Stagnating State Funding for Higher Education and its Effect on Faculty at US Universities

Senan Hogan-Hennessy*
Economics Department, Cornell University

This version: 12 July 2023†
Newest version available here.

Abstract

US universities have systematically substituted away from tenure-track/tenured professors towards contingent lecturers for the last thirty years, while at the same time states have limited how much they fund higher education. This paper connects the changes the faculty composition at US public universities to the fall in the states' funding for their public universities, using a shift-share approach to instrument for state funding and identify the causal effects of stagnating funding for higher education. A fall of 10% in funding for a public university, via a state funding shock, decreases the number of assistant professors per student by 1.4% and full professors by 1.2%, yet increases the number of lecturers per student by 4.4%; long-run estimates show that the faculty composition is affected both in the same year as the funding shock, and two to three years following. Analysis of all the professors at Illinois public universities shows that incumbent professors are not affected by substantial funding shocks over 2011-2021, with suggestive evidence showing that the faculty changes arose by limiting the hiring of new professors to replace leaving tenure-track/tenured professors. These results show the institutional effects of stagnating state funding for higher education, and raise questions about the direction that public education heads as these financial headwinds show no sign of dissipating.

Key-words: State and Local Budget and Expenditures, Higher Education, Public Sector Labour Markets

JEL Codes: H72, I23, J45

---

*For helpful comments I thank Levon Barseghyan, Francine Blau, Ryan Dycus, Ronald Ehrenberg, Michael Lovenheim, Jake Meyer, Douglas Miller, and Evan Riehl, as well as seminar participants at Cornell University (Autumn 2022) for helpful discussion.

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

Public universities educate the majority of higher education students in the US, yet have experienced a secular decline in state funding (per student) over the last three decades. At the same time, both public university student enrolment and employment of contingent lecturers dramatically increased at public universities. I show that four-year, degree-granting public universities have experienced a systematic fall in state funding per student, and this fall led to a substitution away from tenure-track/tenured professors towards contingent lecturers. Falls in state funding for public universities, instrumented by state-level shocks to state-wide higher education, led to a fall in the number of tenure-track/tenured professors per student within a university, and an increase in the number of lecturers. Private universities were not exposed to similar financial constraints during this same time period, and do not exhibit the substitution away from tenure-track/tenured professors, so that the stagnating state support for public universities has implications for the wider structure of US higher education and research.

US universities are widely considered the highest performing in the world, yet there are consequential differences between its universities that operate in the private sector and those established by state governments. Public universities are subject to numerous state-level administrative laws, and rely on their state governments for funding: an average public university received around \$11,600 of state funding per student in 1990, and only \$8,300 in 2021. This fall is driven by a stagnation in the absolute level of state funding for higher education in most states, combined with a large increase of 46% in student enrolment at public universities over the same time period. Similarly, the number of lecturers per student over doubled, while the number of tenure-track/tenured professors per students fell by -23% from 1990 to 2021.

I employ a shift-share instrument to identify changes in state funding for higher education, which exploits how universities differ in their financial reliance on state funding, combined with yearly shocks to the amount an entire state funds higher education — following Deming

& Walters (2017), Chakrabarti, Gorton & Lovenheim (2020). State governments decide how to fund higher education, and everything else, by a complicated process which can be influenced by local economic conditions, changing state priorities, or even lobbying from the state universities themselves. As such, it is necessary to employ an identification strategy, such as the shift-share instrument, to account for endogeneity in universities' state funding. The shift-share instrument interacts reliance on state funding in a base period with the entire state's total funding per higher education student for each year, to exploit changes in funding and how much each university historically relied on state funding for higher education.

TODO: Write section on the data sources. See Lovenheimn (2020) on how to do it.

Falls in state funding affects faculty composition at public universities, which substitute away from tenured and tenure-track professors towards contingent lecturers. A fall of -10% in state funding 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 three to four years after the initial funding shock, showing that the effect is not isolated to the immediate year of the first funding shock. Over the same time period, state funding fell by around -35%, while the count of professors per student fell by -9%, so that these results show that falls in state funding explain around a third of the substitution away from tenure-track and tenure professors towards contingent lecturers. Additionally, I use individual level data on all Illinois public university professors in 2010-2021 to investigate whether the shocks to state funding affected individual professors. 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 the falls in state funding (and by the funding shocks). This implies that faculty composition change arose by limiting the hiring of new professors; public universities increasingly hired contingent lecturers, and increasingly did not replace their retiring (or leaving) professors.

A number of studies have shown that stagnating state funding for higher education negatively impacts student outcomes. Deming & Walters (2017) show that increases in public university spending (via funding shocks) increases enrolment and degree completion among students,[1] that high school students exposed to similar public school funding shocks are less likely to attend college (Jackson, Wigger & Xiong 2021), and that these shocks induce public universities to rely more on tuition as a source of revenue (Bound, Braga, Khanna & Turner 2019). **Faculty outcomes surveyed by Ehrenberg (2003).** Chakrabarti et al. (2020) use the same methodology to show that increases in state funding lead to degree lower completion time and later-life debt for students.[2]

Over the last half century, there have been drastic changes to the heirarchy of US higher education, where the top universities have become more selective for student applicants, and the average university less selective (Hoxby 2009). Similarly, research faculty at US universities are increasingly concentrated among the graduates of highly selective PhD programmes (Wapman, Zhang, Clauset & Larremore 2022). Faculty composition is an interesting outcome on its own, but its relationship with higher education finances has so far not been studied. The closest previous examples study how university endowments react to negative endowment shocks (Brown, Dimmock, Kang & Weisbenner 2014) and the 2008 recession (Turner 2014), and multiple theoretically model university decision-making and faculty hiring (see e.g., Abe, Watanabe et al. 2015, Johnson & Turner 2009, Courant & Turner 2019). The number of professors per student may be particularly important for quality of instruction and thus educational outcomes; small class sizes in secondary schools lead to increases in test scores (Angrist & Lavy 1999), and UK university students perform worse academically in particularly large classes (Bandiera, Larcinese & Rasul 2010). Though, the economics

[1] Miller & Park (2022) further analyse the effects of falls in university revenues, by finding that reductions in public universities tuition prices (suggestively motivated by falling state funding) leads to reductions in provided financial aid.

[2] Bound & Turner (2007) use similar variation in state funding per student to show that lower funding leads to lower completion rates at public universities.

literature is not decided on whether contingent lecturers lead to better or worse outcomes in higher education. **Beef up this part to focus more on negative effects on students.** Lecturers are more effective teachers than research professors at a highly selective university (Bettinger & Long 2010, Figlio, Schapiro & Soter 2015), but students taught by part-time lecturers have worse student outcomes relative to full-time lecturers or faculty (Zhu 2021, Ehrenberg & Zhang 2005, Jaeger & Eagan 2011).

