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

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Abstract

US public universities employ more lecturers and fewer professors 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 professors and full professors per student by 1.4% and 1.2%, 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 the deterioration of student outcomes at public universities since the 1990s.

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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 teach 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 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 receives an extra $1,000 per student (or a 10% increase), do they change how many faculty members they employ? If so, which positions do universities substitute away from, 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 between unviersity for student enrolment (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 guaratee 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 instrumental variables (IV) approach to identify causal effects of state funding cuts. The shift-share instrument identifies exogenous changes in state funding by exploiting differences in how much universities relied 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.

Mine is the first paper to provide causal evidence on the impact of state funding on faculty composition and wages. 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, Brown, Dimmock, Kang & Weisbenner 2014). For faculty outcomes, descriptive work measures how US and Canadian faculty salaries are correlated with other factors (Bratsberg, Ragan Jr & Warren 2003, Martinello 2009, Pfeffer & Davis-Blake 1992), 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 et al. 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 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).[2] 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 discusses the context and implications for the findings. Section 7 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

[2]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.

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.[6] This gives a resulting panel data-set, where each row represents a university-year, and includes columns for university funding and tuition revenue, plus total count[7] 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

[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.

[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 to analyse faculty salaries. Notably, IPEDS data on faculty counts do not suffer from these problems.

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

their university, investigating outcomes are more granular details than total faculty counts. IBHED freely provides this information, as the state of Illinois is required to publicly report base salary and benefits for all administrators, faculty members, and instructors employed by each public college or university.[8] 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,[9] 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.

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.[10] US state governments, by majority, are legally obligated to run a balanced-budget, so that yearly variation in tax revenues (e.g., caused by changing economic conditions) necessarily

[8] 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.

[9] 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, 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.

[10] 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).

affect state expenditures. Public universities have lower lobbying power than other state institutions, so often bear the brunt of state government funding cuts (Delaney & Doyle 2011).[11] 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 1990–2021. 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 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.

[11] 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.

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, yet this number fell by over 20% afterwards only for public universities: in 2021 the average public university has 6 fewer full professors per hundred students than the average private university. Over the same time period, we see the rise in use of lecturers; lecturers were were employed at similar rates in private and public sectors in 1990, but have public universities increased their reliance on lecturers more than private universities ever since.

2.3 Trends in Illinois

Illinois funding for higher education has stagnated, and has experienced 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.[12] 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

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

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 (Young, Wiley & Searing 2020), exhibiting how state-level changes in funding affect public universities thanks to unrelated issues.

3 Conceptual Framework

Universities can respond 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.

Wider changes in the American higher education sector could concurrently explain the 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.

Universities 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.[13] 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.[14] 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, 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 following a state funding cut.

[13] 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.

[14] 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.

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. For example, it may be the case that a state government cuts funding for higher education as the demographics of the state change, and the average age grows older (such as in Maine) At the same time, it may be harder to attract younger faculty to work at universities in a state with an older population, so that faculty outcomes are correlated with state funding thanks to changes in state demographics. 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 to address endogeneity concerns for state governments' funding decisions, for their public universities. Deming & Walters (2017), Chakrabarti et al. (2020) develop 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.

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

The system exploits the fact that institutions who rely more on state funding will be affected by follow-on state-wide funding cuts. $Z_{i,t}$ is the shift-share instrument for institution i in year t. 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.[15] $Z_{i,t}$ 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.[16] State funding has been falling, so that the instrument describes shocks to university revenues, mostly in a negative direction.[17]

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 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-line 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

[15] 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.

[16] 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.

[17] Chakrabarti et al. (2020) 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.

upcoming shocks) to state funding, so that the shift-share approach yields causal estimates by IV (Chakrabarti et al. 2020).[18] 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-in-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 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 (Pei et al. 2019). Yearly and individual fixed effects are included in regressions throughout to implicitly condition on mean 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

[18] 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-line share is not plausible here.

second stage for the effect of state funding on faculty outcomes.[19]

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

I estimate the system by two stage least squares, including institution and year fixed effects.[20] $Y_{i,t}$ 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 changes in state funding among incumbent professors using the Illinois data (IBHED). Incumbent professors are faculty who are already employed at the university; state funding changes may affect faculty who are already at the university (beyond affecting whether they get hired), so I base the instrument in the year that the professor was hired, and include fixed effects for the hiring year.[21] 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

[19]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).

[20]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.

[21]This formulation follows that presented by Chakrabarti et al. (2020), where individual student outcomes are analysed via variation in state funding after their 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.

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

The effects of a change in the universities funding may not be immediate, and faculty may be affected multiple years after a funding cut. Yet, the funding shift-share instrument is significantly auto-correlated year-on-year; a large state-level funding cut in year t is also likely to experience a large funding cut in year $t-1$. Figure A1 shows that the shift-share instrument is correlated with state funding five years into the past and future. This level of time-series correlation would confound IV estimates of the effect of state funding in year t on faculty outcomes in later years $t+k$, providing inconsistent estimates for the causal relationships.

I employ a local projections approach to model how faculty outcomes in years $t+k$ are affected by state funding in year t, for future years $k>0$ (Jordá 2005). The local projections method is an empirical model used to estimate dynamic treatment effects when the treatment is not binary, when time-series confounding is present (Montiel Olea & Plagborg-Møller 2021). Faculty outcomes could be affected in only a transitory manner, where effects in later years are close to zero, or in a persistent manner, where the effects of state funding cuts linger for multiple years. This method allows me to estimate the effect of state funding $X_{i,t}$ on faculty outcomes $Y_{i,t+k}$ in follow-on years $k > 0$, credibly testing whether effects are transitory or long-lasting. The approach accommodates the shift-share instrument for state funding (Olea, Stock & Watson 2021), so that I present results using the shift-share to instrument for state funding (as in the rest of the empirical analysis).[22]

5 Results

5.1 First Stage Estimates

The shift-share instrument has a strong first stage for universities' yearly state funding. Table 3 presents results of the first-stage regression among IPEDS data, separately with and without a control for tuition revenue per student, plus institution and year fixed effects. 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 without fixed effects. Columns (3) and (4) include the tuition revenue as a control (explained in footnote 17) to exhibit estimates with or without this control variable. Column (3) shows similar estimates to column (1) in both Panels A and

[22]The funding shift-share has a persistent effect on state funding, multiple years after the initial funding shift-share, so that the instrument is similarly strong for the local projections method — see Subsection A.1 further evidence on the strength of the first stage in local projections estimation.

B thanks to inclusion of fixed effects, so that 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 form that I proceed with. I use the same empirical strategy in the analysis of Illinois faculty, and Table A2 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 university revenues in the first-stage estimation.

The first stage is strong in both IPEDS and IBHED data, and the argument in Section 4 for exogeneity comes from independence of the state funding mechanism to any individual public university campus. 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. The university–years in the lowest 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 changes in funding. On the other hand, the measures of selectivity (acceptance rate, 6–year graduation rate) are not substantially different across the distribution of the instrument. This allays concerns that state-wide shifts in state funding are targetted more towards less selective universities (a possible confounder), and supports use of the shift-share IV empirical design.

