a falsification test, testing whether the effects for public universities would be picked up among a sample of private universities.[28] Private universities do not rely on state funding in the same way that public universities do,[29] so we would expect state funding to not affect their faculty counts. If the state funding and faculty counts were related among private universities, this would be evidence that the IV model picks up otherwise concurrent trends in higher education, unrelated to stagnating state

[28]This is a robustness check similar to one performed in Chakrabarti et al. 2020, as a robustness check for the same instrument.

[29]Though private universities do receive some state funding, as some states fund smaller scale operating costs and other specific projects at private universities.

funding for public universities. To impute a base share of reliance on state funding, I assign private universities the average reliance on state funding in the base period of universities in the same state with the same Barrons selectivity ranking, and then compute the shift-share instrument from this value. Table A11 shows that the first-stage is not strong among private universities; despite this, the IV results are still not significant for any faculty count, showing that state funding is not related to private universities' faculty counts. The OLS columns show that imputed state funding is highly correlated with lecturer and professor counts at private universities. The IV estimates are not distinguishable from zero, showing that OLS correlations are not causal relationships, and validating the IV approach for inference on universities' faculty counts.

6 Summary and Concluding Remarks

Public universities have systematically substituted away from tenure-track and tenured professors, toward lecturers, following stagnating state funding for higher education. The effects on incumbent professors in Illinois are non-distinguishable from zero, and suggestive evidence shows that funding cuts limited hiring of new professors, implying that substitution towards lecturers is driven by reduced hiring of new professors. Public universities are using more contingent lecturers and fewer professors to teach their students, and each year this trend grows.

This work contributes to the literature along two primary dimensions. First, this work provides an explanation for the increased reliance on lecturers and away from tenure-track and tenured professors at US public universities, by isolating the immediate and long-lasting effects of funding cuts from state-wide funding shifts. Second, this work investigates how individual faculty are affected by changes in state funding for their university using a dataset new in the economic literature (IBHED). These data allow for detailed analysis of thousands of faculty salaries, and employment outcomes, in the Illinois university system, and show that incumbent faculty were relatively unaffected by state funding cuts to their employers.

While state funding for higher education has stagnated, costs of education has been rising at the same time, so that funding cuts have even more impact today than they did three decades ago. I show that these financial headwinds led to systematic change at public universities, leading to a substitution away from stable employment contracts (tenure, professorship) and towards less stable arrangements (adjunct contracts, lecture positions). These results show large changes in faculty composition, and that stagnation in state funding explains at least a third of the observed shift away from tenured professors and towards lecturers. This likely had knock-on effects on instruction, contributing to worsening student outcomes at US public universities since the early 1990s — while private universities were not exposed to financial headwinds of the same magnitude or persistence over the same time period. Furthermore, public universities have been making personnel decisions, with long-run effects on their institutional capacity, based on short-run funding constraints. While public universities educate the majority of US higher education students, we should worry about the effects of stagnating state funding on faculty, and the wider impact on higher education as a whole.

Credit Author Statement

As the only author on this paper, I am responsible for all contributions in this paper.

Data Statement

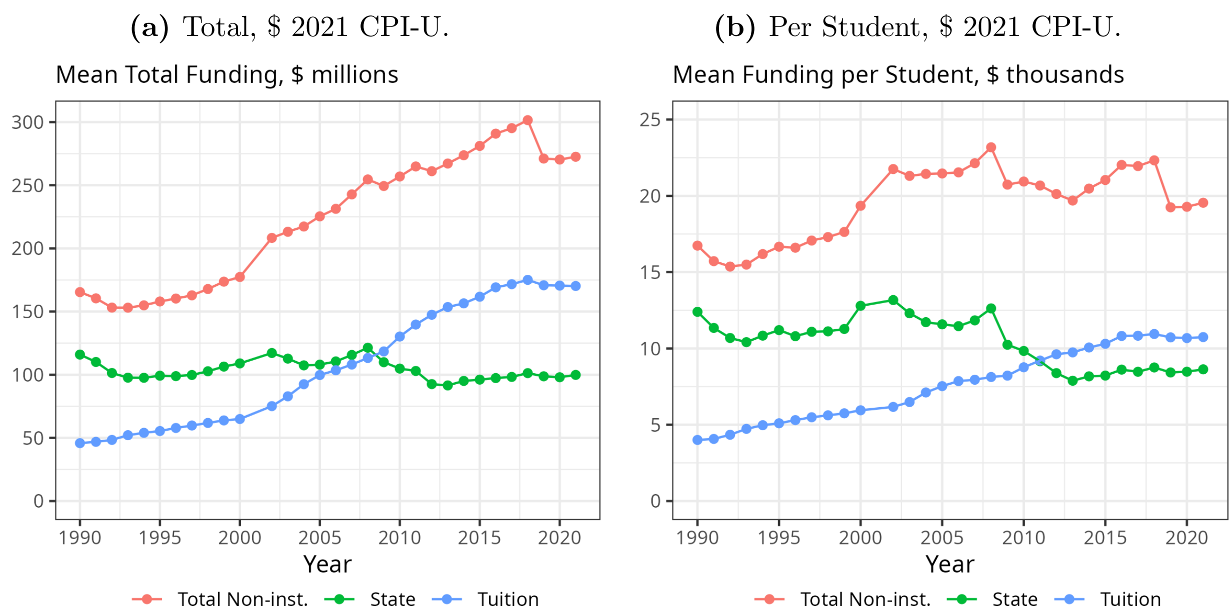
Every source of data, and code to fully replicate the entire analysis, is freely available at the following link: `https://doi.org/10.5281/zenodo.11373226`. IBHED data, while public knowledge, include personally identifiable names, so the data included in the replication package have names replaced with non-identifiable placeholders.

Declaration of Competing Interest

I have no competing interests to declare. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

7 Figures

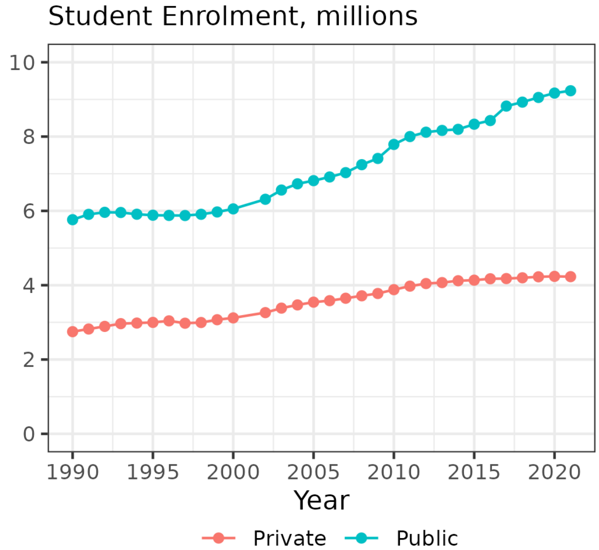
Figure 1: Mean Total Funding among Public Universities, by Year.



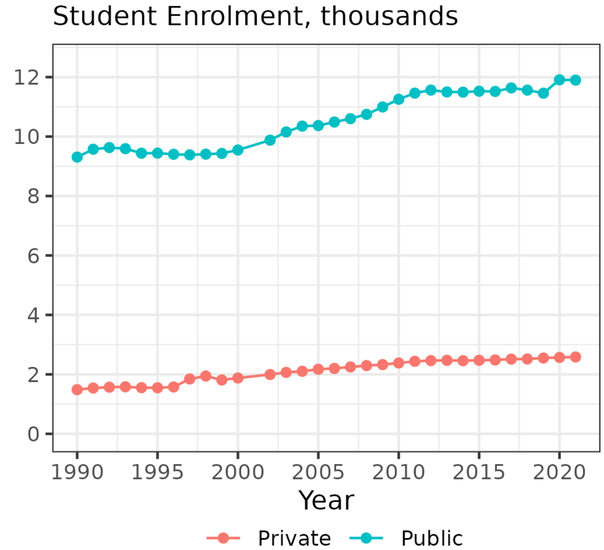
Note: This figure shows the mean funding for US public universities as a total (in figure a.) and divided by student enrolment (figure b.). The numbers are adjusted to 2021 figures by CPI-U. Non-institutional revenues refers to the sum of federal, state, and local funding plus tuition revenues; these sum to the majority of university funding, but exclude numbers such as university income from capital projects. These figures are calculated with IPEDS data.

Figure 2: Total Student Enrolment, by University Sector and Year.

(a) Total Enrolment, Nation-wide.



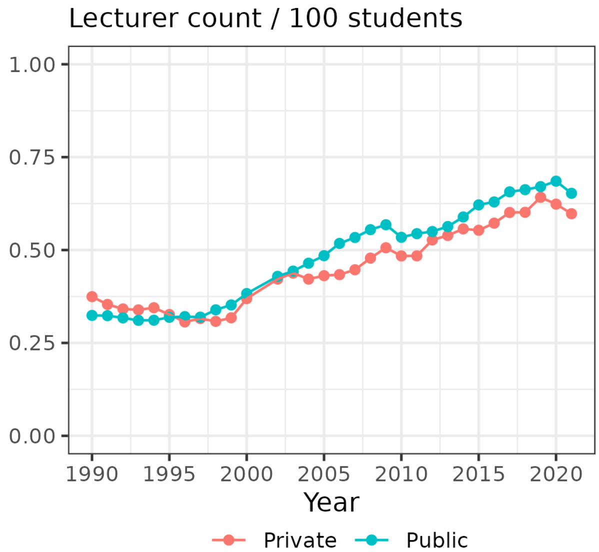
(b) Mean Enrolment, per University.



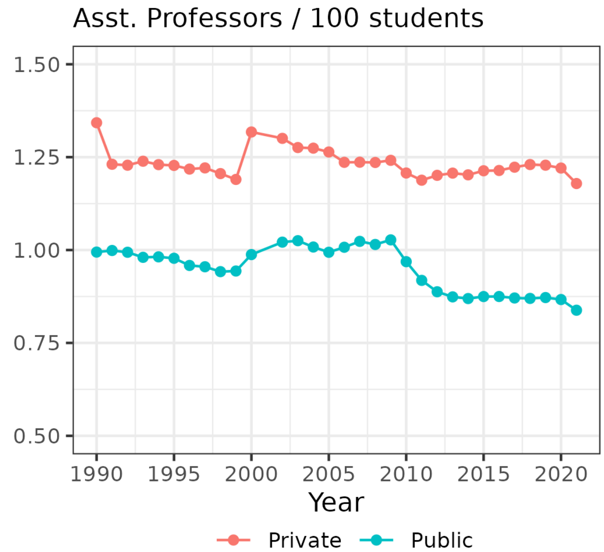
Note: This figure shows the total and mean enrolment for US universities, comparing public and private universities. Most of the higher education enrolment increase for the last 30 years was in public universities, who continue to enrol the vast majority of higher education students in the US. These figures are calculated with IPEDS data.

