The Impacts of Price and Spending Subsidies on U.S. Postsecondary Attainment

David J. Deming
Harvard University and NBER

Christopher R. Walters
UC Berkeley and NBER*

January 2017

Abstract

The rising price of college is seen as a major barrier to increasing U.S. postsecondary attainment. Most Federal and state policy efforts focus on reducing college costs, yet declining state funding has also led to sharp spending cuts at public institutions. This paper investigates the impacts of changes in tuition and spending on enrollment and degree completion at non-selective public postsecondary institutions between 1990 and 2013. We estimate these impacts using a newly assembled data set of legislative tuition caps and freezes combined with variation in exposure to state budget shocks that is driven by differences in historical reliance on state appropriations. We find large causal impacts of spending on enrollment and degree completion. In contrast, we find limited impacts of price changes. Our estimates suggest that spending increases are more effective per-dollar than price cuts as a means of increasing postsecondary attainment.

*Emails: david_deming@gse.harvard.edu; crwalters@econ.berkeley.edu. Thanks to seminar participants at Northwestern University, the UC Berkeley Goldman School of Public Policy, the 2016 and 2017 American Economic Association Annual Meetings, and the 2016 APPAM Fall Conference for helpful comments. Olivia Chi, Patrick Lapid, and Tomas Monarrez provided superb research assistance.

1 Introduction

From 1990 to 2013, U.S. college enrollment as a share of the age 18-24 population grew from 37 percent to 54 percent.[1] Yet over this same period the wage gap between those with a high school degree and a college degree grew steadily, suggesting that the supply of college-educated labor has not kept pace with demand (Autor, 2014). College costs are frequently cited as a key reason for the slowdown in the growth of U.S. educational attainment, and tuition and fees at U.S. public institutions have risen much faster than the rate of inflation over the last quarter century (Dynarski, 2008; Deming and Dynarski, 2010; Baum and Ma, 2014). Policymakers have responded to rising prices with a variety of programs to reduce college costs, including increasing the generosity of Federal Pell Grants, state merit aid programs, and proposals to make community college free or to drastically reduce the cost of attendance (Dynarski, 2008; White House, 2015).

A less visible but equally important trend is the decline of state support for public higher education. Between 2000 and 2014, inflation-adjusted state appropriations per full-time equivalent public college student fell by 28 percent (Baum and Ma, 2014). Formal and informal pressure from state legislatures and taxpayers has kept tuition at public institutions from increasing fast enough to compensate for the lost state revenue. As a result, per-student spending at public institutions has actually declined by 16 percent since 2000, despite rising prices.[2]

The implications of reduced public spending for college attainment are unclear. One view is that higher education spending pays for administrative bloat and consumption amenities, in which case spending cuts may improve cost-effectiveness (see, e.g., Ginsberg, 2011; Ehrenberg, 2012; and Jacob et al., 2013). On the other hand, per-student spending net of tuition is higher at more selective colleges, which also produce higher graduation rates (Winston, 1999; Hoxby, 2009). If part of the gap in outcomes between more- and less-selective institutions reflects a causal impact of spending, the combination of lower prices and lower spending may decrease postsecondary attainment. More broadly, spending cuts may reduce enrollment and persistence by limiting the number and variety of course offerings, increasing class size, or moving students into non-credit-bearing remedial courses (Bettinger and Long, 2009; Bahr, 2014).

We use data from the Integrated Postsecondary Education Data System (IPEDS) to study impacts of changes in spending and tuition at U.S. public postsecondary institutions between 1990 and 2013. The thought experiment that motivates our analysis is as follows. Suppose a U.S. public institution receives an unexpected increase in state appropriations of \$1,000 per student. One option is to pass this extra \$1,000 on to students in the form of tuition cuts or scholarships. This would reduce the price of college, but keep per-student spending constant. Alternatively, the college might elect to keep tuition constant and spend the extra \$1,000 per student on smaller classes, fancier athletic facilities, or other educational inputs or amenities. We seek to determine which of these choices would lead to a larger impact on student enrollment and degree completion.

[1] Authors' calculations using the Integrated Postsecondary Education Data System (IPEDS) and the U.S. Census.
[2] Authors' calculations using the IPEDS.

Our focus is on nonselective higher education, which includes both nonselective four-year public institutions and community colleges. Compared to selective public universities, nonselective institutions mostly serve local markets, are more reliant on state appropriations, and have fewer potential margins of adjustment in response to budget cuts. Changes in state funding therefore have large impacts on core operations at nonselective schools.

Our analysis exploits cross-sectional variation in institutions' historical reliance on state appropriations combined with state-level changes in funding over time to identify impacts of state funding on spending, tuition and enrollment. State appropriations for higher education fluctuate with the business cycle, and policy decisions about higher education funding generally operate at the state level (Kane et al., 2003; Barr and Turner, 2013). Yet the impact of a state-level budget cut is likely to be greater for institutions that rely more heavily on state appropriations as a source of revenue. This idea motivates an instrumental variables (IV) strategy that uses the interaction between total state appropriations for higher education and each institution's baseline dependence on state support to instrument for state funding. Our IV strategy discards variation in funding driven by policymakers' decisions about which institutions to support in particular years, and allows us to control for permanent differences across institutions, changes in outcomes common to all institutions within a state, and important time-varying determinants of the demand for higher education such as state and local unemployment rates. This approach parallels identification strategies commonly used in studies of local labor markets, immigration, and trade, which also construct instruments combining cross-sectional exposure with aggregate changes in the treatment of interest (Bartik, 1991; Blanchard and Katz, 1992; Card, 2001; Autor et al., 2013).

Schools can respond to budget cuts by reducing spending or raising tuition. The reduced form effect of a budget shock on enrollment measures the net impact of adjustments on both margins. Identification of the partial effects of prices and spending requires an additional instrument that induces independent variation in these two variables. To this end, we construct instruments for tuition using a newly assembled data source of tuition caps and freezes imposed by state legislatures. Using the budget shock and price cap instruments together in a two-stage least squares (2SLS) framework allows us to separately estimate the impact of a price change holding spending constant, and a spending change holding price constant.

We find large impacts of spending on student enrollment. Our estimates imply that a 10 percent increase in spending increases current enrollment by 3 percent, an effect that is similar for both two-year and four-year institutions. In contrast, estimated impacts of price changes are statistically insignificant. While we cannot reject modest price elasticities, our estimates are precise enough to reject equal elasticities of enrollment with respect to prices and spending at the five percent level.

We also find positive and statistically significant causal impacts of spending on degree completion, including bachelor's degrees. Our estimates imply an increase of one bachelor's degree for every \$145,000 to \$200,000 of additional spending, an effect that passes a benefit-cost test under conservative assumptions about the private labor market returns to college completion. We present suggestive evidence that spending impacts are driven mostly by increased persistence and degree completion among already-enrolled students, rather than increases in initial college matriculation. An analysis of impacts on nearby private institutions indicates that at most 20 percent of the impact of spending at public institutions can be explained by crowd-out of degrees from private schools. In other words, increased public funding of postsecondary institutions appears to increase total degree completion, rather than simply shifting students across sectors. Finally, we find no evidence of price or spending changes on financial aid, suggesting that changes in sticker price also lead to changes in the net price paid by students.

Our results relate to studies of "cohort crowding" and college quality, which find that changes in per-student spending and other measures of quality have contributed to declining college completion rates and increased time to degree over the last twenty years (Turner, 2004; Dynarski, 2008; Bound and Turner, 2007; Bound et al., 2010, 2012). The most closely related paper is by Bound and Turner (2007), who discuss the importance of resources and show that the supply of public funding for education responds inelastically to student demand. They find that larger state cohorts have lower degree attainment rates and argue that lower public subsidies per student are the key causal mechanism. Our work builds on Bound and Turner (2007) by providing direct evidence regarding the impact of public spending on degree attainment.

We find that changes in state funding lead to large impacts on core academic spending. Instruction alone accounts for about 40 cents of every dollar increase in spending. Moreover, we find that academic support spending - including tutoring, advising and mentoring - is particularly responsive to state budget shocks. This is important because a number of recent studies have found large impacts of student supports on persistence and degree completion (Angrist et al. 2009; Bettinger and Baker 2011; Carrell and Sacerdote 2013; Barrow et al. 2014; Scrivener et al. 2015). While ultimately the mechanisms are only suggestive, we argue that our results are most consistent with spending improving quality by lifting informal capacity constraints such as course waitlists and inadequate advising (e.g. Bound et al., 2012).

Further afield, our findings are also consistent with evidence that increased resources at primary and secondary schools boost educational attainment and other outcomes (Card and Krueger, 1992; Jackson et al., 2016; Lafortune et al., 2016). Finally, the results reported here may help explain findings from studies of merit aid and targeted grant programs, which typically show positive impacts on college enrollment but small or zero impacts on degree completion (Dynarski, 2008; Scott-Clayton, 2011; Sjoquist and Winters, 2012; Fitzpatrick and Jones, 2012; Cohodes and Goodman, 2014; Bettinger et al., 2016; Goldrick-Rab et al., 2016; Scott-Clayton and Zafar, 2016).

The rest of the paper proceeds as follows. Section 2 describes the data. Section 3 gives background information on state higher education budgeting processes and efforts to regulate tuition by state legislatures, along with a descriptive analysis of relationships between state appropriations, spending, tuition and enrollment. Section 4 lays out our strategy for estimating causal effects of spending and tuition, and explores the validity of our approach. Section 5 presents estimates of the effects of price and spending changes on enrollment and degree completion. Section 6 describes additional results and discusses some policy implications of our findings. Section 7 concludes.

2 Data

The data used here come from the Integrated Postsecondary Education Data System (IPEDS). IPEDS is a survey of colleges, universities and vocational institutions conducted annually by the U.S. Department of Education (DOE). The Higher Education Act requires postsecondary institutions to participate in IPEDS to retain eligibility to administer Federal Title IV student aid (Pell Grants and Stafford Loans).[3] IPEDS collects information on student enrollment overall and by race, gender, age and student status (part-time/full-time, freshman/continuing student, undergraduate/graduate, degree-seeking), as well as degree completion by level (certificate, associate's, bachelor's) and field of study. IPEDS also collects detailed information on institutional finances, including revenues and expenditures by source. IPEDS data on all variables relevant for our study are available back to 1990.

IPEDS collects data at the campus level using a unique longitudinal identifier, and includes basic information about each campus such as level, control, degree-granting status and geographic location. Campus-level data allows us to separate enrollment and finances for branch campuses of university systems.[4] We supplement the IPEDS data with state legislative appropriations data from Grapevine, an annual survey compilation of data on state support for higher education administered by the State Higher Education Executive Officers (SHEEO) Association and the Center for the Study of Education Policy at Illinois State University.[5] We also match the IPEDS to publicly available data on state and county unemployment rates collected by the Bureau of Labor Statistics, as well as annual data on state tax receipts and other forms of state government spending such as Medicaid. Finally, we match IPEDS to state- and county-level data from the Census and the American Community Survey (ACS).[6]

Table 1 presents descriptive statistics for our analytic sample. The first nine rows display financial information for public institutions by sector and selectivity. Selective public four-year universities are those ranked "Most Competitive" or "Highly Competitive" - the two highest categories - in the 2009 Barron's Profile

[3]Postsecondary institutions that do not administer Title IV aid are not required to report to IPEDS. There are many of these institutions, but they are very small and generally offer non-degree certificate programs and other short courses. Nearly all non-Title IV institutions are for-profit - see Cellini (2010) for a more detailed discussion.

[4]To ensure the accuracy and consistency of our data over time, we compare the raw IPEDS data to data from the Delta Cost Project (DCP), a collaboration between the DOE and the American Institutes for Research that makes IPEDS longitudinally consistent and matches branch campuses of individual institutions together. Jaquette and Parra (2016) show that the DCP database collapses multiple institutions within some public university systems into a single administrative unit, which would be problematic for our analysis. We therefore use the raw IPEDS data rather than the DCP, although results are generally similar in either case.

[5]The Grapevine data can be found at https://education.illinoisstate.edu/grapevine/historical/. We measure appropriations from Grapevine rather than IPEDS because of concerns about duplicate reporting of state funding across campus branches of institutions, as well as errors in administrator survey responses. IPEDS appropriations aggregated to the state-year level are similar to corresponding measures in Grapevine (the correlation equals 0.83).

[6]County identifiers appear in the IPEDS from 1990 to 1999, and then again from 2008 onward. For over 95 percent of institutions and 99 percent of publics, county codes were consistent in 1999 and 2008, and alternative measures of geography (MSA, address, city, zip code) also did not change. In these cases we interpolate county IDs for the intervening years. In the small number of cases where location changed or was missing, we use other institutions with the same alternative geography to fill in missing values. Geographic information is left missing in cases where we cannot reliably locate an institution.

of American Colleges. All financial data are in per-student terms, weighted by enrollment and adjusted for inflation using the Higher Education Price Index. Financial data are collected as of the fiscal year, which usually begins in July. Enrollment data are counted for the fall of each calendar year.

The sample is restricted to institutions in the 50 U.S. states (excluding Puerto Rico) and excludes schools with missing values for state appropriations in 1990. To address concerns about reporting and measurement error in IPEDS spending data, we also eliminate the less than 3 percent of institutions with per capita spending of less than \$100 or more than \$100,000 per college-age student in any year in the panel. Note that total spending includes capital costs such as operation and maintenance in addition to core academic functions.

Table 1 reveals four key facts. First, per-student spending in public institutions derives largely from three sources: state (and local) appropriations, tuition and fees, and financial aid grant programs (mainly Federal Pell Grants, but also including state and local grants). This is particulary true for less selective schools. In 1990, the combined contributions of these three categories to total spending at selective four-year, less selective four-year, and two-year institutions equaled 64, 79 and 90 percent, respectively. The relatively small contributions of other categories such as endowment spending means that budgets are strongly affected by cuts in state funding, especially for less selective institutions.

Second, more than half of total spending is accounted for by the core categories of instruction, academic support and student services, and the share of total spending devoted to these core categories has grown over time. Core academic spending is a higher share of total spending for less selective institutions. Third, while less selective schools receive much lower levels of state funding in dollar terms, they rely more heavily on state support. In 1990, state and local appropriations represented about 44 percent of total spending for selective four-year institutions, compared to 51 percent for less-selective four-year institutions and 62 percent for two-year institutions. This means that a state budget cut should have greater relative impacts on less selective institutions. Fourth, all types of public institutions received less public support and became more reliant on tuition revenue between 1990 and 2013.

It is clear from Table 1 that selective public institutions operate somewhat differently from less selective four-year and two-year institutions. Selective institutions charge much higher tuition and have many more alternative sources of revenue. For this reason, we exclude selective four-year public universities from the remainder of our analysis, although our results are robust to including them.

3 Background

3.1 Higher Education Appropriations and Tuition

Our description of state legislative higher education funding relies on a SHEEO survey of state budgetary processes (Parmley et al., 2009). While the details differ across states, a typical budgetary process unfolds as follows:[7]

1. One to two years in advance of the fiscal year, a state higher education coordinating board develops a budget request that covers all public institutions in the state.

2. The governor proposes a budget based on the request. The legislature then enacts its preferred budget, and the governor can subtract individual items or veto the budget entirely, while the legislature can accept (or override in some cases) the modified budget. Protracted negotiations are common and can become quite complicated.

3. The end result is a budget that is typically ratified in the spring and takes effect the following fall. A key source of uncertainty in this process is the possibility that budget requests will not be fully funded, and this is especially likely when tax revenues are less than expected.

An important difference between state and Federal budgeting processes is that states are mostly unable to smooth business cycle fluctuations in tax revenue. Nearly all states have some sort of balanced budget requirement, and higher education spending often serves as the "balance wheel" used to meet these requirements when tax revenues fall short of projections (Kane et al., 2003; Delaney and Doyle, 2011; Barr and Turner, 2013).

States differ markedly in their support for higher education. Appendix Figure A1 presents trends in per capita appropations in four large states. The figure shows substantial differences in levels of funding and in trends over time. For example, in California real per-capita state appropriations for higher education grew from around $5,000 in 1990 to over $6,000 in the early 2000s, before plummeting to less than $4,000 in 2013. In contrast, public support for higher education in Texas remained roughly constant at around $4,000 per student over this period. These heterogeneous patterns are typical of the wide variation in public higher education spending across states, even those with similar demographics.[8]

State policies influence both spending and tuition at public institutions. As noted by Bell et al. (2011), states vary in the extent of legislative control over tuition setting.[9] Tuition setting is generally less centralized than the state appropriations process, with institutions setting tuition either completely on their own or in

[7]The SHEEO survey, which received responses from 43 states, covers topics such as how budget requests are developed, how funds are administered across campuses, and which organizations have primary authority over spending and tuition setting. All but one surveyed state had a coordinating board of some kind. Institutions submit budget requests individually in only six states. Most respondents indicated that budget requests are based on past and future projections of enrollment, changes in costs such as salaries, and any special projects or initiatives. In 14 cases, respondents indicated that governors vetoed or reduced specific budget line items. The executive branch fully funded the initial budget request in about half of cases, and that number is slightly lower for the legislative budget. Open-ended responses to the survey indicated that economic conditions and other legislative priorities were key reasons that higher education budget requests were not fully funded.

[8]For example, appropriations per capita were about 50 percent higher in New Mexico compared to Arizona, and that gap has widened considerably since 2010. Arkansas, Tennessee and Kentucky all spent about $3,100 per capita in 1990. In the early 2000s Kentucky had the highest per capita spending (around $5,600, compared to $4,300 in Arkansas and $3,500 in Tennessee), but by 2013 Arkansas was spending the most ($5,500, compared to $4,700 in Kentucky and only $3,000 in Tennessee).

[9]Bell et al. (2011) describe a SHEEO survey of tuition, fee and financial assistance policies, which received responses from 35 states. Only four states indicated that formal tuition-setting authority for either the two-year or four-year sector lies with the legislature. In nearly all other states, tuition is set by the coordinating board in consultation with individual institutions, and changes in tuition are not necessarily uniform across institutions. In all but six of the states that responded, tuition revenue is controlled and retained by individual campuses.

non-binding consultation with the higher education coordinating board. However, state legislatures can exert formal control over prices through tuition caps, defined as statutory limits on increases in public college tuition from one year to the next. Tuition caps affect higher education budgets by shutting down one margin of adjustment. Institutions operating under a legislative tuition cap cannot respond to appropriations shocks by increasing prices, and thus are much more likely to cut spending.

