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

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Abstract

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 falling state funding caused a substitution away from professors towards lecturers at US public universities, using a shift-share approach to instrument for state funding cuts relative to enrolment. Universities employ 4.4% more lecturers per student following a 10% funding cut, relying less on professors by employing 1.4% fewer assistant professors and 1.2% fewer full professors per student. Incumbent professors' salaries, promotion rate, and quit rate at Illinois universities are not affected by funding cuts, so that the substitution arose by limiting hiring of new tenure-track/tenured professors. Stagnating public funding affects faculty and public universities as institutions, likely contributing to worsening student outcomes at public universities since the 1990s.

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†This project's repository, with all materials and anonymised data needed for replication, is available at `https://github.com/shoganhennessy/state-funding-faculty`. Any comments or suggestions may be sent to me at `seh325@cornell.edu`, or raised as an issue on the Github project.

States fund their public universities with roughly the same amount today as they did in the 1990s, despite their enrolment rising by over 50% on average. 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 declining in state funding led to worsening student outcomes (Deming & Walters 2017, Chakrabarti, Gorton & Lovenheim 2020), but there is little evidence on whether this funding decline has impacted faculty. In this paper, I show that falling state funding caused a substitution away from professors toward lecturers at US public universities.

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 assistant professors and 1.2% fewer full professors per student. In a secondary analysis of all public university faculty in the state of Illinois, I show that incumbent faculty were relatively 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. 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) 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), 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 they employ? If so, which positions do universities substitute away from, or towards, and do these funding cuts affect the faculty themselves?

It is a priori unclear how faculty may be affected, as there are various margins that universities may to respond to funding cuts. For example, university administrations may directly cut salaries or lay-off incumbent staff. This happened in 2015 when the state of Illinois shut-down without setting a state budget, and the University of Illinois furloughed faculty unable to pay salaries (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, some faculty positions may grow at universities in response to funding cuts. Lecturers can fill in teaching duties when professors are unavailable, and may do so at a lower cost on on short-term and contracts with less employment protections. But it is not certain that universities would hire more lecturers in the face of budget cuts; they may not hire any more lewcturers or professors at all. Similarly, the universities may be limited from hiring more lecturers by competitive pressures from peer institutions (Hoxby 2009, Urquiola 2020), and instead focus on filling the funding gap by courting private funding or raising tuition prices.

State governments decide how to fund higher education by a complicated process, which could be influenced by lobbying, changing state priorities, or local economic conditions. 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 variable 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 that funding, interacted with state-wide changes in higher education funding — following 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 changes in higher education funding, allowing the shift-share approach to estimate causal effects among more reliant unversities. Additionally, I estimate effect of state funding on faculty multiple years after the initial funding cuts, using the local projections method thanks to time-series confounding between the funding shock and later years' level of state funding.[1] This approach allows me to test whether universities recover in years following the funding cuts e.g., by resuming faculty hiring in later years.

In my national-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 $1,000 per student leads to an average university employing 6 more lecturers; in percentage terms, 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 many years after the initial funding shock, showing that the effect is not isolated to the year of the funding cut. 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 (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. Yet the hiring rate for new professors at public universities was negatively impacted by state funding cuts. This implies that faculty substitution arose by limiting the hiring of new

[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.

professors, which is supported by suggestive evidence on cumulative faculty hiring counts. The substitution is persistent for up to ten years, meaning that universities did not resume professor hiring in years following the funding cut, making the substitution towards lecturers long-run.

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, Braga, Khanna & Turner 2019, Brown, Dimmock, Kang & Weisbenner 2014). For faculty outcomes, applied theory work models university decision-making and faculty hiring (see e.g., Abe, Watanabe et al. 2015, Johnson & Turner 2009, Courant & Turner 2019). In addition, empirical papers measure how universities responded to 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 on faculty composition or salaries, or other outcomes related to university instruction.

Another contribution of my paper is to provide evidence on possible mechanisms connecting state funding cuts for higher education and worsening student outcomes. Substitution towards lecturers is likely a cost-cutting measure for funding constrained universities, though relying on these faculty — who are often over-worked and not granted long-term employment protections — may lead to worse student outcomes (Ehrenberg & Zhang 2005, Zhu 2021, Jaeger & Eagan 2011). Lastly, my results provide evidence that the long term trends in higher education funding are causally related, contributing to the literature on faculty outcomes (Ehrenberg 2003) and trends in US higher education and funding (Hoxby 2009, Ehrenberg 2012).

This paper proceeds as follows. Section 1 describes the data for university finances and faculty in Illinois, and trends in public university funding for the last three decades. Section 2 gives the conceptual framework for how state funding may affect faculty. Section 3 draws the empirical framework for isolating the causal effects of state funding on faculty composition and individual faculty, with Section 4 presenting the empirical results. Section 5 discusses the context and implications for the findings. Section 6 concludes.

1 Data and Institutional Context

1.1 Data Description

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

IPEDS is a survey of higher educational institutions in the US, and legally requires institutions to participate in order to receive Federal Title IV student aid.[2] Data are consistent between the years 1990 and 2021,[3] and provide information on the total revenues a university received from every source (including state governments), enrolment, plus faculty count and total expenditures on salaries.[4] I restrict analysis to public, four-year, degree-granting institutions, as these institutions adhere to a standardised concept of faculty profile, where tenure and title of appointment (lecturer, assistant professor, etc.) are relatively standardised. 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

[2]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.

[3]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.

[4]I combine the Urban Institute's 2018 compilation of IPEDS data for the years 1990–2017, and manually combine raw 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.

at a four-year institution (Mountjoy 2022), so that these institutions are not considered.

IPEDS reports the count of professors employed by position, as well as total salary expenditures by position. This gives a resulting panel data-set, where each row represents a university-year, and includes columns for university finances, plus total count and average salary[5] for professors by position (lecturer, assistant, tenured, total). Table 1 presents summary statistics for relevant variables in these data.

IPEDS provides information at the university level, but only provides aggregated information within a university.[6] To investigate the distribution, I integrate individual-level data for every public university professor in the state of Illinois between the years 2010-2021. IBHED hosts the information; Public Act 96-0266 (effective 1 January 2010) requires that each university report base salary and benefits all administrators, faculty members, and instructors employed by the college or university.[7] These publicly available data provides the basis to build a panel of Illinois public university professors 2010-2021; I define a professor as an individual by their first plus last name and university pairing, and link this database to IPEDS regarding finances for their employing institution. 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. Additionally, further analysis using the first year of a professor's employment focuses on the subset of professors with observed year of hiring between the years 2011 and 2021, representing 1,778 professors in 2011, and 9,099 in 2021.

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

[6]IPEDS additionally gives a mean salary measure for faculty by rank (inconsistently) for each university. Unfortunately, this measure of professors' salaries is particularly crude in measuring on professors' salaries and other individual-outcomes; summary statistics on IPEDS data do not agree with trends in average professor salary over the sample time period compared to summary statistics provided in American Association of University Professors 2021. Similarly, IPEDS reports of the average salary paid to professors at private institutions also disagree with other sources (including those calculated for Illinois in IBHED data later in this section) so are not considered in this analysis.

[7]The universities included are all campuses of the 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.

1.2 Trends in Finances, Enrolment, and Faculty Composition

States vary largely in how much they fund their public university systems, thanks in part to the state-wide budgeting process. 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.[8] US state governments, by majority, are legally obligated to run a balanced-budget, so that yearly variation in tax revenues (caused by changing economic conditions or otherwise) necessarily affect state expenditures. Public universities have relatively lower lobbying power than other funding beneificaries, so often bear the brunt of state government funding cuts (Delaney & Doyle 2011).[9] These features lead to yearly variation in state funding not seen in other revenues sources (such as federal funding), since US states differ in their support for higher education, and are subject to fiscal constraints. 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 for neighbouring years, leading to more student demand for limited public university places for students turning 18 in 1989 (Bound & Turner 2007). This leads to variation in the amount of funding per student across years, showing that per student state funding varies on multiple dimensions.

Public university revenues on average 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

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

[9] 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.

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, with most of the increase occurring over the years 2000-2021. 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 revenues per student have stagnated across all measures (seen in Figure 1b), and particularly fallen from a mean of $11,000 per student in 1990 to less than $8,000 per student in 2021.