5.2 University Level, IPEDS

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 a change in state funding on the number of faculty at the university, 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 number 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 subsitutional towards lecturers over this 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, Figure 1b, 3).

Once the funding cut has passed, universities do not re-adjust to hiring more professors to make up for last year's substitution towards lecturers. Figure 5 shows local projection estimates, where the estimate is the elasticity for professor count per student in year $t+k$ with respect to state funding in year t for later years $k = 0, \ldots, 10$. These estimates correlespond to the elasticity estimates in Table 4 Panel B, where the outcome is faculty count per students in later years. State funding cuts affectthe 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 confident interval) more lecturers per student the following year, and around 3.1% (0.6–5.5 "") more lecturers nine years later. A 10% state funding cut leads to 1.5% (0.6–2.2 in a 95 percent confident interval) fewer assistant professors per student the following year, and around 1.1% (0.2–2.0 "") fewer nine years later; the same cut leads to 1.2% (0.6–1.8 in a 95 percent confident interval) fewer full professors per student the following year, and around 0.9% (0.1–1.7 “”) fewer nine years later. The effects are a substitution with the composition of faculty, as the total number of faculty per students are relatively unaffected in the follow-on years.

5.3 Illinois Faculty, IBHED

Incumbent professors at Illinois universities are relatively unaffected by state funding cuts for 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, so that faculty who are already at the university (incumbent faculty) seem to have little or no state funding cuts passed on to them for these outcomes. Additionally, local projection estimates show that professors' salaries are also not affected in the years after a state funding cut (Figure 6). Similarly, promotion rate and exit rate among incumbent faculty (from the Illinois public university system) are unaffected in the years after an initial funding shift-share (Figure A3, A4). There is evidence that lecturers see a 0.75% increase in salary in the second and third year after a 10% increase in state funding (Figure 6a), though this is the only evidence that incumbent faculty are affected by state funding cuts in the Illinois public university system.

These findings show that public universities increase (decrease) their count of tenure-track and tenured professors per student in years when revenues are more (less) plentiful. In the same vein, when funding increased, count of tenure-track and tenured professors per student increased — and the opposite in years of funding cuts. These findings are in line with the observation that universities froze hiring for a couple of years after the 2008 recession and funding cuts (Turner 2014). For lecturers, we see a negative effect which lines up with two trends noted in Subsection 2.2: state funding for public universities (per student) stagnated while usage of lecturers increased substantially.

5.4 Reduced Hiring of New Professors

The results above present a condundrum: there are large substitution effects among faculty, but faculty themselves are unaffected by funding cuts. The analysis of Illinois faculty (IBHED) studies the effect of state funding cuts on faculty already at the university — i.e., incumbent faculty. The findings above imply that subsitution towards lecturers came about by limiting hiring of new professors, to replace leaving or retiring professors, so that they are replaced by hiring lecturers.

To further study this issue, I take recent data on the total faculty hired at US public universities over 2011–2021 provided by Wapman, Zhang, Clauset & Larremore (2022*b*,*a*). Wapman et al. (2022*b*) study the composition of professor hiring in the years 2011–2021, and publiccally released data on the number of professors (not lecturers) hired at US universities.[23] I combine this measure, with total state funding for public universities acorss the same time period from IPEDS, to validate the claim that state funding cuts led to faculty subtitution via limiting hiring of new professors.

There is a strong correlation between the number of professors hired (relative to student enrolment), where an extra $1,000 of state funding per student is associated with the university hiring 0.12 more professors per hundred students. I apply the shift-share model to these data, summing the state funding and funding shifts for the decade of 2012–2021. I find that a state funding cut of 10% leads to 13% fewer professor hires (relative to enrolment). See Subsection A.3 for further details on this additional analysis of professor hiring.

These results provide suggestive evidence that funding cuts caused faculty substitution by disrupting hiring of new professors at public universities. This provides a coherent mechanism for how incumbent faculty (those who are already hired at the university) were not meaningfully impacted by funding cuts, yet their wider composition nonetheless changed

[23]These data are not panel data, instead only give the total professors hired over the ten year period 2011–2021.

when their universities experienced funding cuts.

6 Discussion

Universities received less state funding, relative to increasing enrolment, and reacted by increasing their reliance on lecturers relative to assistant and full professors in both the short and medium-run; these results imply that lecturers can be considered substitutes for professors in the tenure-system.[24] The average public university's state funding fell by 36% per student, while the number of lecturers per student increased by 113%, and assistant and full professors fell by 17% and 23%, respectively. Stagnating state funding explains about 40% of the observed substitution towards lecturers away from tenure-track and tenured professors.

These effects are persistent: public higher education in the US was not exposed to one large funding cut, but systematic funding short-falls since the 1990s. The results in this paper show that state funding cuts had persistent effects on universities and faculty for multiple years after the initial funding cut, which were compounded by many years of further funding cuts. These long-run changes resulted in large changes in the composition of faculty, with more lecturers and fewer professors at public universities.

At the same time, incumbent faculty in the state of Illinois are unaffected by the state funding cuts in terms of salary, promotion rate, and rate of leaving their faculty position. These results imply that composition change arose by lower hiring of tenure-track faculty in the public university system. The private university system did not grow in any corresponding amount, implying that there are fewer tenure-track openings at US universities.[25] Securing academic employment on the tenure-track is more selective than ever, so that more PhD

[24]Additional results in Appendix Subsection A.4 formalises the marginal rate of substitution between lecturers and professors on tenure-track, showing how assistant and full professors were substituted for lecturers while there is no substitution between assistant and full professors.

[25]At the same time as these changes occurred, the number of PhD graduates in the US has continued to rise (AAUP 2021, Wapman et al. 2022*b*).

graduates will end up teaching as lecturers or leaving academia.

The results here are in line with theories explaining the increased competition and inequality between US universities. Urquiola (2020) interprets the success of research in US higher education as a result of free market policies, where increased competition in a free market in the early 1900s led to improvements in university research among US private universities. The rate of selectivity among US universities has become increasingly polarised, where top (and mostly private) universities with the most resources have become more selective at the undergraduate level (Hoxby 2009), and increasingly dominate academia at the graduate level (Wapman et al. 2022*b*). Public universities are by-in-large not selective, so are caught in a relative decline when their selective and private competitors are more selective, and have research and student outcomes.

While market forces have been effective in the successes of US higher education research, we should worry about the effects on education. Enrolment in higher education has increased drastically since 1990, and public universities educate more than twice as many undergraduates in 2021 as their private counterparts. Increasingly these students are being taught by lecturers, and not professors. Lecturers are often employed on short-term or part-time contracts (adjunct), with limited job stability. While we should worry about the effect on faculty working conditions, there is credible evidence that relying on adjunct lecturers leads to worse education and student outcomes, relative to full-time lecturers and professors (Zhu 2021). As tenure has increasingly becomes a private sector phenomenon, and most US undergraduate attend public universities, we should worry about the long-term effects of stagnating funding for higher education.

7 Summary and Concluding Remarks

This paper studies how stagnating state funding for higher education affected faculty, and their composition, at US public universities. This work contributes to the literature along two primary dimensions. First, by isolating changes in state funding on public universities via state funding shocks, this work provides an explanation for the increased reliance on lecturers and away from tenure-track and tenured professors at US public universities. This approach used multiple methods to estimate the short- and medium-run effects of state funding cuts on faculty outcomes. 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.