Figure 3: Trends in Mean Student Enrolment per Professor, by University Sector and Faculty level.

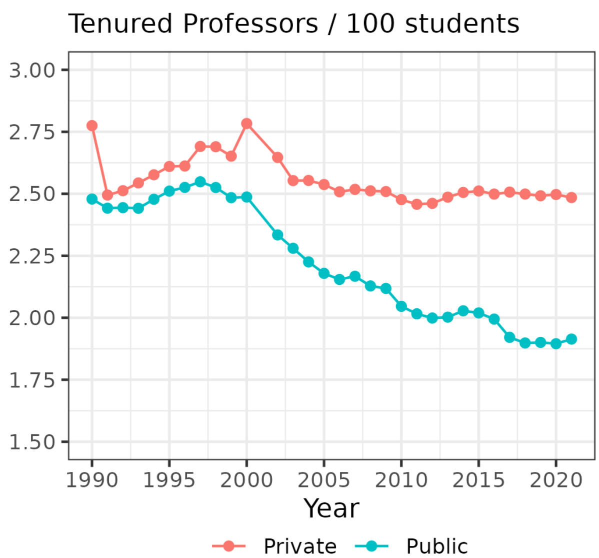
(a) Lecturers.



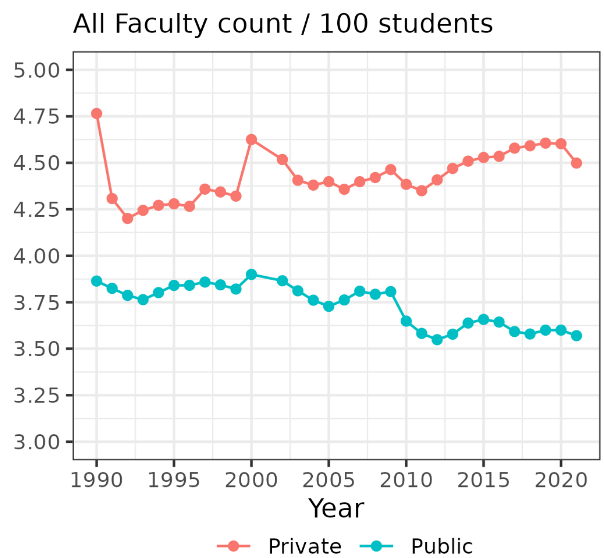
(b) Assistant Professors.



(c) Full Professors.



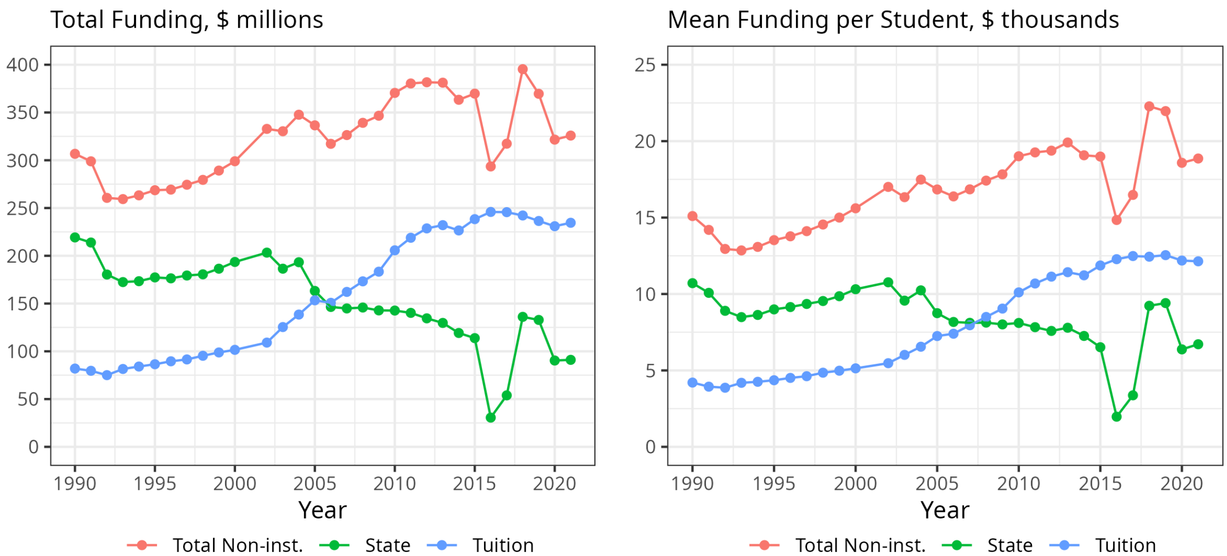
(d) All Faculty.



Note: This figure shows the average number of students per faculty member, by different faculty position, at US public universities. E.g., panel A calculates the mean of (student enrolment) / (lecturer count) at US public universities, for each year of 1990–2017, to show the average trend in faculty composition compared to student enrolment. These figures are calculated with IPEDS data.

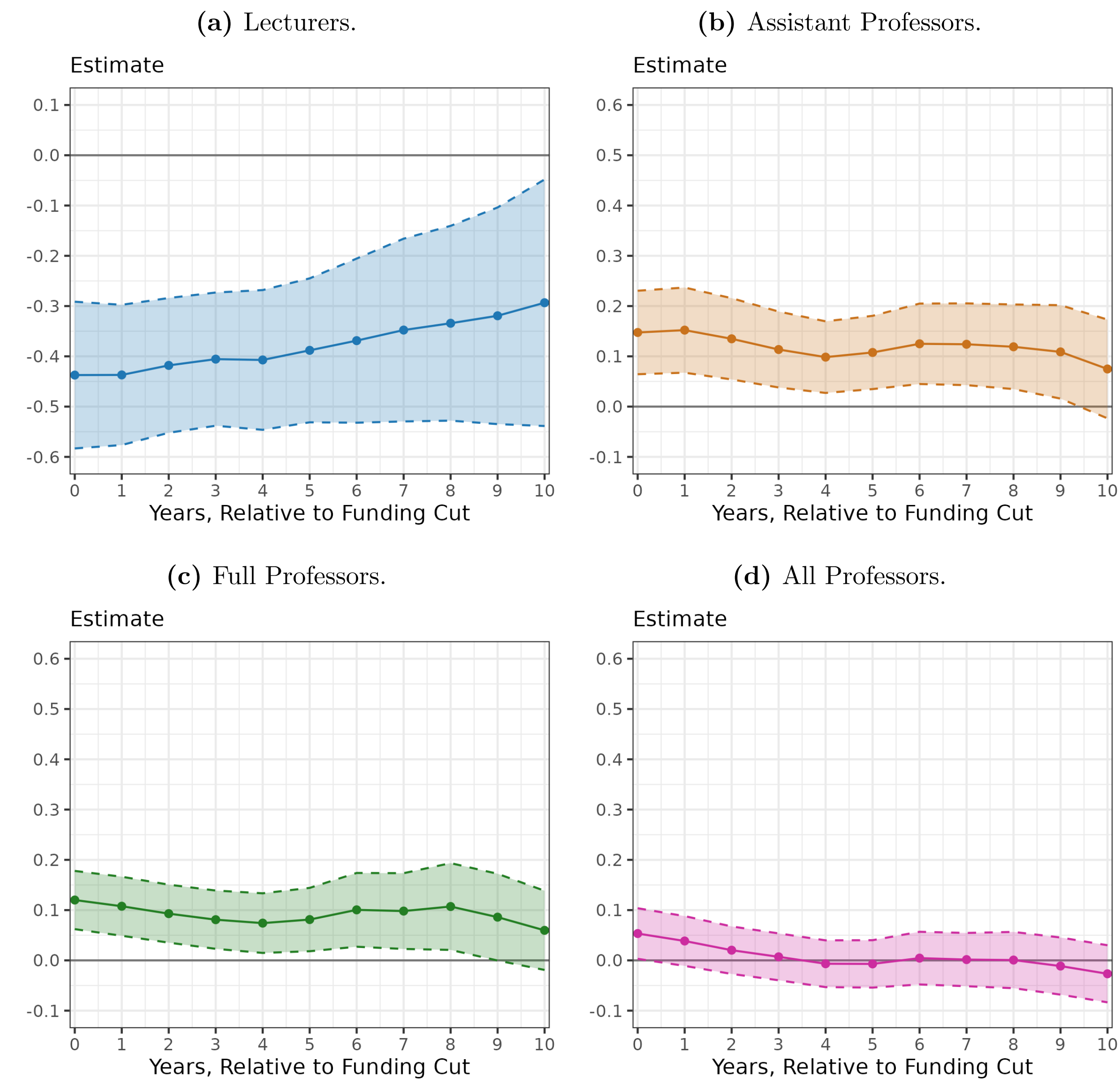
Figure 4: Mean Funding Sources among Illinois Public Universities, by Year.

(a) Total, $ 2021 CPI-U. **(b)** Per Student, $ 2021 CPI-U.



Note: This figure shows the mean funding for Illinois public universities as a total (in figure a.) and divided by student enrolment (figure b.). The numbers are adjusted to 2021 figures by CPI-U. Non-institutional revenues refers to the sum of federal, state, and local funding plus tuition revenues; these sum to the majority of university funding, but exclude numbers such as university income from capital projects. These figures are calculated with IPEDS data.

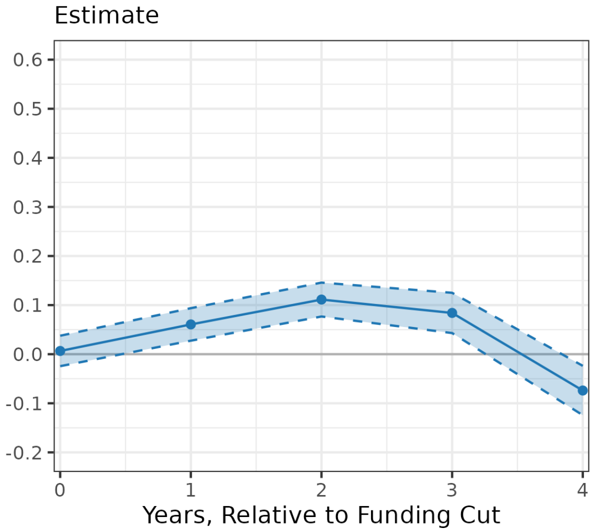
Figure 5: Local Projection Estimates for Effect of State Funding on Faculty Count per Student at Universities, by Professor Group.



