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EdWorkingPaper No. 20-303

Did Spending Cuts During the Great Recession Really Cause Student Outcomes to Decline?

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Jackson, Wigger, and Xiong (2020a, JWX) provide evidence that education spending reductions following the Great Recession had widespread negative impacts on student achievement and attainment. This paper describes our process of duplicating JWX and highlights a variety of tests we employ to investigate the nature and robustness of the relationship between school spending reductions and student outcomes. Though per-pupil expenditures undoubtedly shifted downward due to the Great Recession, contrary to JWX, our findings indicate there is not a clear and compelling story about the impact of those reductions on student achievement. Moreover, we find that the relationship between K-12 spending and college-going rates is likely confounded with contemporaneous higher education funding trends. While we believe that K-12 spending reductions may have negative impacts on student outcomes, our results suggest that estimating generalizable causal effects remains a significant challenge.

VERSION: October 2020

Suggested citation: Goldstein, Jessica, and Josh B. McGee. (2020). Did Spending Cuts During the Great Recession Really Cause Student Outcomes to Decline?. (EdWorkingPaper: 20-303). Retrieved from Annenberg Institute at Brown University: https://doi.org/10.26300/qzrd-0323

Did Spending Cuts During the Great Recession Really Cause Student Outcomes to Decline?

By JESSICA GOLDSTEIN AND JOSH B. MCGEE *

Jackson, Wigger, and Xiong (2020a, JWX) provide evidence that education spending reductions following the Great Recession had widespread negative impacts on student achievement and attainment. This paper describes our process of duplicating JWX and highlights a variety of tests we employ to investigate the nature and robustness of the relationship between school spending reductions and student outcomes. Though per-pupil expenditures undoubtedly shifted downward due to the Great Recession, contrary to JWX, our findings indicate there is not a clear and compelling story about the impact of those reductions on student achievement. Moreover, we find that the relationship between K-12 spending and college-going rates is likely confounded with contemporaneous higher education funding trends. While we believe that K-12 spending reductions may have negative impacts on student outcomes, our results suggest that estimating generalizable causal effects remains a significant challenge.

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I. Introduction

Since Coleman et al. (1966), researchers have sought to understand the relationship between school expenditures and educational outcomes. Early studies cast doubt on the idea that school spending is strongly linked with student performance (Clark, 2003; Hanushek, 2003; Papke, 2008; Roy, 2011). More recently, however, researchers have used causal identification strategies to provide evidence that overall spending plays a more influential role than previously thought (Jackson et al., 2016; Candelaria & Shores, 2017; Hyman, 2017; Miller, 2017; Gigliotti & Sorensen, 2018; Lee & Polachek, 2018; LaFortune et al., 2018; Jackson et al., 2020). The extent to which school expenditures impact student outcomes is of particular interest today as the COVID-19 pandemic creates significant state budget shortfalls while simultaneously increasing fiscal demands on schools.

Evidence from previous recessions may provide pertinent information that can be used to ease the impact of the COVID-19 pandemic on schools and students. Prior studies have claimed to uncover significant causal relationships between recessionary changes and important educational factors such as teacher quality and retention (Nagler, Piopiunik, & West, 2017; Fuchsman & Zamarro, 2019). The focus of this paper is one such study, a forthcoming *American Economic Journal: Economic Policy* article titled "Do School Spending Cuts Matter? Evidence from The Great Recession," that investigates the impact of spending cuts related to the Great Recession on test scores and college-going rates (Jackson, Wigger, and Xiong, 2020a; JWX hereafter). The paper exploits state-level variation in education spending using an instrumental variables (IV) approach to identify the causal effect of recessionary spending cuts on student outcomes.

JWX uses pre-recession (i.e., 2008) K-12 state revenue share to instrument for the effect of expenditures on educational outcomes. This approach relies on the

assumption that states which depend more heavily on state-generated education funding are more vulnerable to recessionary changes. The authors argue state-share captures recession vulnerability because it is subject to crowd-out from other more-pressing budgetary demands, such as Medicare and unemployment benefits, and because state income and sales tax revenues are more susceptible to the business cycle than local revenue, namely property taxes.

We replicate JWX as a first step in modeling the potential effects of the pandemic on K-12 spending and outcomes. This paper describes our process of duplicating JWX and highlights a variety of tests we employ to investigate the nature and robustness of the relationship between school spending reductions and student outcomes. Specifically, we explore how the findings differ when we implement different modeling choices around state groupings and year-specific controls. We also investigate the extent to which K-12 spending may be confounded with higher education spending and the implications this may have on capturing changes in college enrollment.

While we are able to reproduce the JWX findings, we do not find consistent evidence that spending cuts resulting from the Great Recession had a causal effect on student outcomes. Instead, we find:

- the JWX group IV model categorizes very few states as having low-reliance (***three states***) or high-reliance (***four states***) on state revenue to fund K-12 education, and while there may be an effect at the extremes of the distribution, the results are sensitive to relatively small changes in group composition;
- the JWX linear IV uses a non-standard specification for year fixed effects, and the results are sensitive to using other reasonable specifications to control for year-specific shocks; and
- post-recession K-12 and higher education funding trends are related, and as a result, the JWX finding that K-12 spending reductions

impacted state college-going rates is likely confounded with contemporaneous higher education funding trends.