Public universities have systematically substituted away from tenure-track and tenured professors, toward lecturers, in the face of persistent declines in state funding for higher education. The effects on incumbent professors in Illinois are non-distinguishable from zero, with suggestive evidence for reduced hiring of new professors, implying that the faculty substitution is driven by reduced hiring of new professors. Public universities are using more contingent lecturers to teach their students, while private universities continue to employ more tenure-track and tenured professors than their public counterparts, and each year the gap widens.

At the same time as higher education costs have been rising in the US, public universities have also dealt with declining state funding. I show that these headwinds led to systematic change at public universities, changes that affect their faculty, and likely limiting public universities in their goals in research and education. These results show large changes in faculty composition, and that stagnation in state support explains at least a third of the observed shift away from tenured professors and towards lecturers. At the same time, private universities were not exposed to financial headwinds of the same magnitude or persistence.

While public universities continue to educate the majority of higher education students in the US, we should worry about the effects of restricting their funding has on faculty, and the wider impact on higher education as a whole.

Data Statement

Every source of data, and the code to fully replicate the entire analysis is freely available at the following link: https://github.com/shoganhennessy/state-funding-faculty. IBHED data, while public knowledge, include personally identifiable names, so the data included in the replication package have names replaced with non-identifiable placeholders.

Credit Author Statement

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

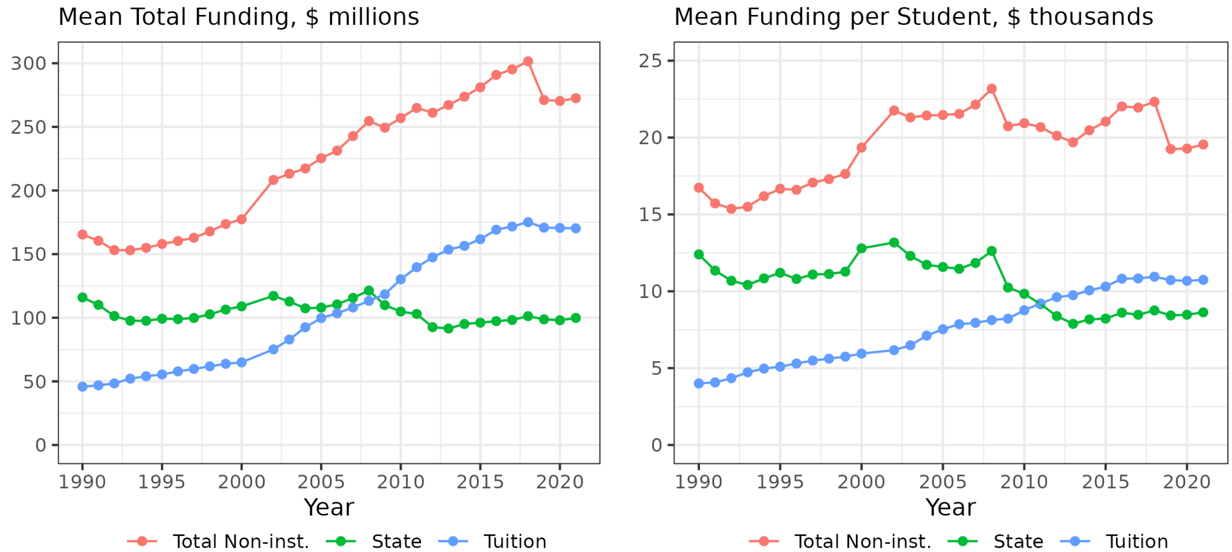
Declaration of Competing Interest

I have no competing interests to declare.

8 Figures

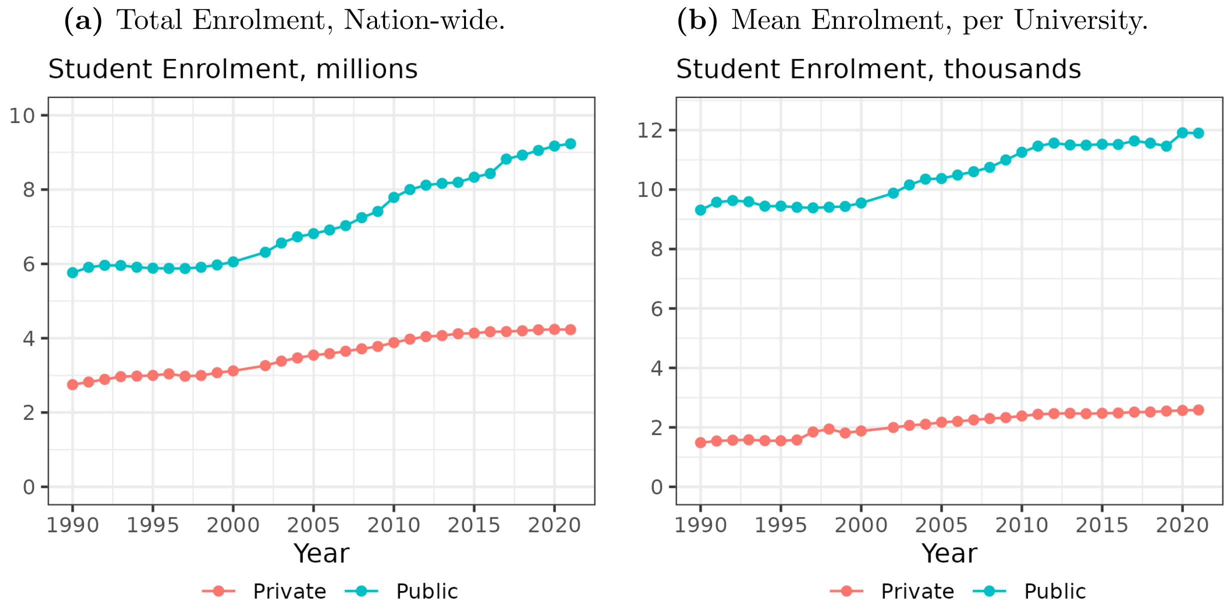
Figure 1: Mean Total Funding among Public Universities, by Year.

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



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.

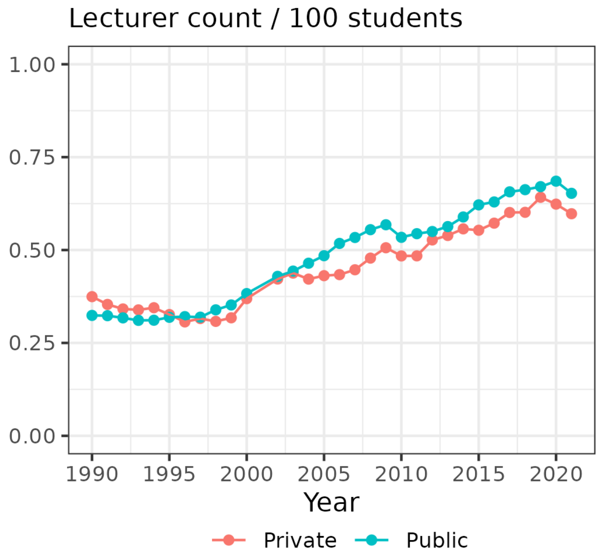
Figure 2: Total Student Enrolment, by University Sector and Year.