Seventeen states imposed formal price controls on public institutions at least once between 1990 and 2013. The complete list appears in Appendix Table A1. We compiled these data by referencing official sources when available, combined with Lexis-Nexis searches of state newspapers going back to 1990. Some states impose uniform tuition caps, while others single out particular sectors or even institutions. Tuition caps appear to be more frequent in economic boom times (e.g. 1994-2000, 2006-2009), but there is no obvious geographic or demographic pattern in which states impose price caps. The five states with the highest (enrollment-weighted) exposure to tuition caps are Ohio, Idaho, Virginia, New York and Maryland. Across all years in our sample, about 9 percent of students were enrolled in public institutions operating under a legislative tuition cap or freeze.

3.2 Descriptive Analysis

To characterize the basic patterns in the data, we begin with a descriptive analysis of relationships between enrollment, spending and tuition based on the following simple panel regression:

$$Y_{i,t} = \gamma_i + \psi_t + \sum_{\ell=-L}^{L} \delta_\ell X_{i,t-\ell} + u_{i,t}, \tag{1}$$

where $Y_{i,t}$ represents log enrollment for institution i in year t, γ_i and ψ_t are institution and year fixed effects, and $X_{i,t}$ is log total spending or log tuition. The coefficient δ_ℓ describes the relationship between enrollment in year t and tuition or spending ℓ years earlier, controlling for permanent differences across institutions, changes over time common to all institutions, and tuition or spending in other years. Standard errors are clustered by institution.

Figure 1 plots estimates of equation (1), with coefficients arranged in event time so that positive indices correspond to lagged spending and tuition. The top panel shows results for log spending. Spending increases are correlated with contemporaneous increases in enrollment. The base year coefficient suggests that a 10 percent increase in spending in year t is associated with a 2.1 percent increase in enrollment in this year. Year t spending is also associated with smaller increases in enrollment in subsequent years. The bottom panel shows results for log tuition. A 10 percent tuition cut in year t is associated with a 0.24 percent enrollment increase in the same year. This estimate is somewhat smaller than estimates reported by Hemelt and Marcotte (2011), a study that uses a similar panel framework with additional controls and finds an elasticity of enrollment with respect to tuition equal to -0.08 for non-selective public institutions.

A key concern with interpreting the patterns in Figure 1 is that changes in tuition or spending may be correlated with unobserved determinants of changes in enrollment. For example, some institutions may be located in labor markets that experience changes in the demand for higher education. Changing demand would lead to simultaneity bias, with enrollment affecting tuition prices rather than tuition prices affecting enrollment. Similarly, spending may increase in anticipation of growth in demand, and increased enrollment tends to generate higher tuition revenue and therefore more spending, another reverse causality problem.

Indeed, the bottom panel of Figure 1 shows that higher tuition in year $t+1$ is associated with higher enrollment in year t, which suggests that institutions lower tuition both before and after increases in enrollment. Likewise, we find a statistically significant and positive pre-trend coefficient for the association between spending in year $t+1$ and enrollment in year t. Overall, the patterns in Figure 1 suggest that while enrollment tends to change contemporaneously with spending and tuition, naive regressions of enrollment on changes in spending and price should not be interpreted causally.

A possible solution to this endogeneity problem is to study changes in spending and prices that are induced by state-level policy changes. Figure 2 presents estimates of equation (1) with log total spending, log tuition and log enrollment as the dependent variables, and log state appropriations as the key right-hand side variable. As above, these models include institution and year fixed effects.

The top panel shows that state appropriations are strongly linked to current spending. A 10 percent increase in appropriations in year t is associated with a 3.1 percent increase in spending in the same year. The middle panel shows that state funding also affects tuition prices, with a 10 percent increase in appropriations linked to a price cut of about 0.6 percent. Finally, the bottom panel indicates that while increases in appropriations are linked to contemporaneous and later increases in enrollment, there is evidence of significant pre-trends.

Figure 2 shows that there are at least two problems with using changes in state appropriations to estimate the impacts of spending on college enrollment. First, as shown in the bottom panel, future appropriations changes predict current enrollment. This pattern may reflect funding decisions that anticipate changes in the demand for higher education. For example, state legislatures may allocate more total funds for higher education when enrollment is projected to grow quickly, or target extra funds to institutions within a state where demand is growing especially fast.

A second problem highlighted by Figure 2 is that even exogenous changes in state funding would not be sufficient to identify the effects of spending or tuition on enrollment. The top and middle panels show that institutions appear to adjust both spending and tuition in response to higher appropriations. The impact of state funding on enrollment therefore measures the net effect of both a spending increase and a tuition cut. This issue complicates the interpretation of studies that seek to study the effects of tuition or school resources in isolation (e.g., Hemelt and Marcotte, 2011): these variables tend to move together in response to changes in state appropriations, obscuring the partial effect of either variable. In the next section, we develop an instrumental variables strategy that combines a plausibly exogenous component of state funding with price variation from legislative caps and freezes to separate the impacts of spending and tuition.

4 Identification Strategy

4.1 Budget Shocks and Tuition Caps

As discussed above, state budget changes are typically - but not always - made "across the board" (i.e. all institutions in the state receive 90 percent of their funding request).[10] However, an across the board budget cut is likely to have a greater proportionate impact on institutions that rely on state appropriations for a larger share of operating revenue. Thus some schools' budgets are more sensitive to business cycle fluctuations than others. We exploit *ex ante* differences across institutions in their reliance on state revenue to estimate the impact of funding changes.

Specifically, we construct a budget shock instrumental variable (IV) that multiplies yearly state appropriations by each public institution's share of total revenue from state appropriations in 1990, the first year that IPEDS data are available. This instrument is constructed as

$$Z_{i,t} = \left(\frac{Approp_{i,90}}{Rev_{i,90}}\right) \times \left(\frac{StApprop_{s(i),t}}{Pop_{s(i),t}}\right), \tag{2}$$

where $Approp_{i,90}$ and $Rev_{i,90}$ measure state appropriations and total revenue for institution i in 1990, $s(i)$ denotes state for institution i, and $StApprop_{s,t}$ and $Pop_{s,t}$ represent total appropriations and college-age population for state s in year t. The first factor in (2) is each institution's revenue from state appropriations divided by total revenue in 1990. This captures a school's dependence on state funds at baseline. Using the 1990 revenue shares shuts down variation in exposure to state budget shocks that might be driven by endogenous institutional responses. For example, institutions might become more or less dependent on state appropriations over time based on changing selectivity, increased ability to attract out-of-state students, or other sources of unobserved heterogeneity.

The second factor in (2) calculates state appropriations per college-age (age 19-23) student in each state and year, using Grapevine data rather than institution-level appropriations from IPEDS. Restricting variation in state appropriations to the state-year level addresses the concern that schools receiving more or less funding within a particular state and year may differ in unobserved ways. For example, a budget cut for an individual institution may be more or less severe depending on the current political influence of its leadership. State legislatures might allocate additional funds to colleges in labor markets that have been hit particularly hard by economic downturns. Because of the timing of data collection mentioned above, estimated impacts of spending on contemporaneous enrollment are the impact of funding that arrives over the summer on enrollment the following fall.

Our second source of identifying variation leverages legislatively imposed tuition caps and freezes. We use the information in Table A1 to code two instruments related to tuition caps. The first, $TuitCap_{i,t}$, equals

[10] Despite the multiple rounds of negotiation and attention to specific line items, more than half of respondents to the 2009 SHEEO survey indicated that appropriations are distributed as lump sum amounts rather than individual line items that are earmarked for a particular use (Parmley et al. 2009). In some cases, appropriations are distributed to the coordinating board to disburse to schools, while in other cases funding goes directly to schools.

one if institution i is subject to a cap or freeze in year t. The second, $TuitMax_{i,t}$, equals the maximum percentage increase allowed by the state legislature between years $t-1$ and t for institution i. For example, this variable equals zero for institutions subject to tuition freezes, and 0.1 for institutions where tuition growth is constrained to no more than 10 percent. We include both of these variables in our estimating equations and code $TuitMax_{i,t}$ to zero for cases where $TuitCap_{i,t} = 0$. Thus the coefficient on $TuitCap_{i,t}$ can be interpreted as the impact of a tuition freeze, i.e. when the maximum percentage increase allowed equals zero. The combination of these two variables allows us to exploit variation in both the existence and intensity of tuition cap legislation.

4.2 Assessing the Validity of the Instruments

The instrument defined in equation (2) can be viewed as a shock to the supply of funds available for higher education. Thus the key threat to validity is that the instrument is correlated with determinants of the demand for college. We use this instrument to estimate the impact of state budget shocks in a panel framework, with institution and year fixed effects. Institution fixed effects control for permanent differences in productivity and other unobserved determinants of the demand for college.[11]

One possible threat to the validity of the instrument is that institutions with greater baseline reliance on state appropriations may be more sensitive to business cycle-driven demand fluctuations. For example, schools that are more reliant on state appropriations might be located in areas that experience greater local economic shocks during recessions and expansions.

We assess this concern by regressing the budget shock instrument on both state and county unemployment rates, controlling for institution effects, year effects, state-specific trends, and institution and county covariates:

$$Z_{i,t} = \Gamma_i + \Psi_t + \xi_{s(i)} \times t + W'_{i,t}\Theta + \tau_1 StUR_{s(i),t} + \tau_2 CtyUR_{c(i),t} + e_{i,t}. \tag{3}$$

Here $StUR_{st}$ and $CtyUR_{ct}$ measure unemployment rates in year t for state s and county c, respectively, and $c(i)$ denotes the county for institution i. The vector $W_{i,t}$ includes time-varying institution characteristics such as highest degree offered and eligibility to distribute Federal financial aid, county average demographic and economic characteristics, and interactions of these variables with time.[12] We also control for state-specific linear time trends, represented by $\xi_{s(i)} \times t$. Standard errors for this analysis are clustered at the state-year

[11] If we regress 1990 budget shares (the first factor of the instrument) on state fixed effects and institution and county covariates, we find that the strongest predictor of dependence on state appropriations is selectivity, with two-year schools having the highest revenue shares. Dependence on state appropriations is also higher for institutions in counties with high shares of nonwhite and poor residents. In our analytic sample, the mean revenue share of state appropriations in 1990 was 0.438 with a standard deviation of 0.163. The standard deviation is 0.126 after controlling for state fixed effects.

[12] The institutional covariates are sector, highest degree offered, Title IV eligibility, degree-granting status, urban status and indicators for missing values of these covariates in each year. These covariates rarely change within institutions over time, but we include them for completeness. The county covariates are log population, percent black, percent hispanic, percent male, percent below the poverty line, log median income, share with some college education, and share with bachelor's degree. County covariates are only available from the U.S. Census for 1990 and 2000, and from the ACS for 2005 and onward. To complete the county data, we linearly interpolate values for missing years.

level.[13] Here and in our subsequent results, we divide $Z_{i,t}$ by 1,000 for ease of interpretation.

Estimates from equation (3) appear in the top panel of Table 2. Column 1 presents results with no controls other than state and year fixed effects. There is a clear negative relationship between the state unemployment rate and state higher education funding. A one percentage point increase in the state unemployment rate is associated with a decline in the state budget shock of 0.096, which is a change of about 0.1 standard deviations. There is a smaller but statistically significant positive relationship between county unemployment rates and the budget shock. Column 2 shows that these coefficients change very little when we control for time-varying institution and county characteristics. Column 3 adds state-specific linear time trends. With the addition of these controls, we no longer find a statistically significant relationship between state or local unemploment rates and the budget shock IV. We therefore include state trends in our main analyses.

The bottom panel of Table 2 present analogous estimates of equation (3), with the dependent variable equal to an indicator for the existence of a tuition cap in state s and year t. Since the tuition caps vary mostly at the state-year level, we do not include the county unemployment rate in these specifications. As with our budget shock IV, the key threat to validity is that the timing of tuition caps is correlated with changes in the demand for higher education. We find no evidence of a correlation between state economic conditions and the existence of a tuition cap, and this conclusion holds both in the simple model in column 1 and the heavily-controlled model in column 3.

4.3 Reduced Form Estimates and Tests for Pre-Trends

Table 2 shows that - conditional on controls - our instruments are uncorrelated with time-varying local economic conditions. Yet it is still possible that budget shocks and price caps are correlated with unobserved time-varying determinants of the demand for education. To assess this concern, we test directly for pre-trends with the following reduced form model:

$$Y_{i,t} = \alpha_i + \mu_t + \zeta_{s(i)} \times t + W_{i,t}'\theta + \sum_{\ell=-L}^{L} \left[\rho_\ell^Z Z_{i,t-\ell} + \rho_\ell^C TuitCap_{i,t-\ell} + \rho_\ell^M TuitMax_{i,t-\ell}\right] + v_{i,t}. \quad (4)$$

The vector $W_{i,t}$ is now augmented to include the unemployment rates from equation (3). The coefficients on the leads of the policy variables check whether there are differential prior trends in outcomes for institutions that later experience differential changes in the instruments. Our baseline model includes 4 leads and 5 lags of each instrument and both unemployment rates (for ten years total), although our results are not sensitive to this particular number of years.

Figure 3 presents estimates of equation (4) for log enrollment, our key outcome of interest. The top panel shows coefficients and 95 percent confidence intervals for the budget shock instrument, while the middle and bottom panels show results for the tuition cap indicator and the maximum tuition increase. In contrast to the results using actual appropriations in Figure 2, we find no evidence of pre-trends in the relationship

[13] The results here and throughout the paper are robust to clustering at the institution level, state-year level, or both.

between the budget shock and log enrollment. The coefficients on all four leads are near zero and not statistically significant. We fail to reject the hypothesis that all four pre-trend coefficients are jointly equal to zero ($p = 0.64$). Additionally, we find a positive impact of the budget shock on log enrollment in the same year. This estimate, which is statistically significant at the one percent level, implies that a $1,000 increase in the instrument increases enrollment in year t by 2.8 percent. We also find statistically significant and positive impacts of the budget shock on enrollment in future years.

The second and third panels of Figure 3 show no evidence of pre-trends in the relationship between the tuition cap instruments and log enrollment. All of the pre-trend coefficients are close to zero and statistically insignificant, and we fail to reject the joint hypothesis that they are jointly equal to zero in both cases ($p = 0.73$ and 0.47 for the tuition cap indicator and maximum tuition increase). Unlike the budget shock, however, we find no reduced form impact of tuition caps on log enrollment.

Figure 4 repeats the exercise above for another key outcome - total degrees and certificates awarded. While there is no contemporaneous impact of the budget shock instrument on degrees and certificates, we do find statistically significant positive impacts of a budget shock in year t on degrees in years $t+1$ and $t+5$ of 41 and 27 awards per $1,000 respectively. We reject the hypothesis that the sum of the coefficients on degrees and certificates in years t through $t+5$ equals zero ($p = 0.00$). Moreover, we fail to reject the joint hypothesis that the pre-trend coefficients are all equal to zero ($p = 0.84$), and there is no visual evidence of pre-trends. As with enrollment the middle and bottom panels of Figure 4 show no consistent impact of tuition caps on total awards. While there is some evidence of a negative impact of a tuition freeze in later years, we fail to reject the hypothesis that the sum of the coefficients in years t through $t+5$ is equal to zero ($p = 0.82$). Together, the results in Figures 3 and 4 show that our policy instruments are unrelated to pre-trends in key outcomes.[14]

The analysis to follow uses budget shocks and tuition caps as instruments for tuition and spending. To explore the first stage relationships underlying this strategy, Figures 5 and 6 present estimates of equation (4) for log total spending and log tuition. The top panel of Figure 5 shows clear evidence that the budget shock IV affects total spending. The coefficients in Panel A imply that a $1,000 increase in the instrument increases spending in year t by 6 percent. We also find smaller but still statistically significant impacts on spending in the second and fifth years following the budget shock.

The middle and bottom panels of Figure 5 show some evidence that tuition caps affect spending. However, we also find negative coefficients on the leads of tuition caps and positive coefficients on the leads of the maximum tuition cap amount, which suggests that the impact of tuition caps on log spending may reflect a longer-run trend rather than a sharp policy response. This is less worrisome than a pre-trend for enrollment, because the key exclusion restriction required for our approach is that the instruments are conditionally uncorrelated with potential enrollment and degree outcomes. Nonetheless, the pre-trends in Figure 5 suggest

[14] Figure A2 assesses the sensitivity of these findings to functional form by reestimating equation (4) with the enrollment level rather than its log as the dependent variable. Figure A3 repeats the exercise but with log total degrees and certificates. These analyses yield similar conclusions.

that the tuition cap instruments are not as good as random conditional on our control variables. We address this issue below by estimating first-differenced models, which focus on sharper yearly changes in the policy IVs and endogenous variables.

Figure 6 presents results for tuition prices. We find that a $1,000 increase in the budget shock in year t decreases tuition in year t by 4.8 percent and year $t+1$ by 5.8 percent. The impact is closer to zero in subsequent years. This suggests that public institutions react to state budget cuts in part by increasing tuition to make up for lost revenue. The middle and bottom panels of Figure 6 show that the tuition cap instruments have bite: prices are significantly lower following the imposition of a tuition freeze. Moreover, conditional on the presence of a cap, the level of the cap is strongly predictive of yearly tuition increases. There is a strong and immediate impact of the instruments in all three panels of Figure 6, and little evidence of pre-trends.[15]

The patterns in Figures 3 through 6 are robust to a number of alternative specifications and modeling choices. These results are also similar when we exclude covariates or add lags and leads of census variables. However, our findings are sensitive to controls for state-by-time variation. Specifically, state-specific linear trends are necessary to eliminate pre-trends in Figures 3 through 6 in many cases. In principle, we could include a full set of state-by-year fixed effects for models including the budget shock IV. It is not possible to control for state-by-year fixed effects when studying the impact of tuition caps, however, because these vary primarily at the state-year level. To probe the robustness of our estimates to alternative state-by-time controls, we estimate versions of equation (4) with state-by-four-year-period fixed effects (1990 to 1993, 1994 to 1997, etc.) instead of state trends. Those results - reported in Appendix Figures A4 through A7 - are generally very similar to our main findings.