Tenure research (McPherson & Schapiro 1999, McPherson & Winston 1983)

While it is not immediately clear whether a systematic substitution towards lecturers away from professors reduces teaching effectiveness, it is clear that stagnating state funding has negatively impacted student outcomes (Deming & Walters 2017, Chakrabarti et al. 2020). **REWRITE:** where faculty composition is a possible mechanism for how the stagnating state funding for higher education transmits to students, and has led to worsening education outcomes at public universities for the last thirty years.

TO-DO: This paper precedes as follows.

1 Data and Institutional Context

1.1 Data Description

The data used in this analysis 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.[3] Data are consistent

[3]IPEDS does not necessarily cover the universe of US higher education institutions, yet in practice every

between the years 1990 and 2021,[4] 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.[5] 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 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[6] 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.[7] 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

public university and not for-profit four-year institution is represented.

[4]The years 1987-1989 are represented in these data in an incompletion fashion, so I focus on the years 1990 onwards. Year refers to the calendar year of the spring term — i.e., 1987 refers to the academic year that ran August 1986 to July 1987.

[5]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.

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

[7]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 in Illinois in the IBHED data later in this section) so are not considered in this analysis.

instructors employed by the college or university.[8] 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.

1.2 Trends in Finances, Enrolment, and Faculty Composition

The institutional environment for how states appropriate funding allows for wide variation in state funding for higher education, both between states and across years in each state. A state government plans an annual budget a couple of years ahead of the fiscal year, and the legislature chooses to approve or reject a budget request put forth by the governor's office.[9] 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. This process leads to yearly variation in state funding not seen in other revenues sources (such as federal government appropriations), since US states differ in their support for higher education, and are subject to fiscal constraints. State funding for higher education are a particularly attractive area of state spending to absorb negative shocks to state finances (Delaney & Doyle 2011).[10] Additionally, there is yearly

[8]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.

[9]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).

[10]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

variation in the number of higher education students in each state (Turner 2014), so that per-student state funding varies on multiple dimensions.

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

At the same time, student enrolment at public universities rose precipitously. 6.2 million students were enrolled in public universities in 1990, and this number rose by 47% to 9.1 million, 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 100 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

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.

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.

2010–2021 saw not only a decline, but also large yearly funding variation, 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.[11] While 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 variation in public university revenues via the state funding channel, stemming entirely from political disagreements — not from state

[11] Fiscal year 2016 refers to June 205 to June 2016, so is the same as the academic year definition.

decisions regarding higher education and its finances (Young, Wiley & Searing 2020) — mean 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.

2 Conceptual Framework

While state support for public higher education has stagnated at the same time as education costs rose, there are multiple possible ways that a university can respond. Deming & Walters (2017) established that corresponding rises in tuition did not offset the falling state support, so that university spending (per student) fell in response to these persistent, negative state funding shocks. There are multiple ways that these changes in finances may affect the faculty composition at public universities.

It is a priori unclear that stagnating state support and changes in faculty composition at public universities would be causally linked. Over the 21st Century there have been drastic changes to college selectivity, 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, so that over time public universities (on average) substitute towards contingent lecturers. This is one way in which the trends may be concurrent, but not causal.

Employment composition changes likely arise via differences in hiring rate across levels of professor seniority. Universities hire new professors most years, either to expand their departments or to replace leaving professors, but not hire at the same rate for each level of seniority. The number of professors hired in each year is usually highest among non-tenured adjunct faculty, as these instructors are mostly on short-term or contingent contracts, so are less costly to hire (or to let go) in response to yearly changes. Tenure-track assistant professors are mostly hired with a four to six year contract, and formal agreement for tenure consideration at the end of this term. Lastly, tenured professors have successfully secured a full-time appointment at their university with no expiration date; this position has the lowest yearly hiring rate among most universities. Similarly, there is highest turn-over (including leaving the university) among lecturers, and lowest among full professors. The differences in yearly hiring and turnover rate mean that if hiring is affected by state funding, then there will be faculty composition change in the years following budget cuts.

Faculty salaries may be affected by changes in public university finances. When the university has a lower budget for its yearly hiring, it may respond by lowering the salary they offer to new hires. This possible effect may not be the same across each position of professor; tenured faculty are often hired away from another university, so that new tenured professor hires may be less likely to accept the lower salary offers from public universities.[12] Yet salary for all the professors, not just new hires, may also be affected: multiple universities passed a university-wide pay-cut for their faculty in response to state budget cuts around the 2008 recession, for example.[13] Additionally, it is not immediately clear which faculty (among those already hired) will be most affected by the changes in their university's funding. Yet, there is one empirical fact worth noting: the average assistant or tenured professor earns more than double that of a lecturer (see Table 2). If a public university's primary obligation is to teach, and they must fulfil this objective with less resources, then they may substitute away from tenure-track and tenured professors towards lecturers.

Similarly, its is not clear when the effects of funding short-falls 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

[12] Faculty often consider their outside options, as in offers for employment and/or promotion from other universities. See Blackaby, Booth & Frank (2005) for an overview of faculty outside options.

[13] Indeed, Cornell University implemented hiring freezes and a nominal salary reduction for professors, in anticipation of a financial shock in early 2021. The salary cut was not permanent, as the oncoming financial shock turned out to not be as serious as projected, so that the cut was returned to professors in the year 2021.

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 year-long 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 in response. As such, this paper investigates the dynamics of state funding shocks' effects on faculty, for the years following a university funding shock.

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 treatment selection-on-outcome threat to identification. Importantly for this analysis, revenues received from an institution's state government provide opportunity to address such endogeneity.

3.1 State Funding Shocks

This analysis uses 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.

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

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.[14] $Z_{i,t}$ 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 has been negative. State funding has been falling, so that the instrument describes shocks to university revenues, mostly in a negative direction.[15] The 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 A1). 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 finances fopr the university 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

[14] 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.

[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.

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.

The shift-share instrument has a strong first stage for universities' yearly state funding. Table 3 presents results of the first-stage regression, separately with and without a control for tuition revenue per student, plus institution and year fixed effects; Panel A shows estimates of a funding shock of $1 per student in the state on state funding per student at the university,

[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.

and Panel B the % increase effects of a 1% increase in the shock per student on state funding per student. **TO-DO: Add description the dollar-by-dollar, of the first stage.** We note columns (1) and (2) estimate that a funding shock (per student in the entire state) of 10% is associated with 9.8% change in state funding per student at the university; the instrument is strong, and we note similarity in estimates with and without inclusion of 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 columns (1), (2) thanks to inclusion of fixed effects, so that the fixed effects was effective in soaking variation in per-student tuition revenues at the institution-year level. 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.