There are large differences in the average number of professors per student between the private and public sector. Figure 3 shows that private universities start with a higher baseline of around 4.5 professors per hundred students, and exhibited yearly variation of less than 0.5 professor per hundred students over the thirty years. Public universities start with 3.9 professors per hundred students, and this number falls to around 3., with the largest fall in the 2008-2011 time period. We see a similar difference in baseline, and fall for the years 2008-2011 for assistant professors. Private and public universities have similar numbers of associated and full professors before the year 2000, yet this number has fallen by over 20% in the next 20 years only for public universities: in 2021 the mean public university has 6 fewer full professors per hundred students than the mean private university. Over the same time period, we see the rise in use of non-tenure track instructor positions (referred to as lecturers from here on), who were employed at similar rates in both sectors in 1990, yet have been utilised by public universities at a higher rate since.

1.3 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 among the seven Illinois public university campuses has fallen by over 50% for the last decade, on both an absolute and per student basis (see Figure 4). Similar to the figures for the rest of the country, there has been a corresponding substitution towards tuition revenue.

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.[10] While most public universities were able to stay open, there were drastic revenue and spending cuts in response to the budget impasse, as it continued through fiscal year 2017, and ended with a new budget restoring funding to state institutions for 2018. This means that Illinois public universities exhibit sizable changes in their state funding over 2010–2021, of similar order to those for the rest of the country over 1990–2021. Additionally, the 2016 episode stemmed entirely from political disagreements, and not from state decisions regarding higher education and its finances (Young, Wiley & Searing 2020), exhibiting how state-level changes in funding affect public universities thanks to unrelated issues.

2 Conceptual Framework

Universities can respond multiple ways to the falls in per student state funding. Deming & Walters (2017) established that public universities who experienced state funding cuts did

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

not fully off-set by raising tuition, and cutting total spending. But it is not clear how these spending cuts went on to affect faculty — or whether they affected faculty at all.

Wider changes in the American higher education sector may 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 causal. I address this issue by using shift-share instrument 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.[11] Funding cuts could also limit the amount public universities can offer to new faculty hires, leading to fewer or less accomplished faculty accepting these offers.[12] 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: the average Illinois assistant

[11] 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.

[12] 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.

professor is paid \$76,897, tenured professor \$109,283, while lecturers earn \$31,449 more than double that of a lecturer (annual salary for 2010–2021 in 2021 USD, see Table 2). Secondly, lecturers are (by definition) granted shorter contracts than professors; assistant professors mostly work on 5–6 year long contracts, full professors on indefinite contracts (tenure), lecturers on yearly or term-wise contracts. If a public university's primary obligation is to teach, and they must fulfil this objective with fewer resources, substituting away from tenure-track and tenured professors towards lecturers is rationalisable.

It is not clear when the effects of funding cuts will be realised. University departments often employ faculty on multiple-year contracts (e.g., the tenure contract), and individual professors' decisions to retire, move university, or leave academia are multiple-year commitments, so that it may take multiple years for university funding to change the faculty composition, or trickle down to faculty. For example, university departments coordinate hiring in annual cycles, so that a budget short-fall in year t may have no effect on the in-progress hiring committee and resulting hiring decisions, yet the hiring cycle in year $t+1$ may be postponed or cancelled. As such, this paper investigates the dynamics of state funding shocks' effects on faculty, for the years following a state funding cut.

3 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, or exogenous to internal institutional decisions. Instead, the state government and university administration undertake a complex process of allotting resources across multiple different priorities, including instruction, research, or between departments. For example, it may be the case that a state government restricts funding for only its lowest performing universities in response to a budget shock, introducing a selection-on-outcomes threat to identification.

Importantly, funding from a university's state government provides opportunity to address such endogeneity.

3.1 State Funding Shocks

I use a shift-share instrument to address endogeneity concerns for the amount of funding a state allots to each of its public universities. Deming & Walters (2017), Chakrabarti et al. (2020) develop the instrument for public university finances by exploiting a shift-share instrument for changes in state-level funding interacted with university 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 on state funding more will be affected by state funding shocks. $Z_{i,t}$ is the instrument for state funding for institution i in year t, 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.[13] $Z_{i,t}$ is constructed as negative to reflect the fact that the long term trend in, and most of the short-run shocks to, state funding for higher education have been negative.[14] State funding has been falling, so that the instrument describes shocks to university revenues, mostly in a negative direction.[15] The

[13] 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.

[14] 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.

[15] 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 produces results of very similar magnitude and direction, and so are omitted.

instrument approach relies on the conditional independence assumption, that the instrument is independently assigned to the universities. While this assumption is fundamentally untestable, we see that universities are by-in-large smaller (in terms of enrolment, total revenues, and professor count) at the top of the state funding shock distribution (see Table A2). Though on a per student basis, there is little difference across the distribution (except in the outcomes under consideration). The state funding shock 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 shock. So that the other sources of finances are not clear confounders for the instrumental variables strategy, as they exhibit balance with respect to the funding shock instrument (Pei, Pischke & Schwandt 2019). Yearly and individual fixed effects are included in regressions throughout to implicitly condition on mean differences between universities and years, leading to the assumption of conditional independence of the instrument with respect to state funding for each public university.

The state funding shock is an instrument the level of state funding for each university in each year. 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.

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

We note the conditions for exogeneity in the instrument (following the discussion presented by Chakrabarti et al. 2020). The instrument is exogenous if state policy decisions for funding of public universities are uncorrelated with unobserved institutional changes of any specific college or university in the state (Borusyak, Hull & Jaravel 2022). 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. In this case, we satisfy the second: universities' institutional-level decisions are not correlated with contemporaneous or upcoming shocks to state funding.[16] Lastly, the shift-share approach assumes that state funding shocks affect faculty outcomes only via affecting university finances.

3.2 Instrumental Variables Model

I use the instrument defined in Equation (1) to overcome the endogeneity concerns for state funding to each public university, so the primary empirical model is an instrumental variables model. Equation (2) is the first stage for exogenous variation in the state funding for university i in year t, and Equation (3) the second stage for the effect of state funding on faculty outcomes.[17]

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

I estimate the system by two stage least squares, including institution and year fixed effects.[18] $Y_{i,t}$ 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

[16] 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.

[17] It is important to note the treatment effect isolated here; the instrumental variables approach identifies the local average treatment effect, one weighted to level of exposure when treatment is continuous as is the case here. So we interpret this treatment effect as a weighted average of effects on faculty at public universities to state funding changes, specific to state funding shocks, among the complier group — i.e., among universities who respond to funding shocks and would not have made faculty-outcome changes absent the funding shock. Also, we assume that no universities state funding increased in response to the negative state funding shock (monotonicity).

[18] 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.

that the professor was hired, and include fixed effects for the hiring year.[19] The instrument exogeneity and exclusion follows the same argument as above, where the Illinois legislature did not target any single campus for funding cuts and no single Illinois campus takes the majority of state funding.

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 shock instrument is a strong predictor for the average university's level of state funding in either unit; a funding shock of \$1,000 per student in the entire state leads to around \$1,176 per student at the university, while a funding shock of -10% leads to around 9.77% less state funding per year. Yet, the level of state funding (and the outcome variables) vary greatly between states for the unit of analysis. For example, the average Illinois public university receives \$10,709 in state funding per student in 1990 and \$6,713 in 2021 (a fall of over 30%), while California went from \$19,224 per student to \$12,915 in the same time span (a fall of 37%). While most states are not exactly the same to California and 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 similar order to 30%, so that the stagnation in state funding has been a percent change trend over this time period. 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.

3.3 Effects in Years After the Initial Funding Shock

The effects of a change in the universities funding may not be immediate, and faculty may be affected multiple years after a funding shock. Yet, the funding shock instrument is

[19] 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 3.2 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.

significantly auto-correlated year-on-year; a large state-level funding shock in year t is also likely to experience a large funding shock in year $t-1$. Similarly, funding shocks to higher education in a year are highly correlated with state funding per student in the 5 years before and after the initial shock in IPEDS data (see Figure A1). Thus, a linear model correlated state funding in year t with outcomes in year $t+k$ will suffer from time-series confounding.