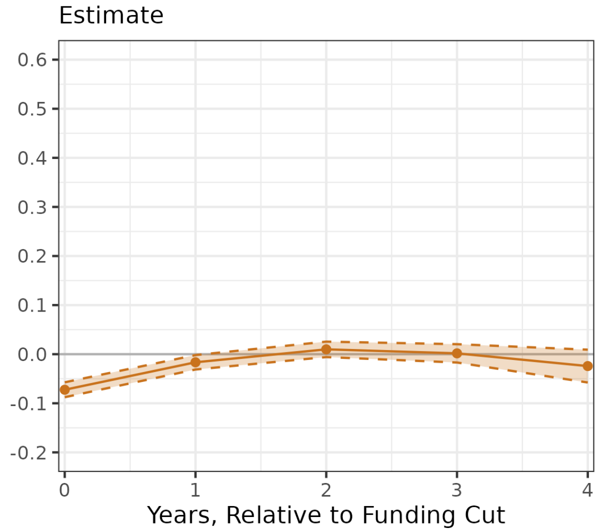
Note: These figures show the local projections estimates of regression specification (3), with the state funding shift-share as an instrument for state funding. The unit of analysis is the university, and uses IPEDS data. The x-axis represents the year relative to the state funding shift-share (i.e., $x = 0$ represents the year of the state funding cut) and the y-axis represents the estimated effect in years relative to initial state funding shift-share. The coefficient estimate is effect of state funding ($X_{i,t}$) on faculty count per student ($Y_{i,t}$), using the state funding shift-share instrument ($Z_{i,t}$), while accounting for auto-correlation between different time periods — i.e., between $X_{i,t}, X_{i,t-1}$ and $Y_{i,t}, Y_{i,t-1}$. These results use a $\log - \log$ specification, so the estimates are for the elasticity of professor count per student in a year $t + k$ with respect to state funding in year t, where years $k = 0, \ldots, 10$ are on the x-axis. Standard errors are clustered at the state-year level.

Figure 6: Local Projection Estimates for Effect of State Funding on Faculty Salaries Illinois Public Universities, by Professor Group.

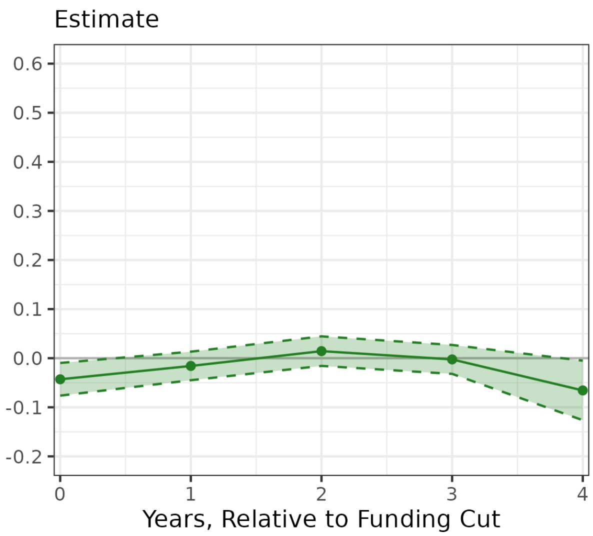
(a) Lecturers.



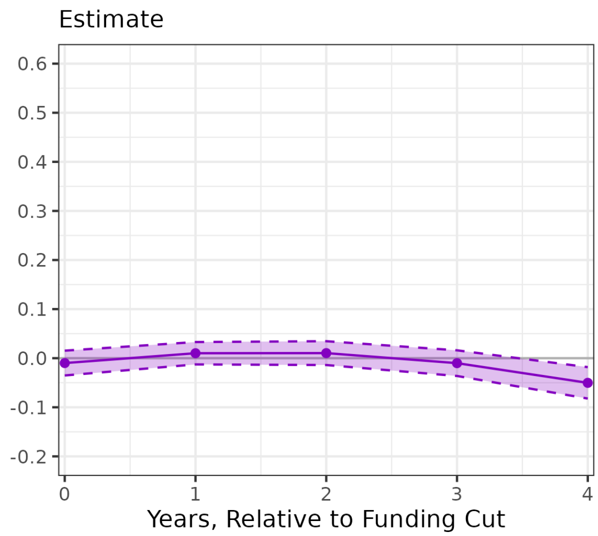
(b) Assistant Professors.



(c) Full Professors.

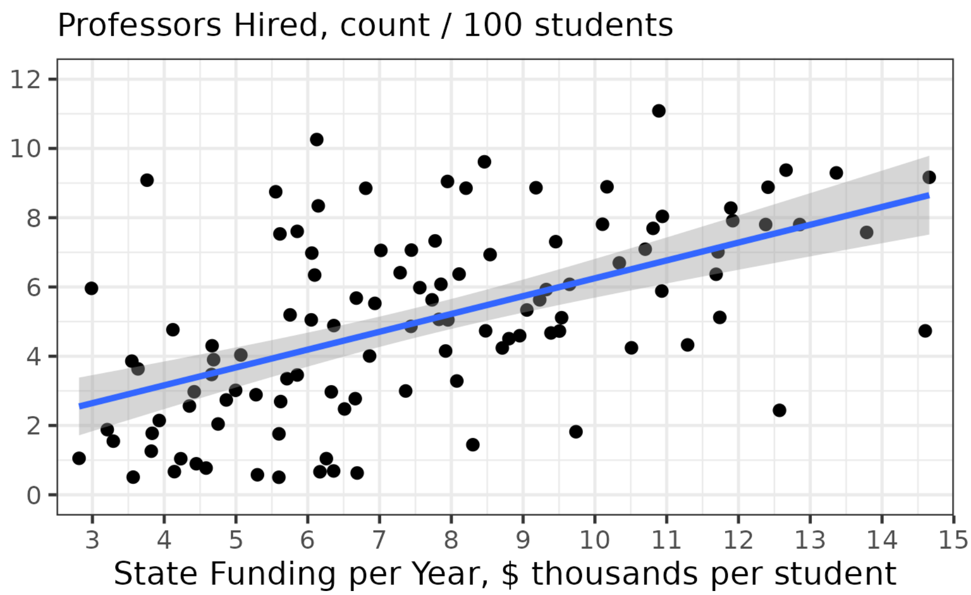


(d) Administrator Professors.



Note: These figures show the local projections estimates of regression specification (3), with the state funding shift-share as an instrument for state funding. The unit of analysis is an individual faculty member (at an Illinois public university); funding data come from IPEDS, and faculty salaries from IBHED. The x-axis represents the year relative to the state funding shift-share (i.e., $x = 0$ represents the year of the state funding cut) and the y-axis represents the estimated effect in years relative to initial state funding shift-share. The coefficient estimate is effect of state funding ($X_{i(j),t}$) on faculty salaries ($Y_{j,t}$), using the state funding shift-share instrument ($Z_{i(j),t}$), while accounting for auto-correlation between different time periods — i.e., between $X_{i(j),t}, X_{i(j),t-1}$ and $Y_{i(j),t}, Y_{i(j),t-1}$. These results use a $\log - \log$ specification, so the estimates are for the elasticity of faculty salaries student in a year $t + k$ with respect to state funding in year t, where years $k = 0, \ldots, 4$ are on the x-axis. Standard errors are clustered at the university-year level, and Subsection A.2 fully describes the differences in empirical specification when unit of analysis is an individual faculty member.

Figure 7: State Funding and Total Professor Hiring at Public Universities, Total for 2011–2021.



Note: This figure shows the correlation between state funding and total number of professors hired at each public university between 2011–2021. Each dot is a US public university, with the y-axis the total number of professors (not lecturers) they hired 2011–2021, the x-axis the total state funding per student 2011–2021; the line is an OLS line of best-fit, with shaded region for 95% confidence region of the correlation. Data for the number of professors hired at public universities are provided by Wapman et al. (2022*b*), Wapman, Zhang, Clauset & Larremore (2022*a*), and funding data from IPEDS.

8 Tables

Table 1: IPEDS Summary Statistics, Public Universities Panel 1990–2021

Statistic	Mean	St. Dev.	N
Enrolment	11,870	10,876	17,012
State Funding (millions 2021 USD)	104	127	17,012
Total revenues (millions 2021 USD)	450	818	17,012
Non-institutional revenues (millions 2021 USD)	224	295	17,012
Lecturers count	59	73	17,012
Assistant professors count	116	102	17,012
Full professors count	269	287	17,012
All faculty count	453	445	17,012

Note: This table shows the summary statistics for every public university–year observation in IPEDS data. The numbers are adjusted to 2021 figures by CPI-U. Non-institutional revenues refers to the sum of federal, state, and local funding plus tuition revenues; these sum to the majority of university funding, but exclude numbers such as university income from capital projects.

Table 2: IBHED Summary Statistics, Faculty Panel 2010–2021.

Statistic	Mean	St. Dev.	N
Lecturer, percent	27	44	187,634
Assistant professor, percent	21	41	187,634
Full professor, percent	37	48	187,634
Administrator professor, percent	15	36	187,634
Lecturer salary (2021 USD)	31,449	25,786	50,588
Assistant salary (2021 USD)	76,897	38,059	39,421
Full salary (2021 USD)	109,283	48,919	68,774
Administrator salary (2021 USD)	119,249	61,321	28,851
All salary (2021 USD)	83,027	55,843	187,634
Lecturer benefits (2021 USD)	2,342	6,470	50,588
Assistant benefits (2021 USD)	2,965	7,096	39,421
Full benefits (2021 USD)	6,722	13,624	68,774
Administrator benefits (2021 USD)	3,599	15,928	28,851
All benefits (2021 USD)	4,272	11,513	187,634

Note: This table shows the summary statistics for every faculty–year observation in the IBHED data, which represents every faculty member in the Illinois public university system over years 2010–2021. The numbers are adjusted to 2021 figures by CPI-U. Lecturer is a binary for whether the faculty member is designated as a lecturer in the databse, and similarly for the assistant professors, full professors, and administrative faculty; salary refers the sum of base salary and benefits. All salary and benefits refers to summary statistics on the salary and benefits, respectively, of all faculty (regardless of position).