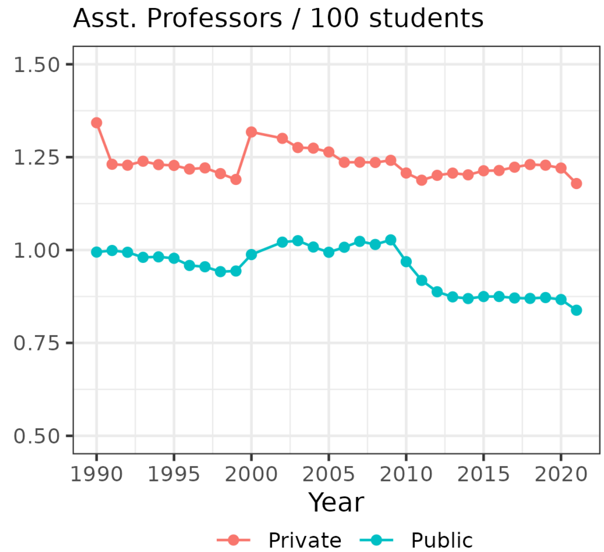
Note: This figure shows the total and mean enrolment for US universities, comparing public and private universities. Most of the higher education enrolment increase for the last 30 years was in public universities, who continue to enrol the vast majority of higher education students in the US. These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

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

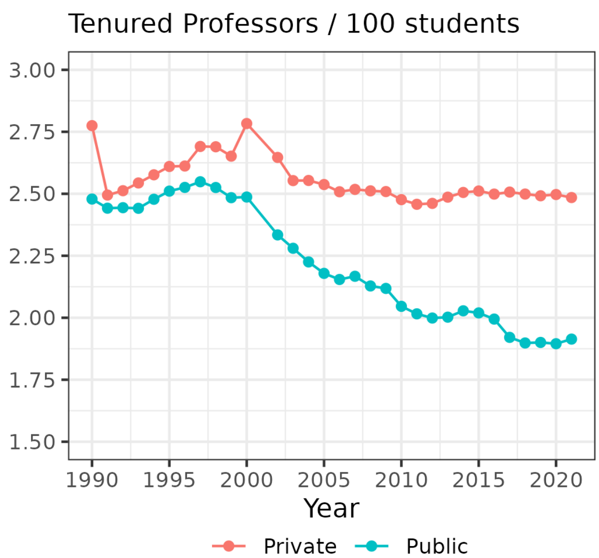
(a) Lecturers.



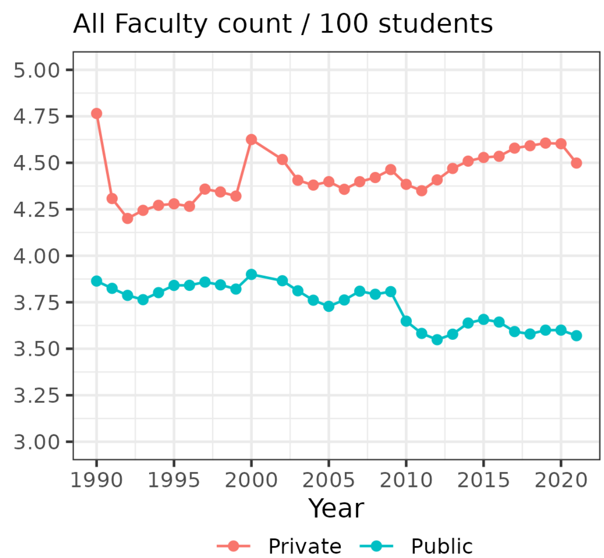
(b) Assistant Professors.



(c) Full Professors.



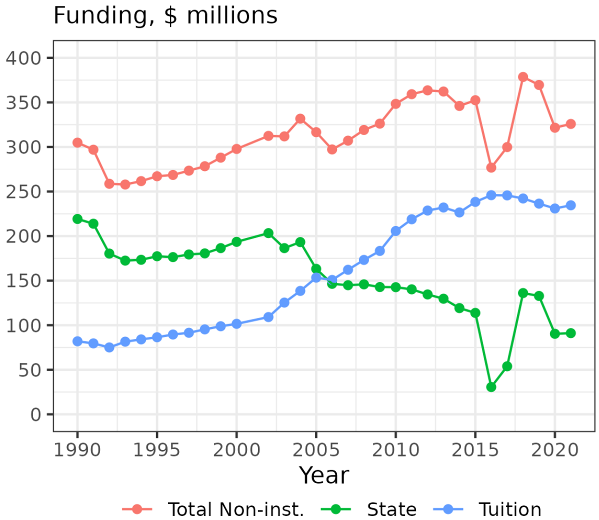
(d) All Faculty.



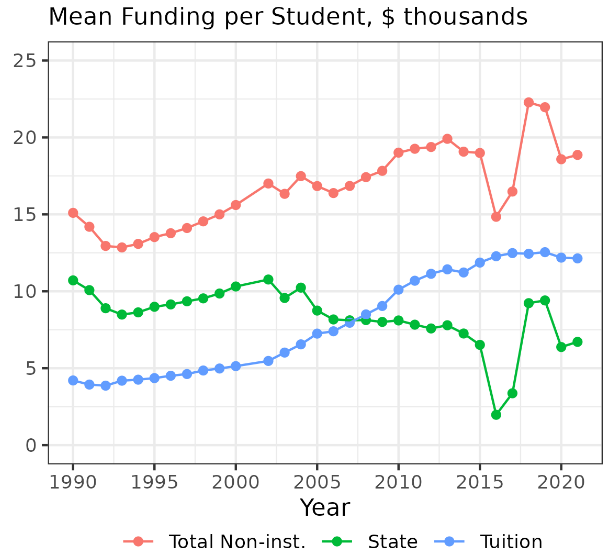
Note: This figure shows the average number of students per faculty member, by different faculty position, at US public universities. E.g., panel A calculates the mean of (student enrolment) / (lecturer count) at US public universities, for each year of 1990–2017, to show the average trend in faculty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