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, so that time-series confounding (i.e., treatment in time t is correlated with treatment in time $t-1$) is present (Montiel Olea & Plagborg-Møller 2021). This method estimates the effect of state funding $X_{i,t}$ on faculty outcomes $Y_{i,t+k}$ in follow-on years $k>0$, while accounting for the auto-correlation between state funding in surrounding years.[20] Additionally, the approach accommodates the shift-share instrument for state funding (Olea, Stock & Watson 2021), so that I present instrumental variables estimates for this method as in the rest of the empirical analysis.

4 Results

4.1 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. I use the same empirical strategy in the analysis of Illinois faculty, so Table 3 presents similar first-stage estimates among the IBHED data. Table 3 Panel A shows estimates of a funding

[20] The funding shock has a persistent effect on state funding, multiple years after the initial funding shock, so that the instrument is similarly strong for the local projections method (see Figure A2).

shock of \$1 per student in the state on state funding per student at the university, and Panel B the % increase effects of a 1% increase in the shock per student on state funding per student. Column (1) shows that a funding shock of \$10 (per student in the entire state) is associated with \$11.76 less state funding per student at the university, with the corresponding -10% funding shock leads to -9.77% less funding (column 1, panel B), with similar estimates with and without including fixed effects. Column (2) shows estimates of the first-stage without including fixed effects, and gives less precise estimates for the funding shock, likely thanks to systematic differences in universities unaccounted for without fixed effects. Columns (3) and (4) include the tuition revenue control (explained in footnote 15) to exhibit estimates with the inclusion of this possible collider (or bad control). Column (3) shows similar estimates to column (1) in both Panels A and B thanks to inclusion of fixed effects, so that the uncertainty in including tuition revenue as a possible bad control for the level of state funding does not matter thanks to the inclusion of fixed effects. Column (1) represents the estimates for Equation (2) with fixed effects, omitting the tuition revenue control, and is the preferred form that I proceed with.

The above shows that the first stage is strong among both IPEDS and IBHED data, and the argument in Section 3 for exogenity comes from independence of the state funding mechanism to any indivdiaul public university campus. Table A1 provides a balance test, showing that the shift-share instrument is correlated with the professor outcomes, but not with other sources of university funding. These results, together with the case for exogeneity, show the funding shock instrument strongly predicts university revenues in the first-stage estimation.

4.2 National Level, IPEDS

Changes in state funding have clear effects on the composition of faculty public universities employ. Table 4 presents OLS and IV estimates for the effect of a change in state funding on the number of faculty at the university, individually by position (and for the total faculty), in both count of professors and in percent terms for faculty per student ratio. 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 in absolute measure (Table 4, Panel A). However, Panel A Table 4 measures professor count in percentage terms for professors per student. A 10% increase in state funding lead to a 4.4% decrease in the number of lecturers per student, an increase of 14% for both assistant and full professors, leading to a 0.6% increase in the total number of faculty per student.

Faculty composition is not only impacted in the same year as a state funding shock, but also for a number years following. Figure 5 shows local projection estimates, as a series of impulse responses, where the estimate is the elasticity for professor count per student in year $t+k$ with respect to state funding in year t for follow-on years $k = 0, \ldots, 10$. A 10% decrease in state funding increases count of lecturers per student by 4% for the first two years after the initial shock. While count of assistant professors decreases 10 to 18.5% three years later; count of tenured professors decreases 9 to 6% three years later. Together, the total count of professors per student decreases around 1% for three years after the initial funding shock, and the effect is not distinguishable from zero after this point.

4.3 Illinois Faculty, IBHED

This section refers to results using data on every professor at a public university in the state of Illinois. Incumbent professors are relatively unaffected by changes in the state funding for their university in the years following their hire. Table 5 show estimates of a 1% 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 no effects of state funding cuts passed on to them. Additionally, local projection estimates show that professors' salaries are also not affected on average in yeard following a funding shock (Figure 6). Lecturers on the other hand, see a 0.75% increase in salary in the second and third year after a 10% increase in state funding (Figure 6a), reflecting how lecturers are again more affected by changes in public university funding. Similarly, promotion rate and exit rate among incumbent faculty (from the Illinois public university system) are unaffected in the years after an initial funding shock (Figure A3, A4).

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 in response to 2008 negative budget shocks, particularly for tenure-track positions (Turner 2014), and similarly from shocks to university endowments (Brown et al. 2014). For lecturers, we see a negative effect which lines up with two trends noted in subsection 1.2: funding for public universities (per student) decreased while relative usage of lecturers increased substantially.

The composition of faculty changed at public universities 1990–2017 thanks to stagnating state funding, but there are little discernible effects on incumbent faculty. This implies that changes in faculty composition arose by state funding cuts impacting the rate that public universities hired new professors. 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*), to show that universities with lower state funding (per student) also hired fewer professors in the same time period — shown in Figure A5. Similarly, the funding shock IV model shows that a 10% cut in per student state funding leads to 13% fewer faculty hires per student across the decade 2011–2021.[21] These results provide limited evidence that changes in faculty composition arose by disrupting hiring of new professors at public universities, corresponding

[21] This limited sample of data are a cross-section for count of professor hires 2011–2021, so that local projection estimates are not possible here. See subsection A.3 for further details.

to the concurrent results that faculty composition changed while incumbent faculty were not by meaningfully affected by the funding cuts.

5 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.[22] A public university's state funding per student fell by an average of 36%, and the number of lecturers per student increased by 113% (fell by 17% for assistant and 23% full professors). The estimates of elasticity for faculty count with respect to state funding imply that stagnating state funding explains about 40% of the observed substitution towards lecturers and away from tenure-track and tenured faculty.

These effects are persistent: public higher education in the US was not exposed to one large instance of funding cuts, but systematic funding short-falls across the last three decades. The long-term estimates (Figure 5) show that state funding cuts have effects on universities for multiple years after the initial funding cut, and these effects are compounded by the fact that public universities received persistent funding cuts for so many years. The end result is large changes in faculty composition, the long-run trend in stagnating state funding leading to a long-run substitution towards lecturers 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 corre-

[22] 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.

sponding amount, with the clear implication that there are fewer tenure-track openings at US universities.[23] Securing academic employment on the tenure-track is more selective than ever, so that more PhD graduates will end up teaching as lecturers or leaving academia.

The results here are squarely 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. These changes have not just affected research, they have affected education, too. 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 peers are increasingly more selective, and better performing in terms of 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 tenured faculty. 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 become a private sector phenomenon, and the majority of US higher education students attend public institutions, we should worry about the long-term effects of stagnating funding for higher education in the US.

[23]While the number of PhD graduates has continued to rise (American Association of University Professors 2021).

6 Summary and Concluding Remarks

This paper investigates how the recent stagnation in state support for higher education has affected faculty, and their composition, at US public universities. This work contributes to the literature along two primary dimensions. Firstly, by isolating changes in state funding on public universities via state funding shocks, this work provides an explanation for the increased relaiance 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. Secondly, this work asks investigates 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, towards lecturers, in the face of persistent declines in state funding for higher education. The effects on incumbent professors in the state of Illinois are non-distinguishable from zero, with suggestive evidence for falls in faculty hiring, implying that the changes in faculty composition are 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.

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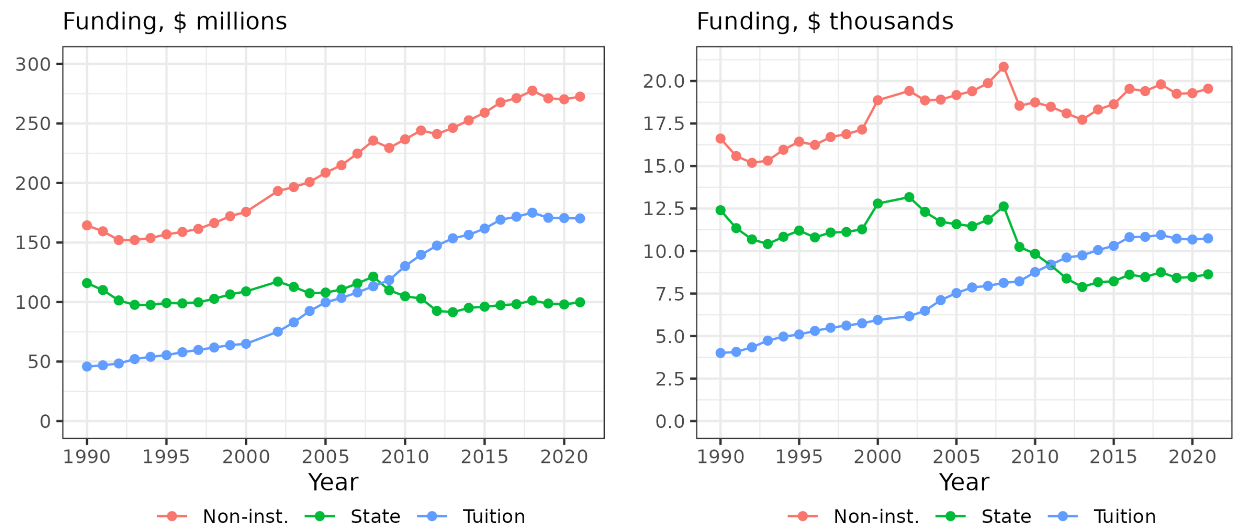
7 Figures