Table 3: First Stage Estimates, Predicting State Funding by Funding Shift-Share, in IPEDS Data.

Panel A: units in \$ per student

	Dependent Variable: State Funding			
	(1)	(2)	(3)	(4)
Funding Shift-Share	−1.176	−0.160	−1.100	−1.071
	(0.226)	(0.265)	(0.242)	(0.264)
Tuition Revenue			−0.295	1.012
			(0.136)	(0.329)
Constant		9,716.437		−1,708.334
		(1,805.394)		(2,716.150)
Uni. + Year fixed effects?	Yes	No	Yes	No
F stat.	20.712	16.512	26.999	0.365
Observations	17,012	17,012	17,012	17,012
R^2	0.918	0.0004	0.919	0.074

Panel B: units in log \$ per student

	Dependent Variable: State Funding			
	(1)	(2)	(3)	(4)
Funding Shift-Share	−0.977	−0.302	−0.986	−0.573
	(0.066)	(0.093)	(0.062)	(0.067)
Tuition Revenue			0.058	0.535
			(0.059)	(0.065)
Constant		6.419		−0.484
		(0.769)		(0.844)
Uni. + Year fixed effects?	Yes	No	Yes	No
F stat.	249.662	74.022	218.171	10.558
Observations	17,012	17,012	17,012	17,012
R^2	0.790	0.047	0.790	0.180

Note: These tables show the first stage OLS estimates of regression specification (2), showing the effect of the state funding shift-share on state funding to gauge performance as an instrument. Each observation is a public university-year, in the IPEDS data. Panel A shows the effect of a state funding shift-share of \$-1 per student in the state on the number of \$'s of state funding per student at the university — i.e., \$-1 state funding shift-share per student in the state leads to \$1.176 less state funding per student at the university according to preferred specification column 1. Panel B shows the effect of a −10% change state funding shift-share per student in the state on 10% change in state funding per student at the university — i.e., −10% state funding shift-share per student in the state leads to −9.77% less state funding per student at the university according to prefferred specification column 1. Standard errors are clustered at the state-year level, and university + year fixed effects are included where noted. The F statistic is for the excluded instrument (not for overall regression), after accounting for fixed effects and cluster dependence (Olea & Pflueger 2013).

Table 4: Effects of State Funding on Faculty Counts, in IPEDS Data 1990–2021, OLS and 2SLS Estimates.

Panel A: units in $ per student

	Dependent Variable: Faculty Count per 1,000 Students, by Position							
	Lecturers		Asst. Professors		Full Professors		All Faculty	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	−0.451	−5.957	−0.479	1.031	−0.104	2.288	−1.198	−3.333
	(0.177)	(1.725)	(0.211)	(1.232)	(0.275)	(2.910)	(0.612)	(4.259)
Outcome Mean	59.253	59.253	116.121	116.121	269.103	269.103	452.507	452.507
Observations	17,012	17,012	17,012	17,012	17,012	17,012	17,012	17,012
R^2	0.742	0.595	0.887	0.881	0.973	0.971	0.954	0.954

Panel B: units in log $ per student

	Dependent Variable: Log Faculty Count per Students, by Position							
	Lecturers		Asst. Professors		Full Professors		All Faculty	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	−0.137	−0.437	0.082	0.135	0.123	0.137	0.077	0.065
	(0.032)	(0.100)	(0.047)	(0.068)	(0.056)	(0.038)	(0.047)	(0.030)
Outcome Mean	0.572	0.572	1.194	1.194	2.298	2.298	4.128	4.128
Observations	17,012	17,012	17,012	17,012	17,012	17,012	17,012	17,012
R^2	0.660	0.646	0.705	0.704	0.797	0.797	0.810	0.810

Note: These tables show the second stage OLS and 2SLS estimates of regression specification (3), showing the effect of state funding changes on faculty outcomes, using the state funding shift-share to instrument for state funding in the columns labelled 2SLS. Each observation is a public university-year, in the IPEDS data. Panel A shows the effect of a fall in state funding $\$-1,000$ per student on the number of professors — i.e., an extra $\$1,000$ per student leads to 6 fewer lecturers according to column 2. Panel B shows the effect of a 10% change in state funding per student at the university on the 10% change in the number of professors per students — i.e., an extra 10% of state funding per student leads to 4.37% fewer lecturers per student according to column 2. Outcome-mean is the mean of the outcome, for Panel A the number of professors per student, for Panel B the number of faculty per student. Panel B uses log faculty count per student as the outcome, though the outcome mean is count of faculty per student (not in log terms). Standard errors are clustered at the state-year level, and university + year fixed effects are included through-out.

Table 5: Effects of State Funding on Faculty Salaries and Exit Rate, in IBHED Panel Data 2010–2021, 2SLS Estimates.

	Dependent Variable: Annual Salaries				
	Lecturer	Assistant	Full	Admin	All
	(1)	(2)	(3)	(4)	(5)
State Funding	0.007	−0.072	−0.043	−0.010	−0.012
	(0.095)	(0.041)	(0.038)	(0.049)	(0.086)
Observations	26,324	22,328	9,065	11,529	69,246
R^2	0.220	0.051	0.069	0.144	0.163

	Dependent Variable: Exit rate				
	Lecturer	Assistant	Full	Admin	All
	(1)	(2)	(3)	(4)	(5)
State Funding	−0.003	0.003	−0.002	−0.003	−0.004
	(0.024)	(0.007)	(0.009)	(0.020)	(0.016)
Observations	23,841	19,904	7,244	10,241	61,230
R^2	0.013	0.005	0.013	0.072	0.016

	Dependent Variable: Promotion Rate			
	Lecturer	Assistant	Associate	All
	(1)	(2)	(3)	(4)
State Funding	0.015	0.036	0.029	0.016
	(0.007)	(0.019)	(0.065)	(0.008)
Observations	16,420	16,972	4,340	42,132
R^2	0.008	0.022	0.031	0.007

Note: These tables show the second stage 2SLS estimates of regression specification (3), showing the effect of state funding changes on faculty outcomes at Illinois universities, using the state funding shift-share to instrument for state funding. The shift-share instrument is based in the year the professor was hired, following definition in Subsection A.2. Each observation is a faculty member–year at an Illinois public university, where funding data come from IPEDS and faculty outcomes from IBHED data. The panels shows the effect of a 1% change in state funding per student at the university on faculties' salaries (base salary + benefits), promotion rate (e.g., assistant professor to associate professor), and rate of leaving their university (i.e., by quitting, retiring, or moving to another university). Standard errors are clustered at the university-year of hire level, and university + year of hire fixed effects are included through-out.

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A Appendix

This project used data which are fully public, and computational tools which are fully open-source. As such, all code and data (anonymised versions where necessary) involved in this project are available at this project's Github repository, available at `https://github.com/shoganhennessy/state-faculty-composition`. They may be used for replication, or as the basis for further work, as needed. Any comments or suggestions may be sent to me at `seh325@cornell.edu`, or raised as an issue on the Github project.

A number of statistical packages, for the *R* language (R Core Team 2022), made the empirical analysis for this paper possible.

- *Tidyverse* (Wickham, Averick, Bryan, Chang, McGowan, François, Grolemund, Hayes, Henry, Hester, Kuhn, Pedersen, Miller, Bache, Müller, Ooms, Robinson, Seidel, Spinu, Takahashi, Vaughan, Wilke, Woo & Yutani 2019) collected tools for data analysis in the *R* language.
- *LFE* (Gaure 2013) implemented linear fixed effect models, with instruments, crucial for the empirical estimation in Section 4.
- *Stargazer* (Hlavac 2018) provided methods to efficiently convert empirical results into presentable output in LaTeX.
- *Lpirfs* (Adämmer 2019) implemented estimation of the Jordá (2005) local projections methods, with instrumental variables, crucial to the local projections estimates presented in this project.

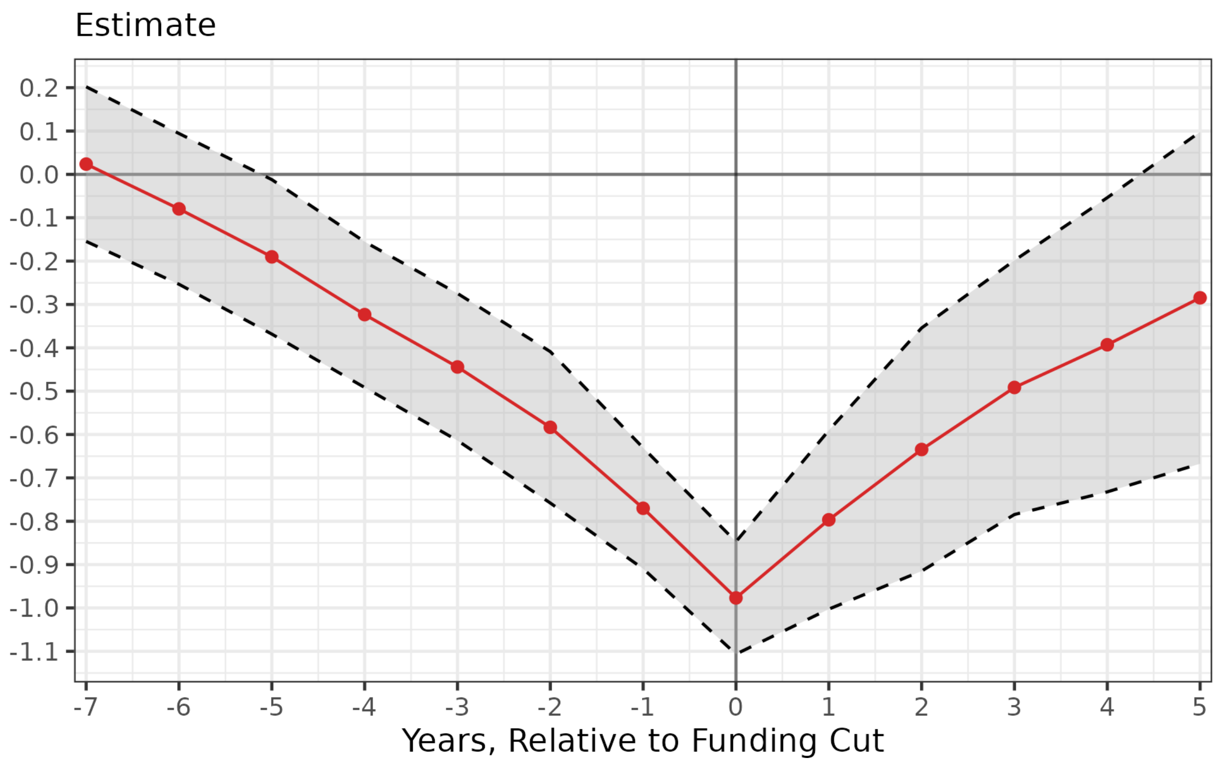
A.1 IPEDS First Stage

Table A1: Shift-Share Instrument Balance, Mean Characteristics Across Instrument Distribution.