4.4 Two-stage Least Squares Framework

Public institutions can respond to budget cuts through a combination of price increases and spending cuts. Tuition caps generate independent variation in tuition prices. Thus we can use the budget shock together with the price cap instruments to disentangle the causal impacts of spending and tuition. To this end, we estimate 2SLS models relating changes in outcomes to changes in spending and tuition, instrumented with policy variables. The first stage equation for log spending is:

$$\triangle \log spend_{i,t} = \phi_{s(i)} + \omega_t + \Delta W'_{i,t}\lambda + \pi_1 \triangle Z_{i,t} + \pi_2 \triangle TuitCap_{i,t} + \pi_3 \triangle TuitMax_{i,t} + \eta_{i,t}. \qquad (5)$$

This equation relates the change in spending relative to the previous year to changes in the budget shock

[15] The middle panel of Figure 6 shows some evidence of a pre-trend in the relationship between tuition caps and tuition - but in the opposite direction of the estimated impact of imposing a cap. This suggests that tuition caps may be imposed in response to particularly high tuition in a prior year. Since pre-trends can be interpreted as evidence of anticipation effects (e.g. Malani and Reif 2015), one possible concern is that students may time enrollment decisions in response to anticipated price changes. We address this concern in two ways. First, we estimate 2SLS models in differences, which focuses attention only on sharp yearly changes in tuition. Second, we address the sensitivity of the differences specification by excluding the first lead and using the difference between the 2nd lead and the base year as the endogenous first stage variable in Section 5. This leaves the results nearly unchanged.

and tuition cap instruments, controlling for state and year fixed effects and changes in covariates. The first stage equation for changes in tuition replaces the change in log spending with the change in log tuition on the left-hand side of (5).

The second stage equation is:

$$\triangle Y_{i,t} = \Phi_{s(i)} + \Omega_t + \Delta W'_{i,t}\Lambda + \beta_1 \Delta \log \widehat{spend}_{i,t} + \beta_2 \Delta \log \widehat{tuition}_{i,t} + \epsilon_{i,t}, \tag{6}$$

where $\Delta \log \widehat{spend}_{i,t}$ and $\Delta \log \widehat{tuition}_{i,t}$ are predicted changes in log spending and log tuition from the first stage. Compared to the fixed effects specifications discussed in Section 4.3, the first-differences specifications in (5) and (6) focus on the impacts of sharp yearly changes in the instruments on the endogenous variables and outcomes. When using only two years of data, the two approaches are equivalent; in our longer panel, the first differences model may be less efficient but captures causal effects under less restrictive assumptions. In general, our results are similar when we estimate 2SLS models in first differences or in levels with institution fixed effects, year fixed effects and state-specific linear trends as in equation (4).

5 Effects of Price and Spending Subsidies

5.1 Two-stage Least Squares Estimates for Enrollment

Table 3 reports first-stage impacts of the budget shock and tuition cap instruments on log spending and tuition, along with second-stage impacts on log enrollment. The first stage effect of the budget shock on spending, reported in column 1, equals 0.061. This implies that a $1,000 increase in the instrument increases total spending by about 6.1 percent. Since mean total spending is about $104 million per year for the institutions in our analysis sample, a 6.1 percent increase is about $6.34 million in additional spending. In contrast, the tuition cap variables are weakly related to log spending.

As shown in column 2, a $1,000 increase in the budget shock decreases log tuition by 8.1 percent, or about $303. Tuition freezes lower in-state tuition by about 3 percent. The stringency of the cap strongly predicts the size of the tuition change: a ten percentage point increase in maximum tuition growth leads to a 3 percent increase in tuition. Both instruments are jointly highly statistically significant, and Angrist and Pischke (2009) partial F-statistics indicate that the instruments generate substantial independent variation in log tuition and log spending.

The second-stage estimates imply that enrollment is more sensitive to spending than to tuition. As can be seen in column 3 of Table 3, a 10 percent increase in log spending increases current-year enrollment by 3 percent, and this estimate is statistically significant at the 5 percent level. In contrast, the estimated elasticity of enrollment with respect to tuition is close to zero and statistically insignificant. The standard errors allow us to reject impacts of a 10 percent tuition cut larger than about 1.7 percent. We can also reject that the elasticities of enrollment with respect to tuition and spending are equal in absolute value

($p < 0.01$). Importantly, this null result for tuition holds despite the strong first stage predictive power of the instruments shown in column 2.

5.2 Enrollment Effects Over Time

Table 4 reports impacts on log enrollment for up to three years after changes in tuition and spending. Columns 1 through 4 report separate estimates for years t through $t + 3$ based on the 2SLS framework in equations (5) and (6). Differences for the outcomes here are taken relative to the base year before the policy variables are measured, so that the specification for year $t + 1$ uses $Y_{i,t+1} - Y_{i,t-1}$ as the dependent variable, and similarly for other years. Panel A shows results for the full sample of institutions. Overall, we find that spending increases have larger impacts on enrollment in subsequent years. The coefficient on log enrollment increases from 0.3 in the base year to 0.8 one year after the change (p<0.001), with modest increases thereafter. This suggests that the new students induced to attend by changes in state funding persist for multiple years of enrollment. In contrast, the coefficients on tuition in subsequent years are small, never statistically significant, and sometimes wrong-signed.

Panels B and C show results separately for two- and four-year institutions. In both cases, we find large and statistically significant impacts of spending on enrolllment, but little or no impact of price. We find larger impacts of spending at two-year institutions than at four-year institutions. The coefficients in Panel B for two-year institutions suggest that a 10 percent increase in total spending in year t boosts enrollment by around 10 percent in years $t + 1$ through $t + 3$. Corresponding estimates for four-year institutions are smaller but still substantial: a 10 percent increase in spending in year t increases enrollment by 2.3 percent in year t, 4.5 percent in year $t + 1$, 6.5 percent in year $t + 2$ and 5.5 percent in year $t + 3$. All four of these estimates are statistically significant at the one percent level.

While these estimates are large, it is important to note that they reflect increases in total enrollment-years, not individual students. If changes in spending induce students to matriculate or to persist through college, this will affect enrollment counts in multiple years. Additionally, the log differences specification implies that a spending shock in year t leads to a persistent 8 percent enrollment gain relative to year $t - 1$, not continued growth of 8 percent in each subsequent year. A related issue is that spending shocks are serially dependent, so that changes in state funding are likely to persist for multiple years. We discuss this issue further in Section 6.

The outcomes in Table 4 capture total fall enrollment, including part-time, non-degree and graduate students. Appendix Table A2 presents additional results for part-time and full-time undergraduate enrollment. Undergraduates account for about 92 percent of total enrollment in the sample. About 45 percent of undergraduates are enrolled part-time, and this breaks down sharply by institution type, with 63 percent of undergraduates enrolled part-time at two-year colleges compared to only 24 percent at four-year colleges. We find that the large impacts of spending at two-year institutions are driven by increases in part-time enrollment, while impacts at four-year institutions are due to increases in both part-time and full-time undergraduate enrollment. Moreover, while most of the estimated tuition elasticities are small and statistically insignificant, Appendix Table A2 shows statistically significant effects of price changes on part-time enrollment at four-year institutions. This is consistent with Seftor and Turner (2002), who find greater price sensitivity among older, independent students who are more likely to be enrolled part-time.

5.3 Impacts on Certificates and Degrees

Table 5 shows that increases in spending boost degree attainment in addition to college enrollment. Panel A shows results for certificates, and Panel B shows results for associate's degrees - both within the sample of two-year institutions. We find that a 10 percent increase in total spending in year t leads to an average increase of only 3.7 certificates in year t, but 60.1 certificates awarded in year $t+1$. The impacts on certificates in subsequent years remain positive, but only the impact in year $t+1$ is statistically significant at the 10 percent level. This mirrors the pattern of reduced form results for the budget shock in Figure 4. We find a similar pattern of results for associate's degrees, with impacts that are generally positive but only statistically significant in year $t+1$.

The impacts of spending on certificate and associate's degree completion, while relatively short-lived, are substantial. Two-year institutions in our sample award about 259 certificates and 525 associate's degrees per year on average. Thus a 10 percent increase in spending in year t boosts the number of certificates completed in year $t+1$ by about 23.2 percent and the number of associate's degrees completed by about 10.6 percent. There is no statistically significant impact of price changes on certificates or associate's degrees in any year.

Panel C reports results for bachelor's degrees. We find no effect of either spending or price changes in year t on bachelor's degrees awarded in year t or $t+1$. However, we find positive and statistically significant impacts of spending in year t on bachelor's degree receipt in year $t+2$ (694, $p=0.02$) and $t+3$ (546, $p=0.09$). The non-selective four-year institutions in our sample award an average of 1,425 bachelor's degrees per year. Thus a 10 percent increase in spending increases bachelor's degrees awarded in years $t+2$ and $t+3$ by 4.9 percent and 3.8 percent, respectively. Impacts on bachelor's degrees awarded in years $t+4$ and $t+5$ are also positive and similar in magnitude, but not statistically significant.[16]

In contrast, the estimated effects of tuition on bachelor's degree attainment are always statistically insignificant. Appendix Table A3 presents results with log total awards as the outcome, both overall and separately for two-year and four-year institutions. The log specification yields results that are similar to the estimates in Table 5, both in magnitude and precision.

The estimated impact of spending on degree receipt is a combination of extensive margin impacts on initial enrollment and intensive margin impacts on persistence and degree completion among students who are already enrolled. Since most bachelor's degrees take a minimum of four years to complete, the positive and statistically significant coefficients in years $t+2$ and $t+3$ strongly suggest that spending increases

[16] When we estimate models like those in Table 5 for bachelor's degree receipt in future years, the coefficients and standard errors for the impact of log total spending on bachelor's degree receipt in years $t+4$,$t+5$, and $t+6$ are 550 (396), 553 (496), and 36 (499).

persistence among currently-enrolled students. We discuss this in more detail in the next section.

6 Additional Results and Discussion

6.1 Spillover Impacts on Private Institutions

A key question is whether price and spending changes in public institutions have spillover impacts on nearby private institutions. We test for spillovers by estimating the impact of public budget shocks and tuition caps on enrollment in private institutions. Specifically, we compute the average (enrollment-weighted) budget shock for all public institutions in a county, and create an indicator for whether any public institution in the county was operating under a tuition cap. We then estimate the differences model in equation (5) with these modified IVs on the right-hand side and enrollment and degrees in private institutions on the left. Unfortunately, data limitations preclude us from estimating a similar equation for spending at private institutions. However, we are able to estimate impacts on enrollment and prices at private schools.

As can be seen in Table 6, we find limited evidence of spillovers. Panel A shows impacts on log total enrollment in private (not-for-profit and for-profit) institutions. A comparison of the year t enrollment impact in column 1 of Panel A to the reduced form impact of the budget shock IV on public enrollment suggests that crowd-out of private school enrollment accounts for approximately 60 percent of the effect of the shock on current enrollment. However, this same calculation for years $t+1$ and later yields a spillover effect that is near zero and in the wrong direction. We find no initial impact of public tuition caps on private enrollment, although there is some suggestive evidence that public sector tuition caps negatively affect private sector enrollment in later years.

Panels B and C show impacts on two-year awards (certificates and associate's degrees) and bachelor's degrees for private institutions. The coefficient in column 2 of Panel B, while not statistically significant, implies that about 25 percent of the impacts on public two-year awards in year $t+1$ reflects crowd-out of private awards. Similarly, the estimates in Panel C for years $t+2$ and $t+3$ imply that about 20 percent of the impact of spending on bachelor's degrees reflects crowdout of degrees from private institutions. However, none of those estimates are statistically significant.[17] We find no consistent evidence that public tuition caps affect private enrollment or degrees, although the coefficients are consistently negative in later years. Finally, in Panel D we do not find an impact of public budget shocks or of tuition caps on tuition for private institutions.

Our results contrast somewhat with Cellini (2009), who finds that for-profit college enrollment responds to changes in local funding of community colleges in California. Interestingly, we do find somewhat larger impacts on private institutions when we restrict the sample to California. However, our confidence intervals

[17] For column 2 of Panel B, multiplying the coefficient of -3.45 by the ratio of private schools to public schools (3.3) yields 11.39, which is about 25 percent of the combined reduced form impacts on certificates and awards from Table 5 (45.10). For columns 3 and 4 of Panel C (bachelor's degrees), the summed impact of -3.11 times 3.3 equals 10.26, which is about 20 percent of the combined reduced form impact on public bachelor's degrees in Table 5 (51.36) in years $t+2$ and $t+3$.

for the full sample do not allow us to reject estimates that are equal to the magnitudes in Cellini (2009).

6.2 Impacts On Financial Aid and Spending by Category

Our price cap instruments affect tuition sticker prices, not the net price offered to students. Thus one possible explanation for our small estimated tuition effects is that colleges adjust sticker and net prices differently in response to tuition caps. For example, institutions might offset overall price changes by targeting additional financial aid to students who are most likely to benefit from it. Relatedly, a possible mechanism for the positive impacts of spending increases is that the extra state funds are used to price discriminate more effectively by targeting marginal students.

We test for changes in financial aid in Table 7 by estimating the 2SLS system in equations (5) and (6) with institutional spending and revenue categories as outcomes. Panel A shows results for all institutions, while Panels B and C split the sample into two-year and four-year institutions. The first three columns show results for institutional scholarships, Pell grants and total financial aid. We find no overall impacts of changes in prices or spending on financial aid. However, we do find that a 10 percent increase in spending increases institutional aid by 11.8 percent in four-year institutions. Since scholarship aid is about 4.6 percent of total spending at public institutions, a $1 increase in spending yields about 5.4 cents in additional scholarship funds. Targeted financial aid therefore accounts for a small share of the impact of spending on enrollment and degree completion in four-year institutions.

The null impacts on total financial aid in Column 3 imply that public institutions are generally unable to buffer changes in tuition sticker prices with scholarships and other sources of aid. This suggests that changes in the posted tuition price generally lead to changes in net price, although we cannot rule out the possibility that schools use additional funds and tuition increases to engage in revenue-neutral price discrimination.

Interestingly, we find little impact of changes in price or spending on Pell Grant aid. Although the estimated price effects here are never statistically significant, they are consistently negative. This is puzzling, because price increases should be partially offset by an increase in Pell Grant aid dollars. In fact, in a 1987 *New York Times* opinion piece, then-Secretary of Education William Bennett famously claimed that U.S. colleges and universities intentionally raise tuition to capture Federal aid dollars (Bennett, 1987). While Cellini and Goldin (2014) find evidence that for-profit institutions raise tuition in response to increases in Federal aid, Turner (2013) finds that public institutions capture less than 5 percent of Pell Grant increases through price discrimination. One possible explanation is that tuition increases lead to compositional changes in the student body, with fewer Pell-eligible students enrolling and thus a reduction in total Pell Grant dollars.

Columns 4 through 6 of Table 7 present results for selected categories of institutional spending. In general, we find increases in core academic spending categories that are roughly proportional to the total increase in spending. Instructional spending constitutes about 41 percent of total spending across all public institutions in the sample, and so the estimates in Column 4 imply that instructional spending increases by about 40 cents for every dollar of total spending. We find particularly large increases in academic support spending, category that includes activities such as tutoring, mentoring and counseling services. The estimates here indicate that a 10 percent increase in total spending increases academic support spending by 17 percent, which implies an increase of about 11 cents for every dollar. Overall, the results by spending category in Table 7 suggest that changes in state funding have large impacts on core academic spending at non-selective public institutions.

6.3 Interpreting Magnitudes

Our results can be used to compare the impact of tuition subsidies to revenue-neutral increases in per-student spending. For illustrative purposes, consider the impact of a $1,000 per student tuition subsidy on current enrollment. The estimates from Table 3 imply that this would increase enrollment by a total of 40 students, and would cost the average institution about $8 million in revenue.[18] The equivalent dollar amount distributed as a spending subsidy would increase enrollment by 187 students.[19] Thus spending has a larger per-dollar impact than price on total enrollment, even contemporaneously. The larger coefficients on spending relative to price in subsequent years shown in Table 4 magnify this conclusion.

The estimates in Table 5 can also be used to compare the cost of increasing degree attainment via public spending to projections of the lifetime earnings gains associated with a college degree. The sum of the spending coefficients for bachelor's degrees in Panel C of Table 5 yields a total increase of 134 bachelor's degrees for a 10 percent increase in spending in year t. Since the average non-selective four-year institution in our sample spends $196 million per year, the implied cost per bachelor's degree is $146,269. A complication is that budget shocks are serially dependent, so that increased spending in one year translates into further spending in future years. In results not reported, we adjust for the persistence of budget shocks and degree effects by directly estimating the extent of serial correlation, and find a total cost per degree equal to roughly $200,000, only modestly higher than our baseline estimate.[20] For purposes of comparison, dividing average total yearly spending at non-selective four-year institutions by the average number of bachelor's degrees awarded per year yields an implied cost of $141,516 per degree. The average cost of a bachelor's degree is therefore slightly smaller than our estimated marginal costs.

Avery and Turner (2012) estimate lifetime net returns to bachelor's degree receipt under a variety of assumptions about discount rates and heterogeneous returns to ability. Their most conservative projections imply returns of around $250,000 in present value, with the median estimate around $450,000 for women

[18] Mean enrollment in our sample is 8,114 and mean inflation-adjusted tuition is $3,738, yielding total revenue of $30.3 million. A $1,000 tuition cut lowers tuition to $2,738 and increases enrollment by $(1,000/3,738) \times 0.0017 = 0.45$ percent, or about 40 students, yielding total revenue of $(8,114 + 40) \times (2,738) = \$22.3$ million in year t.

[19] $8 million represents a spending increase of about $(8/104) = 7.7$ percent for the mean public institution in our sample. This spending increase multiplied by the coeffiient on enrollment in Table 2 yields an enrollment increase of 2.3 percent, or about 187 students.