These results, together with the case for exogeneity, show the funding shock instrument strongly predicts university revenues in the first-stage estimation.

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]

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

[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).

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. Incumbent professors are faculty who are already employed at the university; state funding changes may affect faculty who are already at the university (beyond affecting whether they get hired), so I base the instrument in the year that the professor was hired, and include fixed effects for the hiring year.[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 how much the funding higher education in 1990, but most have experienced a decline on order of 30%, so that the stagnation in state funding has been a percent change trend over this time period.

[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.

[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.

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 Funding Shock

The effects of a change in the universities funding may not be immediate, and faculty in may be effected multiple years after a funding shock. Yet, the funding shock instrument is 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 year are highly correlated with state funding per student in the 5 years before and after the original shock in IPEDS data (see Figure A1). Thus, a linear model correlated state funding in year t with outcomes in year t 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, even for instrumental variable models (Basso, Miller & Schaller 2022). This method estimates the effect of treatment $X_{i,t}$ on outcome $Y_{i,t+k}$ in follow-on years $k>0$, while accounting for the auto-correlation between the other years.[20] I present estimates in graphical form, where the x-axis represents the year relative to the funding shock (i.e., $x=0$ represents the year of the state funding shock) and the y-axis represents the estimated effect of the funding shock on that year's outcome.[21]

[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).

[21]See Figure 5 for the graphical format, and the corresponding note for further explanation.

4 Results

Changes in state funding have clear effects on the composition of faculty public universities employ. Table 5 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, with no discernible effect on the count of total professors (Table 5, Panel A). In percentage terms, 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. In the state of Illinois, using the count of professors represented in the IBHED databse, state funding is correlated with the number of faculty, but lacks precision to identify the exact effects given the 144 university-year observations in the panel for 2010–2021.

Faculty composition is not only impacted in the same years 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 $k = 0, \dots, 10$. 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.

Incumbent professors are relatively unaffected by changes in the state funding for their university in the years following their hire. Table 7 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.

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 may imply that the rate that public universities hired faculty was impacted by state funding cuts. I take recent data on the total faculty hired at US public universities over 2011–2021 (provided by Wapman et al. 2022), to show that universities with lower state funding (per student) also hired fewer professors in the same time period — shown in Figure A3. 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.[22] These results provide limited evidence that changes in faculty composition arose by disrupting hiring of new professors at public universities, corresponding to the results that incumbent faculty were not by meaningfully effected 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.[23] 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.

[22] See subsection A.3 for further details.

[23] 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.

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 (i.e., 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 corresponding amount, with the clear implication that there are fewer tenure-track openings at US universities.[24] 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). 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.

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

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 for faculty, and their working conditions, there is credible evidence that relying on adjunct lecturers leads to worse student outcomes, relative to full-time lecturers and professors (Zhu 2021). As tenure has increasingly become a private sector phenomenon, we should worry about the long-term effects on higher education, and the effect on the average student who attends a public university in the US.

6 Summary and Concluding Remarks

This analysis 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.

I found that 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, while suggestive information shows falls in hiring, which together implies 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.

While costs education 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, 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 contingent 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 composition, research at public universities, and the impact on higher education as a whole.

References

Abe, Y., Watanabe, S. P. et al. (2015), 'Implications of university resource allocation under limited internal adjustability', *Theoretical Economics Letters* **5**(05), 637. https://doi.org/10.4236/tel.2015.55074. 3

Adämmer, P. (2019), 'lpirfs: An R Package to Estimate Impulse Response Functions by Local Projections', *The R Journal* **11**(2), 421–438. https://doi.org/10.32614/RJ-2019-052. 36

American Association of University Professors (2021), *2020-21 Faculty Compensation Survey Results*. https://www.aaup.org/2020-21-faculty-compensation-survey-results. 5, 19

Angrist, J. D. & Lavy, V. (1999), 'Using maimonides' rule to estimate the effect of class size on scholastic achievement', *The Quarterly journal of economics* **114**(2), 533–575. https://doi.org/10.1162/003355399556061. 3

Bandiera, O., Larcinese, V. & Rasul, I. (2010), 'Heterogeneous class size effects: New evidence from a panel of university students', *The Economic Journal* **120**(549), 1365–1398. https://doi.org/10.1111/j.1468-0297.2010.02364.x. 3

Basso, G., Miller, D. & Schaller, J. (2022), Dynamic treatment effects for empirical microeconomists: Local projections and quasi-experimental research designs, Working paper. 16

Bettinger, E. P. & Long, B. T. (2010), 'Does cheaper mean better? the impact of using adjunct instructors on student outcomes', *The Review of Economics and Statistics* **92**(3), 598–613. https://doi.org/10.1162/REST_a_00014. 4

Blackaby, D., Booth, A. L. & Frank, J. (2005), 'Outside offers and the gender pay gap: Empirical evidence from the uk academic labour market', *The Economic Journal* **115**(501), F81–F107. https://doi.org/10.1111/j.0013-0133.2005.00973.x. 10

Borusyak, K., Hull, P. & Jaravel, X. (2022), 'Quasi-experimental shift-share research designs', *The Review of Economic Studies* **89**(1), 181–213. https://doi.org/10.1093/restud/rdab030. 13

Bound, J., Braga, B., Khanna, G. & Turner, S. (2019), 'Public universities: The supply side of building a skilled workforce', *RSF: The Russell Sage Foundation Journal of the Social Sciences* **5**(5), 43–66. https://www.rsfjournal.org/content/5/5/43. 3

Bound, J. & Turner, S. (2007), 'Cohort crowding: How resources affect collegiate attainment', *Journal of public Economics* **91**(5-6), 877–899. https://doi.org/10.1016/j.jpubeco.2006.07.006. 3

Brown, J. R., Dimmock, S. G., Kang, J.-K. & Weisbenner, S. J. (2014), 'How university endowments respond to financial market shocks: Evidence and implications', *American Economic Review* **104**(3), 931–62. https://doi.org/10.1257/aer.104.3.931. 3

Chakrabarti, R., Gorton, N. & Lovenheim, M. F. (2020), State investment in higher education: Effects on human capital formation, student debt, and long-term financial outcomes of students, Working Paper 27885, National Bureau of Economic Research. https://doi.org/10.3386/w27885. 2, 3, 4, 11, 12, 13, 15, 40