Instrument Quantile:	1st	2nd	3rd	4th	5th
IV Components, $ per student:					
Funding shift–share	-1,473.7	-2,589.5	-3,566.4	-5,002.1	-8,208.1
Shift in state–wide funding	-6,138.0	-7,111.6	-8,593.2	-10,575.5	-14,017.6
Share reliance on state funding, % in 1990–1993	25.7	37.8	42.4	47.9	59.0
University Funding and Spending, $ millions:					
State funding	110.3	99.2	99.8	107.1	107.1
Tuition revenue	216.5	124.2	93.2	77.0	58.0
Total non-inst. revenues	355.4	241.0	203.4	190.8	169.6
Instruction spending	219.0	139.4	108.1	100.8	92.9
Research Spending	150.0	74.6	53.9	35.9	25.5
University Funding and Spending, $ per student					
State funding	12,900.1	9,956.2	9,334.7	9,304.9	12,766.7
Tuition revenue	13,129.7	8,530.4	6,874.6	6,046.5	5,507.4
Total non-inst. revenues	30,501.7	20,393.8	17,194.5	15,876.6	18,822.8
Instruction spending	21,680.2	12,526.0	9,798.1	8,482.0	9,953.2
Research spending	16,750.0	5,092.8	3,327.7	2,226.0	2,432.4
Selectivity:					
Reported enrolment	14,087.6	12,433.8	11,328.8	11,546.2	10,252.9
Full-time equivalent enrolment	12,452.8	10,597.3	9,638.4	9,876.6	8,554.9
Acceptance rate, %	70.7	73.2	70.8	64.5	60.2
6 Year graduation rate, %	55.6	47.3	44.1	44.7	45.2

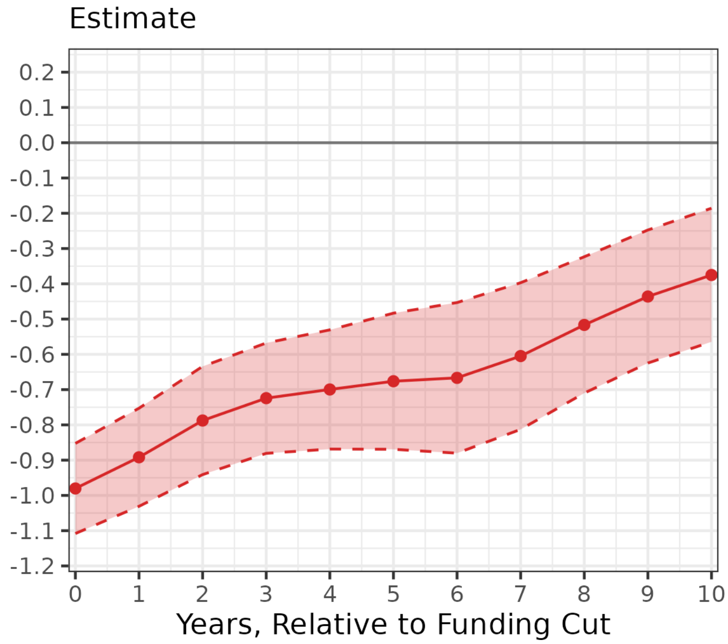
Note: This table shows the summary statistics for every public university–year observation in IPEDS data, for each of the 5 quantiles of the funding shift-share instrument. Funding shift-share is the instrument defined in Section 4, the product of (second row) state-wide funding shift and (third row) share reliance on state funding. State-wide funding shift is total funding for higher education in that university's state (divided by the count of state students); share reliance on state funding is the the total amount of state funding received by the university in 1990–1993 divided by total revenues for those years. The column labelled "1st" refers to the mean for all university-year observations in the first quintile (bottom 20%) of the funding shift-share distribution, and so on. The numbers are adjusted to 2021 figures by CPI-U. Non-institutional revenues refers to the sum of federal, state, and local funding plus tuition revenues; these sum to the majority of university funding, but exclude numbers such as university income from capital projects. Acceptance rate and 6 year graduation rate are for university undergraduates, and are calculated from IPEDS data available for academic years 1997 through 2018.

Figure A1: Correlation Between State Funding Shift-Share and Public University State Funding in Surrounding Years.



Note: This figure shows the correlation between state funding in year $t+k$ with the funding shift-share in year t for a university, where $k = -7, \ldots, 5$ are the years on the x-axis. This shows that state funding and the funding shift-share are correlated across years, so that dynamic effects must be estimated by local projections — and not simple OLS or 2SLS. The estimates are of (2), calculated with IPEDS data, separately for each year relative to initial shock, using the log − log specification, including fixed effects for university + year, and clustering standard errors by university + year.

Figure A2: Local Projection Estimates for Funding Shift-Share on State Funding, in IPEDS Data.



Note: These figures show the local projections estimates of regression specification (2), with the funding shift-share as an instrument for state funding, using IPEDS data. The coefficient estimate is effect of funding shift-share ($Z_{i,t}$) on state funding ($X_{i,t}$), while accounting for auto-correlation between different time periods — i.e., between $Z_{i,t}, Z_{i,t-1}$ and $X_{i,t}, X_{i,t-1}$. These results use a $\log - \log$ specification, so the estimates are for the elasticity of state funding per student in a year $t + k$ with respect to funding shift-share in year t, where years $k = 0, \dots, 10$ are on the x-axis. Standard errors are clustered at the state-year level.

Table A2: Effect of State Funding on Areas of University Spending, IPEDS Data, IV Estimates.

Panel A: units in $ per student

	Dependent Variable: University Spending									
	Instruction	Research	Public Service	Student Services	Academic Support	Inst. Support	Operations	Grant Aid	All Spending	Tuition Revenue
State Funding	0.409	0.218	0.225	0.042	0.136	0.226	0.080	−0.009	1.321	−0.267
	(0.066)	(0.129)	(0.142)	(0.016)	(0.027)	(0.043)	(0.029)	(0.023)	(0.275)	(0.071)
Outcome Mean	12.175	4.911	2.138	1.648	2.903	3.452	2.48	1.55	31.256	7.895
Observations	14,799	14,639	14,720	14,799	14,799	14,799	14,796	14,770	14,799	14,799
R^2	0.920	0.878	0.654	0.666	0.917	0.852	0.885	0.700	0.926	0.812

Panel B: units in log $ per student

	Dependent Variable: University Spending									
	Instruction	Research	Public Service	Student Services	Academic Support	Inst. Support	Operations	Grant Aid	All Spending	Tuition Revenue
State Funding	0.132	0.037	0.116	0.164	0.206	0.170	0.120	0.145	0.103	−0.164
	(0.060)	(0.142)	(0.138)	(0.038)	(0.057)	(0.049)	(0.068)	(0.085)	(0.058)	(0.036)
Outcome Mean	12.175	4.911	2.138	1.648	2.903	3.452	2.48	1.55	31.256	7.895
Observations	14,799	14,639	14,720	14,799	14,799	14,799	14,796	14,770	14,799	14,799
R^2	0.944	0.907	0.834	0.823	0.893	0.872	0.843	0.621	0.961	0.918

Note: These tables show the IV estimates of regression specification (3), showing the effect of state funding (instrumented with the shift-share) on areas of university spending. Outcomes are measured in $ student spending, so that the estimates representat the relationship between a $1 increase in state funding on area of spending (or 1% increase). The "outcome mean" rows are spending in thousands $ per student.

A.2 Illinois IBHED First Stage

This paper uses data on individual professors in the Illinois university system, to investigate the effects of changes in university revenues on the individual professors at the universities. The outcomes here now refer to individual professors (e.g., their salary and promotion rate), so requires adjustment to the empirical approach, leveraging variation in university funding for the years after a professor joins the university.

Equation (6) defines a rolling-share variant of the instrument, $\widetilde{Z}_{i(j),t}$, where the university's state funding share exposure is based in the year a professor joins the university — and not the base period 1990–1993. j indexes each professor in year t, $\tau(j)$ for the year the professor first joins their institution. Identifying $\tau(j)$ is possible for j by restricting to all professors hired 2011-2021 — i.e., in the years after the start of the full panel. It is not possible to discern the hiring year for professors who were hired in the years preceding 2011, and so the entire sample is only possible to analyse using the base-share in years 1990-1993 formulation.

$$\widetilde{Z}_{i(j),t} := - \left[\left(\frac{\text{Total State Funding}_{s(j),t}}{\text{Student Population}_{s(j),t}} \right) \left(\frac{\text{State Funding}_{\tau(j)}}{\text{Total Revenues}_{i,\tau(j)}} \right) \right] \tag{6}$$

This approach leverages an insight, made available by level of the data: that an individual professor is affected by changes in university revenues after they have joined the university. Subsection 4.2 considers the number of professors employed by the university; whether a professor becomes employed at the university is likely affected by that university's finances. The formulation here takes as given that the professor is already employed at the university, and then projects the effect of changes in state funding on these *incumbent* professors following the state funding shift-share. Table A3 presents the first-stage results in Illinois data.

Exogeneity and relevance of the rolling-share instrument, $\widetilde{Z}_{i(j),t}$, follows the same reasoning as that for the base-share instrument, $Z_{i,t}$, discussed in Subsection 4.1. The base-share instrument is appropriate for some outcomes with the individual Illinois professors, where appropriate. We satisfy the assumptions for exogeneity by noting that none of the Illinois public campuses take the majority of state funding, and that the identification strategy relies on exogeneity in changes in state funding to individual professor-outcomes, following the year they joined the university. Additionally, within-institution changes resulting from share reliance on state funding may be correlated with unobserved changes in the outcomes, so that Chakrabarti et al. (2020) note the importance of controlling for the base share and state student population. The formulation here implicitly controls for these factors via the fixed effects; results are relatively similar while including these controls with and without including fixed effects, and so are omitted.