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

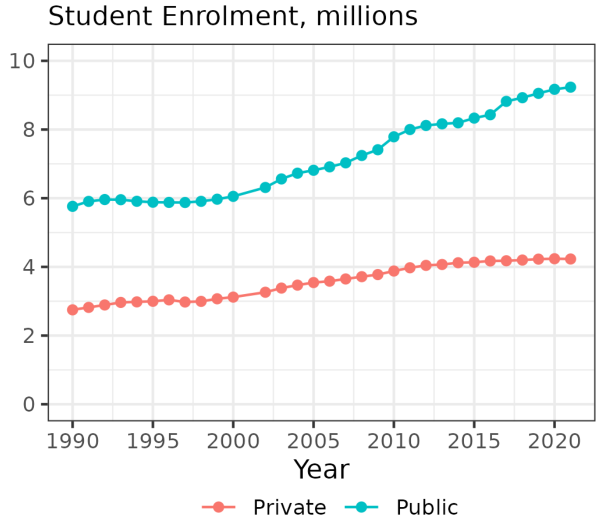
(a) Total, $ 2021 CPI-U. **(b)** Per Student, $ 2021 CPI-U.



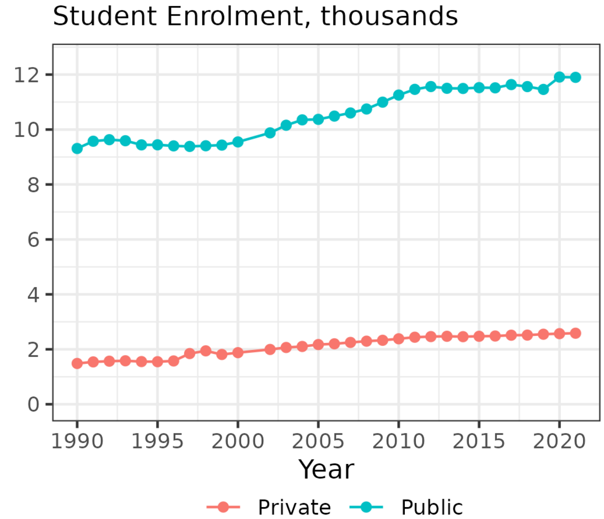
Note: This figure shows the mean funding for US public universities as a total (in figure a.) and divided by student enrolment (figure b.). The numbers are adjusted to 2021 figures by CPI-U. Non-institutional revenues refers to the sum of federal, state, and local funding plus tuition revenues; these 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.

(a) Total Enrolment, Nation-wide.



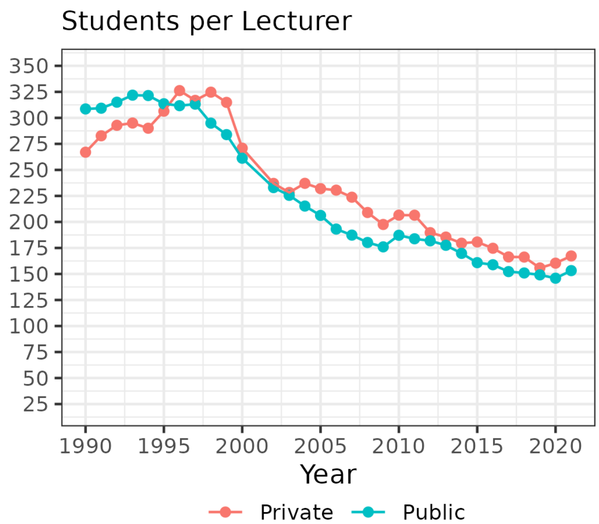
(b) Mean Enrolment, per University.



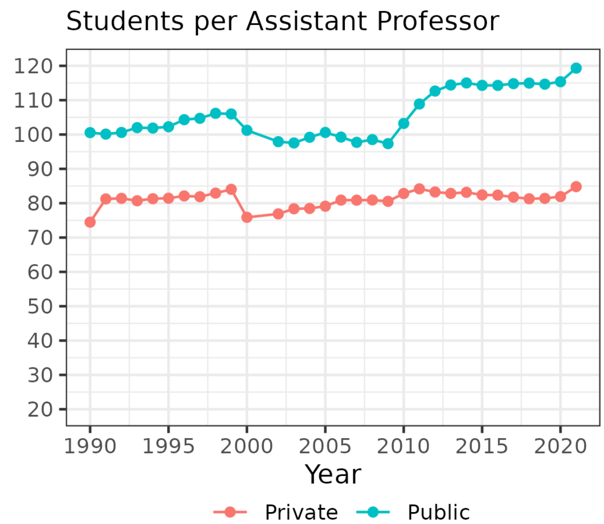
Note: This figure shows the total and mean enrolment for US universities, comparing public and private universities. Most of the higher education enrolment increase for the last 30 years was in public universities, who continue to enrol the vast majority of higher education students in the US. These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

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

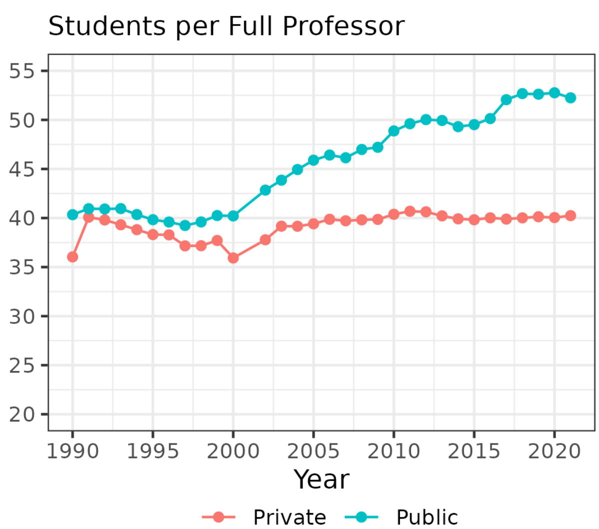
(a) Lecturer.



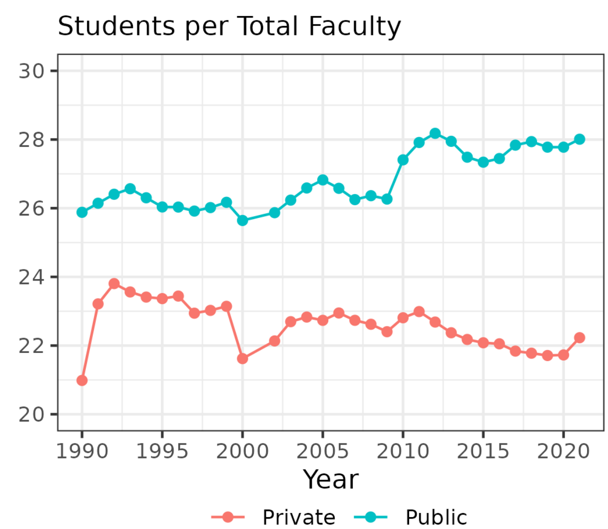
(b) Assistant.



(c) Full.