Courant, P. N. & Turner, S. (2019), *Faculty Deployment in Research Universities*, in 'Productivity in Higher Education, University of Chicago Press', pp. 177–208. http://www.nber.org/chapters/c13879. 3

Delaney, J. A. & Doyle, W. R. (2011), 'State spending on higher education: Testing the balance wheel over time', *Journal of Education Finance* pp. 343–368. https://doi.org/10.1007/s11162-013-9319-2. 6

Deming, D. J. & Walters, C. R. (2017), The impact of price caps and spending cuts on u.s. postsecondary attainment, Working Paper 23736, National Bureau of Economic Research. https://doi.org/10.3386/w23736. 1, 3, 4, 6, 9, 11, 12, 15

Ehrenberg, R. G. (2003), 'Studying ourselves: The academic labor market: Presidential address to the society of labor economists, baltimore, may 3, 2002', *Journal of Labor Economics* **21**(2), 267–287. https://doi.org/10.1086/345558. 3

Ehrenberg, R. G. & Zhang, L. (2005), 'Do tenured and tenure-track faculty matter?', *Journal of Human Resources* **40**(3), 647–659. https://doi.org/10.3368/jhr.XL.3.647. 4

Figlio, D. N., Schapiro, M. O. & Soter, K. B. (2015), 'Are tenure track professors better teachers?', *Review of Economics and Statistics* **97**(4), 715–724. https://doi.org/10.1162/REST_a_00529. 4

Gaure, S. (2013), 'lfe: Linear group fixed effects', *The R Journal* **5**(2), 104–117. https://journal.r-project.org/archive/2013/RJ-2013-031/RJ-2013-031.pdf. 36

Hlavac, M. (2018), *stargazer: Well-Formatted Regression and Summary Statistics Tables*, Central European Labour Studies Institute (CELSI). R package version 5.2.2, https://CRAN.R-project.org/package=stargazer. 36

Hoxby, C. M. (2009), 'The changing selectivity of american colleges', *Journal of Economic perspectives* **23**(4), 95–118. https://doi.org/10.1257/jep.23.4.95. 3, 9, 19

Illinois Board of Higher Education (2021). Public University Administrator and Faculty Salary and Benefits Database, accessed 10 January 2022. https://salarysearch.ibhe.org/. 4

Jackson, C. K., Wigger, C. & Xiong, H. (2021), 'Do school spending cuts matter? evidence from the great recession', *American Economic Journal: Economic Policy* **13**(2), 304–335. /10.1257/pol.20180674. 3

Jaeger, A. J. & Eagan, M. K. (2011), 'Examining retention and contingent faculty use in a state system of public higher education', *Educational Policy* **25**(3), 507–537. https://doi.org/10.1086/345558. 4

Johnson, W. R. & Turner, S. (2009), 'Faculty without students: Resource allocation in higher education', *Journal of Economic Perspectives* **23**(2), 169–89. https://doi.org/10.1257/jep.23.2.169. 3

Jordá, O. (2005), 'Estimation and inference of impulse responses by local projections', *American Economic Review* **95**(1), 161–182. https://doi.org/10.1257/0002828053828518. 16, 36

McPherson, M. S. & Schapiro, M. O. (1999), 'Tenure issues in higher education', *Journal of Economic Perspectives* **13**(1), 85–98. https://doi.org/10.1162/003355398555892. 4

McPherson, M. S. & Winston, G. C. (1983), 'The economics of academic tenure: A relational perspective', *Journal of Economic Behavior & Organization* **4**(2-3), 163–184. https://doi.org/10.1016/0167-2681(83)90005-7. 4

Miller, L. & Park, M. (2022), 'Making college affordable? the impacts of tuition freezes and caps', *Economics of Education Review* **89**, 102265. https://doi.org/10.1016/j.econedurev.2022.102265. 3

Mountjoy, J. (2022), 'Community colleges and upward mobility', *American Economic Review* **112**(8), 2580–2630. https://doi.org/10.1257/aer.20181756. 5

Parmley, K., Bell, A., L'Orange, H. & Lingenfelter, P. (2009), 'State budgeting for higher education in the united states', *Report, State Higher Education Executive Officers* . https://eric.ed.gov/?id=ED506284. 6

Pei, Z., Pischke, J.-S. & Schwandt, H. (2019), 'Poorly measured confounders are more useful on the left than on the right', *Journal of Business & Economic Statistics* **37**(2), 205–216. https://doi.org/10.1080/07350015.2018.1462710. 13

R Core Team (2022), *R: A Language and Environment for Statistical Computing*, R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/. 36

Turner, S. E. (2014), *The impact of the financial crisis on faculty labor markets, in 'How the Financial Crisis Affected Higher Education'*, University of Chicago Press, pp. 133–176. https://www.nber.org/chapters/c12863. 3, 7

Urquiola, M. (2020), *Markets, Minds, and Money: Why America Leads the World in University Research*, Harvard University Press. 19

US Department of Education Integrated Postsecondary Education Data System (2021). Education Data Portal (Version 0.14.0), Urban Institute, accessed 10 January 2022. https://educationdata.urban.org/documentation/, made available under the ODC Attribution License https://opendatacommons.org/licenses/by/1-0/. 4

Wapman, K. H., Zhang, S., Clauset, A. & Larremore, D. B. (2022), 'Quantifying hierarchy and dynamics in us faculty hiring and retention', *Nature* **610**(7930), 120–127. https://doi.org/10.1038/s41586-022-05222-x. 3, 18, 19

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S. M., Müller, K., Ooms, J., Robinson, D., Seidel, D. P., Spinu, V., Takahashi, K., Vaughan, D., Wilke, C., Woo, K. & Yutani, H. (2019), 'Welcome to the tidyverse', *Journal of Open Source Software* **4**(43), 1686. https://doi.org/10.21105/joss.01686. 36