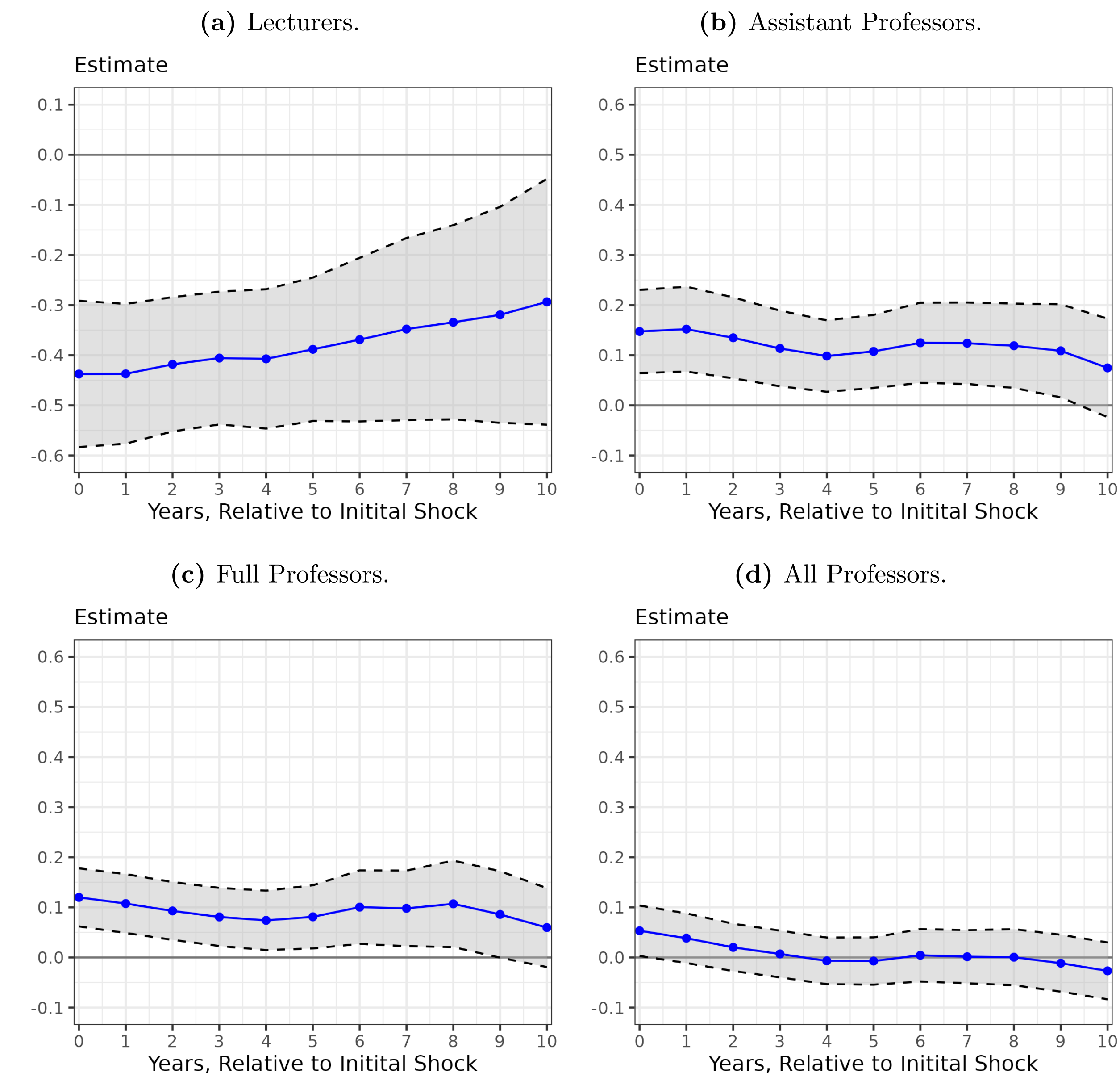


(b) Per Student, $ 2021 CPI-U.



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.

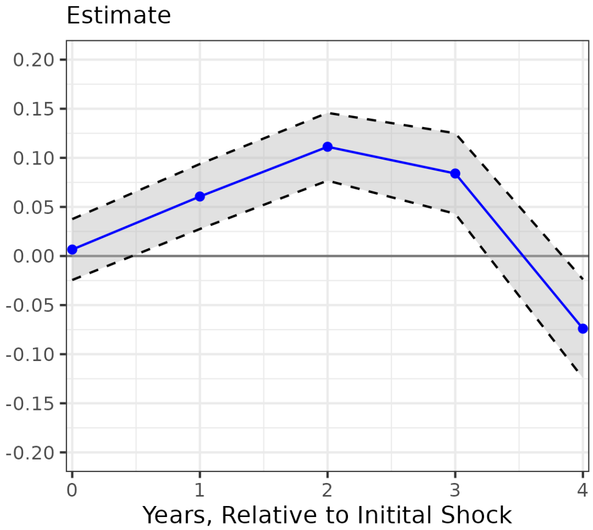
Figure 5: Local Projection Estimates for Effect of State Funding on Faculty Count per Student at Universities, by Professor Group.



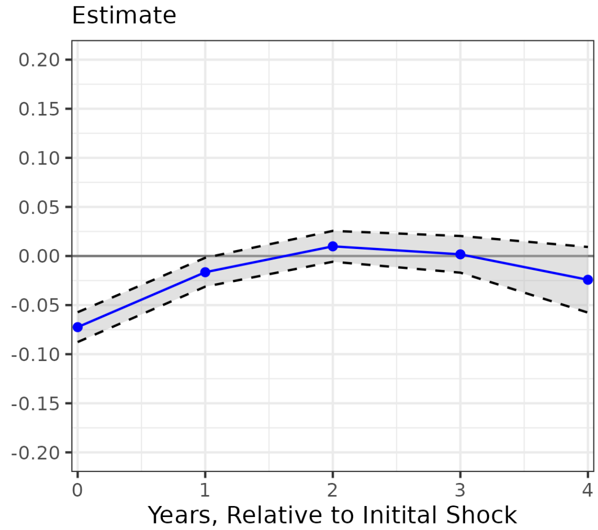
Note: These figures show the local projections estimates of regression specification (3), with the state funding shift-share as an instrument for state funding. The unit of analysis is the university, and uses IPEDS data. The x-axis represents the year relative to the state funding shift-share (i.e., $x = 0$ 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.

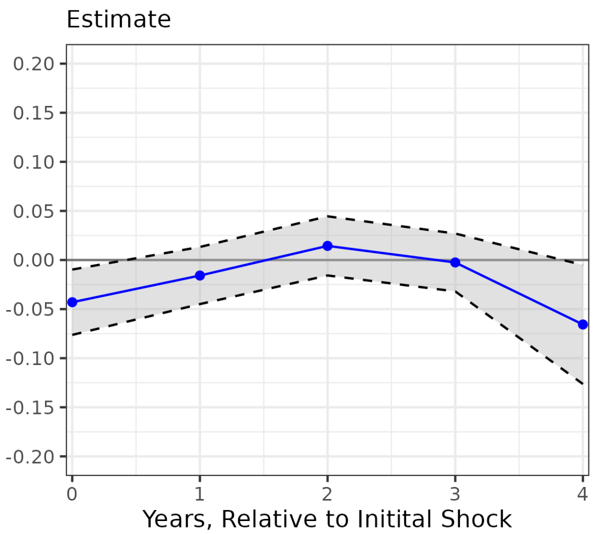
(a) Lecturers.