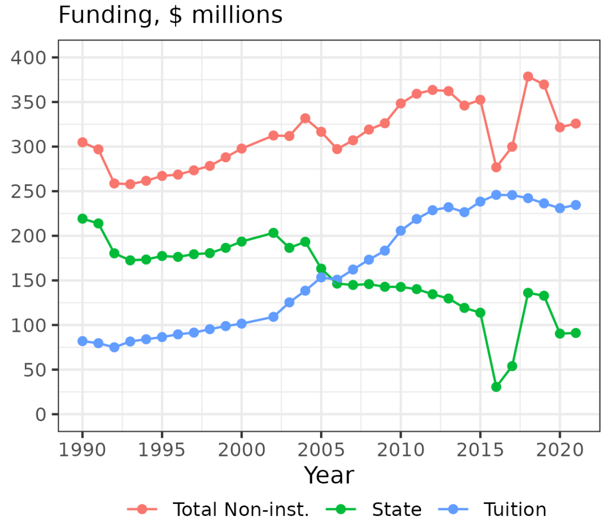
(d) All.



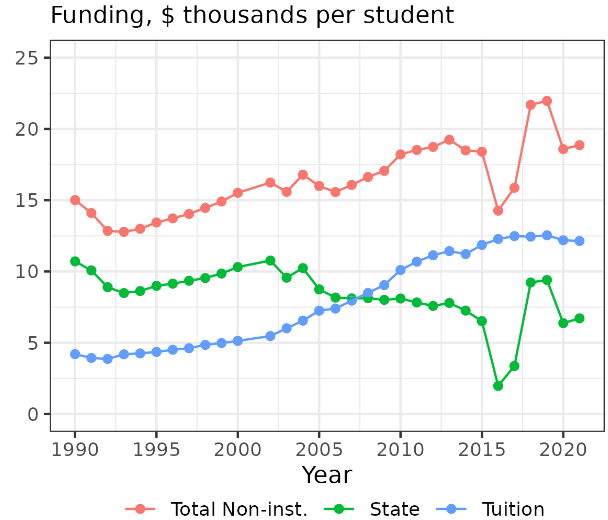
Note: This figure shows the average number of students per faculty member, by different faculty position, at US public universities. E.g., panel A calculates the mean of (lecturer count) / (student enrolment) at US public universities, for each year of 1990–2017, to show the average trend in faculty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



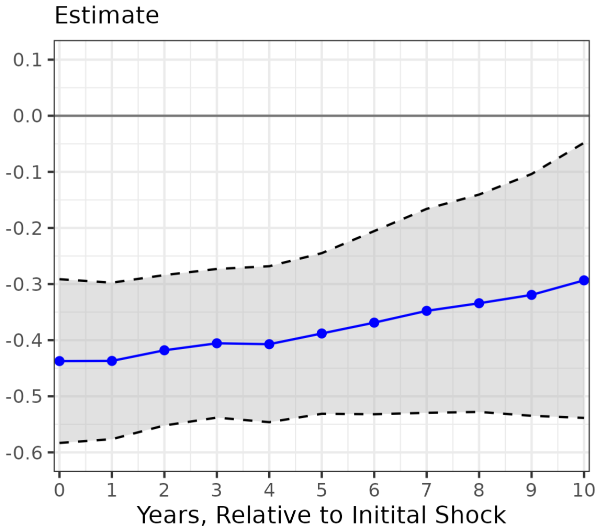
(b) Per Student, $ 2021 CPI-U.



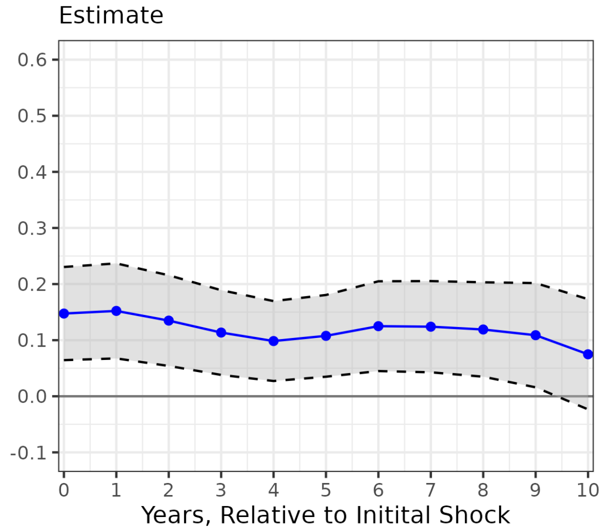
Note: This figure shows the mean funding for Illinois public universities as a total (in figure a.) and divided by student enrolment (figure b.). The numbers are adjusted to 2021 figures by CPI-U. Non-institutional revenues refers to the sum of federal, state, and local funding plus tuition revenues; 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.

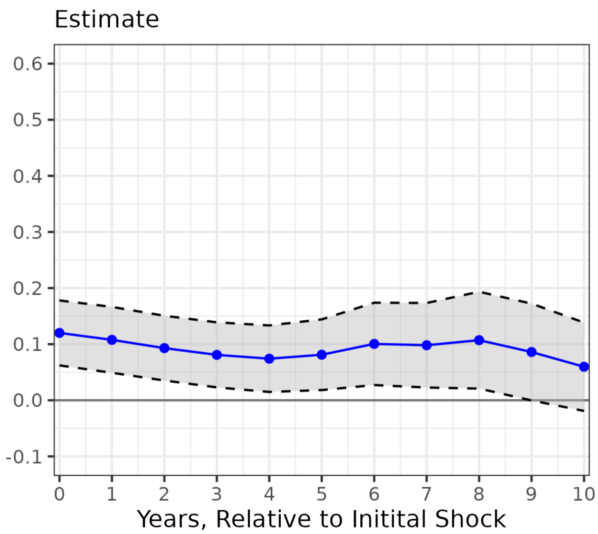
(a) Lecturers.



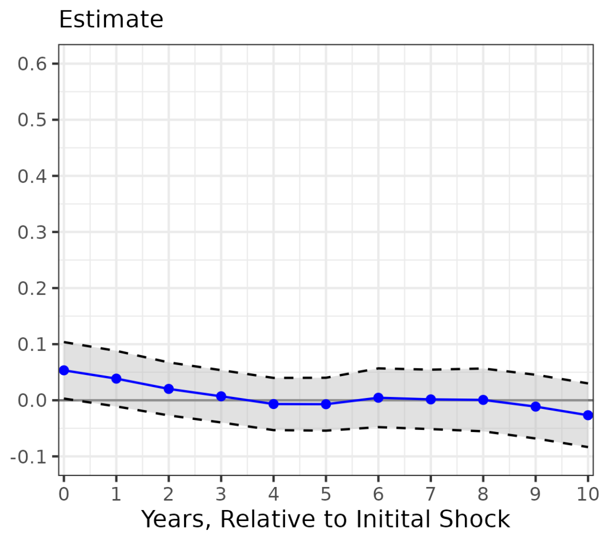
(b) Assistant Professors.



(c) Full Professors.