[20] We assess persistence by estimating versions of equation (4) treating future budget shocks as outcomes. This exercise shows that budget shocks are persistent; for example, regressing $Z_{i,t+1}$ on $Z_{i,t}$ plus five additional lags and lags of the tuition cap instruments yields a coefficient of 0.55, suggesting that about 55 percent of the budget shock persists into the next year. Summing the coefficients from similar models for years $t+1$ through $t+4$ yields a total of 0.94. This suggests that accounting for serial dependence roughly doubles the impact of the budget shock IV on costs. Dividing the sum of the coefficients on bachelor's degrees for years t through $t+4$ (1,890) by 1.94 equals 974, which implies a cost of $201,185 per bachelor's degree. The dollar cost per degree would be somewhat smaller if we considered impacts in years $t+5$ or later.

and \$600,000 for men. Thus the private return on public investment in the production of bachelor's degrees passes a benefit-cost test under conservative assumptions.

Another way to assess the magnitude of our estimates is to compare them to the cross-sectional relationship between per-student spending and bachelor's degree completion rates at non-selective four-year institutions. We regress degree completion rates for the four-year institutions in our sample on log total spending and log tuition, controlling for other covariates.[21] This regression shows that a 10 percent increase in total spending is associated with a 0.52 percentage point increase in the graduation rate ($p < 0.01$). A 0.52 percentage point increase yields an additional 34.8 bachelor's degrees per year for a four-year institution of average size. By comparison, the estimates in Table 5 imply that a 10 percent increase in spending generates about 33.5 additional bachelor's degrees per year. Thus the cross-sectional relationship between spending and degree completion closely matches the magnitude of the IV estimates in Table 5. This suggests that the observed correlation between spending and graduation rates for non-selective institutions may be largely due to causal effects of spending rather than selection bias.

6.4 Discussion

The pattern of results reported here helps explain several trends and stylized facts in U.S. higher education. In view of the recent decline in spending at public institutions, our findings provide a possible explanation for increases in time to degree at nonselective public institutions, as well as the decline of college completion rates over the last 25 years (Turner, 2004; Dynarski, 2008; Bound et al., 2010, 2012). The importance of spending for increasing graduation rates also explains the dramatic success of programs like the Accelerated Study in Associate Prorams (ASAP), which provided comprehensive academic and support services to students in the City University of New York (CUNY) community college system. A randomized evaluation found that CUNY's ASAP program increased associate's degree completion rates by 84 percent (Scrivener et al., 2015). However, the program also increased average spending per full-time equivalent student by about 67 percent over two years (Levin et al., 2012). If we sum the coefficients on associate's degrees in columns 1 and 2 of Table 5 (Panel B) and multiply this by 0.67, we obtain a coefficient of 424, which is an increase of about 81 percent relative to the average number of associate's degrees awarded at two-year institutions in our sample. Thus the magnitudes of our estimates are comparable to the results from the CUNY ASAP program.

While it is easy to understand why price changes might affect student enrollment choices, the impact of spending is less obvious. One possibility is that students observe spending increases through smaller classes, increased course offerings or other amenities, and make matriculation decisions accordingly. This seems unlikely to be the main explanation for our results, for three reasons. First, while we do find contemporaneous impacts of spending on total enrollment, these are smaller than impacts in subsequent years. This suggests

[21] This exercise uses the 200 percent IPEDS graduation rate file, which computes the share of an initial cohort of full-time, degree-seeking undergraduates that complete a bachelor's degree within 6 years of entry. IPEDS began collecting graduation rate data in 2002. In addition to log total spending and log tuition, we also control for county demographics, institution sector and selectivity, highest degree offered, urban status, and state and year fixed effects.

that the impacts of spending on enrollment might be driven by longer-run changes in course staffing or program offerings. Second, since median time to bachelor's degree completion in the U.S. is about five years, large causal impacts on bachelor's degrees awarded two and three years after a spending increase suggests that the mechanism is persistence among already-enrolled students. Third, in results not reported we find suggestive evidence of larger impacts on enrollment for upper division students compared to freshmen.[22]

Spending cuts could affect persistence and degree completion through formal capacity constraints at overcrowded public institutions. For example, Bound et al. (2012) find that open-access institutions in California have turned students away in recent years because of budget cuts. However, we think this is unlikely to fully explain our results, for two reasons. First, a literature review and Lexis-Nexis newspaper search turned up little evidence of formal capacity constraints, and all of the existing evidence comes from recent years and from a very small number of states. Second, the fact that we find increases in persistence for currently enrolled students suggests that not all of our results can be explained by formal capacity constraints.

Our results are consistent with the much broader trend of informal capacity constraints in public institutions, including reduced course offerings, long waitlists, little or no student guidance, and larger class sizes (Bahr et al., 2013). Bound and Turner (2007) argue that informal capacity constraints caused by "cohort crowding" dilute college quality, while Bound et al. (2010) argue that resources per student and other supply side factors explain a large portion of the decline in college completion rates between 1972 and 1992. Bound et al. (2012) assemble qualitative evidence from 12 states which suggests that inadequate student advising, decreased course availability and overcrowding have contributed to recent increases in time to degree in public universities. Unfortunately, IPEDS data do not contain information about course waitlists or student advising loads. The fact that we find particularly large increases in academic support spending, and that student advising and mentoring programs have been highly successful in other settings, suggests that informal capacity constraints may be an important driver of our results (Angrist et al. 2009; Bettinger and Baker 2011; Carrell and Sacerdote 2013; Barrow et al. 2014; Scrivener et al. 2015).

7 Conclusion

This paper studies the impacts of changes in prices and spending on U.S. postsecondary attainment. Using differential exposure to state budget shocks across institutions combined with a newly assembled data set of legislative tuition caps, we estimate the partial effects of changes in prices and spending on enrollment and degree completion. We find large causal impacts of spending - but not tuition - on these outcomes. This pattern holds for both two-year and four-year institutions and across all types of degrees and certificates.

Our results suggest that efforts to reduce college costs - holding spending constant - may have little

[22] 2SLS estimation of equations (3) and (4) with full-time undergraduate enrollment in year t as the outcome yields coefficients on upper division enrollment about four times larger than the impacts on freshmen enrollment. However, the impacts on freshmen and upper division students are difficult to study over multiple years of data, because upper division enrollment is conditional on first being a freshman.

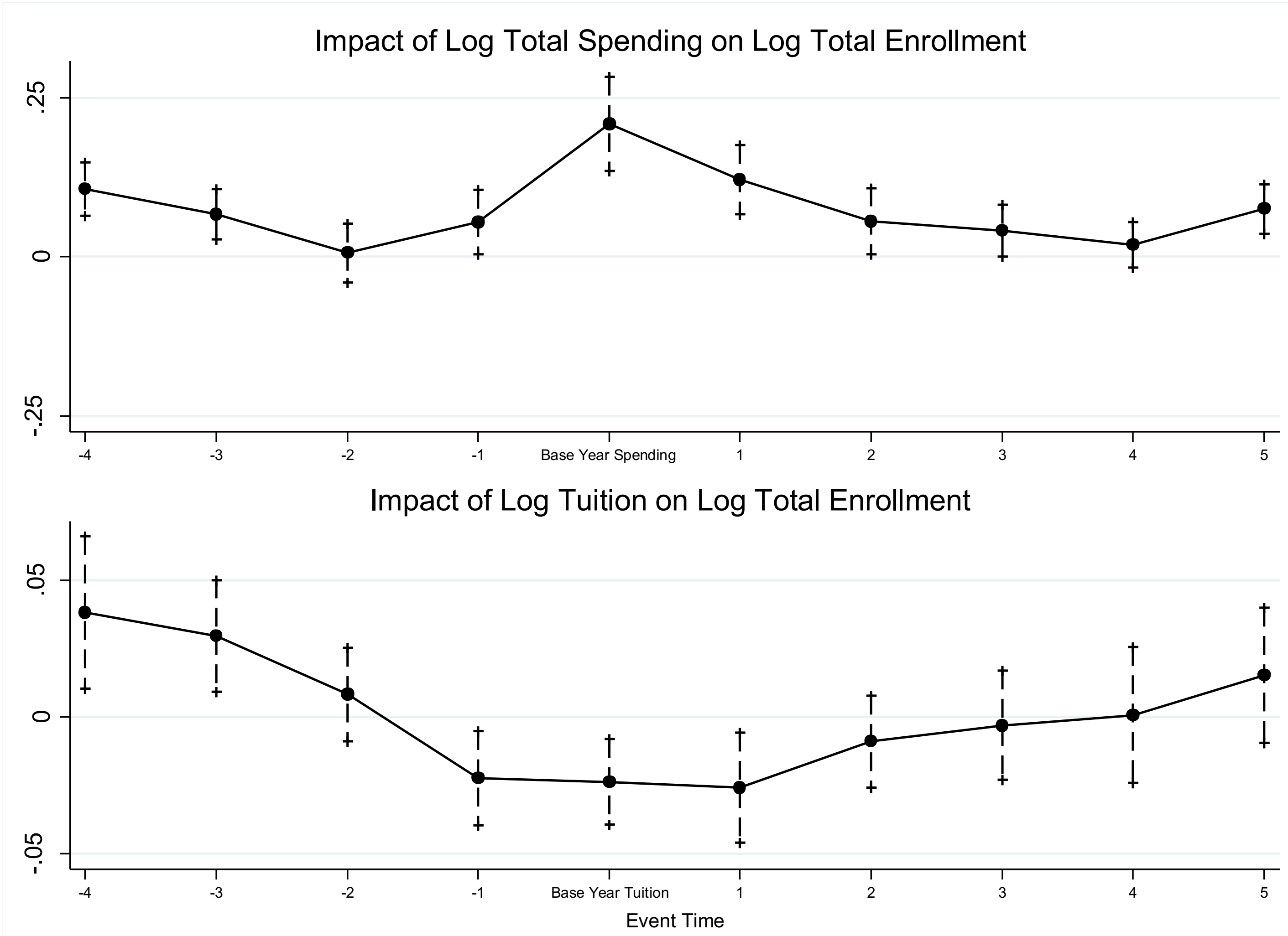
impact on degree attainment. Broadly speaking, this pattern of results helps to explain why the move of many states since 1990 toward a lower-spending, lower-tuition equilibrium has led to increases in the share of students who are enrolled part-time, and to higher college dropout rates.

Cohodes and Goodman (2014) show that a Massachusetts scholarship program that induced students to switch from better-resourced private colleges to Massachusetts public institutions caused a decline in graduation rates. This suggests that gaps in outcomes between higher- and lower-spending institutions may partly reflect a causal impact of school resources. Consistent with this evidence, we find a large impact of spending changes *within* institutions on degree completion, and across the broad range of public colleges and universities that are attended by a majority of U.S. students. Recent evidence suggests that mid-tier public institutions in our sample are important mediators of intergenerational mobility in the U.S. (Chetty et al., 2017). Our findings indicate that spending has large effects on educational outcomes for these institutions.

The Federal government has played an increasing role in the financing of higher education since 2000. Nearly all Federal dollars are allocated toward price reduction in the form of Title IV aid, with the Pell Grant becoming much more generous in recent years. Our results suggest that for the purposes of increasing educational attainment, Federal support of higher education might be allocated more effectively as a supply side subsidy provided directly to public institutions, similar to the Federal Title I program for K-12 schooling. It is also worth noting that Federal financial aid policy creates incentives for state policymakers to reduce higher education funding, because some share of state budget cuts can be passed on as tuition increases and returned to students in the form of unmet Federal need (Kane et al., 2003). This contrasts with Federal support of Medicaid, which creates incentives for states to increase spending because it is structured as a matching grant.

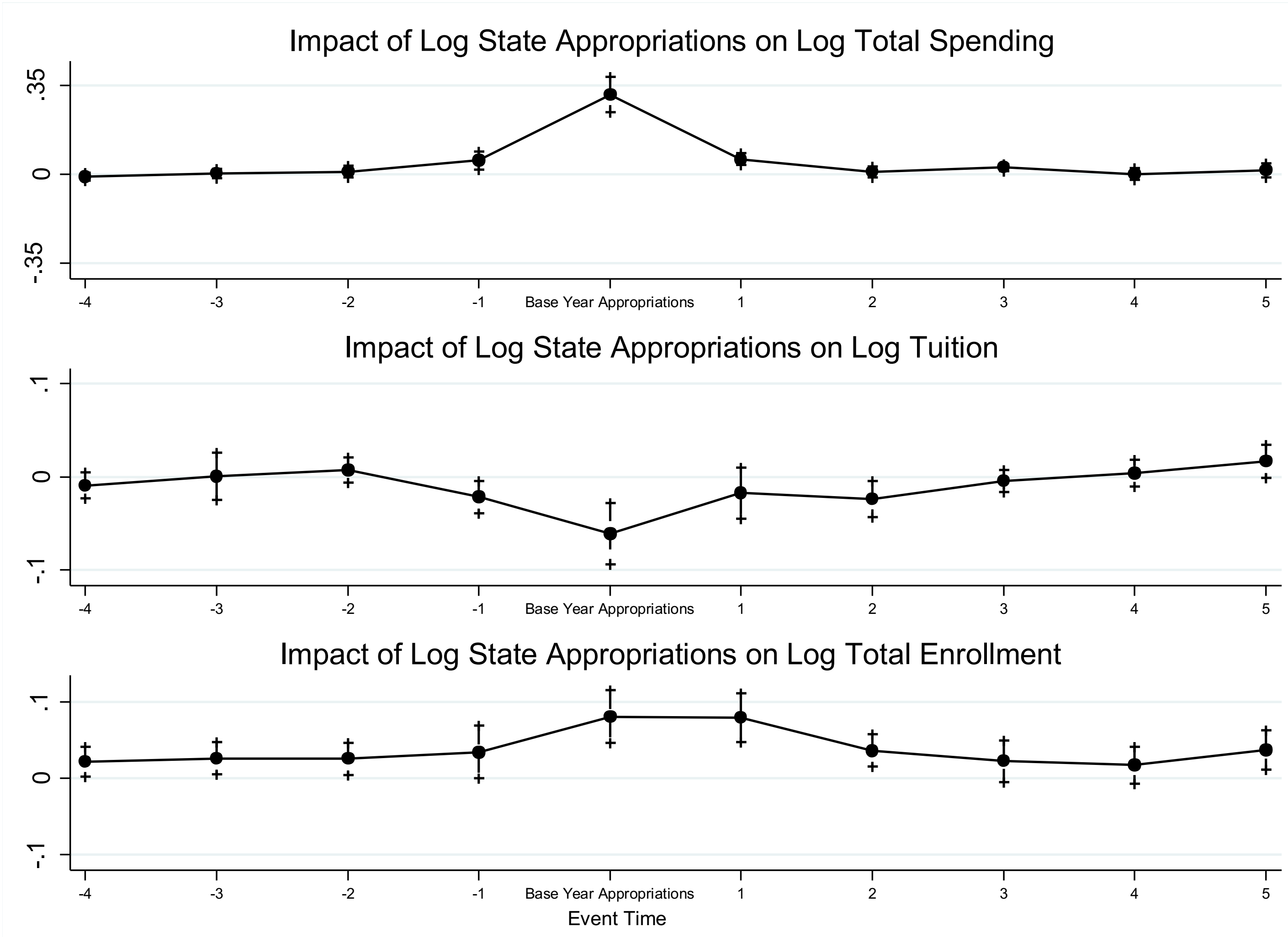
Broadly, our findings suggest that government programs aimed at reducing college costs will not increase degree attainment if cost reduction is achieved by reducing per-student spending. Contrary to the narrative of administrative bloat, our results suggest that spending cuts affect core instruction and academic support, generating large downstream impacts on educational attainment. An important caveat is that our results are identified from variation within non-selective public institutions, where per-student spending is relatively low and extravagant consumption amenities are rarely found.

Figure 1



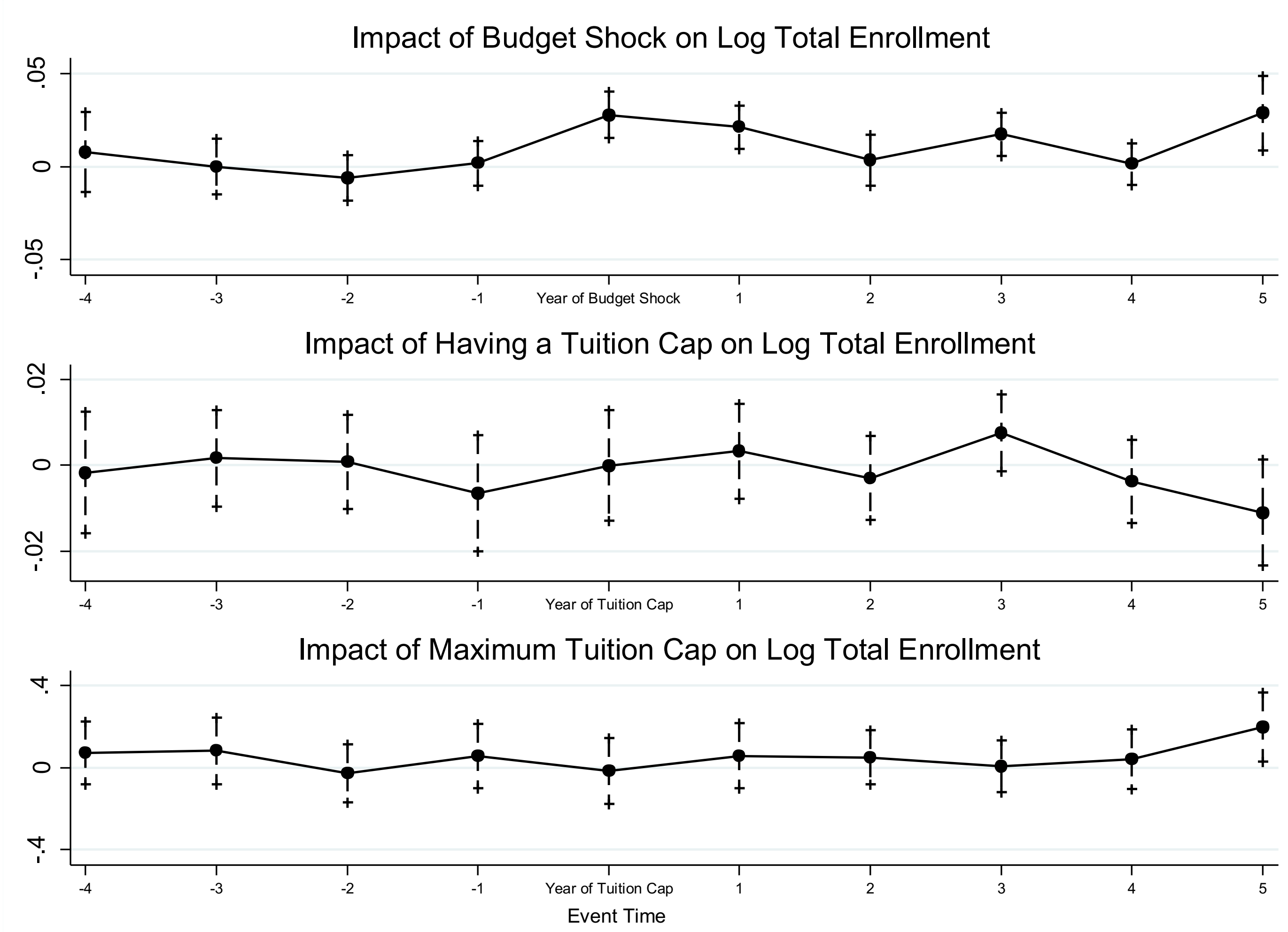
Notes: Figure 1 presents point estimates and 95 percent confidence intervals from separate regressions of log total enrollment on lags and leads of log total spending (top panel) and log tuition (bottom panel). The regressions also control for institution and year fixed effects. Standard errors are clustered at the institution level.