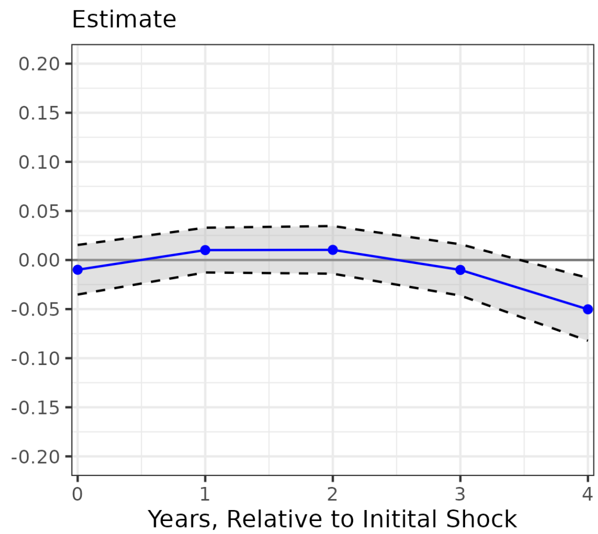
(b) Assistant Professors.



(c) Full Professors.

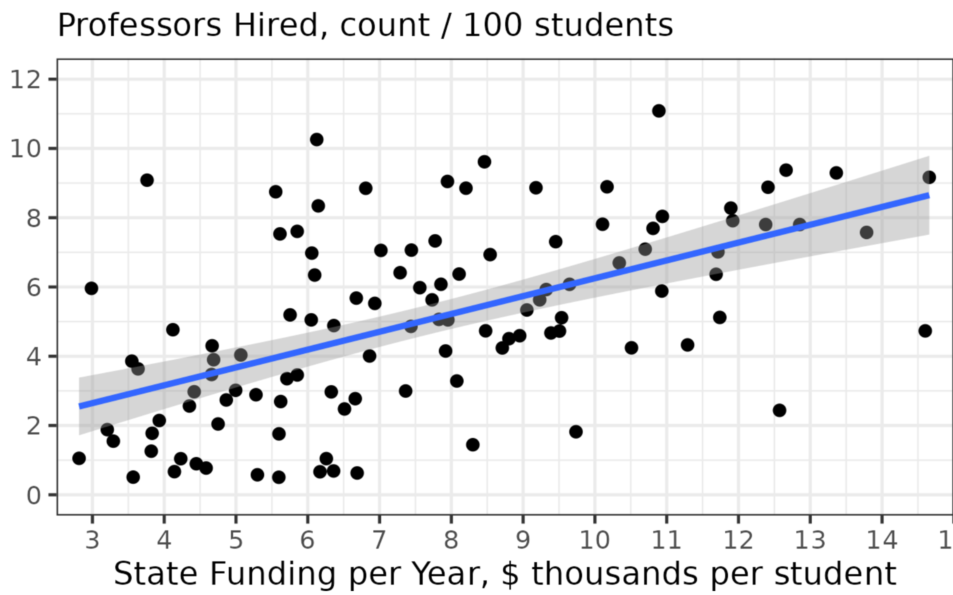


(d) Administrator Professors.



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*,*a*), and funding data from IPEDS.

9 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)	213	272	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 Shift-Share shift-share in IPEDS Data.

Panel A: units in $ per student

	Dependent Variable: State Funding			
	(1)	(2)	(3)	(4)
Funding Shock	−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 Shock	−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.

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

Panel A: units in $ per student

	Dependent Variable: Faculty Count per 100 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 Changes in State Funding on Faculty Salaries and Exit Rate, in Illinois 2010–2021, 2SLS Estimates.

	Dependent Variable: Salaries by Professor Group				
	Lecturer	Assistant	Full	Admin	All
	(1)	(2)	(3)	(4)	(5)
State Funding	0.083	−0.121	−0.048	−0.003	0.014
	(0.116)	(0.064)	(0.062)	(0.060)	(0.099)
Observations	26,324	22,328	9,065	11,529	69,246
R^2	0.212	0.046	0.040	0.139	0.157

	Dependent Variable: Exit rate by Professor Group				
	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 by Professor Group			
	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.

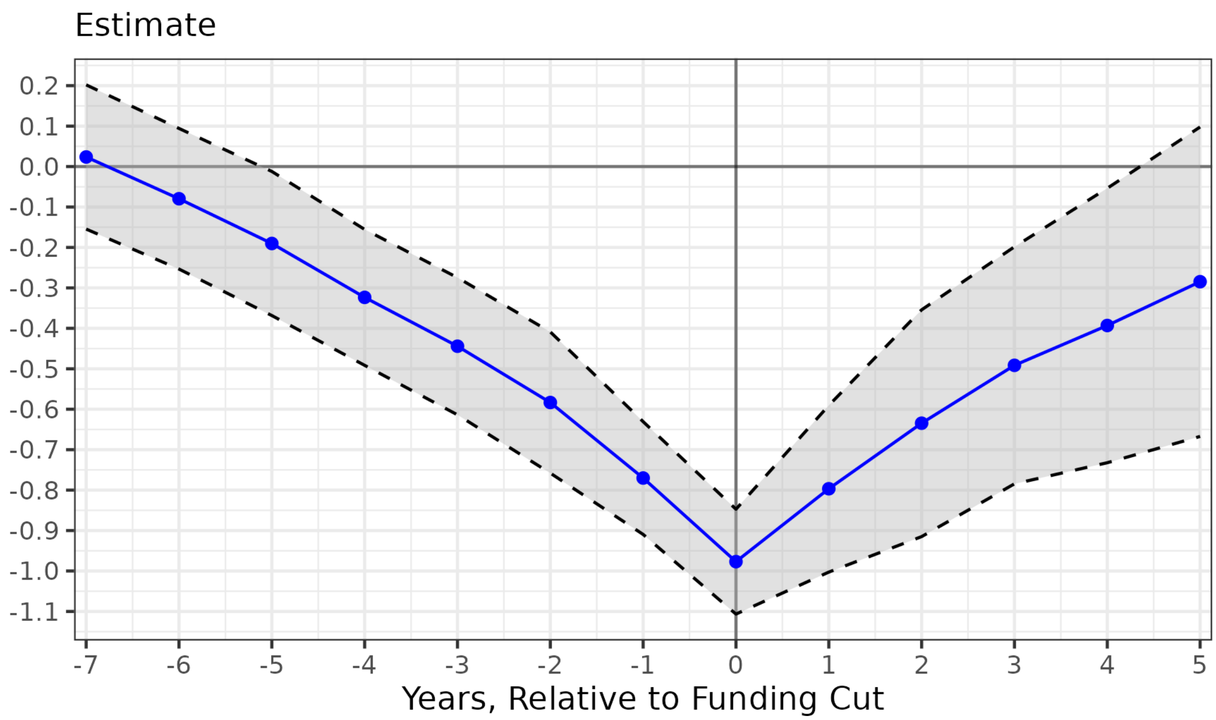
A.1 IPEDS First Stage

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	-1,474	-2,589	-3,566	-5,002	-8,208
Shift in state–wide funding	-6,138	-7,112	-8,593	-10,575	-14,018
Share reliance on state funding, % in 1990–1993	0.26	0.38	0.42	0.48	0.59
University Funding and Spending, $ millions:					
State funding	110	99	100	107	107
Tuition revenue	216	124	93	77	58
Total non-inst. revenues	329	225	194	185	166
Instruction spending	219	139	108	101	93
Research Spending	152	76	55	36	26
University Funding and Spending, $ per student					
State funding	12,900	9,956	9,335	9,305	12,767
Tuition revenue	13,130	8,530	6,875	6,047	5,507
Total non-inst. revenues	26,223	18,625	16,304	15,445	18,346
Instruction spending	21,680	12,526	9,798	8,482	9,953
Research spending	16,956	5,172	3,384	2,229	2,443
Selectivity:					
Reported enrolment	14,088	12,434	11,329	11,546	10,253
Full-time equivalent enrolment	12,453	10,597	9,638	9,877	8,555
Acceptance rate, %	0.71	0.73	0.71	0.64	0.60
6 Year graduation rate, %	0.56	0.47	0.44	0.45	0.45