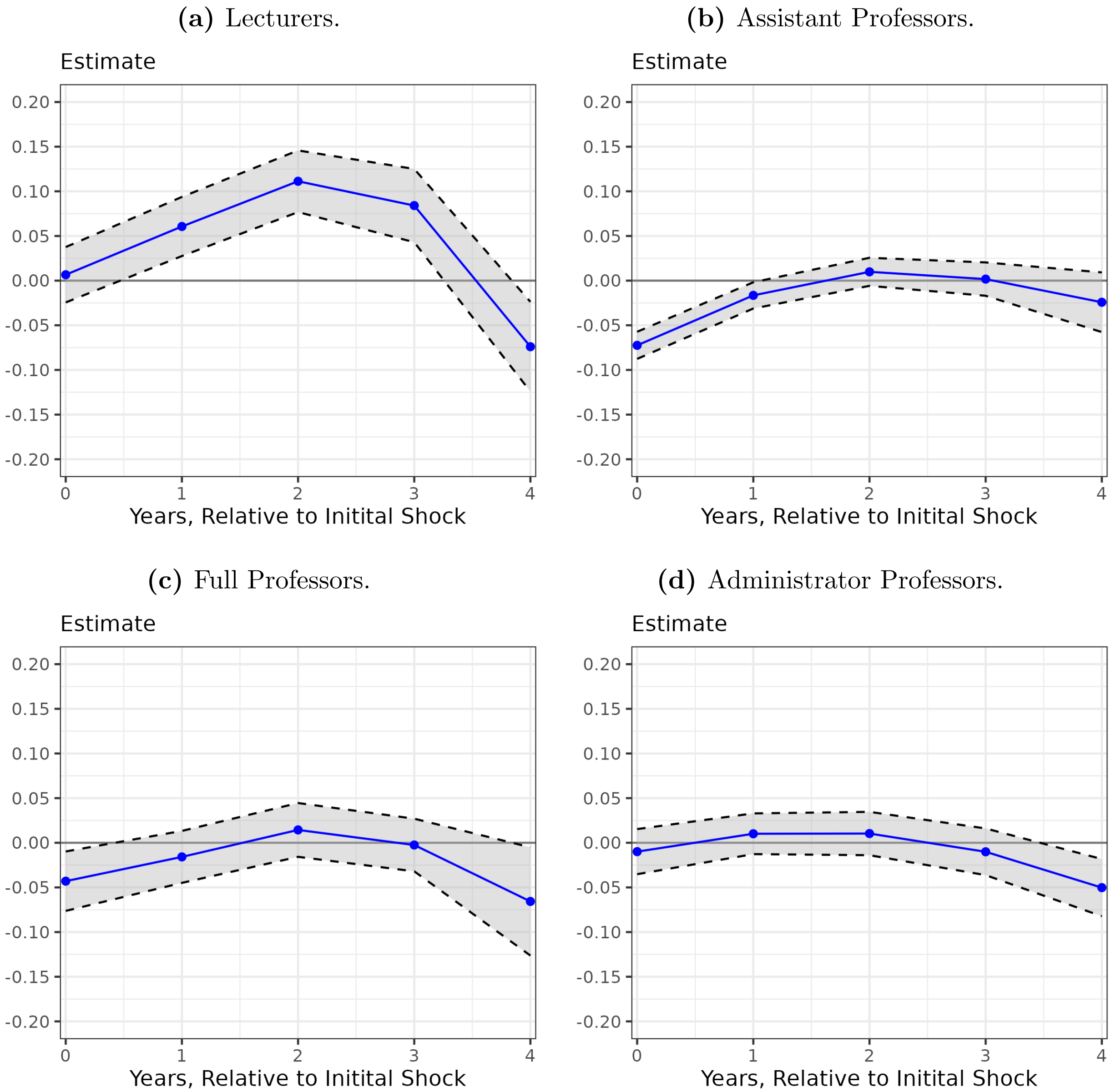
(d) All Professors.



Note: These figures show the local projections estimates of regression specification (3), with the funding shock 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 funding shock (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 funding shock. The coefficient estimate is effect of state funding ($X_{i,t}$) on faculty count per student ($Y_{i,t}$), using the funding shock 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 per Student 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 shock 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 funding shock (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 funding shock. The coefficient estimate is effect of state funding ($X_{i(j),t}$) on faculty salaries ($Y_{j,t}$), using the funding shock 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.

8 Tables

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

Statistic	Mean	St. Dev.	N
Enrolment	11,870	10,876	17,012
State Funding (millions 2021 USD)	104	127	17,012
Total revenues (millions 2021 USD)	450	818	17,012
Non-institutional revenues (millions 2021 USD)	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 professors 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, Professor 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, for State Funding by Funding Shock 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 funding shock on state funding to gauge performance as an instrument. Each observation is a public univeristy-year, in the IPEDS data. Panel A shows the effect of an funding shock of $-1 per student in the state on the number of $'s of state funding per student at the university — i.e., $-1 funding shock 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 funding shock per student in the state on 10% change in state funding per student at the university — i.e., −10% funding shock 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 univeristy + year fixed effects are included where noted.

Table 4: Effects of Changes in State Funding on University Faculty Composition, IPEDS 1990–2017, OLS and 2SLS Estimates.

Panel A: units in $ per student

	Dependent Variable: Faculty Count per 100 Students, 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	−0.451	−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: 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	−0.137	−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 funding shock 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 in the state 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 funding shock 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.

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 3.
- *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 Test, in IPEDS 1990–2017.

Panel A: units in $

	Dependent Variables: University Characteristics						
	Enrolment	State Funding	Total revenues	Non-inst. revenues	Lecturers	Assistant professors	Full prof
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	0.517	−9,217.091	−7,633.377	886.006	0.007	−0.001	−0.0
	(0.199)	(2,451.719)	(12,771.130)	(4,092.780)	(0.002)	(0.001)	(0.00
?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	17,012	17,012	17,012	17,012	17,012	17,012	17,01
	0.960	0.950	0.881	0.932	0.745	0.886	0.97

Panel B: units in log $ per student

	Dependent Variables: University Characteristics						
	Enrolment	State Funding	Total revenues	Non-inst. revenues	Lecturers	Assistant professors	Full prof
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	0.107	−0.870	0.031	−0.091	0.534	−0.024	−0.0
	(0.037)	(0.079)	(0.082)	(0.063)	(0.122)	(0.066)	(0.03
?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	17,012	17,012	17,012	17,012	17,012	17,012	17,01
	0.976	0.914	0.979	0.975	0.782	0.902	0.96

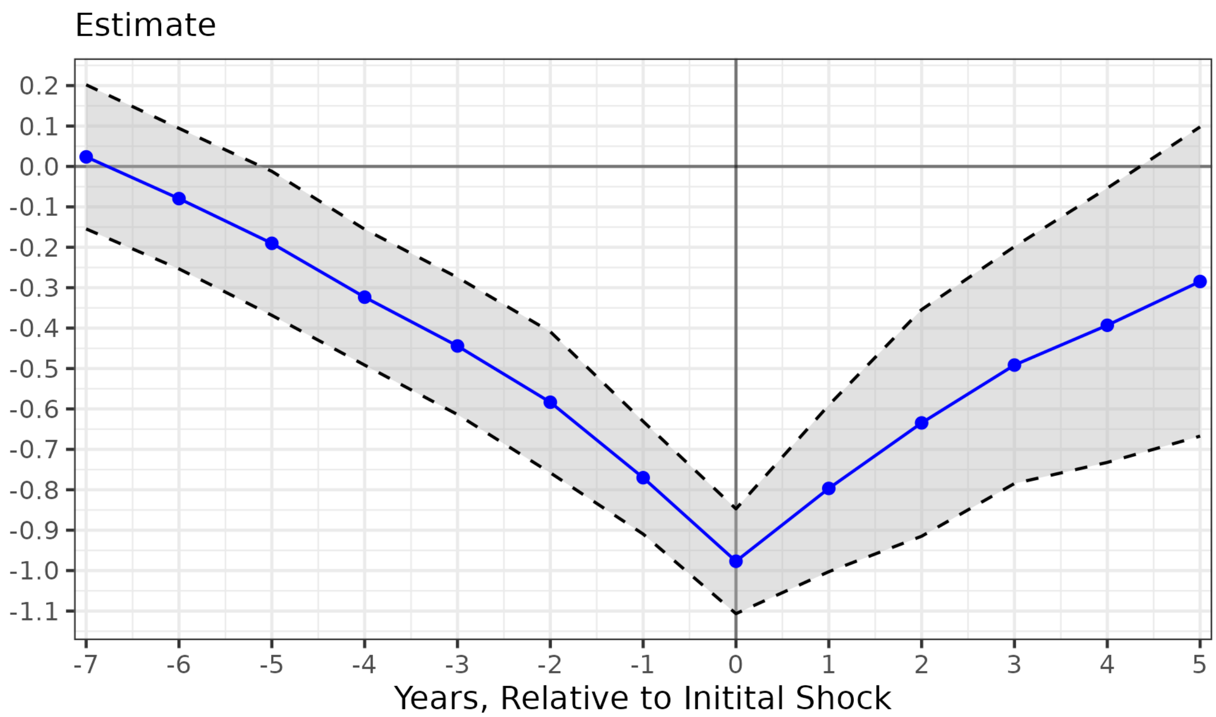
Note: These tables show the OLS estimates of regression specification Equation (2), showing the effect of the funding shock on other outcomes to gauge balance of the instrument with respect to university characteristics Enrolment is measured in thousands of students. Each observation is a public universit–year, in the IPEDS data. Panel A shows the effect of a funding shock of $\$-1,000$ (per student in the state) on the outcome — i.e., $\$-1,000$ funding shock per student in the state is associated with 517 more students (as enrolment is measured in thousands) in column 1. Panel B shows the effect of a -10% change funding shock per student in the state on 10% change in the outcomes — i.e., -10% funding shock per student in the state is associated with an increase in 1.07% more students at the university according to preferred column 1. Standard errors are clustered at the state-year level, and university + year fixed effects are included where noted.