The rest of the paper proceeds as follows. First, we briefly describe the JWX study and findings. Section II describes the data used to reproduce JWX. Section III motivates our robustness checks. Our analytical approach is described in Section IV. Results are outlined in Section V and Section VI concludes the paper, providing implications of our findings.

Description of "Do School Spending Cuts Matter? Evidence from The Great Recession"

JWX uses an instrumental variables (IV) analysis to causally link spending reductions resulting from the Great Recession to student outcomes. Since unobserved factors influence both per-pupil expenditures (PPE) and student outcomes, PPE is considered endogenous. Therefore, researchers cannot directly investigate the causal impact of PPE on student outcomes. Isolating the effect of changes in PPE requires finding an instrument that is causally linked to PPE, has no impact on the outcome measure except through PPE, and is not caused by any factors that also impact student outcomes.

JWX exploits variation in state-appropriations to public education as an instrument for per-pupil spending. Specifically, the authors utilize the share of public-school revenues generated from state sources just prior to the Great Recession in place of per-pupil spending (i.e., 2008 state share of K-12 revenue). This identification strategy relies on the fact that state-level taxes are more susceptible to the business cycle than either local property taxes or federal funding. Therefore, states which are more reliant on state funding are likely to experience larger recession-induced cuts to school spending.

JWX presents evidence that spending reductions cause declines in both student achievement and college matriculation rates. The authors find that for every $1,000 cut in per-pupil spending attributed to the recession, scores on the National Assessment of Educational Progress (NAEP) exam decline by 3.85 percent of a standard deviation. Results are similar for college-going rates, where a $1,000 reduction in per-pupil expenditures results in a decrease in college enrollment of 1.24 percentage-points. In addition to the main analysis, JWX finds that spending reductions also increased achievement gaps by both race and socioeconomic status, and that states that cut K-12 spending hired fewer personnel and reduced capital expenditures rather than core K-12 expense categories.

The JWX findings suggest that both student achievement and attainment may be broadly responsive to fluctuations in education spending. Moreover, their results imply that high-poverty districts – where state aid makes up a larger proportion of revenues – may be the most at-risk to changes in school funding. Naturally, these findings have important implications for policymakers interested in understanding the relationship between education finance and student outcomes.

II. Data

Our dataset, which mirrors the sources and strategies employed in JWX, contains data on all 50 states and the District of Columbia spanning the years between 2001 to 2019. We closely match the mean, standard deviation, and number of observations for all data elements used in JWX's main analyses. Table 1 provides summary statistics for our data and compares them to the JWX data.[1]

Unadjusted test scores for the National Assessment of Educational Progress (NAEP) were obtained from publicly-available data aggregated and hosted by the

[1] See JWX Table 1 for summary statistics.

Urban Institute.[2] To match the JWX data we use public school state-year average scores for 4th and 8th grade math and reading assessments between 2002 and 2017. All scores are standardized to a base year of 2003 using the national public school NAEP test means and standard deviations.[3]

College-going data come from the Integrated Postsecondary Education Data System (IPEDS). The data include information reported by institutions on the number of first-time college freshmen who graduated from high school in the past 12 months, aggregated by state of origin.[4] This portion of the survey is only administered during even years. To compute a college-going rate, we obtain population estimates from the US Census for the number of 17-year-olds in each state the year prior to enrollment.[5] Our college-going rate divides the number of enrollees from each state by the number of 17-year-olds in the state the previous year.[6] This rate is then associated with the year which matches the 17-year-old observation and NAEP administration years.

High school graduation rates are obtained from the National Center for Education Statistics (NCES). NCES changed its high school graduation rate measure in 2014. As a result, data from 2001-2013 represent Average Freshman Graduation Rate (AFGR) values and data from 2014-2019 are Adjusted Cohort Graduation Rates (ACGR).[7]

[2] Five states do not have 2002 NAEP scores: AK, CO, NH, NJ, and SD. To generate a balanced panel of data, we impute the mean reading z-score for those same states in 2003. Results are consistent both including and excluding these observations.

[3] Data obtained from the NAEP Data Tool (https://www.nationsreportcard.gov/ndecore/landing). 2003 National NAEP Exam Statistics: 4th grade reading – Mean = 216, SD = 37; 8th grade reading – Mean = 261, SD = 35; 4th grade mathematics – Mean = 234, SD = 28; 8th grade mathematics – Mean = 276, SD = 36

[4] We use files labeled "Residence and migration of first-time freshmen: Fall 2018" and use the associated downloadable STATA .do file provided by IPEDS to organize and summarize the data.

[5] Data from 2000-2010 come from the State Intercensel Estimates (https://www.census.gov/data/datasets/time-series/demo/popest/intercensal-2000-2010-state.html) and data from 2010-2019 come from the Vintage 2019 Estimates (https://www.census.gov/data/tables/time-series/demo/popest/2010s-state-detail.html).