Figure 2



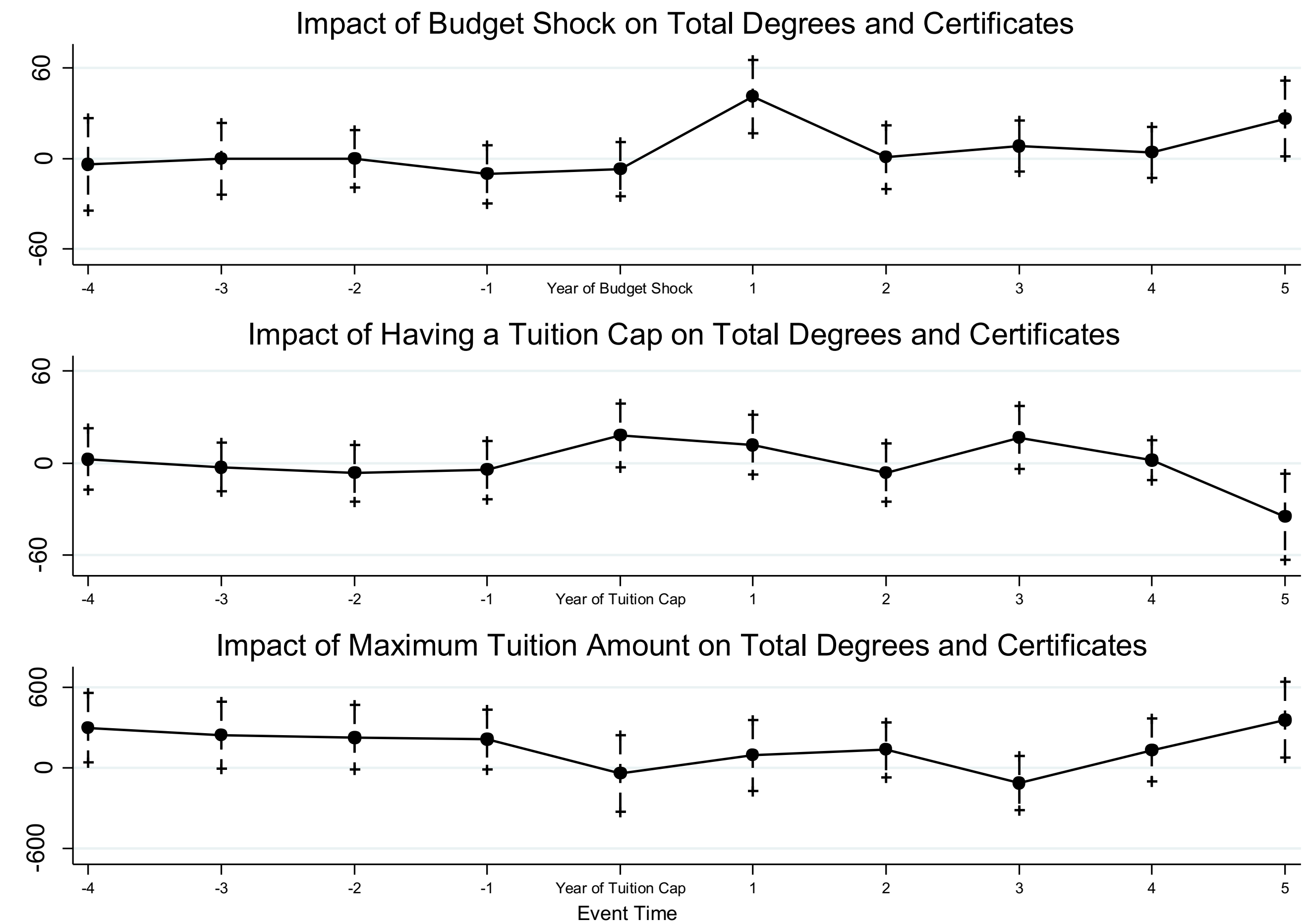
Notes: Figure 2 presents point estimates and 95 percent confidence intervals from separate regressions of log total spending (top panel), log tuition (middle panel) and log total enrollment (bottom panel) on lags and leads of each institution's funding from state appropriations in each year. The regressions also control for institution and year fixed effects. Standard errors are clustered at the institution level.

Figure 3



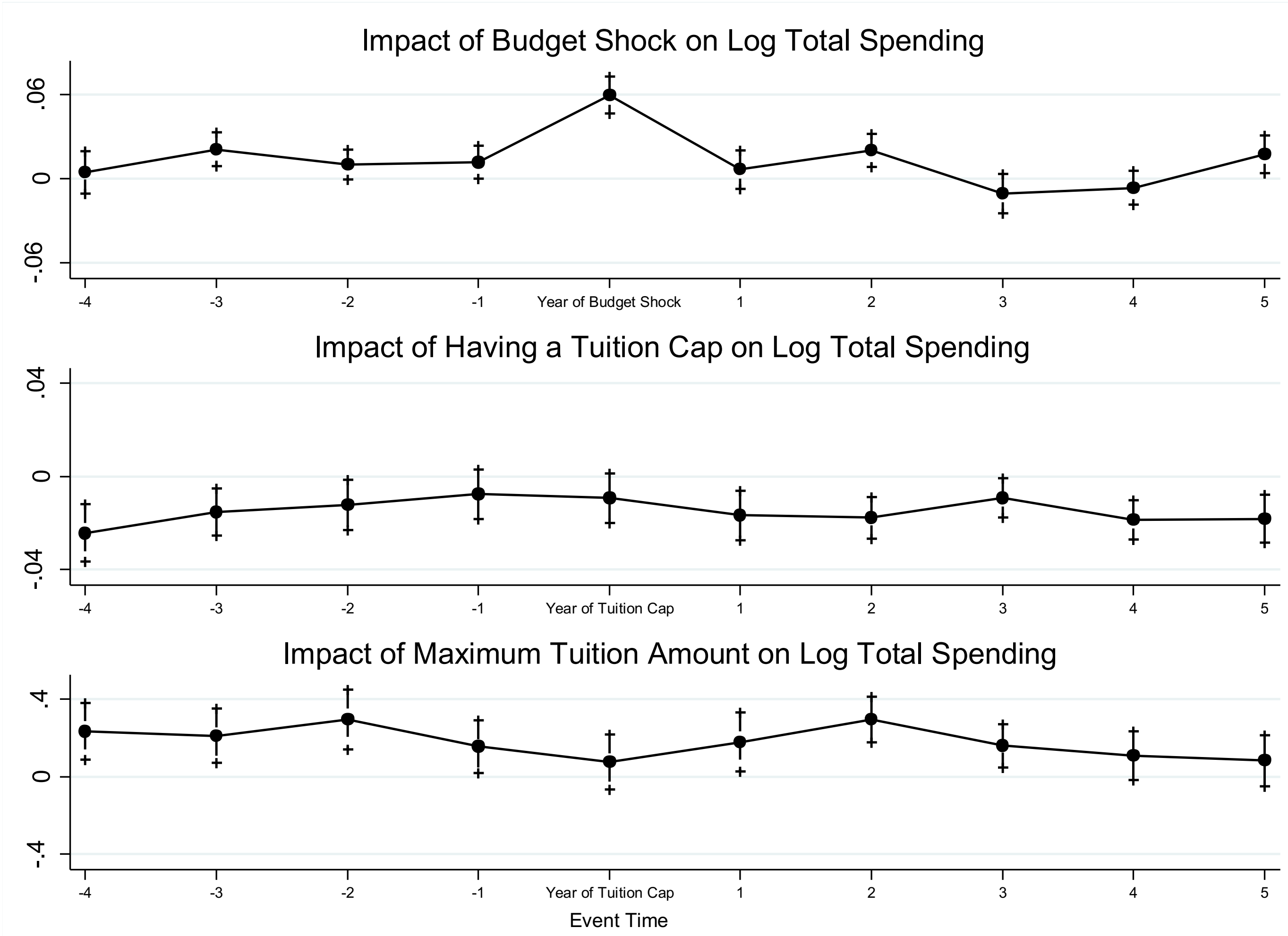
Notes: Figure 3 presents point estimates and 95 percent confidence intervals from a single regression of log total enrollment on the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s), a tuition cap indicator, and the maximum increase allowed by the tuition cap. The model also controls for lags and leads of county and state unemployment rates, time-varying county and institution characteristics, institution fixed effects, year fixed effects and state-specific time trends. Standard errors are clustered at the institution level.

Figure 4



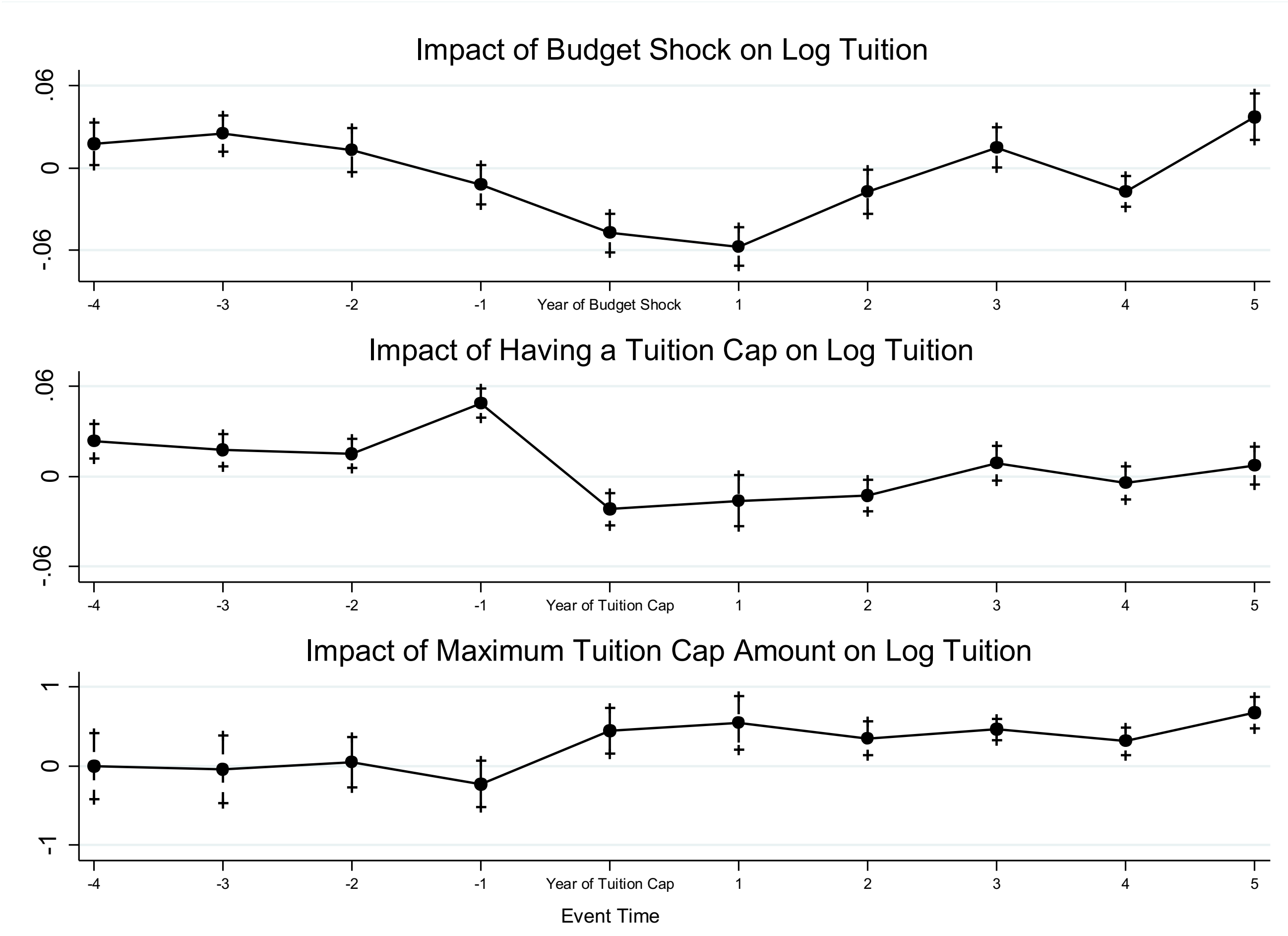
Notes: Figure 4 presents point estimates and 95 percent confidence intervals from a single regression of log total degrees and certificates awarded on the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s), a tuition cap indicator, and the maximum increase allowed by the tuition cap. The model also controls for lags and leads of county and state unemployment rates, time-varying county and institution characteristics, institution fixed effects, year fixed effects and state-specific time trends. Standard errors are clustered at the institution level.

Figure 5



Notes: Figure 5 presents point estimates and 95 percent confidence intervals from a single regression of log total spending on the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s), a tuition cap indicator, and the maximum increase allowed by the tuition cap. The model also controls for lags and leads of county and state unemployment rates, time-varying county and institution characteristics, institution fixed effects, year fixed effects and state-specific time trends. Standard errors are clustered at the institution level.

Figure 6



Notes: Figure 6 presents point estimates and 95 percent confidence intervals from a single regression of log tuition on the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s), a tuition cap indicator, and the maximum increase allowed by the tuition cap. The model also controls for lags and leads of county and state unemployment rates, time-varying county and institution characteristics, institution fixed effects, year fixed effects and state-specific time trends. Standard errors are clustered at the institution level.

Table 1: Descriptive Statistics

	1990			2013		
	Selective, Four Year	Nonselective, Four Year	Two Year	Selective, Four Year	Nonselective, Four Year	Two Year
	(1)	(2)	(3)	(4)	(5)	(6)
Tuition and Fees	4,625	3,235	1,051	14,934	8,396	2,430
State Appropriations	13,597	7,993	2,524	8,531	5,009	1,849
Local Appropriations	31	81	1,013	0	109	1,526
Total Grants	1,555	1,087	491	5,227	3,422	1,976
Instructional Spending	11,087	6,356	2,610	15,585	7,247	3,013
Academic Support	1,536	685	234	4,511	1,649	553
Student Services	782	380	259	1,967	1,111	664
Administration	1,339	733	412	3,343	1,680	976
Scholarships	832	543	260	1,516	1,062	874
Total Spending	31,133	15,700	5,669	43,907	19,359	7,480
Enrollment	20,419	9,584	5,318	25,734	11,879	7,938
Institution Count	30	501	805	28	560	688

Notes: Table 1 presents yearly average values of enrollment and finance variables for U.S. public institutions. Data are from the Integrated Postsecondary Education Data System (IPEDS), years 1990 to 2013. Selective colleges are ranked as "Most Competitive" or "Highly Competitive" by the 2009 Barron's Profile of American Colleges. The column "Two Year" also contains a small number of public institutions that offer only less than two year credentials. The first five rows present categories of institutional revenue. The next three rows present categories of institutional spending, and the last two rows are total Fall enrollment and the number of institutions in each category respectively. All financial figures are in constant 2013 dollars. Total grants includes Federal sources such as the Pell grant, as well as state merit aid and private scholarships. Our analytic sample conditions on institutions existing in 1990. About 4.5 percent of institutions close or were consolidated between 1990 and 2013.

Table 2 - Validity check on the instruments

	(1)	(2)	(3)
Panel A- Budget shock instrument			
State Unemployment Rate	-0.096***	-0.082***	0.002
	(0.011)	(0.010)	(0.043)
County Unemployment Rate	0.018***	0.019***	0.005
	(0.006)	(0.005)	(0.006)
Sample Size	24,760	24,706	24,706
Panel B - Any tuition cap			
State Unemployment Rate	0.0003	0.0013	-0.0425
	(0.0070)	(0.0073)	(0.0260)
Institution and Year Effects	X	X	X
Institution and County Covariates		X	X
State Trends			X
Sample Size	24,760	24,706	24,706

Notes: This table presents estimates from OLS regressions of the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s - Panel A) and a tuition cap indicator (Panel B) on county and state unemployment rates, time-varying county and institution characteristics, institution fixed effects, year fixed effects and state-specific time trends. Column 1 controls for institution and year fixed effects. Column 2 adds institution and county covariates, while Column 3 adds state-specific time trends. Standard errors, clustered at the state-year level, are in parentheses. * - sig. at 10%; ** - sig. at 5%; *** - sig at <1%.