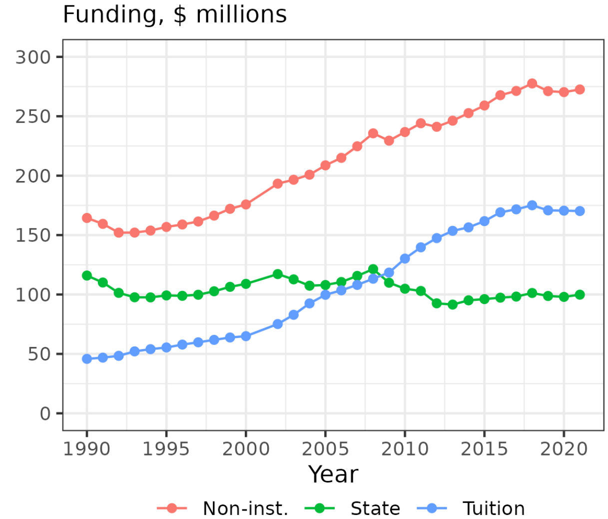
Young, S. L., Wiley, K. K. & Searing, E. A. (2020), '"squandered in real time": How public management theory underestimated the public administration–politics dichotomy', *The American Review of Public Administration* **50**(6-7), 480–488. https://doi.org/10.1177/0275074020941669. 9

Zhu, M. (2021), 'Limited contracts, limited quality? effects of adjunct instructors on student outcomes.', *Economics of Education Review* **85**, 102177. https://doi.org/10.1016/j.econedurev.2021.102177. 4, 20

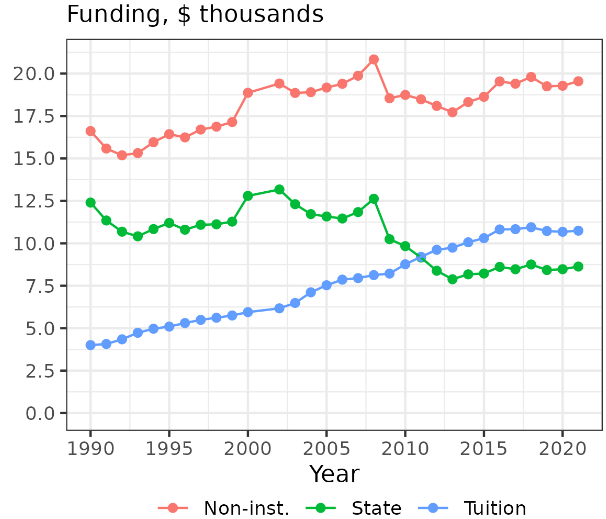
7 Figures

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

(a) Total, $ 2021 CPI-U.



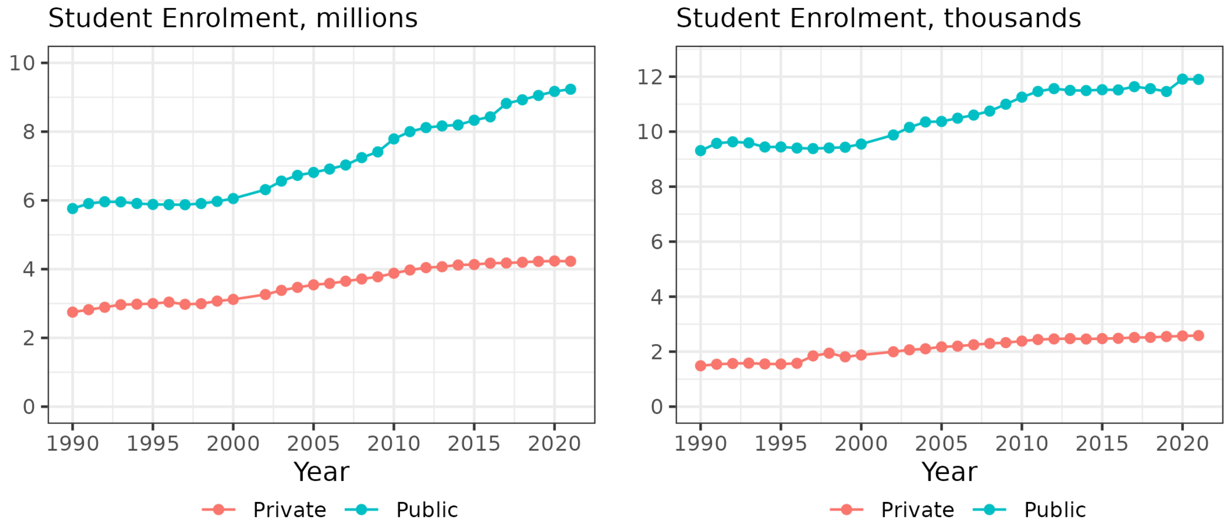
(b) Per Student, $ 2021 CPI-U.



Note:
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

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

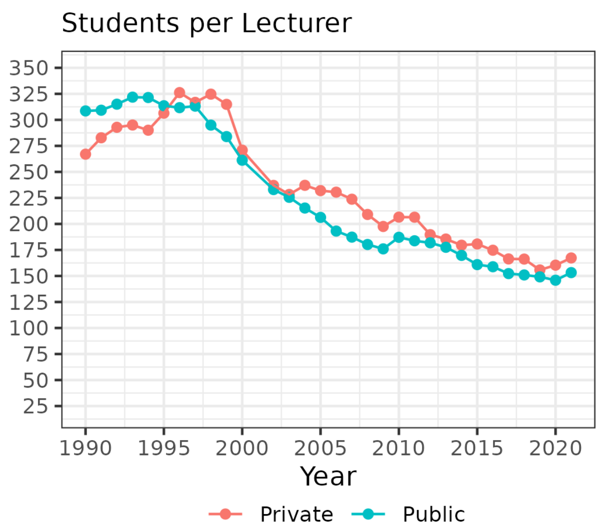
(a) Total Enrolment, Nation-wide. **(b)** Mean Enrolment, per University.



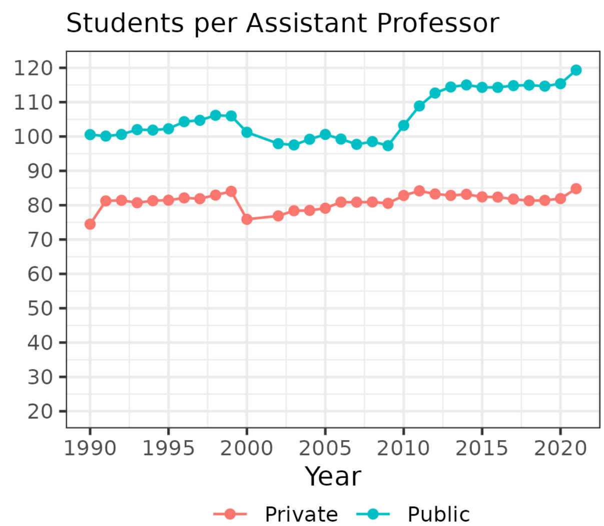
Note:
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

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

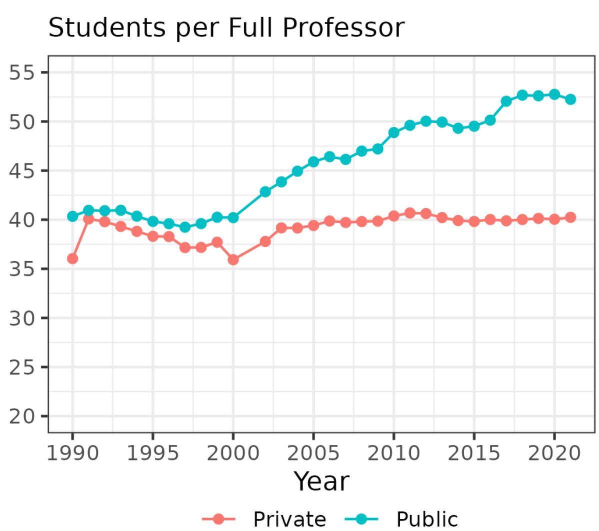
(a) Lecturer.