[6] JWX reports using the average number of 17- and 18-year-olds in their Data Appendix. There was some ambiguity around these data in previous versions of the paper. We use the number of 17-year-olds, which yields a rate that is not statistically different from their measure.

[7] NCES reports a summary of the difference here: https://nces.ed.gov/blogs/nces/post/what-is-the-difference-between-the-acgr-and-the-afgr.

We obtain school finance data from the Census (F33) School District Finance Survey available at the Common Core of Data (CCD) . The data contain information on school revenue and expenditures, as well as the number of students enrolled in each district and state. To obtain per-pupil expenditures, spending variables were CPI-adjusted to 2015 dollars and divided by total district membership in each year.[8]

We also retrieve data on economic conditions in each state and year from the Bureau of Labor Statistics (BLS). Following JWX, we use these data to construct Bartik economic control variables for unemployment and average wage. This process is described in A.2 of the online appendix for JWX. We obtain state employment shares for 2007 – the first year of the recession – using BLS "CSVs By Industry" and "Annual Averages."[9][10] Average wage by industry is obtained from BLS Occupational Employment Statistics data. Unemployment data by industry and year are obtained from the BLS Economic News Release.[11][12]

Information on higher education finance is obtained from two sources. State share of higher education funding comes from the IPEDS finance surveys. Data on state and local appropriations per FTE and tuition and fees per FTE are obtained from the State Higher Education Executive Officers Association (SHEEO, 2019).

[8] JWX winsorizes extreme values for per-pupil expenditures by capping values of districts with expenditures great that 200 percent the 99th percentile of per-pupil revenues or less than 50 percent of the first percentile. Our analysis shows that the mean and standard deviation of spending data are not significantly changed when winsorizing, therefore we utilize the non-winsorized data in our study. Our non-winsorized spending data is not statistically different from JWX winsorized data.

[9] https://www.bls.gov/cew/downloadable-data-files.htm

[10] Census industry code crosswalk used for the BLS unemployment rate can be found here: https://www.census.gov/topics/employment/industry-occupation/guidance/code-lists.html

[11] For example, data for 2019 and 2020 can be found at: https://www.bls.gov/news.release/empsit.t14.htm.

[12] While JWX does not provide any summary statistics for these Bartik control variables, the 2019 NBER working paper version (Jackson et al., 2019) does provide Figure A4 depicting yearly averages for the unemployment rate Bartik. The figure is not well labeled but our values generally match this figure. Our average Bartik control for the unemployment rate is: 2001-4.74%, 2002-5.82%, 2003-5.97%, 2005-4.99%, 2007-4.49%, 2009-9.15%, 2011-8.56%, 2013-6.94%, 2015-4.97%, 2017-4.09%.

III. Motivation for Robustness Checks

Econometric models can be constructed in a variety of ways, and many modeling choices may be somewhat arbitrary or theoretically unimportant. However, if the model's estimates represent the true causal impact, they should be consistent across many different reasonable ways of constructing the model. JWX presents several robustness checks for their analysis; however, there are a few sensitivity tests they do not employ. As part of our replication we test the sensitivity of the analysis to various additional modeling choices we believe are important to assess. The remainder of this section describes the theoretical motivation that underlies our approach and describes the specific tests we use to investigate the nature and robustness of the relationship between school spending cuts due to the Great Recession and student outcomes.

K-12 Spending and Outcomes Trends

To motivate their analysis, JWX compares trends over time for PPE and student outcomes, demonstrating that they seemingly move together. We follow suit, graphing trends in PPE, NAEP scores, and the college-going rate. Figures 1-3 depict these trends. Our figures show that PPE declined during the Great Recession but increased sharply after 2013. We also include NCES's projections for 2018 and 2019 (dashed blue lines), which show that PPE has likely continued to climb in the years after the JWX study period.

As indicated in our graphs, both NAEP scores and the college-going rate increased with PPE during the years leading up to the recession. However, it is less apparent whether PPE and student outcomes have been moving together after the outset of the recession. Figure 1 shows that while PPE rebounded a few years after the recession, NAEP scores have continued to decline. The national college-going rate for 17-year-olds, depicted in Figure 2, leveled off following the recession and

has remained flat even as PPE increases. The recent divergence between PPE and student outcomes, especially NAEP scores, raises the question of whether the seeming correlation between the variables in earlier years was simply a coincidence.

The JWX identification strategy relies on differences between states in post-recession spending. To illustrate how state-level K-12 expenditures changed following the Great Recession, Table 2 provides constant dollar PPE differences over three periods: 2007-10 (3-year), 2007-12 (5-year), and 2007-2017 (10-year). While average PPE decreased following the great recession, not all states experienced declines, and several saw sizeable increases. Only a little over half of states (i.e., 26) states saw spending reductions between 2007 and 2012. Nine states experienced spending increases greater than $1,000 per student over this same period.

Changes in spending appear to only be weakly correlated with JWX's measure of pre-recession state K-12 revenue share. The 3-year spending changes have a 0.28 correlation with state share while the 5-year and 10-year changes have correlations of 0.10 and 0.23, respectively. Sections IV and V more rigorously investigate the relationship between PPE and student outcomes.