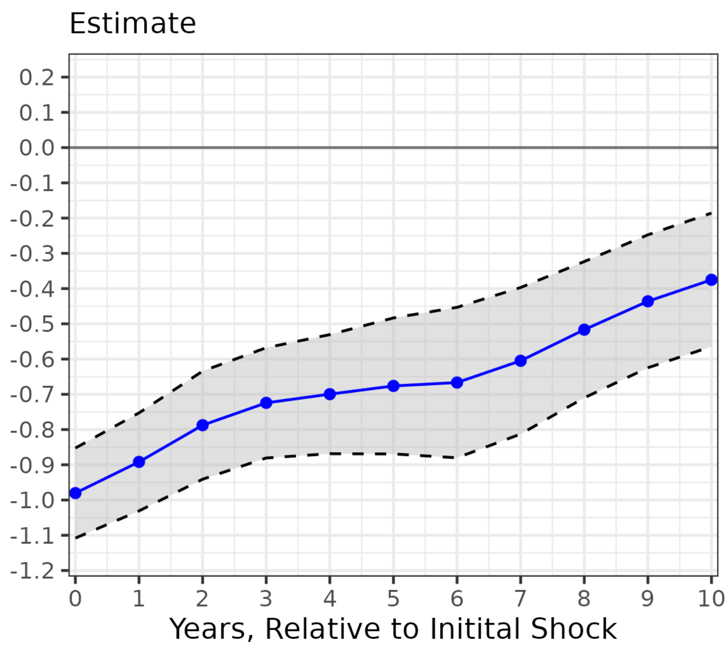
Note: This table shows the summary statistics for every public university–year observation in IPEDS data, for each of the 5 quantiles of the funding shift-share instrument. Funding shift-share is the instrument defined in Section 4 the product of (1) state-wide funding shift and (2) share reliance on 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 $k = 0, \ldots, 10$ are on the x-axis. Standard errors are clustered at the state-year level.

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 (4) 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.

$$\widetilde{Z}_{i(j),t} := -\left[\left(\frac{\text{Total State Funding}_{s(j),t}}{\text{Student Population}_{s(j),t}}\right)\left(\frac{\text{State Funding}_{\tau(j)}}{\text{Total Revenues}_{i,\tau(j)}}\right)\right] \tag{4}$$

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 A2 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 A2: 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 Shock	−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 A: units in log $ per student

	Dependent Variable: State Funding			
	(1)	(2)	(3)	(4)
Appropriations Shock	−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 (5), 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.

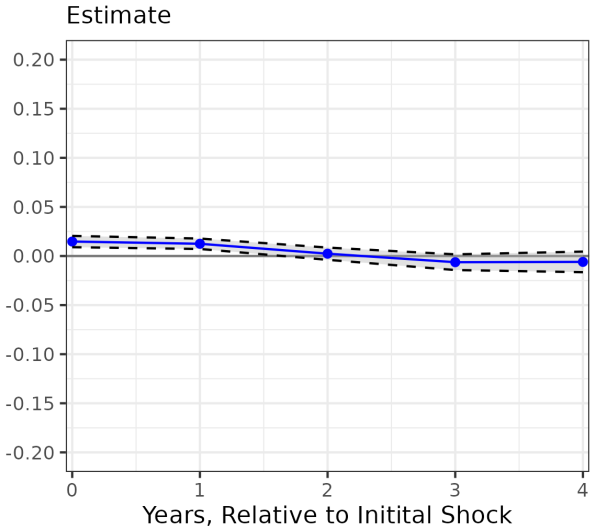
$$X_{i(j),t} = \theta_{i(j)} + \phi_{\tau(j)} + \delta \widetilde{Z}_{i(j),t} + \epsilon_{i(j),t} \tag{5}$$

$$Y_{j,t} = \mu_{i(j)} + \nu_{\tau(j)} + \beta \widehat{X}_{i(j),t} + \varepsilon_{j,t} \tag{6}$$

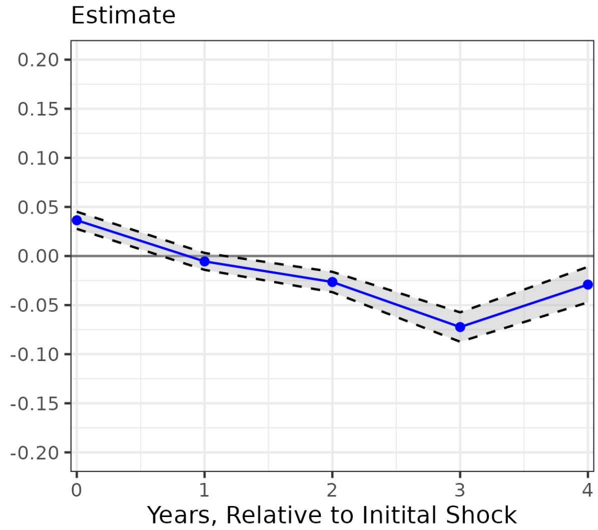
We then interpret parameter β as the effect of changes in state funding at an Illinois public university, via state funding shift-shares, on an individual professor's outcome $Y_{j,t}$.

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

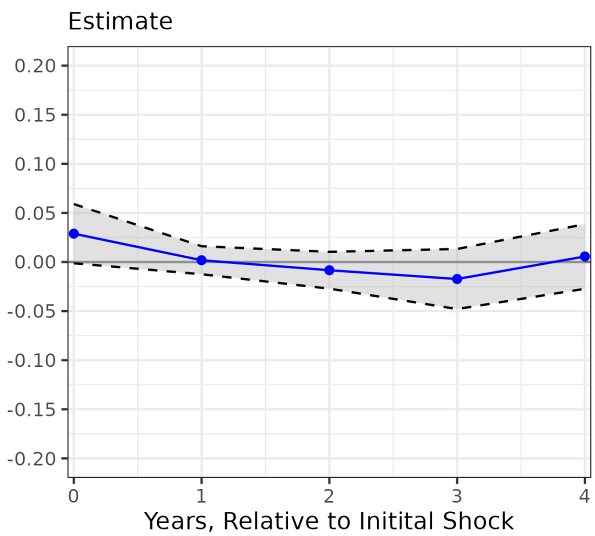
(a) Lecturers.



(b) Assistant Professors.