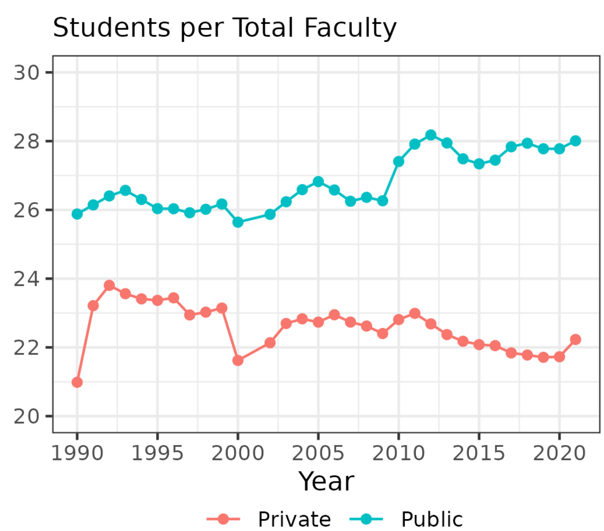
(b) Assistant.



(c) Full.



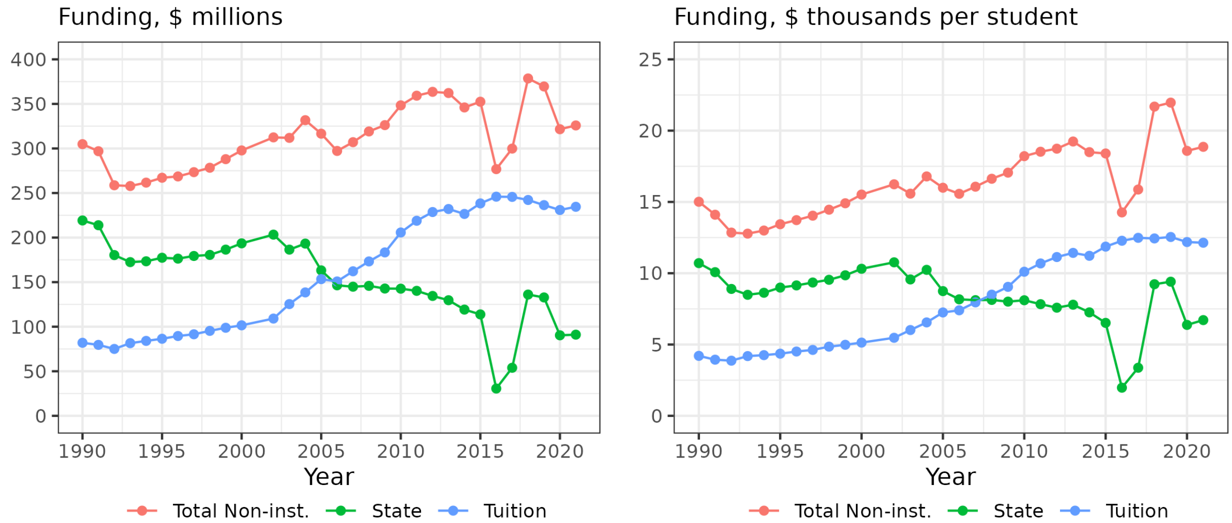
(d) All.



Note:
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

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

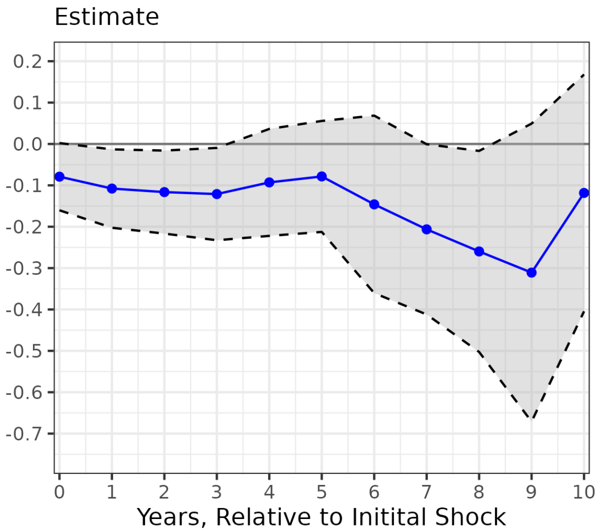
(a) Total, $ 2021 CPI-U. **(b)** Per Student, $ 2021 CPI-U.



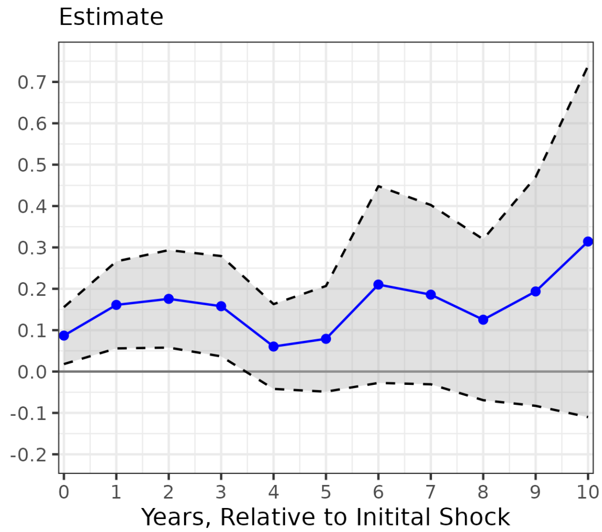
Note:
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

Figure 5: Local Projection Estimates for Professor Count per Student, by Professor Group.