Instrument Data

Both the U.S. Census Bureau and NCES provide data on K-12 revenue by source. JWX uses Census data to define their instrument.[13] These two institutions each make their own unique determinations regarding what is state versus local revenue, leading to significant differences in revenues attributed to each category for some

[13] The JWX state revenue share data can be found in Table A2 of the online appendix for the forthcoming version (Jackson et al., 2020a). The 2008 Census state share data can be downloaded at https://www.census.gov/data/tables/2008/econ/school-finances/secondary-education-finance.html. There are some unexplained differences between JWX's data and Census that may stem from Census data updates.

states. For example, Census lists Arkansas' state revenue share as 76 percent, counting the state mandated minimum local property tax effort as state revenue (see note on page B-1 of the Census 2008 survey documentation). On the other hand, NCES data for 2008 show Arkansas' state revenue share at 56.7 percent, nearly 20 percentage points lower than Census. Given the purpose of the instrument is to capture recession vulnerability, the NCES data for state share is likely, at least for Arkansas, a better fit for the analysis.

Table 3 summarizes the 2008 state revenue share data from JWX (Column 1), Census (Column 2), and NCES (Column 3).[14] In total, there are 13 states where JWX and NCES data for 2008 state revenue share differ by more than two percentage points. Six states differ by more than five percentage points and three states vary by more than 15 percentage points.[15] These differences are potentially important given how few observations are included in the analysis (i.e., the 50 states and Washington D.C.).

For some states, the official data sources do a poor job capturing the unique nature of their school funding systems. In Vermont, for example, public education is largely funded through a dedicated statewide property tax.[16] In total, between 60 and 70 percent of Vermont's K-12 education funding comes from property taxes.[17] Because the property tax is statewide and distribution is managed through the state, both Census and NCES data list Vermont's state share as between 85 percent and 90 percent. JWX lists Vermont as having 68 percent state revue share. The state share instrument is intended to measure reliance on types of taxes and an allocation process that would make education funding more susceptible to cuts during a

[14] NCES also collects information property tax revenue, which is a plausible substitute for the JWX instrument. The 2005-07 state-level property tax share calculated using NCES data (Table 2, column 5) has a 0.65 correlation with the state revenue share documented in table A2 of JWX (Table 2, column 1).

[15] In addition to how state mandated local tax effort is categorized, Census and NCES also handle pension payments somewhat differently.

[16] A description of Vermont's school funding system is available at EdBuild. http://funded.edbuild.org/state/VT

[17] https://ljfo.vermont.gov/assets/Uploads/d76744a36e/The-Education-Fund-and-Education-Finance-v2.pdf

recession. However, that is far from the case for Vermont, which relies in large part on dedicated, stable property taxes. Vermont increased its spending per pupil by $1,919 in the years immediately following the Great Recession (i.e., 2007-12), the second largest increase over this period (Table 2 column 3).

JWX does not explain why state-mandated/collected property tax revenue is handled differently for California than it is for Arkansas and Vermont. California, like the other two states, has a state mandated local property tax effort. JWX argues that California's property tax dollars should be categorized as local revenue because they are not subject to crowd-out and are more stable than other state-level taxes. However, the same is true in Vermont and Arkansas, whose property taxes are counted as state revenue in JWX.

Washington D.C. also presents a challenge when categorizing revenue by source. Like other states, education is primarily financed through a combination of local property taxes, general fund appropriations, and federal funds. However, the D.C. government combines state and local functions under one umbrella.[18] Since it is not technically a state, neither NCES nor Census categorize D.C.'s general fund appropriations as state revenue. NCES simply lists Washington D.C.'s state revenue as "not applicable," while Census reports leave state revenue blank. JWX lists Washington D.C.'s state revenue share as zero. Given the theoretical justification for the instrument and D.C.'s reliance on general fund appropriations for a large share of school funding, a value greater than zero is likely more appropriate. In fact, since the entire school budget is appropriated by the council, there is a reasonable argument that D.C.'s state share should be 100 percent. Because of this uncertainty around how to handle Washington D.C.'s state K-12

[18] A description of Washington D.C.'s school funding system is available at NCES and EdBuild, both linked below.
https://nces.ed.gov/edfin/pdf/StFinance/District.pdf
http://funded.edbuild.org/state/DC

revenue share, we drop the jurisdiction from analyses that use this instrument except when we are explicitly replicating JWX.[19]

The last two columns of Table 2 present our measures of pre-recession state and property tax K-12 revenue share. While JWX uses 2008 as its pre-recession year for the instrument, we want to test measures that more clearly capture the period before the recession began and that smooth out potential year-to-year variation. To that end, both our state and property tax share measures are averaged over the years 2005 to 2007. We include property tax share as an alternative instrument that fulfills the theoretical justification for the instrument outlined in JWX.