Table 3. Two-stage least squares estimates of the impacts of tuition and spending on enrollment

	First stage		Second stage
	Spending	Tuition	Total Enrollment
	(1)	(2)	(3)
Budget shock instrument	0.061***	-0.081***	-
	(0.004)	(0.007)	
Any tuition cap	0.001	-0.030***	-
	(0.002)	(0.003)	
Maximum increase	-0.045*	0.304***	-
	(0.027)	(0.056)	
Log Total Spending	-	-	0.300**
			(0.134)
Log Tuition	-	-	-0.017
			(0.076)
AP partial *F*-statistic	64.67	107.54	-

Notes: This table reports two-stage least squares estimates of the effects of tuition and spending on total fall enrollment. The first stage regresses annual changes in log total spending and log tuition on the change in the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita), the change in an indicator for whether a tuition cap is in place, and the change in the maximum percentage increase allowed under the cap (set to zero when no cap is in place). The second stage regresses annual changes in log enrollment on predicted changes in log tuition and log spending from the first stage. Columns (1) and (2) report first stage results, and column (3) reports second stage results. Both stages also control for time-varying county demographic and economic covariates, institution characteristics, year fixed effects, and state fixed effects. Standard errors, clustered at the institution level, are in parentheses. * - sig. at 10%; ** - sig. at 5%; *** - sig at <1%.

Table 4 - Two-stage least squares estimates for enrollment across multiple years

Outcome is log enrollment	Current year	T+1	T+2	T+3
	(1)	(2)	(3)	(4)
Panel A- all institutions				
Log Total Spending	0.300**	0.800***	0.855***	0.821***
	(0.134)	(0.184)	(0.214)	(0.212)
Log Tuition	-0.017	0.078	0.045	-0.075
	(0.076)	(0.105)	(0.125)	(0.130)
Sample Size	27,659	26,444	25,197	23,956
Panel B - two-year institutions				
Log Total Spending	0.283	1.020***	1.052***	0.951***
	(0.253)	(0.315)	(0.371)	(0.345)
Log Tuition	-0.083	0.097	0.087	-0.100
	(0.133)	(0.169)	(0.201)	(0.204)
Sample Size	16,800	16,109	15,389	14,664
Panel C - four-year institutions				
Log Total Spending	0.234***	0.447***	0.649***	0.551***
	(0.079)	(0.123)	(0.162)	(0.180)
Log Tuition	0.008	-0.040	-0.041	-0.138
	(0.063)	(0.088)	(0.118)	(0.124)
Sample Size	10,859	10,335	9,808	9,292

Notes: This table reports two-stage least squares estimates of the effects of tuition and spending on total fall enrollment by year. Panel A shows results for all institutions, while Panels B and C display results for two-year and four-year institutions. The first stage regresses annual changes in log total spending and log tuition on the change in the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita), the change in an indicator for whether a tuition cap is in place, and the change in the maximum percentage increase allowed under the cap (set to zero when no cap is in place). The second stage regresses changes in log enrollment relative to year (T-1) on predicted changes in log tuition and log spending from the first stage. Both stages also control for time-varying county demographic and economic covariates, institution characteristics, year fixed effects, and state fixed effects. Standard errors, clustered at the institution level, are in parentheses. * - sig. at 10%; ** - sig. at 5%; *** - sig at <1%.

Table 5 - 2SLS estimates of the impacts of tuition and spending on certificates and degrees

	Current year	T+1	T+2	T+3
Panel A: Certificates	(1)	(2)	(3)	(4)
Log Total Spending	37	601*	94	56
	(299)	(322)	(363)	(338)
Log Tuition	22	44	-150	-212
	(155)	(166)	(201)	(185)
Sample Size	16,793	16,076	15,356	14,630
Panel B: Associate's Degrees				
Log Total Spending	79	554*	-25	125
	(416)	(334)	(352)	(315)
Log Tuition	20	202	-114	-83
	(257)	(208)	(215)	(205)
Sample Size	16,793	16,076	15,356	14,630
Panel C: Bachelor's Degrees				
Log Total Spending	-45	145	694**	546*
	(222)	(229)	(302)	(321)
Log Tuition	-84	50	255	173
	(175)	(179)	(219)	(214)
Sample Size	10,779	10,246	9,722	9,210

Notes: This table reports two-stage least squares estimates of the effects of tuition and spending on certificates and degrees awarded. Panels A, B and C report results for certificates, associate's degrees and bachelor's degrees. The first stage regresses annual changes in log total spending and log tuition on the change in the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita), the change in an indicator for whether a tuition cap is in place, and the change in the maximum percentage increase allowed under the cap (set to zero when no cap is in place). The second stage regresses changes in certificates or degrees relative to year (T-1) on predicted changes in log tuition and log spending from the first stage. Both stages also control for time-varying county demographic and economic covariates, institution characteristics, year fixed effects, and state fixed effects. Standard errors, clustered at the institution level, are in parentheses. * - sig. at 10%; ** - sig. at 5%; *** - sig at <1%.

Table 6 - Spillover impacts of public budget shocks on outcomes in private institutions

Panel A: Log Enrollment	Current year	T+1	T+2	T+3
	(1)	(2)	(3)	(4)
County Average Budget Shock	-0.015	0.002	0.006	-0.013
	(0.010)	(0.015)	(0.024)	(0.022)
Any Tuition Cap	0.003	-0.003	-0.008	-0.013*
	(0.006)	(0.007)	(0.007)	(0.007)
Panel B: Certificates and AAs				
County Average Budget Shock	-1.26	-3.45	-4.80	-6.58
	(2.25)	(2.81)	(3.51)	(4.02)
Any Tuition Cap	0.38	-0.06	-2.93	-2.42
	(1.07)	(1.32)	(1.55)	(1.99)
Panel C: Bachelor's Degrees				
County Average Budget Shock	-1.60	-1.61	-2.87	-0.24
	(1.33)	(2.06)	(2.92)	(2.80)
Any Tuition Cap	0.08	0.26	-1.16*	-0.46
	(0.58)	(0.61)	(0.68)	(0.72)
Panel D: Log Tuition				
County Average Budget Shock	-0.0020	-0.0027	0.0157	0.0291**
	(0.0027)	(0.0088)	(0.0097)	(0.0108)
Any Tuition Cap	-0.0019	-0.0023	-0.0062	-0.0060
	(0.0030)	(0.0035)	(0.0045)	(0.0038)
Sample Size	77,014	70,215	64,627	59,325

Notes: This table reports reduced form estimates of the impacts of the change in the average enrollment-weighted budget shock (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s) across public institutions in a county and the change in an indicator for whether a tuition cap is in place in the current state and year on the change in outcomes in non-public (not-for-profit and for-profit) institutions in the same county. Panels A, B, C and D report results for log enrollment, two year awards (certificates and associate's degrees), bachelor's degrees, and log tuition. The regressions also control for time-varying county demographic and economic covariates, institution characteristics, year fixed effects, and state fixed effects. Standard errors, clustered at the institution level, are in parentheses. * - sig. at 10%; ** - sig. at 5%; *** - sig at <1%.

Table 7 - 2SLS Estimates for Spending and Revenue Categories

	Financial Aid			Spending Categories		
	Scholarship Aid	Pell Grant Aid	Total Aid	Instruction	Academic Support	Student Services
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A- all institutions						
Log Total Spending	0.182	-0.362	0.028	0.964***	1.700***	1.051***
	(0.716)	(0.230)	(0.358)	(0.125)	(0.386)	(0.257)
Log Tuition	-0.649	-0.194	-0.166	-0.030	0.377	0.043
	(0.490)	(0.137)	(0.213)	(0.077)	(0.246)	(0.144)
Sample Size	27,099	27,262	27,600	27,666	27,588	27,626
Panel B- two-year institutions						
Log Total Spending	-0.117	-0.466	0.159	0.958***	1.180*	1.076***
	(0.964)	(0.410)	(0.418)	(0.155)	(0.689)	(0.391)
Log Tuition	-0.737	-0.153	-0.097	-0.027	0.163	0.110
	(0.593)	(0.223)	(0.190)	(0.016)	(0.400)	(0.210)
Sample Size	16,337	16,502	16,746	16,812	16,741	16,774
Panel C- four-year institutions						
Log Total Spending	1.180*	-0.089	0.294	0.872***	1.614***	1.143***
	(0.640)	(0.177)	(0.337)	(0.100)	(0.269)	(0.266)
Log Tuition	-0.291	-0.290**	-0.082	-0.105	0.127	0.065
	(0.569)	(0.133)	(0.283)	(0.088)	(0.224)	(0.164)
Sample Size	10,762	10,760	10,854	10,854	10,847	10,852

Notes : This table reports two-stage least squares estimates of the effects of tuition and spending on institutional scholarship aid, Pell grant aid, and categories of spending.In the first stage we regress each institution's yearly change in log total spending and log tuition on the change in their simulated budget shock (the share of each institution’s revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s), the change in an indicator for whether a tuition cap is in place in the current state and year, and the change in the maximum percentage increase allowed under the cap (set to zero when no cap is in place). The second stage regresses each institution's yearly change in each spending category on the changes in tuition and spending from the first stage. Panel A reports all public institutions, while Panels B and C report results for two-year and four-year institutions. Both stages control for time-varying county demographic and economic covariates, time-invariant institution characteristics such as sector, selectivity and highest degree offered, year fixed effects, and state fixed effects. Standard errors, clustered at the institution level, are in parentheses. * - sig. at 10%; ** - sig. at 5%; *** - sig at <1%.

References

Angrist, J., D. Lang, and P. Oreopoulos (2009): "Incentives and services for college achievement: evidence from a randomized trial," *American Economic Journal: Applied Economics*, 1, 136–163.

Angrist, J. D. and J.-S. Pischke (2009): *Mostly Harmless Econometrics*, Princeton, NJ: Princeton University Press.

Autor, D. H. (2014): "Skills, education, and the rise of earnings inequality among the other 99 percent," *Science*, 344, 843–851.

Autor, D. H., D. Dorn, and G. H. Hanson (2013): "The China syndrome: local labor market effects of import competition in the United States," *American Economic Review*, 103, 2121–2168.

Avery, C. and S. Turner (2012): "Student loans: do college students borrow too much – or not enough?" *The Journal of Economic Perspectives*, 26, 165–192.

Bahr, P. R. (2014): "The labor market return in earnings to community college credits and credentials in California," Working paper, Center for the Study of Higher and Postsecondary Education.

Bahr, P. R., J. L. Gross, K. E. Slay, and R. D. Christensen (2013): "First in line: student registration priority in community colleges," *Educational Policy*, 29, 342–374.

Barr, A. and S. E. Turner (2013): "Expanding enrollments and contracting state budgets: the effect of the great recession on higher education," *The Annals of the American Academy of Political and Social Science*, 650, 168–193.

Barrow, L., L. Richburg-Hayes, C. E. Rouse, and T. Brock (2014): "Paying for performance: the education impacts of a community college scholarship program for low-income adults," *Journal of Labor Economics*, 32, 563–599.

Bartik, T. J. (1991): *Who Benefits from State and Local Economic Development Policies?*, Kalamazoo, MI: W. E. Upjohn Institute for Employment Research.

Baum, S. and J. Ma (2014): "Trends in college pricing," College Board, Trends in Higher Education Series.

Bell, A. C., J. Carnahan, and H. P. L'Orange (2011): "State tuition, fees, and financial assistance policies for public colleges and universities, 2010-11," Report, State Higher Education Executive Officers Association.

Bennett, W. J. (1987): "Our greedy colleges," *The New York Times*, February 18th.

Bettinger, E. and R. Baker (2011): "The effects of student coaching in college: An evaluation of a randomized experiment in student mentoring," Tech. rep., National Bureau of Economic Research.

Bettinger, E., O. Gurantz, L. Kawano, and B. Sacerdote (2016): "The long run impacts of merit aid: evidence from California's Cal Grant," NBER working paper no. 22347.

Bettinger, E. P. and B. T. Long (2009): "Addressing the needs of underprepared students in higher education: does college remediation work?" *Journal of Human Resources*, 44, 736–771.

Blanchard, O. and L. Katz (1992): "Regional evolutions," *Brookings Papers on Economic Activity*, 23, 1–76.

Bound, J., M. F. Lovenheim, and S. Turner (2010): "Why have college completion rates declined? An analysis of changing student preparation and collegiate resources," *American Economic Journal: Applied Economics*, 2, 129–57.

——— (2012): "Increasing time to baccalaureate degree in the United States," *Education Finance and Policy*, 7, 375–424.

Bound, J. and S. Turner (2007): "Cohort crowding: how resources affect collegiate attainment," *Journal of Public Economics*, 91, 877–899.

Card, D. (2001): "Immigrant inflows, native outflows, and the local market impacts of higher immigration," *Journal of Labor Economics*, 19, 22–64.

Card, D. and A. B. Krueger (1992): "Does school quality matter? Returns to education and characteristics of public schools in the United States," *The Journal of Political Economy*, 100, 1–40.

Carrell, S. E. and B. Sacerdote (2013): "Why do college going interventions work?" Tech. rep., National Bureau of Economic Research.

Cellini, S. R. (2009): "Crowded colleges and college crowd-out: The impact of public subsidies on the two-year college market," *American Economic Journal: Economic Policy*, 1, 1–30.

——— (2010): "Financial aid and for-profit colleges: does aid encourage entry?" *Journal of Policy Analysis and Management*, 29, 526–552.

Cellini, S. R. and C. Goldin (2014): "Does federal student aid raise tuition? New evidence on for-profit colleges," *American Economic Journal: Economic Policy*, 6, 174–206.

Chetty, R., J. N. Friedman, E. Saez, N. Turner, and D. Yagan (2017): "Mobility report cards: the role of colleges in intergenerational mobility," Working paper.

Cohodes, S. R. and J. S. Goodman (2014): "Merit aid, college quality, and college completion: Massachusetts' Adams scholarship as an in-kind subsidy," *American Economic Journal: Applied Economics*, 6, 251–285.

Delaney, J. A. and W. R. Doyle (2011): "State spending on higher education: testing the balance wheel over time," *Journal of Education Finance*, 36, 343–368.

Deming, D. and S. Dynarski (2010): "College aid," in *Targeting Investments in Children: Fighting Poverty When Resources are Limited*, ed. by P. B. Levine and D. J. Zimmerman, Chicago, IL: University of Chicago Press, chap. 10, 283–302.

Dynarski, S. (2008): "Building the stock of college-educated labor," *Journal of Human Resources*, 43, 576–610.

Ehrenberg, R. G. (2012): "American higher education in transition," *The Journal of Economic Perspectives*, 26, 193–216.

Fitzpatrick, M. D. and D. Jones (2012): "Higher education, merit-based scholarships and post-baccalaureate migration," Tech. rep., National Bureau of Economic Research.

Ginsberg, B. (2011): *The Fall of the Faculty*, Oxford University Press.

Goldrick-Rab, S., R. Kelchen, D. N. Harris, and J. Benson (2016): "Reducing income inequality in educational attainment: experimental evidence on the impact of financial aid on college completion," *American Journal of Sociology*, 121, 1762–1817.

Hemelt, S. W. and D. E. Marcotte (2011): "The impact of tuition increases on enrollment at public colleges and universities," *Educational Evaluation and Policy Analysis*, 33, 435–457.

Hoxby, C. M. (2009): "The changing selectivity of American colleges," *The Journal of Economic Perspectives*, 23, 95–118.

Jackson, C. K., R. C. Johnson, and C. Persico (2016): "The effects of school spending on educational and economic outcomes: evidence from school finance reforms," *Quarterly Journal of Economics*, 131, 157–218.

Jacob, B., B. McCall, and K. M. Stange (2013): "College as country club: do colleges cater to students' preferences for consumption?" NBER working paper no. 18745.

Jaquette, O. and E. Parra (2016): "The problem with the Delta Cost Project database," *Research in Higher Education*, 57, 1–22.

Kane, T. J., P. Orszag, and D. L. Gunter (2003): "State fiscal constraints and higher education spending: the role of Medicaid and the business cycle," Urban Institute Discussion Paper no. 11.

Lafortune, J., J. Rothstein, and D. W. Schanzenbach (2016): "School finance reform and the distribution of student achievement," Working paper.

Levin, H. M., E. Garcia, and J. Morgan (2012): "Cost-effectiveness of Accelerated Study in Associate Programs (ASAP) of the City University of New York (CUNY)," Technical report, Center for Benefit-Cost Studies of Education, Columbia University Teachers College.

Malani, A. and J. Reif (2015): "Interpreting pre-trends as anticipation: impact on estimated treatment effects from tort reform," *Journal of Public Economics*, 124, 1–17.

Parmley, K., A. Bell, H. L'Orange, and P. Lingenfelter (2009): "State budgeting for higher education in the united states," Report, State Higher Education Executive Officers.

Scott-Clayton, J. (2011): "On money and motivation a quasi-experimental analysis of financial incentives for college achievement," *Journal of Human Resources*, 46, 614–646.

Scott-Clayton, J. and B. Zafar (2016): "Financial aid, debt management, and socioeconomic outcomes: post-college effects of merit-based aid," NBER working paper no. 22574.

Scrivener, S., M. J. Weiss, A. Ratledge, T. Rudd, C. Sommo, and H. Fresques (2015): "Doubling graduation rates: three-year effects of CUNY's Accelerated Study in Associate Programs (ASAP) for developmental education students," Report, MDRC.

Seftor, N. S. and S. Turner (2002): "Back to school: Federal student aid policy and adult college enrollment," *Journal of Human Resources*, 37, 336–352.

Sjoquist, D. L. and J. V. Winters (2012): "Building the stock of college-educated labor revisited," *Journal of Human Resources*, 47, 270–285.