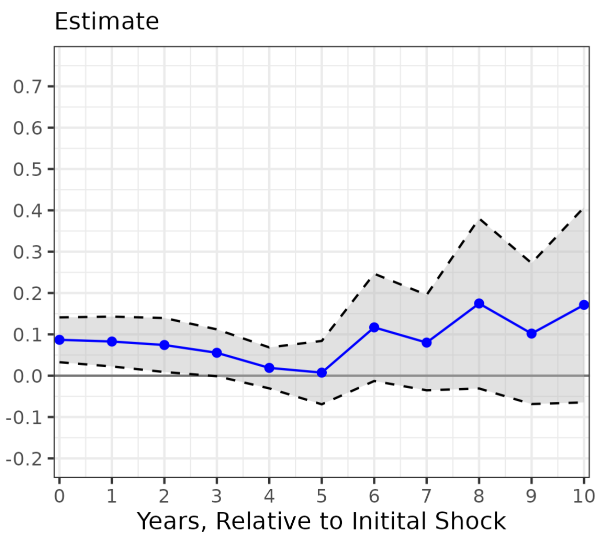
(a) Lecturers.



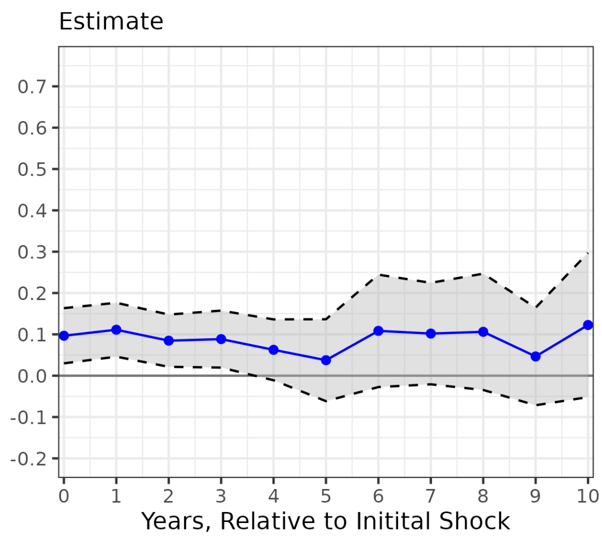
(b) Assistant Professors.



(c) Full Professors.



(d) All Professors.



Note: the coefficient estimate is effect of $X_{i,t}$ on $Y_{i,t}$, while accounting for auto-correlation between $X_{i,t}, X_{i,t-1}$ and $Y_{i,t}, Y_{i,t-1}$. Standard errors are clustered at the state-year level.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

8 Tables

Table 1: IPEDS Summary Statistics, Public Universities Panel 1987–2021

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: Standard errors are clustered at the state-year level.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

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: Standard errors are clustered at the state-year level.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

Table 3: First Stage Estimates, for State Funding by funding shock.

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: Standard errors are clustered at the state-year level.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

Table 4: 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 Lecturers	Assistant Professors	Full Professors	All Professors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Funding Shock	0.517	−9,217	−7,633	886	0.007	−0.001	−0.003	0.004
	(0.199)	(2,452)	(12,771)	(4,093)	(0.002)	(0.001)	(0.003)	(0.005)
Uni. + Year fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17,012	17,012	17,012	17,012	17,012	17,012	17,012	17,012
R^2	0.960	0.950	0.881	0.932	0.745	0.886	0.973	0.954

Panel B: units in log $ per student

	Dependent Variables: University Characteristics							
	Enrolment	State Funding	Total Revenues	Non-inst. Revenues	Lecturers Lecturers	Assistant Professors	Full Professors	All Professors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Funding Shock	0.107	−0.870	0.031	−0.091	0.534	−0.024	−0.027	0.043
	(0.037)	(0.079)	(0.082)	(0.063)	(0.122)	(0.066)	(0.034)	(0.038)
Uni. + Year fixed effects?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17,012	17,012	17,012	17,012	17,012	17,012	17,012	17,012
R^2	0.976	0.914	0.979	0.975	0.782	0.902	0.963	0.965

Note: Standard errors are clustered at the state-year level.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

Table 5: 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: Standard errors are clustered at the state-year level.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

Table 6: 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: Standard errors are clustered at the state-year level.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

Table 7: 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: Standard errors are clustered at the institution and first year of employment level.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON. MENTION THE ROLLING INSTRUMENT.

A Appendix

This project used data which are fully public, and computational tools which are fully open-source. As such, all code and data 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.

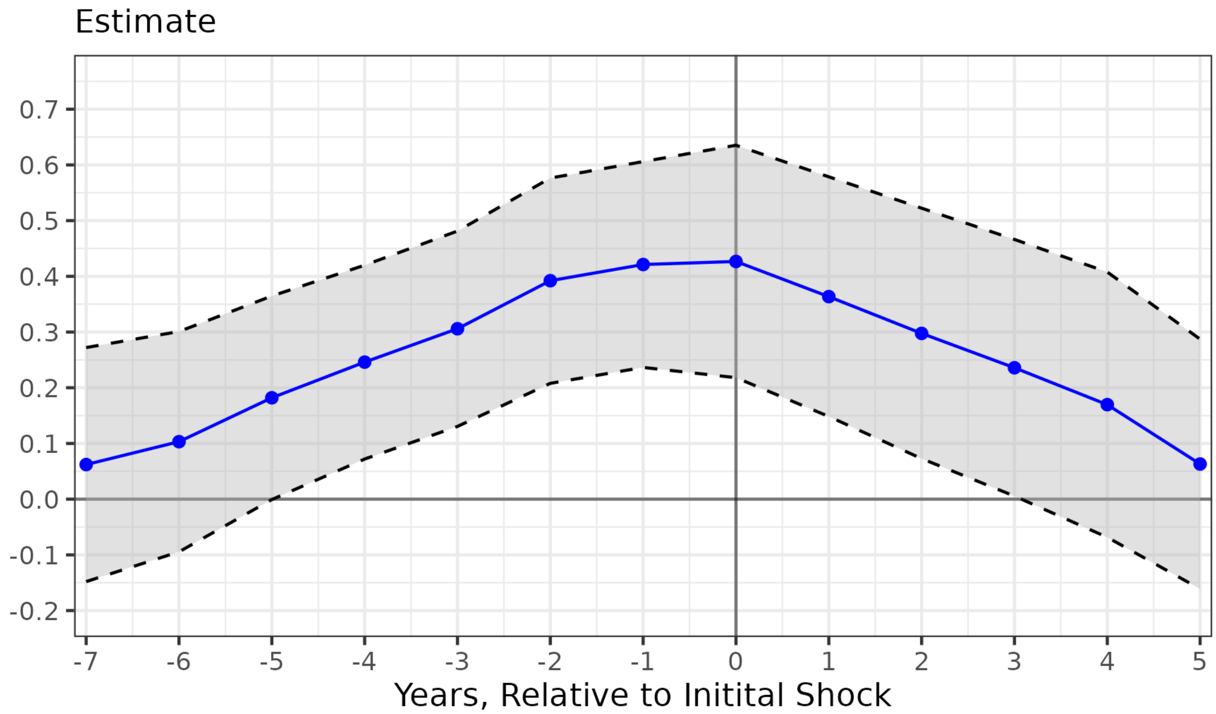
A.1 IPEDS First Stage

Table A1: Mean Characteristics for Public Universities, by State Funding Shock Instrument.