For certain analyses, JWX uses 2008 state K-12 revenue share to group states into high-, medium-, and low-reliance categories. Because of the data differences discussed above, applying the same categorization rules to different data sources yields different groupings. Table 2 includes color coding to indicate high- and low-reliance groups across data sources. Cells colored green are states which are below the 0.33 threshold JWX uses to define low-reliance, and cells colored red are above the 0.67 threshold JWX uses to define high-reliance. We will discuss these thresholds in more detail in the next section. Simply changing data sources from JWX to NCES results in four states changing categories and D.C. dropping from the analysis. While this change only represents approximately 10 percent of observations, as we will show in the next section, these five states represent a very high proportion of JWX's high- and low-reliance groups.

State-Group Definitions

The primary analysis in JWX relies on grouping states into high-, medium-, and low-reliance categories. In addition to the data issue outlined in the previous

[19] JWX provides estimates dropping Washington D.C., Hawaii, and/or California, and finds that their results are robust to these changes.

section, the thresholds JWX use to categorize states result in very few states being placed in the high- and low-reliance categories. JWX does not provide a theoretical or empirical justification for the thresholds used to categorize states and does not test different groupings.

As noted in the previous section, JWX defines high-reliance states as those that depend on state appropriations for more than 67 percent of total revenue and low-reliance as less than 33 percent. Of the 51 jurisdictions included in the analysis (i.e., 50 states and Washington D.C.), the JWX categorization rules result in only ***three*** states being placed in the low-reliance group and ***four*** in the high reliance group. All other states are relegated to the middle-reliance category.

Of the seven states included in the high or low groupings, four of them are based on questionable data, including three of the four states in the high-reliance category. Outlier jurisdictions Washington D.C. (low-reliance with zero percent state share) and Hawaii (high-reliance with 85 percent state share) are included in the low- and high-reliance categories, respectively.[20] In addition, Arkansas (high-reliance with 76 percent state share) and Vermont (high-reliance with 68 percent state share), who's property tax revenues are arguably misclassified as state revenue, are included in the high-reliance category.

The small number of states in the high- and low-reliance groups and the presence of states with problematic data in both groups raises the question of how sensitive the JWX results are to state-group definitions. JWX provides results from robustness tests dropping any combination of one, two, or three states from their analysis (see figure A3 in the online appendix). However, this does little to test the robustness of their results to different state groupings given that the vast majority of states (i.e., 44) are in the middle-reliance category. The results from the test JWX

[20] The school districts in both Washington D.C. and Hawaii combine state and local government levels, making attempts to separate state vs. local revenue challenging.

performs would primarily be generated by dropping states in the large middle reliance category, which we would expect to have a limited effect on the estimate.

We test the impact of state-group definitions by estimating results using four symmetric percentile sets to categorize states, as depicted in the columns of Table 3. We use average 2005-07 state K-12 revenue share calculated using NCES data to determine the percentiles and categorize states. Column 1 of Table 3 depicts the grouping used in JWX, and columns 2-5 represent additional groupings based on the 10^{th} and 90^{th} percentile, 15^{th} and 85^{th} percentile, 20^{th} and 80^{th} percentile, and 25^{th} and 75^{th} percentile, respectively.[21]

In Table 4, states highlighted in red text are those which are different from the JWX grouping (Column 1). States not listed in either the low- or high-reliance groups are in the medium-reliance category. The number of states in each category is listed in parenthesis at the top of each column. Increasing the threshold for low-reliance from the JWX value (0.33 percent) to the 10^{th} , 15^{th}, 20^{th} and 25^{th} percentiles adds 2, 4, 8, and 10 states to that group, respectively.

Figure 3 provides a histogram illustrating the distribution of our pre-recession state revenue share measure. The red lines represent the various percentiles we use to categorize states. Most states are relatively closely clustered between 30 percent and 65 percent, with only six states outside that range. For illustrative purposes Washington D.C. is included in the figure with a value of zero (i.e., the value from JWX). Washington D.C. is the bar on the far left at zero, more than 25 percent below the next state. Hawaii and Vermont are the two outliers on the right side of the figure.

Given the variation in group composition with different threshold rules and data sources, our empirical approach investigates how state group definitions influence

[21] The percentile values for NCES average 2005-07 state K-12 revenue share rounded to four digits are: 10^{th} = 0.3364, 15^{th} = 0.3585, 20^{th} = 0.3862, 25^{th} = 0.4000, 75^{th} = 0.5746, 80^{th} = 0.5937, 85^{th} = 0.6031, and 90^{th} = 0.6273

the JWX results. We believe using percentiles to define state groups is empirically justifiable and testing more inclusive groupings will help us better understand the influence of the groupings on the results. Sections IV and V outline our analytical approach and present findings for different specifications using each grouping included in Table 4.

Controlling for Year-Specific Shocks

The Great Recession was a complex event with multiyear impacts on many aspects of our society. Given the nature of the identifying event, annual stochastic shocks may influence both the outcome measures and the instrument. In circumstances such as these it is common practice to implement individual year fixed effects in empirical models to control for potential annual shocks.

JWX employs the full set of year fixed effects in models that group states into reliance categories (i.e., the group IV models). However, as the previous section outlines, we have reason to believe the results of those models may be sensitive to state-group definitions. The appendix of JWX also presents models that do not rely on state groupings, but instead include 2008 state revenue share as a continuous variable (i.e., linear IV models; see section C.2 of the JWX online appendix). JWX provides these linear models to demonstrate the robustness of the results.