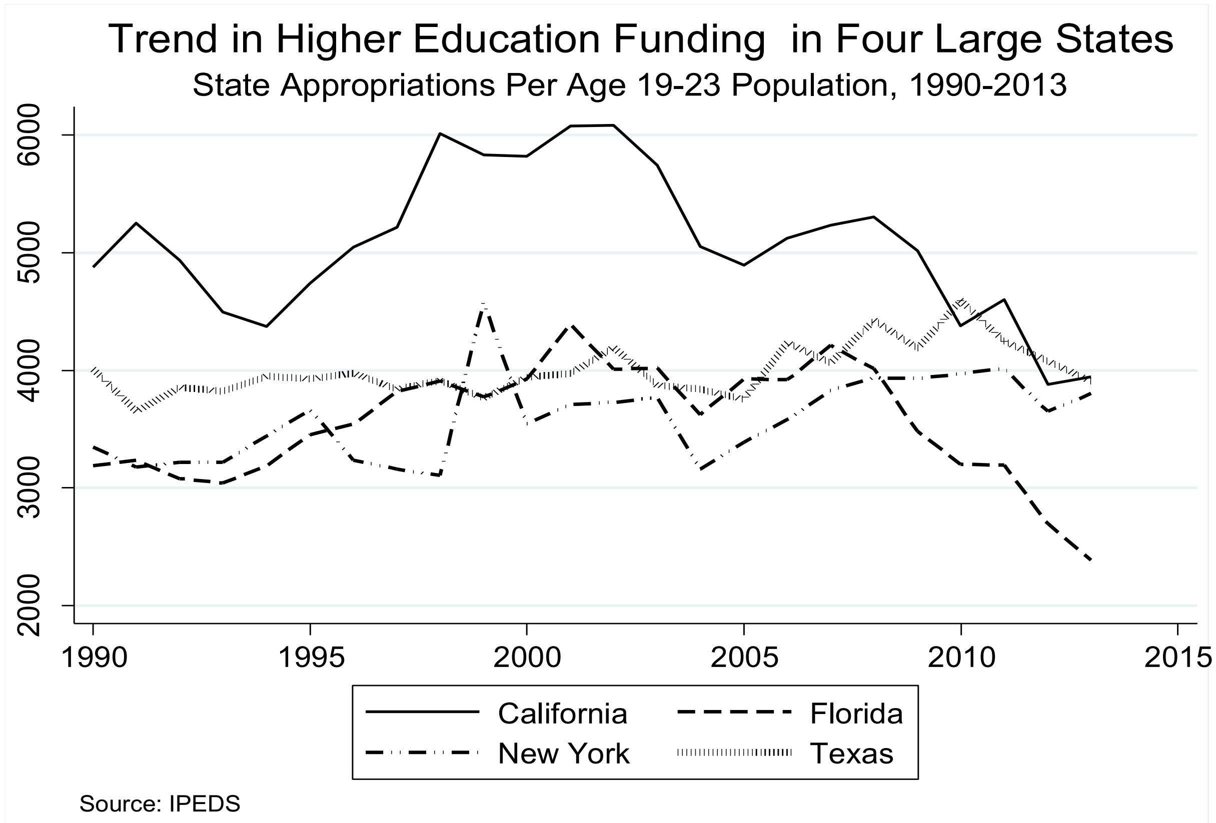
Turner, L. J. (2013): "The road to Pell is paved with good intentions: the economic incidence of Federal student grant aid," Working paper.

Turner, S. (2004): "Going to college and finishing college: explaining different educational outcomes," in *College Choices: The Economics of Where to Go, When to Go, and How to Pay for it*, ed. by C. M. Hoxby, Chicago, IL: University of Chicago Press, chap. 1, 13–62.

White House (2015): "White House unveils America's College Promise proposal: tuition-free community college for responsible students," Fact sheet.

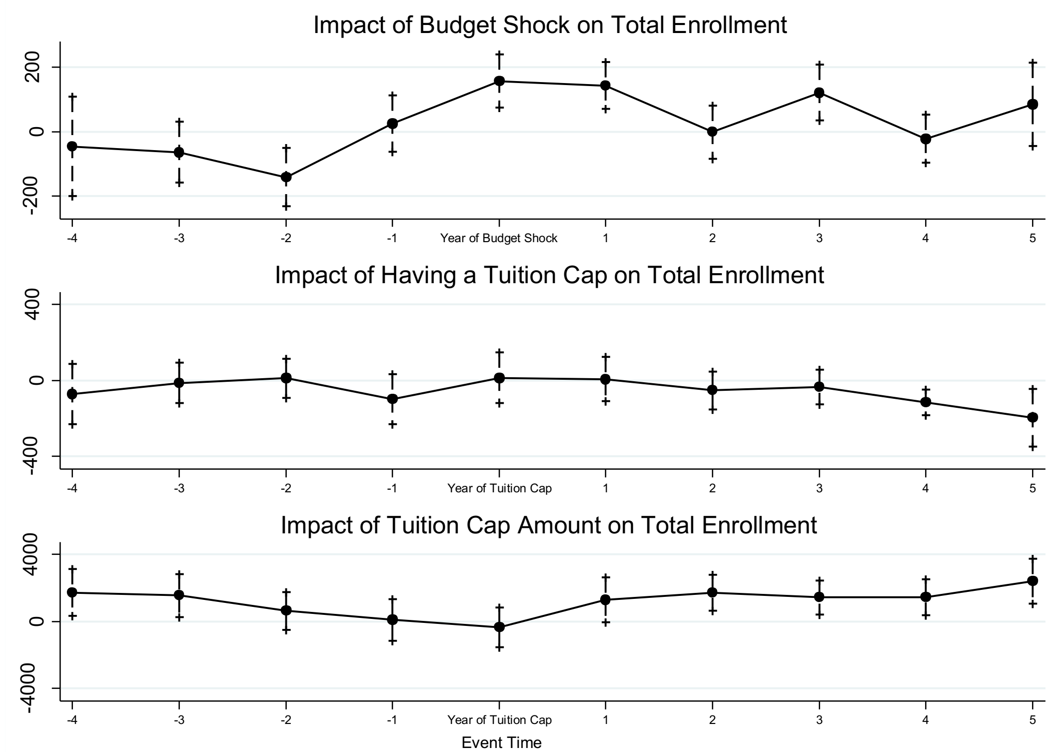
Winston, G. C. (1999): "Subsidies, hierarchy and peers: the awkward economics of higher education," *The Journal of Economic Perspectives*, 13, 13–36.

Figure A1



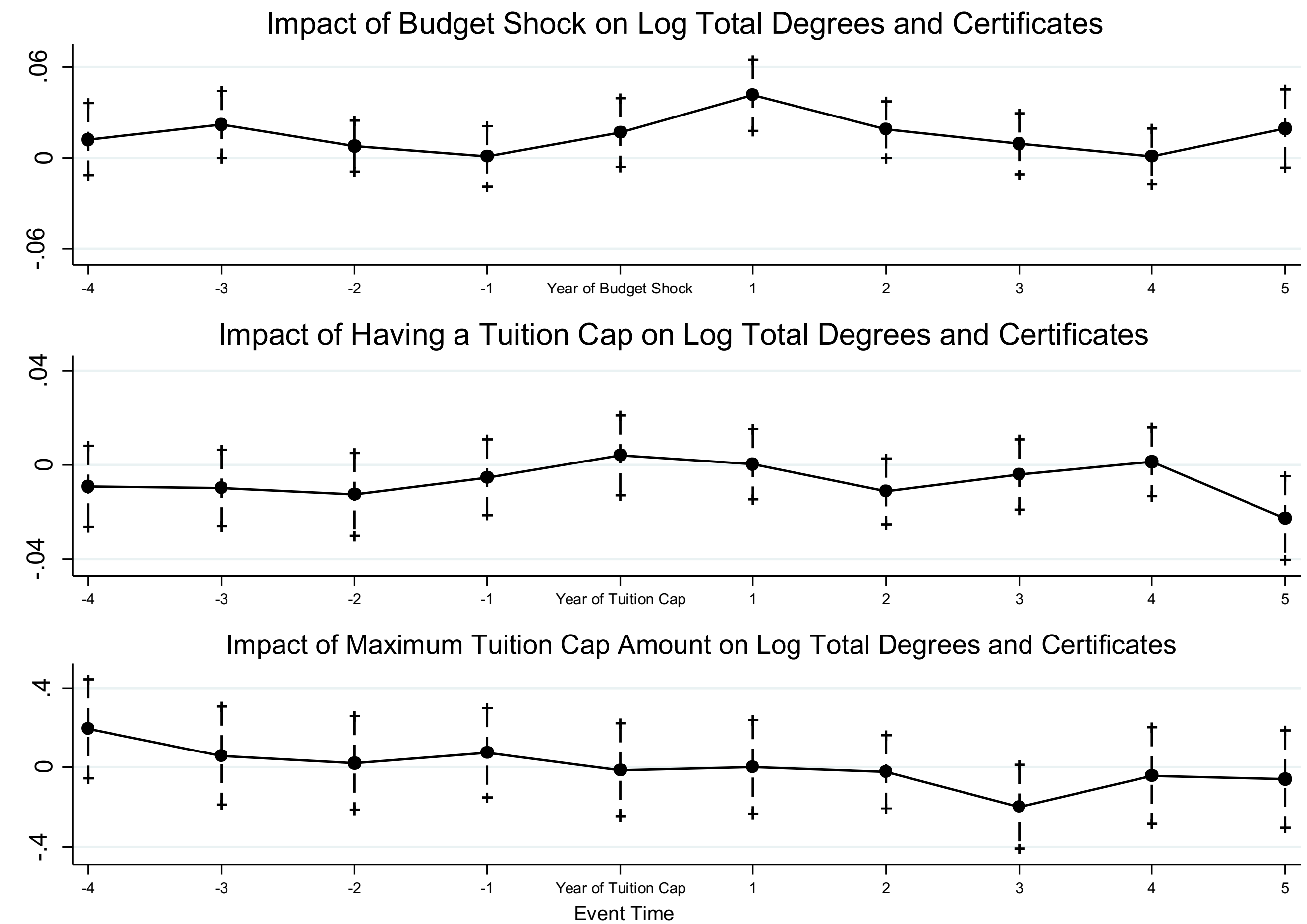
Notes: Figure A1 plots trends in state appropriations for higher education per college-age population for California, Florida New York and Texas. Data come from the Integrated Postsecondary Education Data System (IPEDS) for 1990-2013.

Figure A2



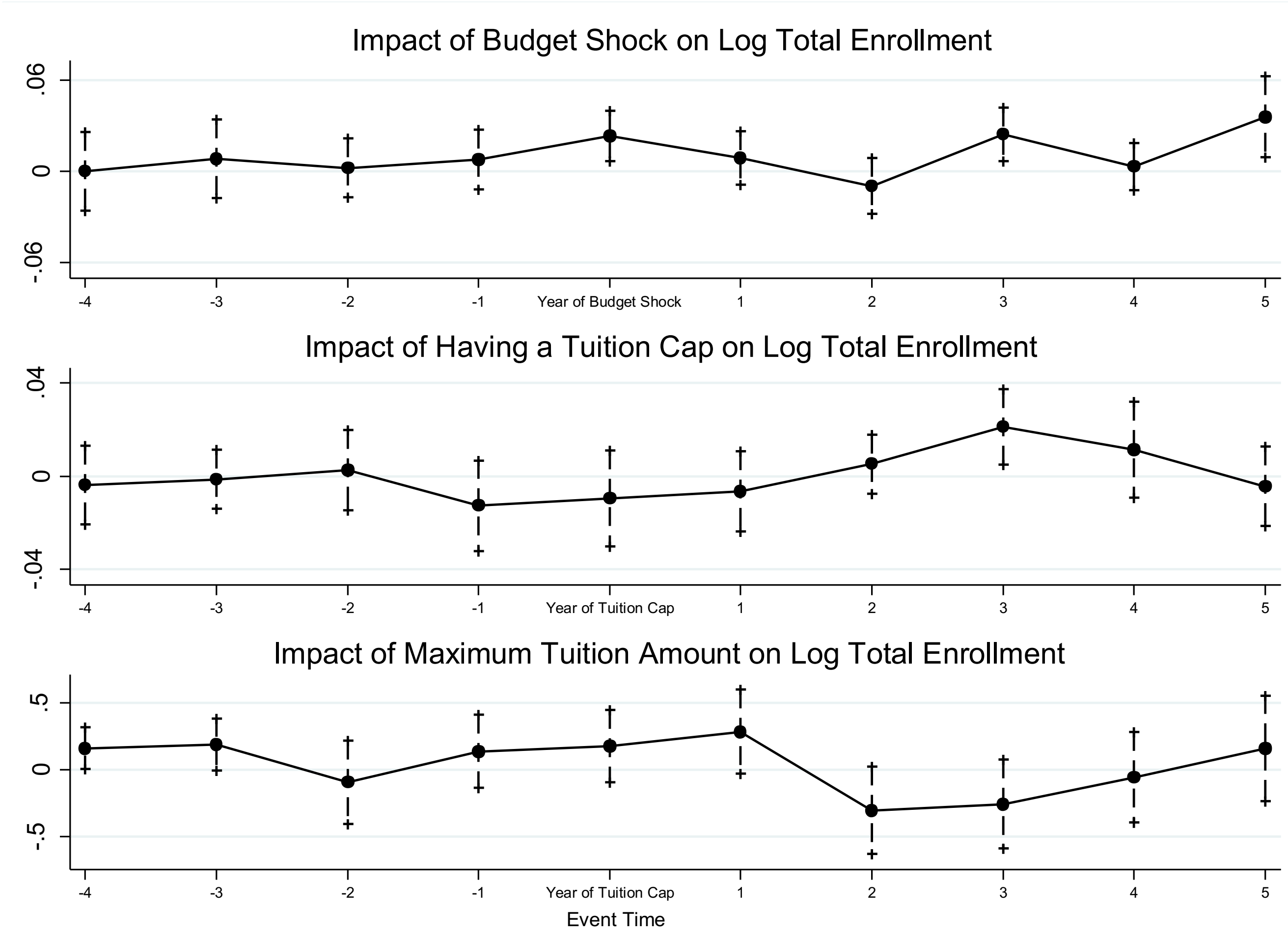
Notes: Figure A2 presents point estimates and 95 percent confidence intervals from a single regression of total enrollment (in levels) on the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s – top panel a tuition cap indicator, and the maximum increase allowed by the tuition cap. The model also controls for lags and leads of county and state unemployment rates, time-varying county and institution characteristics, institution fixed effects, year fixed effects and state-specific time trends.

Figure A3



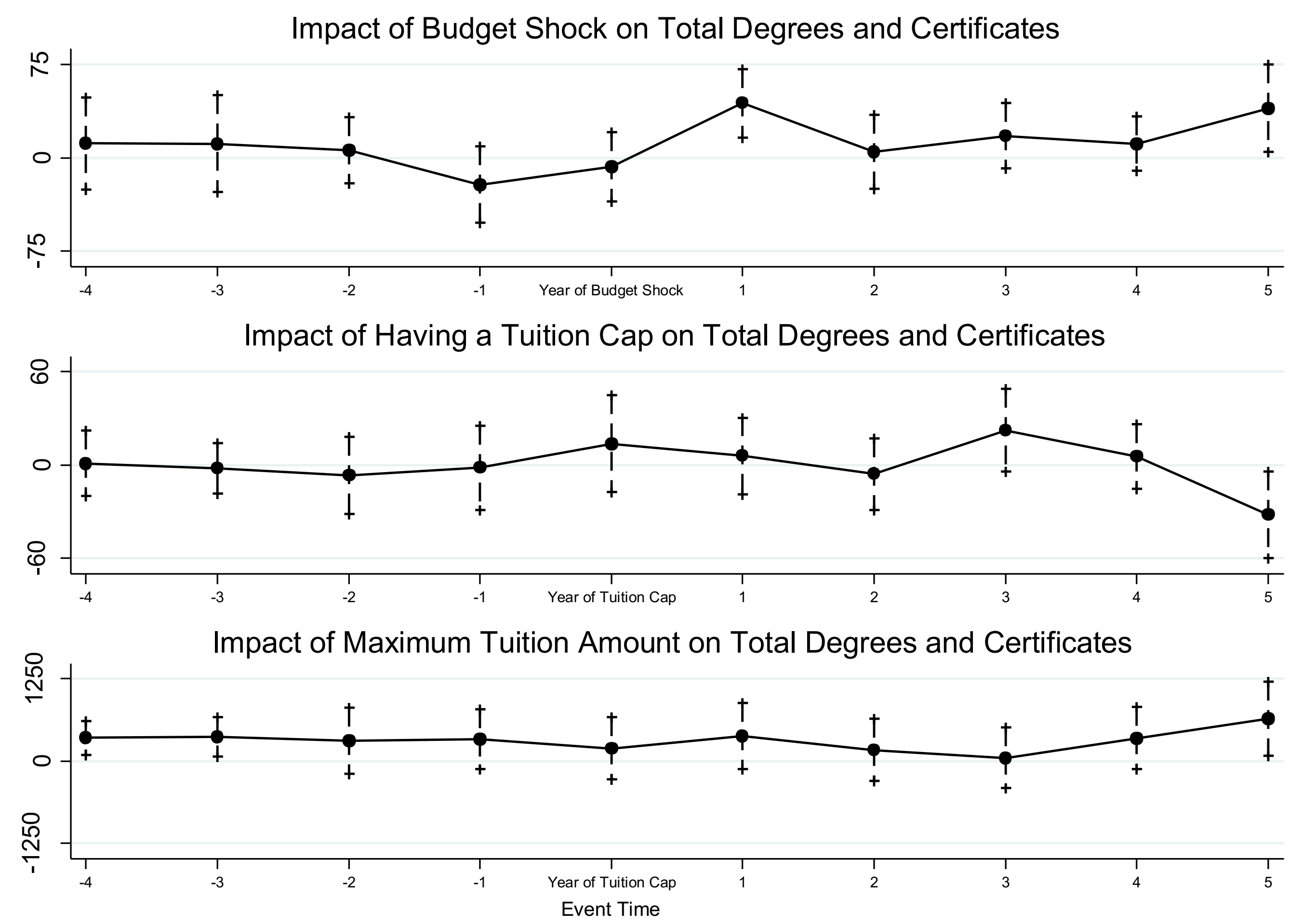
Notes: This figure presents point estimates and 95 percent confidence intervals from a single regression of log total degrees and certificates on the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s – top panel a tuition cap indicator, and the maximum increase allowed by the tuition cap. The model also controls for lags and leads of county and state unemployment rates, time-varying county and institution characteristics, institution fixed effects, year fixed effects and state-specific time trends.