The instrumental variables model is then defined as follows, where $i(j)$ refers to the institution that professor j is employed at, and $Y_{j,t}$ for salary, rate of promotion, and propensity to leave the Illinois public university system. The system includes fixed effects for the institution and first year of employment. The instrument varies by institution, based in

Table A3: First Stage Estimates, for State Funding by Funding Shift-Share in IBHED Data.

Panel A: units in $ per student

	Dependent Variable: State Funding			
	(1)	(2)	(3)	(4)
Funding Shift-Share	−1.176	−0.160	−1.100	−1.071
	(0.226)	(0.265)	(0.242)	(0.264)
Tuition Revenue			−0.295	1.012
			(0.136)	(0.329)
Constant		9,716.437		−1,708.334
		(1,805.394)		(2,716.150)
Uni. + Year fixed effects?	Yes	No	Yes	No
F stat.	20.712	16.512	26.999	0.365
Observations	17,012	17,012	17,012	17,012
R^2	0.918	0.0004	0.919	0.074

Panel B: units in log $ per student

	Dependent Variable: State Funding			
	(1)	(2)	(3)	(4)
State Funding	−1.000	−0.877	−0.987	−0.726
	(0.018)	(0.046)	(0.026)	(0.155)
Tuition Revenue	0.538	0.536		
	(0.334)	(0.270)		
Constant		−3.298		3.004
		(2.477)		(1.259)
Fixed effects?	Yes	No	Yes	No
F stat.	3118.566	364.133	1394.217	21.88
Observations	70,743	187,634	70,743	187,634
R^2	0.928	0.521	0.924	0.414

Note: These tables show the first stage OLS estimates of regression specification (7), showing the effect of the funding shift-share on state funding to gauge performance as an instrument. Each observation is a professor-year, in the IBHED data, and funding data are merged from IPEDS. Panel A shows the effect of a −10% change funding shift-share per student in the state on 10% change in state funding per student at the university — i.e., −10% funding shift-share per student in the state leads to −9.77% less state funding per student at the university according to prefferred specification column 1. Standard errors are clustered at the institution-year level, and institution + year fixed effects are included where noted.

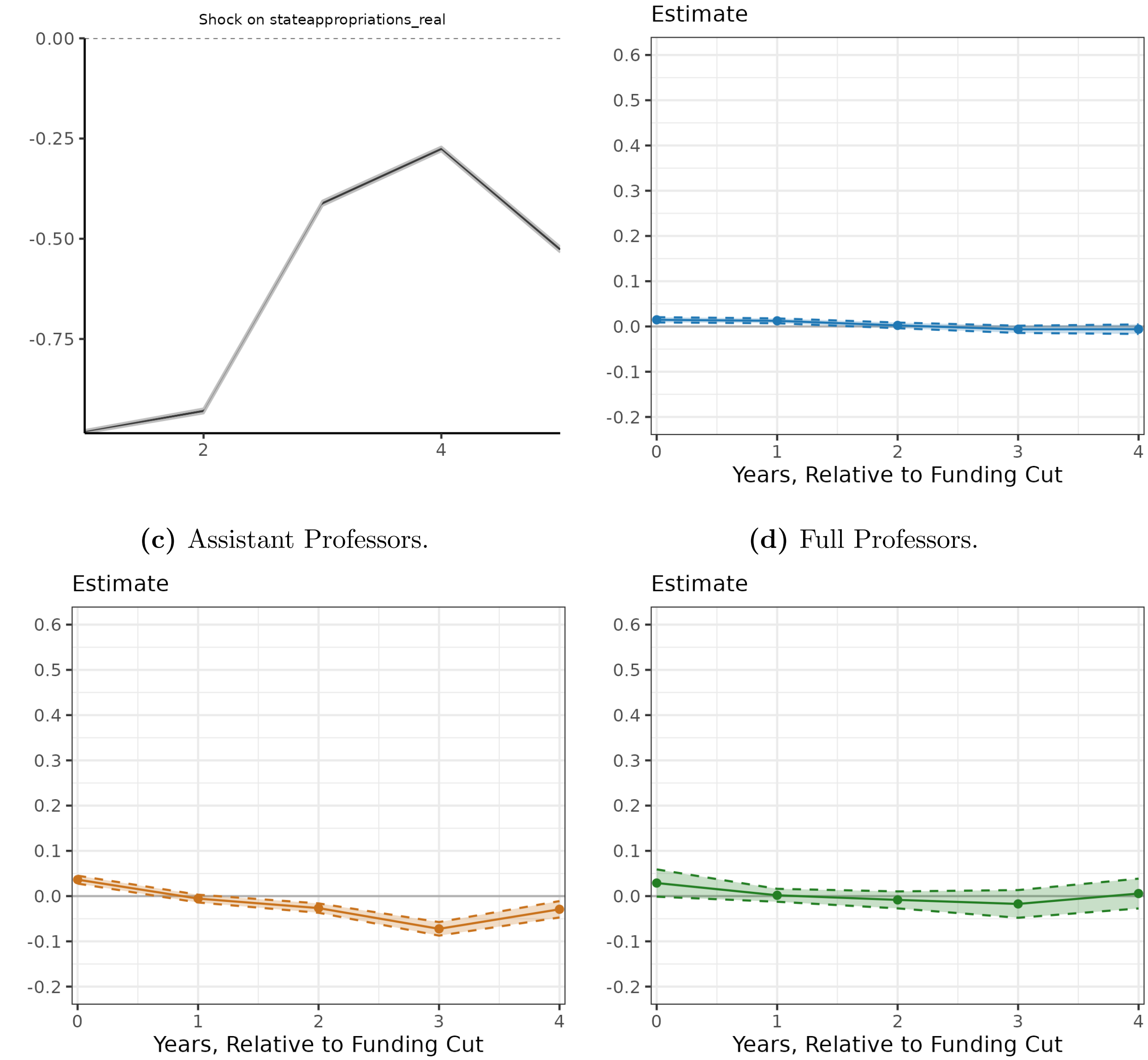
the year of first employment, so that these are the corresponding fixed effects and level of clustered standard errors.

$$X_{i(j),t} = \theta_{i(j)} + \phi_{\tau(j)} + \delta \widetilde{Z}_{i(j),t} + \epsilon_{i(j),t} \tag{7}$$

$$Y_{j,t} = \mu_{i(j)} + \nu_{\tau(j)} + \beta \widehat{X}_{i(j),t} + \varepsilon_{j,t} \tag{8}$$

We then interpret parameter β as the effect of changes in state funding at an Illinois public university, via state funding shift-shares, on an individual professor's outcome $Y_{j,t}$.

Figure A3: Local Projection Estimates for Effect of State Funding on Faculty Promotion Rate at Illinois Public Universities, by Professor Group.



(a) First-stage Estimate.

(b) Lecturers.

(c) Assistant Professors.

(d) Full Professors.

Note: These figures show the local projections estimates of regression specification (3), with the funding shift-share as an instrument for state funding. The unit of analysis is an individual faculty member (at an Illinois public university); funding data come from IPEDS, and faculty promotion rate from IBHED. The coefficient estimate is effect of state funding ($X_{i(j),t}$) on faculty promotion rate ($Y_{j,t}$), using the funding shift-share instrument ($Z_{i(j),t}$), while accounting for auto-correlation between different time periods — i.e., between $X_{i(j),t}, X_{i(j),t-1}$ and $Y_{i(j),t}, Y_{i(j),t-1}$. These results use a $\log - \log$ specification, so the estimates are for the rate of promotion in a year $t+k$ affected by a 1% change in state funding in year t, where years $k = 0, \ldots, 4$ are on the x-axis. Standard errors are clustered at the university-year level, and Subsection A.2 fully describes the differences in empirical specification when unit of analysis is an individual faculty member.

Table A4: Effects of Changes in State Funding on University Faculty Composition, in Illinois 2010–2021, OLS and 2SLS Estimates.

Panel A: units in $ per student

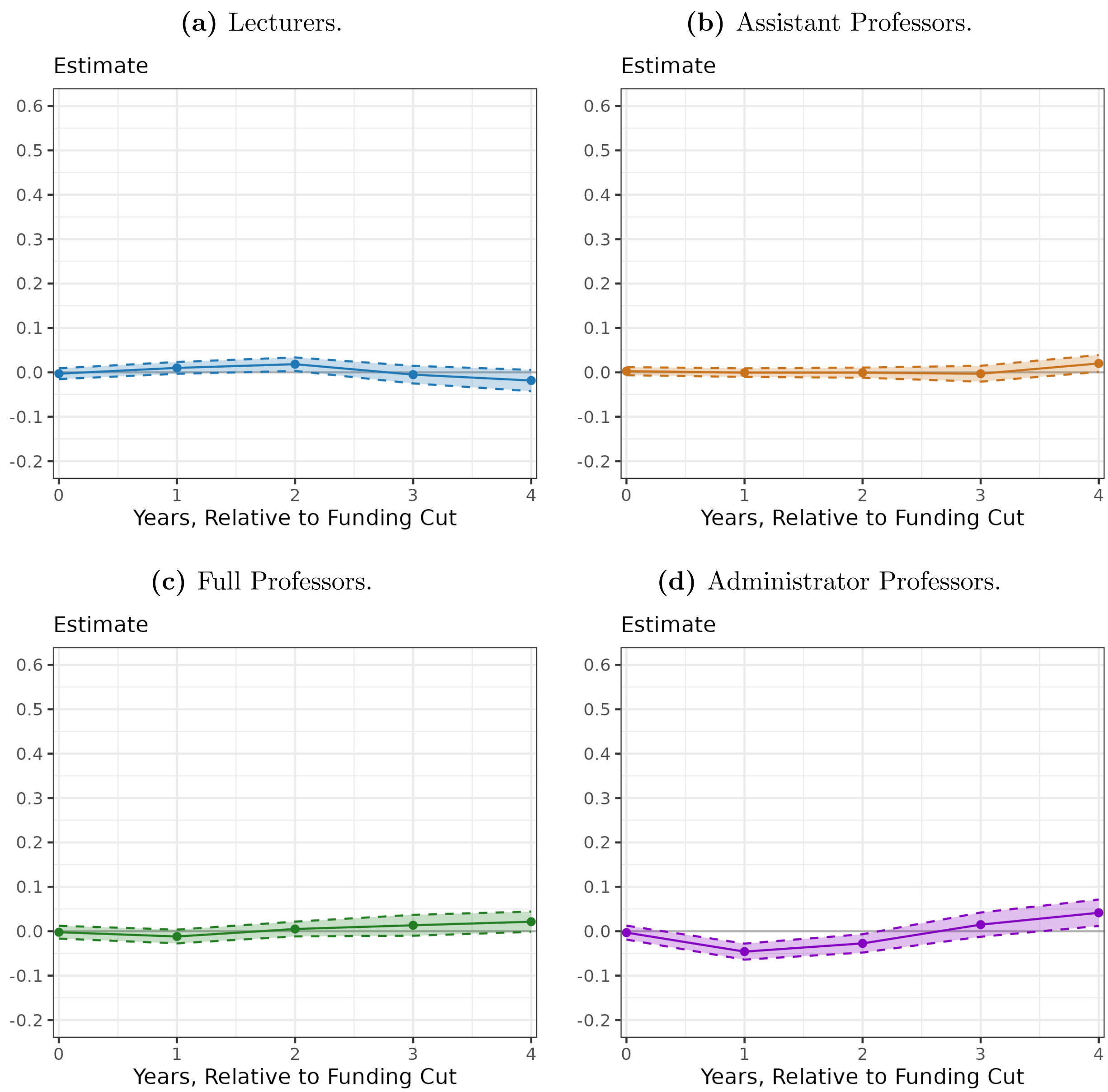
	Dependent Variable: Employment Count by Professor Group							
	Lecturers		Asst. Professors		Full Professors		All Faculty	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	−8.399	−32.989	−1.981	−1.491	−2.567	−2.012	−12.508	27.514
	(4.661)	(31.616)	(2.194)	(22.859)	(2.799)	(10.909)	(9.620)	(84.320)
Outcome Mean	351.306	351.306	273.757	273.757	477.597	477.597	1303.014	1303.014
Observations	144	144	144	144	144	144	144	144
R^2	0.893	0.843	0.973	0.973	0.992	0.992	0.983	0.978