The authors note that including the full set of year fixed effects in the linear specification would be ideal but doing so results in a "weak first stage" (footnote 18 on p. 11 of JWX, 2019 and IV.1 section F of JWX, 2020a). We test this claim and find that when the full set of year fixed effects is included, the first stage coefficient estimate is close to zero and the Kleibergen-Paap Wald F-statistic is lower than the critical value, thus validating that the instrument is weak in the presence of full year fixed effects.

In lieu of using full year fixed effects, JWX's preferred linear specification (see Table A23 of the JWX online appendix) groups years into three period controls representing pre-recession (2001/02-2007), during-recession (2009-2011), and post-recession (2013-2017). There are at least two motivations to test for sensitivity to different specifications of year fixed effects. First, there could be factors related to the recession that vary with year and affect the outcomes through channels other than school spending. Grouping years will not fully account for these factors.

Second, imprecision around the timing of the recession and its impacts recommends caution when grouping years together over this timeframe. The National Bureau of Economic Research (NBER) estimates that the Great Recession began in December of 2007 and ended in June of 2009.[22] Of course, in most states, the budget implications of the downturn lasted beyond the official end of the recession. JWX present models using only the year groupings described above. Given the uncertainty around how best to control for year-specific shocks, we test six different reasonable configurations of the year fixed effects in our analysis. Our approach is outlined in section IV.

Potential Confounding of the JWX College-Going Result

For K-12 state revenue share to be a valid instrument for PPE, it must not affect the college-going rate through any other pathway except through PPE, and it must not be influenced by any other factors which are also causally linked to college-going. We believe that potential confounding between K-12 and higher education funding trends may violate the exclusion restriction necessary to causally estimate the effect of PPE on college-going rates. We also believe there may be economic, political, and institutional factors that influence both pre-recession K-12 state

[22] See https://www.nber.org/cycles.html.

revenue share and post-recession college-going rate. Figure 4 provides a directed acyclic graph (DAG) illustrating our concerns.

To investigate confounding, we first examine time trends to see if K-12 and higher education funding measures move in tandem. Figure 5 depicts the relationship among PPE, state and local higher education appropriations per full-time equivalent (FTE) student, and tuition revenue per FTE. Per-pupil expenditures and higher education appropriations move closely together after the recession, both falling sharply between 2008 and 2012, while tuition revenue steadily increases over time. Figure 6 shows these same three variables indexed to their 2002 values to display percentage change. The magnitude of the changes in higher education appropriations and tuition dwarf those for PPE, raising the prospect that higher education finance might have greater potential to influence college-going rates.

These graphs lead us to believe that K-12 and higher education spending may be confounded and even if a relationship between K-12 PPE and college-going rates exists, it may be overshadowed by the impact of changing higher education appropriations and tuition revenue. It is reasonable to theorize that higher education funding may influence college-going more than K-12 appropriations. Recent studies have shown that college outcomes, including enrollment, are responsive to higher education funding changes (Deming and Walters, 2017 and Bond et al., 2019). While we do not attempt to identify the true effect of higher education spending on college enrollment, we investigate the possibility that higher education appropriations and tuition confound the JWX college-going findings. Section IV provides additional details regarding our approach.

IV. Empirical Approach

Our empirical methods follow JWX closely, with variable definitions matching those described in the Identification Strategy section of JWX. To our knowledge,

we deviate only in areas where we test the robustness of the JWX results. The sections below present our empirical approach for four different analyses: 1) event study graphs, 2) group IV, 3) linear IV, and 4) tests for higher education confounding. Each section describes our methods and approach for robustness checks.[23]

Event Study Graphs

JWX presents event study graphs as suggestive evidence that per pupil expenditures, NAEP scores, and the college-going rates declined more in states with a high reliance on state revenues relative to states with a low reliance on state revenue. Equation 1 describes the event study estimating equation.

$$(1) \qquad Y_{st} = \sum_{t=2003}^{2017} \beta_t \left(I_{\Omega_s > q(50),s} \times I_{T=t}\right) + \alpha_s + \theta_t + (\tau_s \times T) + \upsilon_{st}$$

Subscripts *s* and *t* indicate state and year, respectively. The outcome variable, Y_{st}, is either PPE, average NAEP scores, college-going rates, or high school graduation rates. $I_{\Omega_s > q(50),s}$ is an indicator for states where the 2008 K-12 state share is above the national median of 0.48. We use the JWX state share data for this analysis. $I_{T=t}$ are year-specific indicators. The α_s are state fixed effects, and the θ_t are year fixed effects. τ_s is the pre-recession, state specific linear trend for the left-hand side variable in each equation.[24] β_t is the coefficient of interest and represents the year-specific difference between states above versus below the median. We omit the year 2007, so the calculated differences are relative to that year.

[23] Errors are clustered at the state level in all models.

[24] These linear trends are equal to the slope of the left-hand-side variable between 2001/2002 and 2007. We also ran models where we instead used regression to predict the left-hand-side variables based on pre-recession data with similar results.