Figure A4



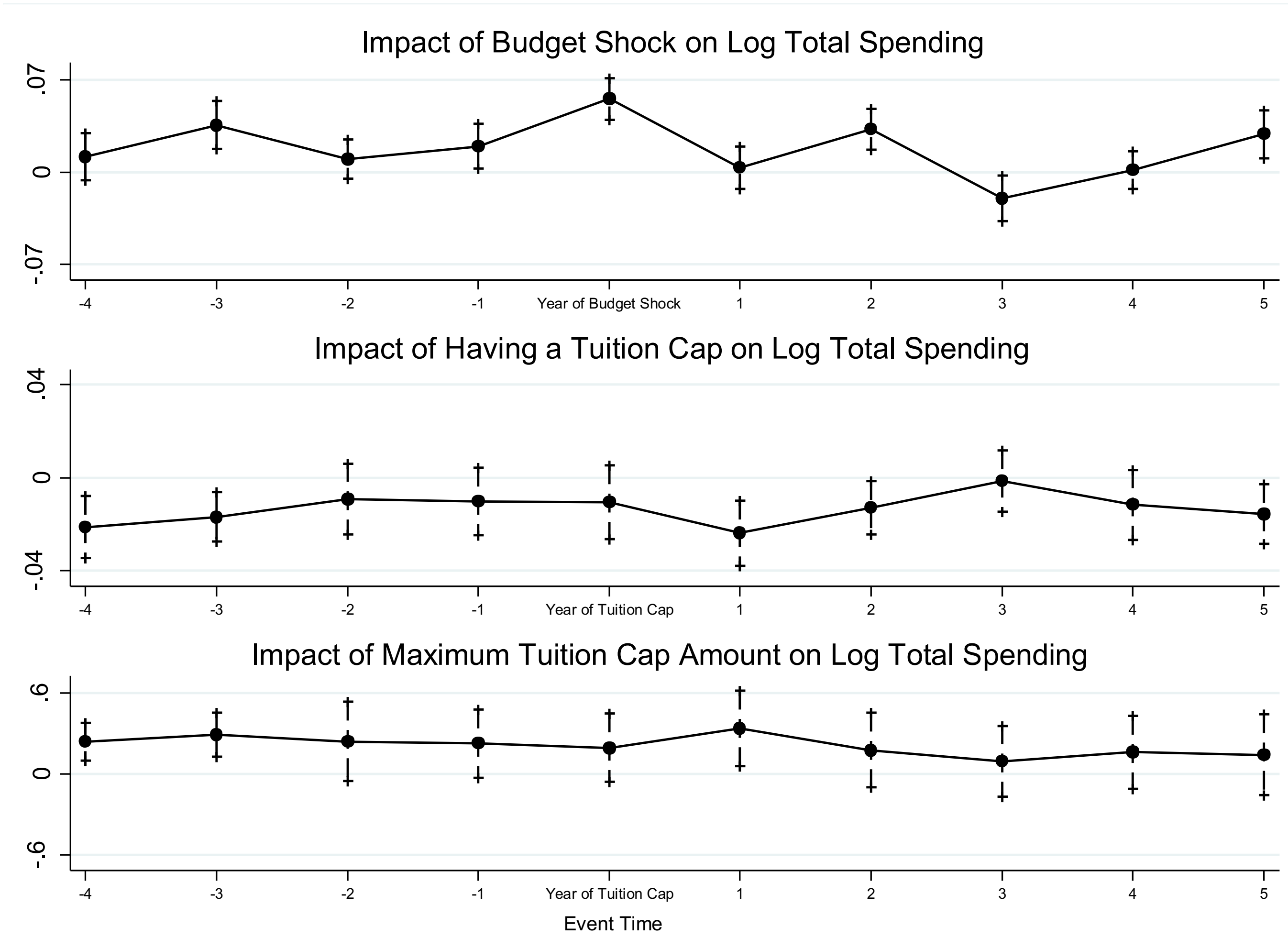
Notes: This figure presents point estimates and 95 percent confidence intervals from a single regression of total spending divided by the college-age (age 19 to 23) population on the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s – top panel a tuition cap indicator, and the maximum increase allowed by the tuition cap. The model also controls for lags and leads of county and state unemployment rates, time-varying county and institution characteristics, institution fixed effects, year fixed effects, and state by four-year period effects (e.g., 2010 to 2013).

Figure A5



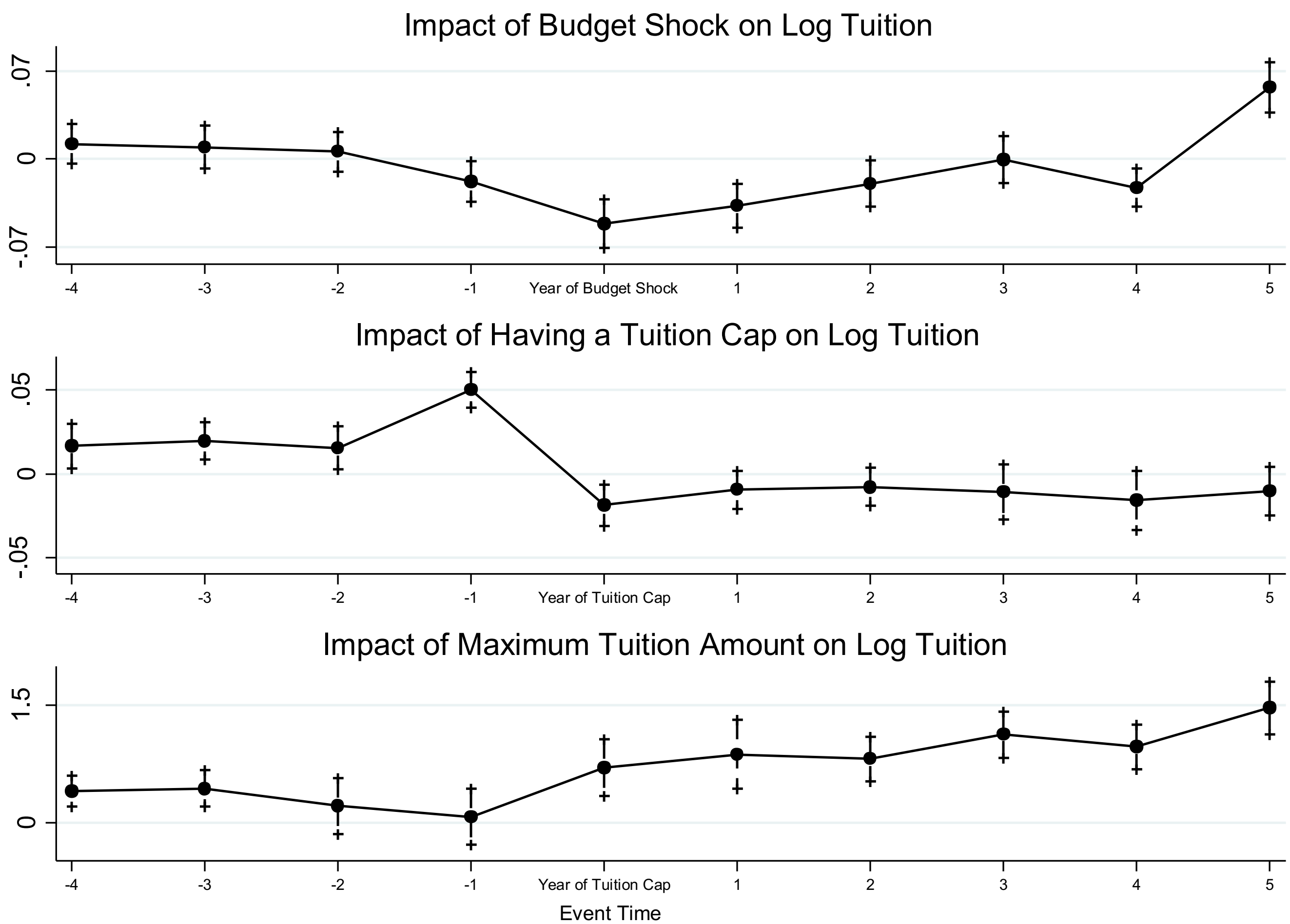
Notes: This figure presents point estimates and 95 percent confidence intervals from a single regression of log tuition on the the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s – top panel a tuition cap indicator, and the maximum increase allowed by the tuition cap. The model also controls for lags and leads of county and state unemployment rates, time-varying county and institution characteristics, institution fixed effects, year fixed effects, and state by four-year period effects (e.g., 2010 to 2013).

Figure A6



Notes: This figure presents point estimates and 95 percent confidence intervals from a single regression of total fall enrollment on the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s – top panel a tuition cap indicator, and the maximum increase allowed by the tuition cap. The model also controls for lags and leads of county and state unemployment rates, time-varying county and institution characteristics, institution fixed effects, year fixed effects, and state by four-year period effects (e.g., 2010 to 2013).

Figure A7



Notes: This figure presents point estimates and 95 percent confidence intervals from a single regression of certificates and degrees awarded on the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita, in $1000s – top panel a tuition cap indicator, and the maximum increase allowed by the tuition cap. The model also controls for lags and leads of county and state unemployment rates, time-varying county and institution characteristics, institution fixed effects, year fixed effects, and state by four-year period effects (e.g., 2010 to 2013).

Appendix Table 1: List of Tuition Caps and Freezes by State, 1990-2013

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Alabama[2]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	0	0	--	--	--
Alaska	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Arkansas	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
California	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Colorado	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Connecticut[1]	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	--	--	--	--	0	--
Delaware	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Florida	--	--	--	--	--	0	--	--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	--
Georgia	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hawaii	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Idaho	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	--	0.1	0.1
Illinois	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Indiana	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Iowa	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Kansas	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Kentucky	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Louisiana	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Maine[2]	--	--	--	--	--	--	--	--	--	--	0	0	0	0	0	0	--	--	--	--	--	0	--	0
Maryland[1]	--	--	--	--	--	--	--	--	0.04	0.04	0.04	0.04	0.04	--	--	--	--	0	0	0	0	0.03	0.03	0.03
Massachusetts	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Michigan	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Minnesota	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mississippi	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Missouri[1]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	--	--
Montana	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	--	--	--	--
Nebraska	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nevada	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New Hampshire[2]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0
New Jersey[1]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.09	0.08	0.08	0.08	--	--	0.03	0.04	--	--
New Mexico	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New York[3]	--	--	--	--	0	0	--	0	0	0	0	0	0	0	--	0	0	0	0	0	--	--	--	--
North Carolina[1]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	--	--	0	--	--	0.065	--
North Dakota	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ohio	--	--	--	--	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	--	--	--	0.06	0.06	0.035	0.035	0.035	0.035	0.035	0.035
Oklahoma[4]	--	--	--	--	--	--	--	--	--	--	--	--	0.07	0.07	--	--	--	--	--	--	0	--	--	--
Oregon[1]	--	--	--	--	--	--	--	--	0	0	0	0	--	--	--	--	0.03	0.03	--	--	--	--	--	--
Pennsylvania	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rhode Island	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
South Carolina	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
South Dakota	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tennessee	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Texas	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Utah	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Vermont	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Virginia	--	--	--	--	--	0.03	0.03	0	0	0	-0.2	0	0	--	--	--	--	--	0.06	0.04	--	--	--	--
Washington	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
West Virginia	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Wisconsin[1]	--	--	--	--	--	--	--	--	--	--	--	0	--	0.08	--	--	--	--	--	--	--	--	0.055	0.055
Wyoming	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes : This table lists states and years where state legislatures impose in-state tuition caps and freezes at public institutions. We compiled these data by referencing official sources when available, combined with Lexis-Nexis searches of state newspapers going back to 1990. In some cases we checked actual tuition data to confirm the imposition of a cap, although in no case did we code a tuition cap or freeze unless it could be independently verified. 1 - Applies only to four-year institutions in the state. 2 - Applies only to two-year institutions in the state. 3 - Applies only to CUNY (except 2003) and Cornell (all years). 4 - Applies to all institutions except the Oklahoma Technology Centers.

Table A2 - 2SLS estimates for additional enrollment outcomes and samples

	Current year	T+1	T+2	T+3
	(1)	(2)	(3)	(4)
Panel A - FTUG, 2-year institutions				
Log Total Spending	0.129	0.130	0.083	0.049
	(0.282)	(0.353)	(0.366)	(0.322)
Log Tuition	-0.021	-0.094	-0.019	-0.200
	(0.151)	(0.177)	(0.193)	(0.187)
Panel B - PTUG, 2-year institutions				
Log Total Spending	0.406	1.787***	1.852***	1.672***
	(0.475)	(0.547)	(0.591)	(0.517)
Log Tuition	-0.175	0.251	0.246	-0.035
	(0.214)	(0.305)	(0.323)	(0.293)
Sample Size	16,797	16,107	15,387	14,662
Panel C - FTUG, 4-year institutions				
Log Total Spending	0.071	0.381***	0.240	0.167
	(0.091)	(0.146)	(0.151)	(0.173)
Log Tuition	-0.079	0.052	-0.055	-0.108
	(0.069)	(0.109)	(0.101)	(0.108)
Panel D - PTUG, 4-year institutions				
Log Total Spending	0.433*	0.127	0.952***	0.615
	(0.254)	(0.308)	(0.323)	(0.415)
Log Tuition	0.066	-0.508**	-0.399	-0.782**
	(0.236)	(0.246)	(0.254)	(0.325)
Sample Size	10,853	10,330	9,803	9,289

Notes: This table reports two-stage least squares estimates of the effects of tuition and spending on total undergraduate enrollment. Panels A and B display results for full-time undergraduates and part-time undergraduates in two-year institutions, while Panels C and D show results for four-year institutions. The first stage regresses annual changes in log total spending and log tuition on the change in the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita), the change in an indicator for whether a tuition cap is in place, and the change in the maximum percentage increase allowed under the cap (set to zero when no cap is in place). The second stage regresses changes in enrollment relative to year (T-1) on predicted changes in tuition and spending from the first stage. Both stages also control for time-varying county demographic and economic covariates, institution characteristics, year fixed effects, and state fixed effects. Standard errors, clustered at the institution level, are in parentheses. * - sig. at 10%; ** - sig. at 5%; *** - sig at <1%.

Table A3 - Two-stage least squares estimates for log total awards

Outcome is log total awards	Current year	T+1	T+2	T+3
	(1)	(2)	(3)	(4)
Panel A- all institutions				
Log Total Spending	0.243	0.835**	1.001***	0.699**
	(0.266)	(0.328)	(0.343)	(0.315)
Log Tuition	0.146	0.269	0.231	0.030
	(0.159)	(0.188)	(0.200)	(0.185)
Sample Size	27,570	26,320	25,074	23,838
Panel B - two-year institutions				
Log Total Spending	0.451	1.455**	1.459**	0.637
	(0.488)	(0.621)	(0.635)	(0.547)
Log Tuition	0.264	0.445	0.244	-0.291
	(0.275)	(0.337)	(0.347)	(0.319)
Sample Size	16,791	16,074	15,352	14,628
Panel C - four-year institutions				
Log Total Spending	0.294	0.367	0.485**	0.528**
	(0.195)	(0.230)	(0.238)	(0.264)
Log Tuition	0.163	0.242	0.316	0.399**
	(0.147)	(0.164)	(0.193)	(0.194)
Sample Size	10,779	10,246	9,722	9,210

Notes: This table reports two-stage least squares estimates of the effects of tuition and spending on total degrees and certificates awarded. Panel A displays results for all institutions, while Panels B and C show results for two-year and four-year institutions. The first stage regresses annual changes in log total spending and log tuition on the change in the budget shock instrument (the share of each institution's revenue from state appropriations in 1990 times yearly state appropriations per capita), the change in an indicator for whether a tuition cap is in place, and the change in the maximum percentage increase allowed under the cap (set to zero when no cap is in place). The second stage regresses changes in log total degrees and certificates relative to year (T-1) on predicted changes in tuition and spending from the first stage. Both stages also control for time-varying county demographic and economic covariates, institution characteristics, year fixed effects, and state fixed effects. Standard errors, clustered at the institution level, are in parentheses. * - sig. at 10%; ** - sig. at 5%; *** - sig at <1%.

Table A4 - 2SLS estimates of main results using actual appropriations

	Current year	T+1	T+2	T+3
Panel A: Log Enrollment	(1)	(2)	(3)	(4)
Log Total Spending	0.348***	0.604***	0.496***	0.361***
	(0.102)	(0.074)	(0.082)	(0.064)
Log Tuition	-0.019	0.045	-0.022	-0.145
	(0.067)	(0.081)	(0.091)	(0.100)
Panel B: Log Total Awards				
Log Total Spending	0.524***	0.684***	0.495***	0.454***
	(0.125)	(0.121)	(0.120)	(0.102)
Log Tuition	0.190	0.244	0.139	-0.020
	(0.137)	(0.153)	(0.152)	(0.155)
Sample Size	27,659	26,444	25,197	23,956
Panel C: Certificates				
	Current year	T+1	T+2	T+3
	(1)	(2)	(3)	(4)
Spending (per $10k)	843	986	-103	60
	(686)	(738)	(182)	(131)
Tuition	151	115	-177	-214
	(179)	(181)	(162)	(167)
Sample Size	16,793	16,076	15,354	14,630
Panel D: Associate's Degrees				
Spending (per $10k)	1,128	1,113	-201	105
	(820)	(765)	(181)	(129)
Tuition	185	292	-147	-87
	(266)	(219)	(182)	(186)
Sample Size	16,793	16,076	15,354	14,630
Panel E: Bachelor's Degrees				
Spending (per $10k)	911**	1,065**	759***	1,064***
	(432)	(429)	(262)	(232)
Tuition	-41	108	252	224
	(195)	(198)	(199)	(213)
Sample Size	10,779	10,246	9,722	9,210

Notes : This table reports two-stage least squares estimates of the effects of tuition and spending on total enrollment and certificates and degrees awarded. In the first stage we regress each institution's yearly change in total spending (per $10k) and tuition on the change in their actual appropriations (per $10k), the change in an indicator for whether a tuition cap is in place in the current state and year, and the change in the maximum percentage increase allowed under the cap (set to zero when no cap is in place). The second stage regresses each institution's yearly change in enrollment, certificates or degrees on the changes in tuition and spending from the first stage. Panels A, B, C and D report results for enrollment, certificates, associate's degrees and bachelor's degrees respectively. Both stages also control for time-varying county demographic and economic covariates, time-invariant institution characteristics such as sector, selectivity and highest degree offered, year fixed effects, and state fixed effects. Expressing the key outcomes and independent variables as differences implicitly controls for permanent differences across institutions. Standard errors, clustered at the institution level, are in parentheses. * - sig. at 10%; ** - sig. at 5%; *** - sig at <1%.