Panel B: units in log $ per student

	Dependent Variable: Employment Count							
	Lecturers		Asst. Professors		Full Professors		All Faculty	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	−0.015	−0.017	0.049	0.058	0.007	−0.029	0.004	−0.008
	(0.033)	(0.026)	(0.045)	(0.038)	(0.021)	(0.032)	(0.028)	(0.022)
Outcome Mean	2.523	2.523	1.491	1.491	2.729	2.729	8.141	8.141
Observations	144	144	144	144	144	144	144	144
R^2	0.700	0.700	0.789	0.789	0.839	0.836	0.633	0.632

Note: These tables show the second stage OLS and 2SLS estimates of regression specification (3), showing the effect of state funding changes on number of faculty per student in Illinois universities, using the funding shift-share to instrument for state funding in the columns labelled 2SLS. Each observation is a public university-year in the state of Illinois, where funding data come from IPEDS and faculty count come from IBHED data. Panel A shows the effect of a fall in state funding $\$-1,000$ per student in the state on the number of professors. Panel B shows the effect of a 10% change in state funding per student at the university on the 10% change in the number of professors per students. Outcome-mean is the mean of the outcome, for Panel A the number of professors per student, for Panel B the number of faculty per student. Panel B uses log faculty count per student as the outcome, though the outcome mean is count of faculty per student (not in log terms). Standard errors are clustered at the university-year level, and university + year fixed effects are included through–out.

Figure A4: Local Projection Estimates for Effect of State Funding on Faculty Exit Rate at Illinois Public Universities, by Professor Group.



Note: These figures show the local projections estimates of regression specification (3), with the funding shift-share as an instrument for state funding. The unit of analysis is an individual faculty member (at an Illinois public university); funding data come from IPEDS, and faculty promotion rate from IBHED. The coefficient estimate is effect of state funding ($X_{i(j),t}$) on faculty promotion rate ($Y_{j,t}$), using the funding shift-share instrument ($Z_{i(j),t}$), while accounting for auto-correlation between different time periods — i.e., between $X_{i(j),t}, X_{i(j),t-1}$ and $Y_{i(j),t}, Y_{i(j),t-1}$. These results use a rate− log specification, so the estimates are for the rate of promotion in a year $t+k$ affected by a 1% change in state funding in year t, where years $k = 0, \ldots, 4$ are on the x-axis. Standard errors are clustered at the university-year level, and Subsection A.2 fully describes the differences in empirical specification when unit of analysis is an individual faculty member.

A.3 Professor Hiring

These results were produced by integrating the total count of professor hires for 2010–2021 for the top-ranked 180 US universities with a sum of the funding variables, and then estimating the models specified in Subsection 4.2. There were no observable differences in the hiring rate of male versus female faculty.

Table A5: OLS and 2SLS Estimates for University Faculty Hires, in Illinois 2011–2021.

Panel A: units in $ per student

	Dependent Variable: Yearly New Hires by Professor Group							
	Lecturers		Asst. Professors		Full Professors		All Faculty	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	−2.551	−2.280	0.060	−5.126	−0.095	−2.562	−2.677	23.012
	(1.420)	(9.168)	(0.675)	(7.210)	(0.249)	(7.051)	(2.185)	(52.652)
Outcome Mean	73.275	73.275	42.771	42.771	12.301	12.301	151.932	151.932
Observations	131	131	131	131	113	113	132	132
R^2	0.839	0.839	0.934	0.902	0.788	0.752	0.918	0.793

Panel B: units in log $ per student

	Dependent Variable: Employment Count							
	Lecturers		Asst. Professors		Full Professors		All Faculty	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	0.120	0.158	0.172	0.174	0.191	0.235	0.046	0.082
	(0.071)	(0.065)	(0.154)	(0.143)	(0.113)	(0.137)	(0.080)	(0.047)
Outcome Mean	0.494	0.494	0.234	0.234	0.051	0.051	0.993	0.993
Observations	131	131	131	131	113	113	132	132
R^2	0.749	0.749	0.482	0.482	0.628	0.627	0.580	0.579

Note: These tables show the second stage OLS and 2SLS estimates of regression specification (3), showing the effect of state funding changes on number of faculty hires at Illinois universities, using the funding shift-share to instrument for state funding in the columns labelled 2SLS. Each observation is a public university-year in the state of Illinois, where funding data come from IPEDS and faculty count come from IBHED data. Panel A shows the effect of a fall in state funding $\$-1,000$ per student in the state on the number of new faculty hires by position. Panel B shows the effect of a 10% change in state funding per student at the university on the 10% change in the number of faculty hires per students. Outcome-mean is the mean of the outcome, for Panel A the number of faculty hires, for Panel B the number of faculty hires per student. Panel B uses new faculty hires per student as the outcome (in log terms), though the outcome mean is count of new faculty hires per student (not in log terms). Standard errors are clustered at the university-year level, and university + year fixed effects are included through–out.

Table A6: OLS and 2SLS Estimates for Professor Hiring, Total for 2011–2020.

	Dependent Variable: Professor Hiring Count					
	Men		Women		Total	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)
State Funding	0.805	1.308	0.845	1.325	0.848	1.306
	(0.222)	(0.365)	(0.235)	(0.335)	(0.220)	(0.352)
Observations	157	157	157	157	157	157
R^2	0.396	0.366	0.415	0.383	0.408	0.381

Note: This table show the second stage 2SLS estimates of regression specification (3), showing the effect of state funding changes on the number of faculty hires (per student) total for 2011–2021 at US public universities, using the funding shift-share to instrument for state funding. Yearly variation in total hires is not observed here, so only the total hires across 2011–2021 for 157 universities, can be considered. Each observation is a public university across the years 2011–2021, where data on total funding across 2011–2021 come from IPEDS and faculty count total from (Wapman et al. 2022*b*,*a*). The panels show the effect of a 1% change in state funding per student at the university (total for 2011–2021) on the number of new faculty hires by gender (and all). Standard errors are clustered at the state level, and state fixed effects are included through–out.

A.4 Robustness Checks

Table A7: Effects of State Funding on Faculty Counts, IPEDS 1990–2021, IV Estimates by Institution Selectivity.

Panel A: units in $ per student

	First-stage	Lecturers	Asst. Professors	Full Professors	All Faculty	Observations
Most Selective:	-1.804	0.176	5.421	3.011	14.298	367
	(0.178)	(1.836)	(2.389)	(4.015)	(10.112)	
	[13036.59]	[0.004]	[0.011]	[0.033]	[0.05]	
Selective:	-5.555	-0.089	0.025	0.044	0.022	815
	(0.324)	(0.019)	(0.006)	(0.004)	(0.003)	
	[12084.012]	[0.005]	[0.011]	[0.03]	[0.046]	
Unranked:	-7.264	-0.058	0.018	0.017	0.008	15830
	(0.272)	(0.005)	(0.002)	(0.002)	(0.001)	
	[10206.27]	[0.006]	[0.012]	[0.022]	[0.041]	

Panel B: units in log $ per student

	First-stage	Lecturers	Asst. Professors	Full Professors	All Faculty	Observations
Most Selective:	-0.944	-0.201	0.162	0.001	-0.01	367
	(0.043)	(0.134)	(0.069)	(0.041)	(0.037)	
	[13036.59]	[0.004]	[0.011]	[0.033]	[0.05]	
Selective:	-1.067	-0.465	0.129	0.229	0.116	815
	(0.022)	(0.092)	(0.031)	(0.018)	(0.016)	
	[12084.012]	[0.005]	[0.011]	[0.03]	[0.046]	
Unranked:	-0.965	-0.436	0.137	0.131	0.062	15830
	(0.019)	(0.032)	(0.015)	(0.012)	(0.009)	
	[10206.27]	[0.006]	[0.012]	[0.022]	[0.041]	

Note: These tables show the IV estimates of regression specification (3), in the same manner as Table 4, but restricting to institutions ranked as most selective, selective, and unranked by Barron's (2009) — and including state The first column presents the coefficient between state funding and shift-share IV, which is a string first-stage among every level of selectivity for public universities. The other columns show the coefficient between state funding the count of faculty per students. For example, Row 1 of panel B shows that a 10% cut in the state shift-share leads to a fall of 9.44% in state funding for the public universities ranked as "most selective." Standard errors for the coefficient estimates are in brackets, and the outcome mean are in square brackets beneath.