(c) 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 A3: 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							
	Lecturer		Assistant		Full		All	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	−3.729	0.376	0.415	3.208	−1.269	0.117	−4.084	3.890
	(1.721)	(1.725)	(1.728)	(2.493)	(1.548)	(1.200)	(4.352)	(5.668)
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	0.886	0.882	0.970	0.969	0.991	0.991	0.981	0.980

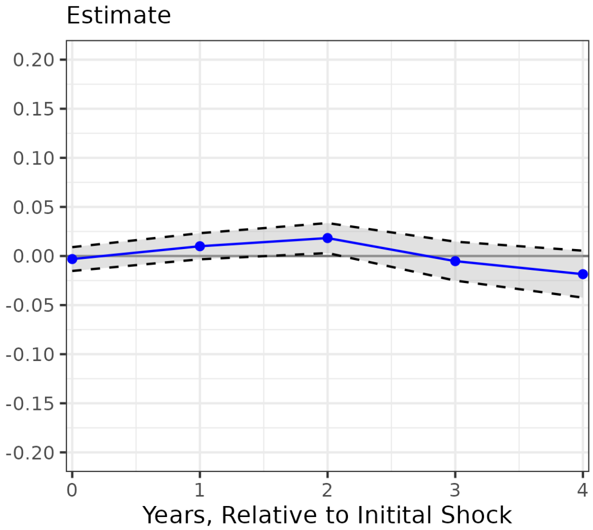
Panel B: units in log $ per student

	Dependent Variable: Employment Count by Professor Group							
	Lecturer		Assistant		Full		All	
	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

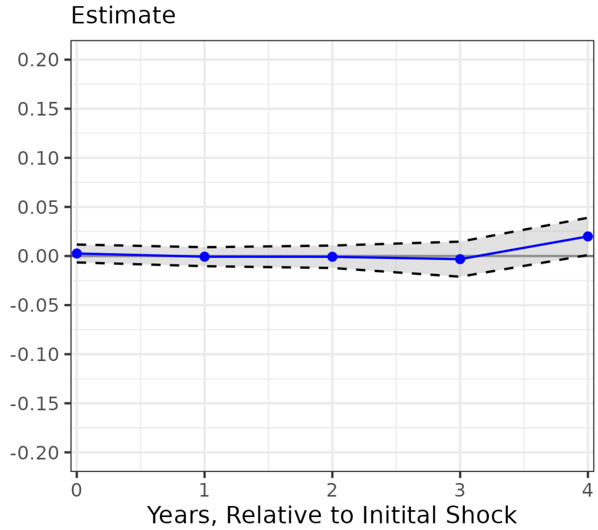
Note: These tables show the second stage OLS and 2SLS estimates of regression specification (3), showing the effect of state funding changes on number of faculty per student in Illinois universities, using the funding shift-share to instrument for state funding in the columns labelled 2SLS. Each observation 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.

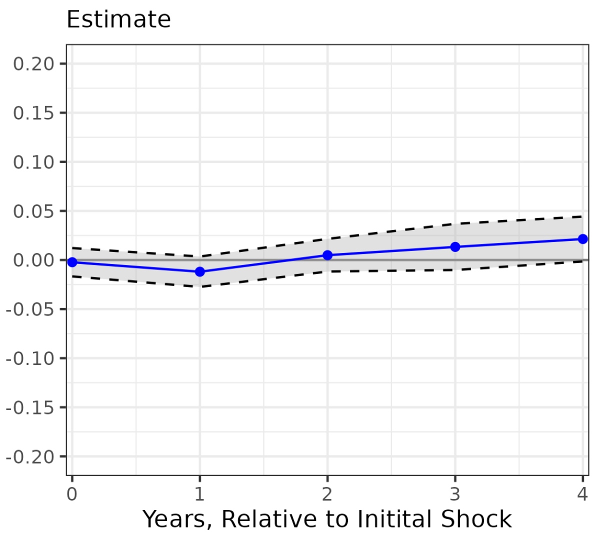
(a) Lecturers.



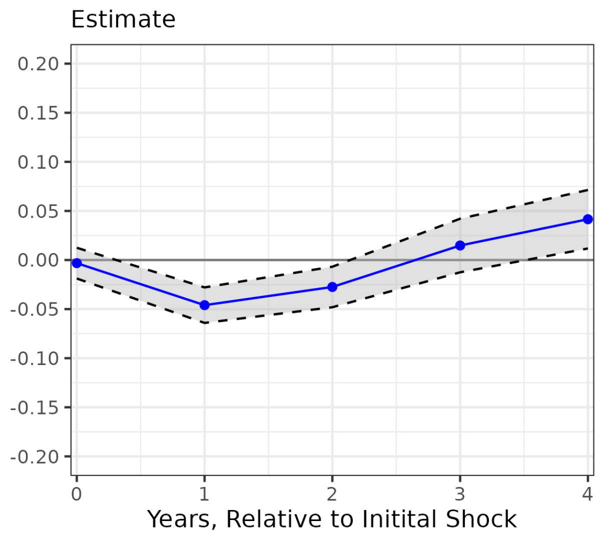
(b) Assistant Professors.



(c) Full Professors.



(d) Administrator Professors.



Note: These figures show the local projections estimates of regression specification (3), with the 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.

Table A4: 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							
	Lecturer		Assistant		Full		All	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State Funding	−0.526	1.383	0.252	0.529	−0.065	0.058	−0.977	0.491
	(0.712)	(0.695)	(0.597)	(0.670)	(0.354)	(0.377)	(1.345)	(1.869)
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	0.805	0.795	0.921	0.921	0.762	0.762	0.907	0.906

Panel B: units in log $ per student

	Dependent Variable: Yearly New Hires by Professor Group							
	Lecturer		Assistant		Full		All	
	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.

There were no observable differences in the hiring rate of male vs female faculty.

Table A5: 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 Rates of Substitution

The funding elasticities can be used to recover the marginal rate of substitution between two outcomes. For example, write Y^1 for the number of lecturers per student at a university, and Y^2 for the number of full professors. I use the above approaches to estimate the funding elasticities, where $\%\Delta$ denotes percent change.

$$\beta_1 = \frac{\%\Delta Y^1}{\%\Delta X}, \text{ and } \beta_2 = \frac{\%\Delta Y^2}{\%\Delta X}$$

As such, it is possible to recover the elasticity for substitution between lecturers and full professors by the universities via the respective funding elasticities.

$$\frac{\%\Delta Y^1}{\%\Delta Y^2} = \frac{\%\Delta Y^1 / \%\Delta X}{\%\Delta Y^2 / \%\Delta X} = \frac{\beta_1}{\beta_2}$$

I present results for the rates of substitution between different levels of faculty by this approach, dividing the relevant coefficient estimates and presenting standard errors calculated by a non-parametric bootstrap. In practice, this corresponds to division of the estimates of the elasticity for employment of professors (by rank) with respect to state funding, presented in Panel B Table 4, and bootstrapping the results to generate standard errors and confidence intervals.

The implied marginal rate of substitution between lecturers and assistant professors is estimated as -3.26 (standard error 0.50), based on 10,000 bootstrap samples. This means that public universities increased their number lecturers per student by 3.26% when they decreased their count of assistant professors, on average and subject to the changes in state funding they experienced 1990–2017. Between lecturers and full professors the rate of substitution is -3.19 (0.34), which implies that universities substitute between lecturers and full professors in the same way. Between assistant and full professors the rate of substitution is 0.99 (0.11), which intuitively implies that universities treated assistant and full professors (i.e., those before and after tenure in the tenure system) as complements.