Instrumental Variables Models

Following JWX, we estimate two different sets of IV models. The first is a group IV in which states are categorized as being high-, medium-, or low-reliance based on state share of K-12 revenue. These category variables are then used to define the instrument. The second model is a linear IV in which state share of education revenue is treated as a continuous variable. While the forthcoming version (Jackson et al., 2020a) focuses exclusively on the group specification, the Northwestern University working paper version of JWX (Jackson et al., 2020b) includes both the linear and group IV specifications. We include both models to test the robustness of the results across multiple dimensions.

Group IV.—For the group IV analysis, we estimate the equations below using two stage least squares (2SLS).

$$(2)\quad PPE_{st} = \sum_{g=2}^{3}\left[\pi_{1g}\left(I_{gs} \times I_{post} \times (T - 2008)\right)\right] + \sum_{g=2}^{3}\left[\emptyset_{1g}\left(I_{gs} \times I_{post}\right)\right] + \rho_{12}\left(I_{post}\right) + \delta \boldsymbol{C}_{st} + \alpha_{1s} + \theta_t + (\tau_{1s} \times T) + \varepsilon$$

$$(3)\quad Y_{st} = \beta\left(\widehat{PPE}_{st}\right) + \sum_{g=2}^{3}\left[\emptyset_{1g}\left(I_{gs} \times I_{post}\right)\right] + \rho_{22}\left(I_{post}\right) + \delta \boldsymbol{C}_{st} + \alpha_{2s} + \theta_t + (\tau_{2s} \times T) + \varepsilon$$

The subscript *g* refers to the reliance categories, with 1 representing low-reliance, 2 representing medium-reliance, and 3 representing high-reliance. I_{gs} is a state specific indicator for group membership, I_{post} is an indicator for years after 2008, and $(T - 2008)$ indicates current year, T, relative to 2008. $\boldsymbol{C}_{st}$ is a vector of state and year-specific Bartik economic controls for the unemployment rate and average annual wage, which are defined in JWX. State (α_{*s}) and year (θ_{*t}) fixed effects are included, along with the pre-recession, state-specific linear trend for the left-hand-

side variables (τ_{*s}). The second stage outcome variable, Y_{st}, is either a) average standardized NAEP scores, b) college-going rate, or c) high school graduation rates.[25] β, the coefficient on the predicted values from the first stage, $\widehat{PPE_{st}}$, is the coefficient of interest.

To test the impact of state group definitions on the results, we vary state-reliance group membership as described in the motivation section above and outlined in Table 4.

Linear IV.—For the linear IV, we estimate the model described below using 2SLS.

$$(4) \quad PPE_{st} = \pi_1\left(\Omega_s \times I_{post} \times (T - 2008)\right) + \rho_{11}(\Omega_s \times I_{post}) + \rho_{12}(I_{post}) + \delta \boldsymbol{C}_{st} + \alpha_{1s} + \theta_{1t} + (\tau_{1s} \times T) + \varepsilon$$

$$(5) \quad Y_{st} = \beta(\widehat{PPE_{st}}) + \rho_{21}(\Omega_s \times I_{post}) + \rho_{22}(I_{post}) + \delta \boldsymbol{C}_{st} + \alpha_{2s} + \theta_{2t} + (\tau_{2s} \times T) + \varepsilon$$

All variable definitions are the same as in the group IV described above. However, in this model the reliance group indicators are replaced with the continuous variable Ω_s, which is 2008 K-12 state revenue share. We use the JWX state share data for this analysis.

Since there is uncertainty about how best to control for year-specific shocks, we test the linear model using seven different specifications for year fixed effects. Table 5 describes each of the specifications we test. Column 2 provides the number of year indicator variables included in the model in each specification. We concentrate our robustness tests on years around (2007-2009) and those after (2011-2017) the Great Recession.

[25] High school graduation rate models include an indicator for the change from AFGR to ACGR.

Higher Education Confounding

We initially test for confounding by adding pre-recession state higher education revenue share, state and local higher education appropriations per FTE, and tuition and fees per FTE into the linear IV as control variables. However, adding these variables as controls creates a multicollinearity problem. The first-stage variation inflation factors (VIFs) for all three variables are well above recommended levels, indicating significant multicollinearity with other included variables. In fact, the statistical software drops pre-recession state higher education revenue share from linear IV models because of collinearity when it is included as a control. Therefore, we proceed by testing confounding in the three ways described below using the linear IV model outlined above.

First, we replace the K-12 instrument with pre-recession state share of higher education revenue. If pre-recession state share of higher education revenue has similar predictive power to K-12 state revenue share, then state funding for K-12 and higher education may be confounded.

Next, we estimate the linear IV described above, but replace the dependent variable with state and local higher education appropriations per FTE and tuition and fees per FTE. If instrumented PPE predicts these higher education funding variables, then the exclusion restriction may be violated in the JWX model.