Instrument Quantile:	1st	2nd	3rd	4th	5th
State Funding Shock, $ per student	1,474	2,589	3,566	5,002	8,208
State Funding, per student	12,900	9,956	9,335	9,305	12,767
Total Full-time Enrolment	14,088	12,434	11,329	11,546	10,253
State Funding, $ millions	110	99	100	107	107
Total Revenues, $ millions	1,038	490	364	304	248
Total Revenues, $ per student	121,064	44,579	31,599	25,411	27,389
Lecturer Count	81	65	60	53	38
Assistant Professor Count	154	120	111	109	94
Full Professor Count	358	273	251	251	245
Total Professor Count	609	466	428	418	387
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

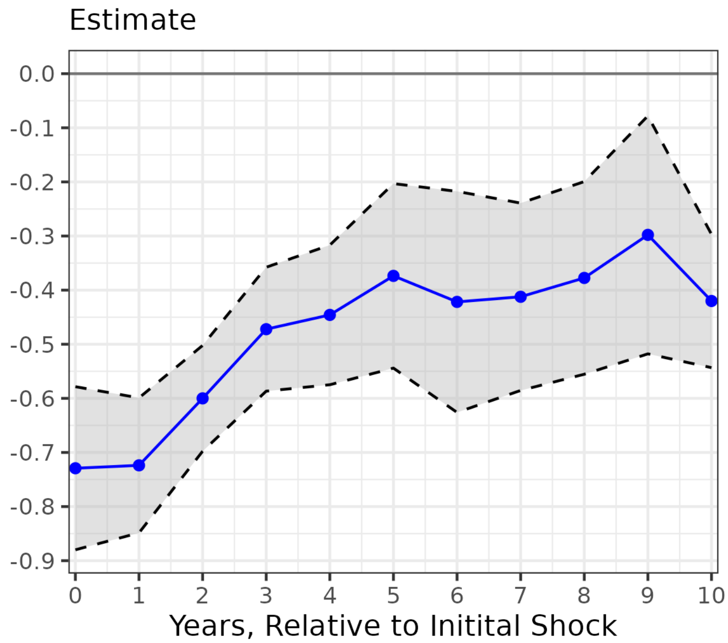
Note: The column labelled "1st" refers to the mean for all university-year observations in the first quintile (bottom 20%) of the funding shock distribution, and so on. The mean of the funding shock within each quintile is shown in the first row of the table.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

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



Note:
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

Figure A2: Local Projection Estimates for First-Stage Equation (2).



Note: Standard errors are clustered at the institution and year level.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

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, $\widetilde{Z}_{j,t}$, 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 (e.g., **??**, **??**).

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

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.

Exogeneity and relevance of the rolling-share instrument, $\widetilde{Z}_{j,t}$, 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. **??** presents results of the first stage estimation, showing that the instrument is strong in the same way as that for the university-level outcomes (Table 3), with very similar estimates for the association between funding shocks and state funding.

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

$$\begin{aligned} X_{i(j),t} &= \theta_{i(j)} + \phi_{\tau(j)} + \delta \widetilde{Z}_{i(j),t} + \epsilon_{i(j),t} \qquad (5) \\ Y_{j,t} &= \mu_{i(j)} + \nu_{\tau(j)} + \beta \widehat{X}_{i(j),t} + \varepsilon_{j,t} \qquad (6) \end{aligned}$$

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 $Y_{j,t}$.

A.3 Additional Results, Faculty Hiring

Write here about the faculty hiring totals among Illinois uni's.

Table A2: 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

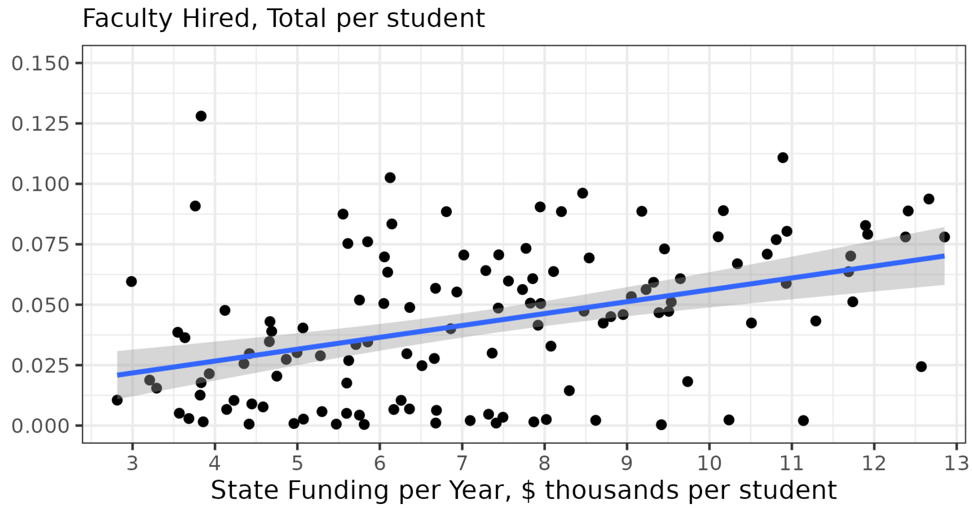
Panel B: units in log $ per student

	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: Standard errors are clustered at the state-year level.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

Beefed explanation goes here: 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 A3: State Funding and Faculty Hired at Public Universities, Total for 2011–2021.



Note: A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

Table A3: 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: Standard errors are clustered at the state level.
A BIGGER NOTE TO EXPLAIN WHAT IS GOING ON.

Yearly variation is not observed here, so that only the aggregate level, for 180 universities, can be considered.

A.4 Additional Results, 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 5, 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 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 subsitution is -3.19 (0.34), which implies that universities subsitute 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.