Table A2: Mean Characteristics for Public Universities, by State Funding Shock Instrument.

Instrument Quantile:	1st	2nd	3rd	4th	5th
State Funding Shock, $ per student	1,474.00	2,589.00	3,566.00	5,002.00	8,208.00
State Funding, per student	12,900.00	9,956.00	9,335.00	9,305.00	12,767.00
Total Full-time Enrolment	14,088.00	12,434.00	11,329.00	11,546.00	10,253.00
State Funding, $ millions	110.00	99.00	100.00	107.00	107.00
Total Revenues, $ millions	1,038.00	490.00	364.00	304.00	248.00
Total Revenues, $ per student	121,064.00	44,579.00	31,599.00	25,411.00	27,389.00
Lecturer Count	81.00	65.00	60.00	53.00	38.00
Assistant Professor Count	154.00	120.00	111.00	109.00	94.00
Full Professor Count	358.00	273.00	251.00	251.00	245.00
Total Professor Count	609.00	466.00	428.00	418.00	387.00
Lecturers, per 100 students	0.73	0.61	0.57	0.50	0.50
Assistant Professors, per 100 students	1.56	1.20	1.13	1.09	1.17
Full Professors, per 100 students	2.73	2.18	2.15	2.18	2.63
Total Professors, per 100 students	5.09	4.04	3.89	3.82	4.43

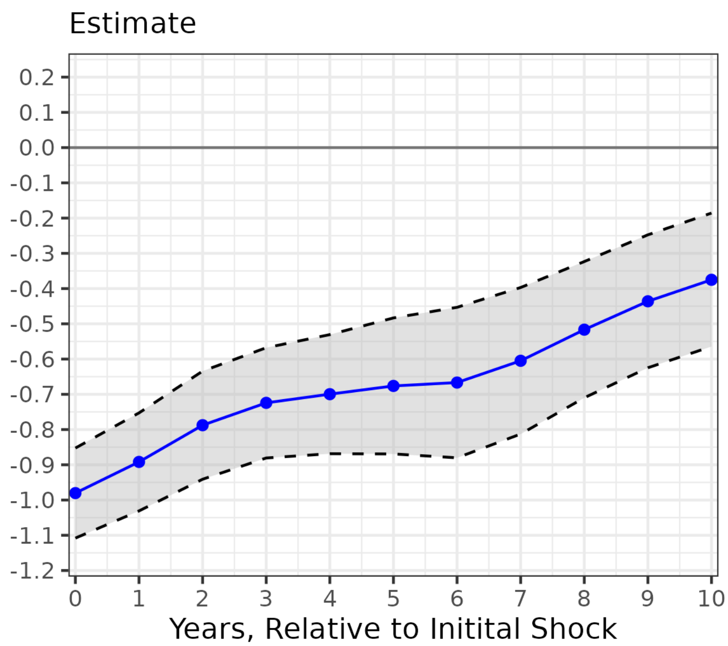
Note: This table shows the summary statistics for every public university–year observation in IPEDS data, for each of the 5 quantiles of the funding shock instrument. The column labelled "1st" refers to the mean for all university-year observations in the first quintile (bottom 20%) of the funding shock 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.

Figure A1: Correlation Between State Funding Shock and Public University State Funding in Surrounding Years.



Note: This figure shows the correlation between state funding in year $t + k$ with the funding shock 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 shock have dynamic correlation, 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 Shock on State Funding, in IPEDS Data.



Note: These figures show the local projections estimates of regression specification (2), with the funding shock as an instrument for state funding, using IPEDS data. The coefficient estimate is effect of funding shock ($Z_{i,t}$) 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 shock 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 3.2 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 shock. Table A3 presents the first-stage results in Illinois data .

Exogeneity and relevance of the rolling-share instrument, $\widetilde{Z}_{i(j),t}$, follows the same reasoning as that for the base-share instrument, $Z_{i,t}$, discussed in subsection 3.1. The base-share instrument is appropriate for some outcomes with the individual Illinois professors, where appropriate. We satisfy the assumptions for exogeneity by noting that none of the Illinois public campuses take the majority of state funding, and that the identification strategy relies on exogeneity in changes in state funding to individual professor-outcomes, following the year they joined the university. Additionally, within-institution changes resulting from share reliance on state funding may be correlated with unobserved changes in the outcomes, so that Chakrabarti et al. (2020) note the importance of controlling for the base share and state student population. The formulation here implicitly controls for these factors via the fixed effects; results are relatively similar while including these controls with and without including fixed effects, and so are omitted.

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

Table A3: First Stage Estimates, for State Funding by Funding Shock in IBHED Data.

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 shock 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 shock per student in the state on 10% change in state funding per student at the university — i.e., −10% funding shock 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.

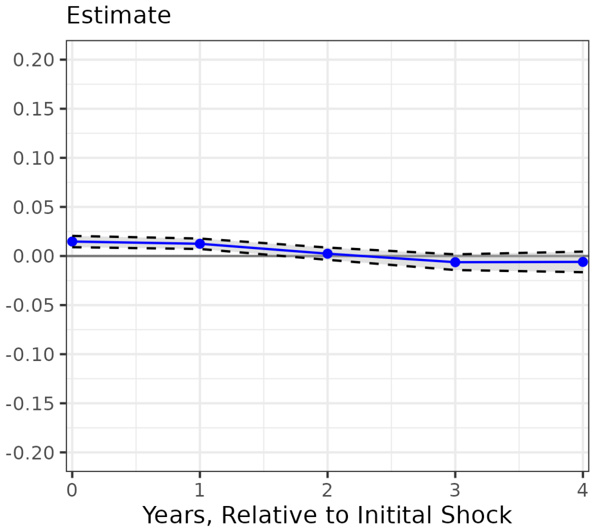
$$X_{i(j),t} = \theta_{i(j)} + \phi_{\tau(j)} + \delta \widetilde{Z}_{i(j),t} + \epsilon_{i(j),t} \tag{5}$$

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

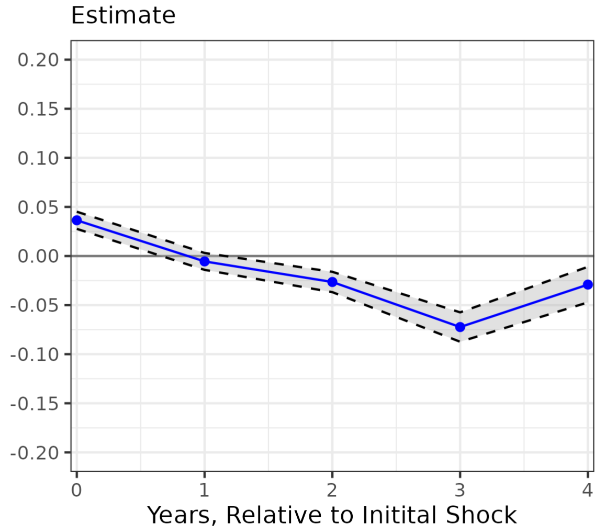
We then interpret parameter β as the effect of changes in state funding at an Illinois public university, via state funding shocks, on an individual professor's outcome $Y_{j,t}$.

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

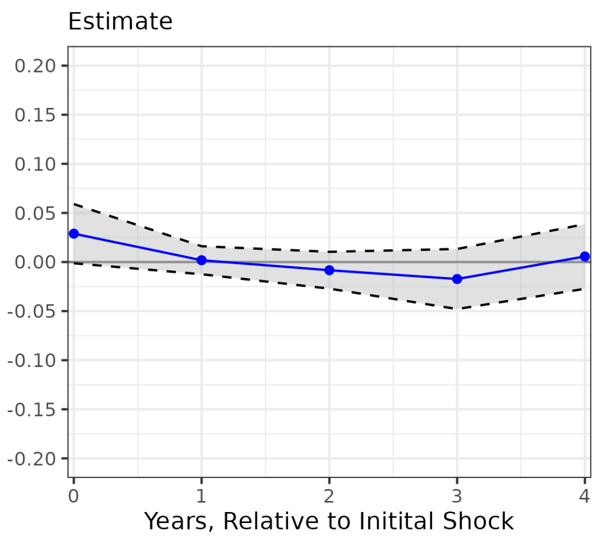
(a) Lecturers.



(b) Assistant Professors.



(c) Full Professors.