Table A8: First-stage Robustness Checks for Effects of State Funding Shift-Share on State Funding, OLS Estimates.

	Dependent Variable: State Funding	
	Raw Count Units	Log Units
	(1)	(2)
State Funding	−1.299	−1.050
	(0.172)	(0.041)
State Funding, Base Share %	−95.489	−0.895
	(40.941)	(0.141)
Acceptance Rate, %	−13.540	−0.012
	(15.208)	(0.046)
6–Year Completion Rate, %	69.341	0.148
	(23.718)	(0.074)
Tuition Revenue, $ millions	1.223	0.350
	(1.433)	(0.040)
Enrolment, FTE thousands	−4.748	−0.669
	(58.129)	(0.055)
State Enrolment, thousands	2.215	0.258
	(1.236)	(0.053)
Percent of State Enrolment	0.803	0.0003
	(3.356)	(0.0001)
Units	Raw counts	Log, % terms
F stat.	57.356	660.878
State + Year fixed effects?	Yes	Yes
Observations	13,687	13,687
R^2	0.382	0.453

Note: These tables show the second stage OLS and 2SLS estimates of regression specification (2), showing the effect of state funding shift-share on each university's state funding. This table differs from the main analysis by replacing University + Year fixed effects with State + Year fixed effects, measuring enrolment in full-time equivalent (FTE), and including controls for (1) State Funding as a percent of total funding in base period, (2) acceptance rate in mid-2000s, (3) 6–year completion rate in mid-2000s, (4) tuition revenue, (5) enrolment measured by full-time equivalent FTE, (6) total public university enrolment in the entire state, (7) percent of public university enrolment for the state enrolled at this university. The first column uses the raw count specification, and the second column uses the log specification for percentage terms.

Table A9: Robustness Checks for Effects of State Funding Cuts on Faculty Composition, OLS and 2SLS Estimates in log Units.

	Dependent Variable: Log Faculty Count per Students, by Position							
	Lecturers		Asst. Professors		Full Professors		All Faculty	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	−0.116	−0.352	0.072	0.069	0.147	0.104	0.095	0.038
	(0.042)	(0.088)	(0.026)	(0.048)	(0.050)	(0.022)	(0.038)	(0.023)
State Funding, Base Share %	−0.053	−0.042	−0.022	−0.022	0.075	0.077	0.025	0.028
	(0.160)	(0.172)	(0.049)	(0.049)	(0.047)	(0.047)	(0.037)	(0.038)
Acceptance Rate, %	0.015	0.00004	0.004	0.004	−0.012	−0.015	−0.013	−0.016
	(0.077)	(0.082)	(0.043)	(0.044)	(0.038)	(0.039)	(0.029)	(0.031)
6–Year Completion Rate, %	−0.029	0.023	0.130	0.130	0.241	0.250	0.156	0.169
	(0.112)	(0.125)	(0.034)	(0.033)	(0.036)	(0.034)	(0.021)	(0.024)
Tuition Revenue, $ millions	0.347	0.421	0.046	0.046	0.235	0.248	0.215	0.233
	(0.153)	(0.163)	(0.053)	(0.055)	(0.033)	(0.033)	(0.038)	(0.033)
Enrolment, FTE thousands	−0.580	−0.698	−0.223	−0.224	−0.278	−0.300	−0.336	−0.364
	(0.179)	(0.198)	(0.062)	(0.065)	(0.039)	(0.036)	(0.048)	(0.037)
State Enrolment, thousands	0.232	0.331	−0.112	−0.111	−0.196	−0.178	−0.102	−0.079
	(0.189)	(0.177)	(0.068)	(0.069)	(0.061)	(0.050)	(0.046)	(0.032)
Percent of State Enrolment	0.150	0.417	0.021	0.024	−0.021	0.027	0.095	0.159
	(0.591)	(0.595)	(0.177)	(0.183)	(0.168)	(0.130)	(0.158)	(0.135)
Outcome Mean	0.681	0.681	1.394	1.394	2.666	2.666	4.816	4.816
Observations	13,687	13,687	13,687	13,687	13,687	13,687	13,687	13,687
R^2	0.341	0.327	0.440	0.440	0.438	0.433	0.543	0.529

Note: These tables show the second stage OLS and 2SLS estimates of regression specification (3), showing the effect of state funding changes on number of faculty per student in Illinois universities, using the funding shift-share to instrument for state funding in the columns labelled 2SLS. This table differs from the main analysis by replacing University + Year fixed effects with State + Year fixed effects, measuring enrolment in full-time equivalent (FTE), and including controls for (1) State Funding as a percent of total funding in base period, (2) acceptance rate in mid-2000s, (3) 6–year completion rate in mid-2000s, (4) tuition revenue, (5) enrolment measured by full-time equivalent FTE, (6) total public university enrolment in the entire state, (7) percent of public university enrolment for the state enrolled at this university.

Table A10: Robustness Checks for Effects of State Funding Cuts on Faculty Composition, OLS and 2SLS Estimates in Raw Count Units.

	Dependent Variable: Faculty Count per 1,000 Students, by Position							
	Lecturers		Asst. Professors		Full Professors		All Faculty	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	−1.001	−1.641	1.032	4.573	7.128	6.836	7.213	10.746
	(0.461)	(1.345)	(0.397)	(2.094)	(1.212)	(3.097)	(1.396)	(5.276)
State Funding, Base Share %	55.056	57.126	15.654	4.200	−38.543	−37.598	18.057	6.627
	(24.373)	(25.604)	(35.625)	(37.658)	(53.606)	(51.900)	(95.185)	(95.017)
Acceptance Rate, %	−7.862	−8.694	6.849	11.450	−41.508	−41.888	−53.375	−48.783
	(10.581)	(9.949)	(9.243)	(14.230)	(21.648)	(20.581)	(26.159)	(29.083)
6–Year Completion Rate, %	8.357	12.754	21.899	−2.429	169.846	171.853	202.607	178.329
	(18.767)	(21.069)	(13.444)	(23.497)	(42.483)	(45.635)	(39.685)	(47.031)
Tuition Revenue, $ millions	0.185	0.186	0.123	0.118	0.215	0.216	0.622	0.617
	(0.035)	(0.035)	(0.027)	(0.028)	(0.064)	(0.064)	(0.137)	(0.137)
Enrolment, FTE thousands	2.580	2.575	7.029	7.060	22.975	22.972	32.420	32.450
	(0.858)	(0.848)	(0.595)	(0.554)	(1.272)	(1.276)	(1.925)	(1.900)
State Enrolment, thousands	0.088	0.086	−0.061	−0.054	−0.218	−0.218	−0.188	−0.182
	(0.021)	(0.021)	(0.020)	(0.020)	(0.069)	(0.067)	(0.098)	(0.098)
Percent of State Enrolment	−7.625	−6.651	126.755	121.370	168.080	168.525	255.309	249.936
	(48.023)	(48.705)	(42.249)	(37.381)	(72.631)	(72.682)	(105.737)	(102.570)
Outcome Mean	59.253	59.253	116.121	116.121	269.103	269.103	452.507	452.507
Observations	13,687	13,687	13,687	13,687	13,687	13,687	13,687	13,687
R^2	0.647	0.646	0.861	0.845	0.942	0.942	0.954	0.954

Note: These tables show the second stage OLS and 2SLS estimates of regression specification (3), showing the effect of state funding changes on count of faculty in Illinois universities, using the funding shift-share to instrument for state funding in the columns labelled 2SLS. This table differs from the main analysis by replacing University + Year fixed effects with State + Year fixed effects, measuring enrolment in full-time equivalent (FTE), and including controls for (1) State Funding as a percent of total funding in base period, (2) acceptance rate in mid-2000s, (3) 6–year completion rate in mid-2000s, (4) tuition revenue, (5) enrolment measured by full-time equivalent FTE, (6) total public university enrolment in the entire state, (7) percent of public university enrolment for the state enrolled at this university.

Table A11: Effects of State–Wide Funding Changes on Private University Faculty Counts, IPEDS 1990–2021, OLS and 2SLS Estimates.

Panel A: units in $ per student

	Dependent Variable: Faculty Count per 1,000 Students, by Position							
	Lecturers		Asst. Professors		Full Professors		All Faculty	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	0.002	−0.099	0.003	0.037	0.005	−0.060	0.011	−0.099
	(0.002)	(0.193)	(0.001)	(0.190)	(0.003)	(0.176)	(0.006)	(0.406)
Outcome Mean	12.392	12.392	35.058	35.058	62.593	62.593	111.495	111.495
Observations	25,309	25,309	25,309	25,309	25,309	25,309	25,309	25,309
R^2	0.617	0.415	0.788	0.778	0.944	0.937	0.904	0.897

Panel B: units in log $ per student

	Dependent Variable: Log Faculty Count per Students, by Position							
	Lecturers		Asst. Professors		Full Professors		All Faculty	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	0.412	−0.728	0.366	−1.716	0.394	−0.331	0.381	−1.563
	(0.079)	(6.354)	(0.058)	(4.346)	(0.063)	(1.819)	(0.060)	(3.969)
Outcome Mean	0.744	0.744	1.935	1.935	3.075	3.075	5.824	5.824
Observations	25,309	25,309	25,309	25,309	25,309	25,309	25,309	25,309
R^2	0.639	0.549	0.741	0.002	0.819	0.734	0.845	−0.125

Note: These tables show the second stage OLS and 2SLS estimates of regression specification (3), among private universities — as described in Subsection 5.5. Each observation is a public university-year, in the IPEDS data. Panel A shows the effect of a fall in state funding $\$-1,000$ per student on the number of professors — i.e., an extra $\$1,000$ per student leads to 6 fewer lecturers according to column 2. Panel B shows the effect of a 10% change in state funding per student at the university on the 10% change in the number of professors per students — i.e., an extra 10% of state funding per student leads to 4.37% fewer lecturers per student according to column 2. Outcome-mean is the mean of the outcome, for Panel A the number of professors per student, for Panel B the number of faculty per student. Panel B uses log faculty count per student as the outcome, though the outcome mean is count of faculty per student (not in log terms). Standard errors are clustered at the state-year level, and university + year fixed effects are included through–out.

A.5 Analysis of IPEDS Salary Data and Years Following the Great Recession

Bigger analysis in here.