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

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

Panel A: units in $ per student

	Dependent Variable: Employment Count by Professor Group							
	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

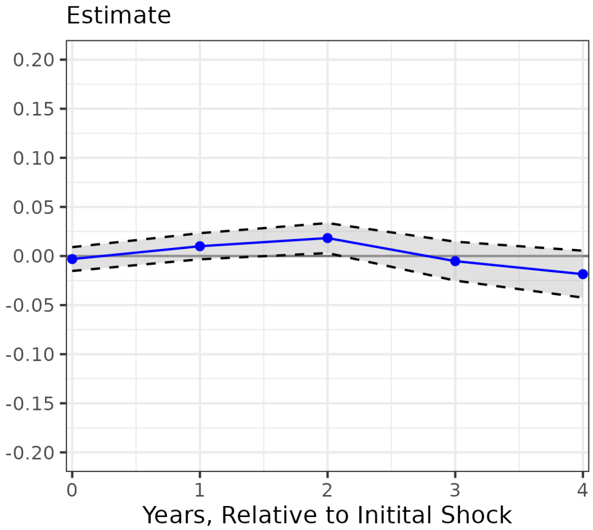
Panel B: units in log $ per student

	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

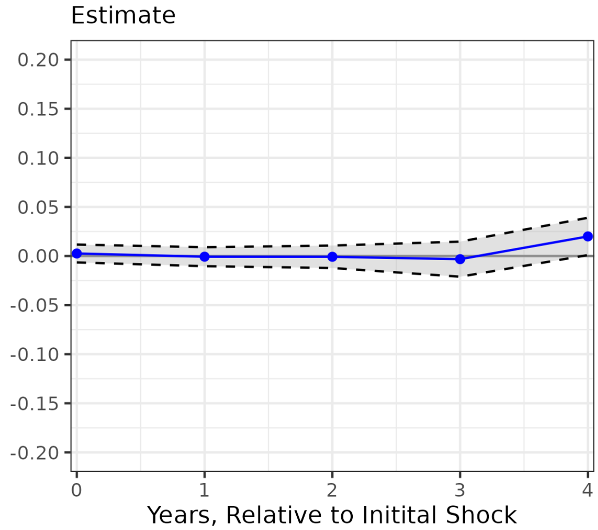
Note: These tables show the second stage OLS and 2SLS estimates of regression specification (3), showing the effect of state funding changes on number of faculty per student in Illinois universities, using the funding shock to instrument for state funding in the columns labelled 2SLS. Each observation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

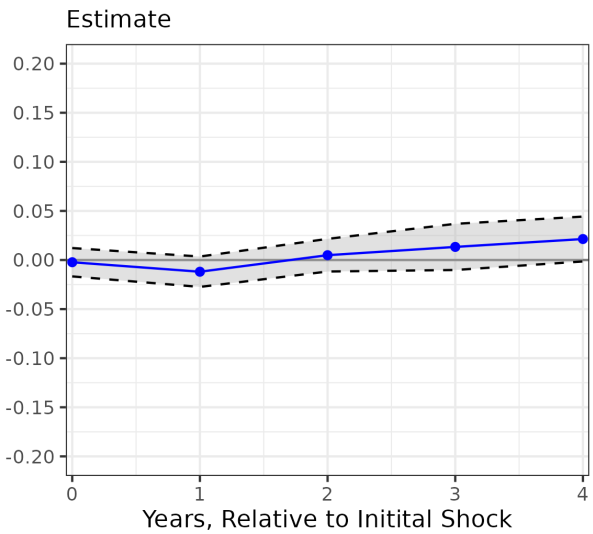
(a) Lecturers.



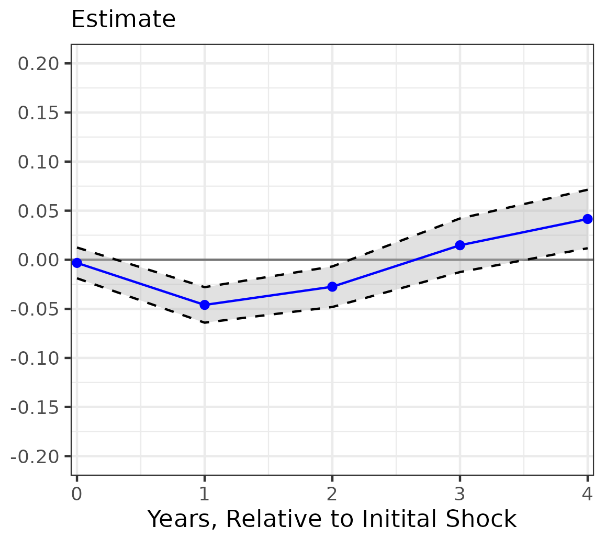
(b) Assistant Professors.



(c) Full Professors.



(d) Administrator Professors.

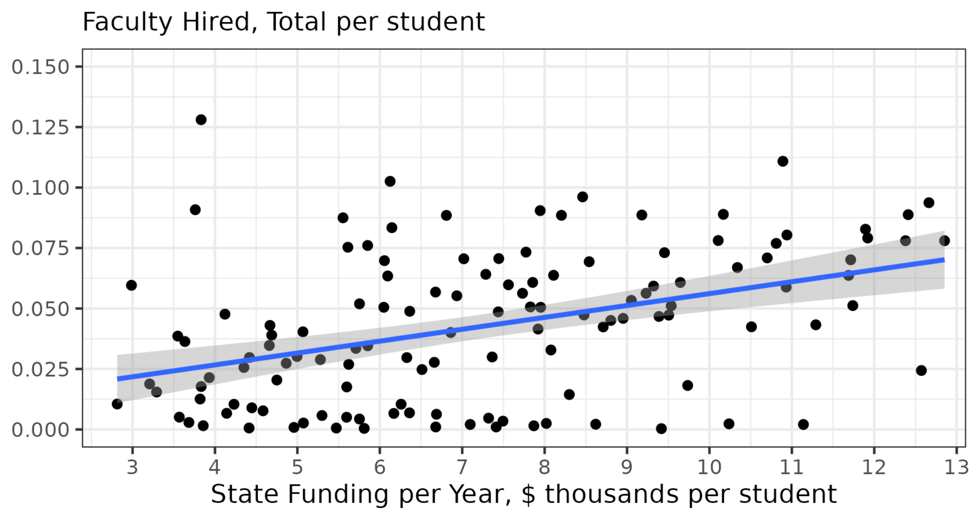


Note: These figures show the local projections estimates of regression specification (3), with the funding shock as an instrument for state funding. The unit of analysis is an individual faculty member (at an Illinois public university); funding data come from IPEDS, and faculty promotion rate from IBHED. The coefficient estimate is effect of state funding ($X_{i(j),t}$) on faculty promotion rate ($Y_{j,t}$), using the funding shock 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 Faculty Hiring

These results were produced by integrating the total count of faculty 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 3.2. There were no observable differences in the hiring rate of male vs female faculty.

Figure A5: State Funding and Faculty Hired at Public Universities, Total for 2011–2021.



Note: This figure shows the correlation between state funding and the number of total number of faculty hired at public universities between 2011–2021, and the line is a line of best-fit. Data for the number of faculty hired at public universities are provided by Wapman et al. (2022*b*,*a*), and funding data from IPEDS.

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

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	−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: 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	0.120	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 shock to instrument for state funding in the columns labelled 2SLS. Each observation is a public university-year in the state of Illinois, where funding data come from IPEDS and faculty count come from IBHED data. Panel A shows the effect of a fall in state funding $\$-1,000$ per student in the state on the number of new faculty hires by position. Panel B shows the effect of a 10% change in state funding per student at the university on the 10% change in the number of faculty hires per students. Outcome-mean is the mean of the outcome, for Panel A the number of faculty hires, for Panel B the number of faculty hires per student. Panel B uses new faculty hires per student as the outcome (in log terms), though the outcome mean is count of new faculty hires per student (not in log terms). Standard errors are clustered at the university-year level, and university + year fixed effects are included through–out.

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

	Dependent Variable: Hiring Count					
	Men		Women		Total	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)
State Funding	0.810	1.307	0.851	1.324	0.854	1.306
	(0.223)	(0.365)	(0.236)	(0.335)	(0.221)	(0.351)
Observations	157	157	157	157	157	157
R^2	0.397	0.367	0.416	0.385	0.409	0.382

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 shock 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.