JWX provides results from a similar robustness test (see Table A18 in the online appendix). However, there are two key differences between our test and theirs: 1) we use per FTE measures analogous to per-pupil spending for K-12 and 2) we perform these robustness checks using the linear IV in which the instrument is a continuous variable rather than based on discrete state groups. Using a per FTE adjusts for state size, similar to K-12 spending, while using the linear IV model eliminates the influence of state groupings on the robustness test.

Finally, we estimate a JWX-style linear IV predicting college-going using state share of higher education to instrument for state and local higher education appropriations per FTE and tuition and fees per FTE. If a similarly specified IV model using higher education variables can predict college-going, then it indicates that higher education is a potential alternative pathway influencing college-going.

V. Results

Event Study Graphs

Figures 7-10 provide the event study graphs from our analysis. These figures include a dot indicating the point estimate for the year-specific difference between states that are above versus below the median for 2008 K-12 state revenue share, as well as 95 percent confidence intervals around the point estimates. Point estimates are relative to 2007, the omitted year in the model.

We find evidence that, following the recession, PPE declined more in states where pre-recession K-12 state revenue share was above the median (Figure 7). However, for NAEP scores (Figure 8), college-going rates (Figure 9), and high school graduation rates (Figure 10) we find no statistically significant differences between states that are above versus below the median K-12 state revenue share.

Our event study results are different from JWX, which finds significant divergence after 2007 in NAEP scores and college-going rates for states that are above versus below the state revenue share median. The threshold used in JWX for the event study graphs has changed significantly across different versions of the paper (i.e., from 0.33 to 0.39 to 0.48 in the current version). Based on our analysis, we believe that the latest version of JWX may present results for a lower cutoff (i.e., 0.39) than is stated in the paper (i.e., 0.48 - the national median).[26]

[26] The change in the cutoff from 0.39 to 0.48 moves 16 states from one group to the other.

Group IV

Tables 6A through 6C present the results of our group IV estimation. The letters A-C in the table names correspond to our three outcome variables: A) NAEP scores, B) college-going rates, and C) high school graduation rates. We estimate results both including (Columns 2-6) and excluding (Columns 7-10) Washington D.C. Column 1 provides the original results from JWX for comparison. We model each of the five state categorization frameworks presented in Table 4: the JWX categorization (Column 2 in Tables 6A-C) as well as categorizations using NCES data for state K-12 revenue share based on the 10^{th} and 90^{th} percentiles (Columns 3 and 7), 15th and 85^{th} percentiles (Columns 4 and 8), 20^{th} and 80^{th} percentiles (Columns 5 and 9), and 25th and 75^{th} percentiles (Columns 6 and 10).[27]

For both NAEP (Table 6A) and college-going (Table 6B), our replication estimates using the JWX categorization (Column 2) are similar in magnitude and significance to the original JWX results (Column 1). When we apply other categorizations based on percentiles of state K-12 revenue share, the point estimates shrink toward zero and lose significance. In the NAEP models, all estimates using percentiles to categorize states are statistically insignificant, and in our preferred specifications, which excludes Washington D.C., the point estimates switch sign when using the bottom and top 15 percent or greater to categorize low/high-reliance states. For college-going, the point estimates are somewhat more stable – although attenuated and insignificant in all percentile-based specifications. We also provide results for high school graduation rates (Table 6C), which are insignificant across all specifications.

Our estimates indicate that the JWX group IV results are sensitive to changes in state group composition. Using the top and bottom decile of pre-recession state K-

[27] For NCES state share, we use average state share from 2005-2007 instead of 2008 state revenue share. This ensures that the instrument is measured pre-recession and captures persistent state share.

12 revenue share only changes two states in the low-reliance group and three states in the high-reliance group relative to the JWX categorization, but even this small change yields statistically insignificant results for both NAEP and college-going. Given that the point estimates when using top/bottom decile are not statistically different from the original JWX results, we cannot rule out the possibility that there is an effect at extreme values of the instrument for both outcomes. However, the NAEP results strongly suggest that any potential effect on achievement dissipates relatively quickly as group composition becomes less extreme. The college-going point estimates are somewhat more persistent, but we are concerned that these results may be confounded by higher education funding. In a subsequent section, we present evidence for the potential confounding of the college-going results with contemporaneous higher education funding trends.

Linear IV

As noted in the motivation section, a key component of the linear IV specification is how year fixed effects are modeled. JWX groups years into three indicator variables for pre-, during-, and post-recession. To better understand the model's robustness around this choice, we test different specifications for year fixed effects. Table 5 describes each of the specifications we employ.

Tables 7A-C present the results of our linear IV. As in the previous section, the letters in the table names correspond to our outcomes: A) NAEP scores, B) college-going rates, C) high school graduation rates. Column 1 provides the original JWX results for comparison, and Column 2 provides our replication results for the JWX specification. The remaining columns (3-9) in Tables 7A-C correspond to rows in Table 5, which outline the various year fixed effect specifications we test. We exclude Washington D.C. from the models presented in columns 3-9.

We replicate similar magnitudes and significance levels for the impact of instrumented PPE on both NAEP and the college-going rate when using the JWX year-group specification (Columns 1 and 3). For NAEP scores, all other specifications for the year fixed effects yield insignificant results and point estimates that are negative or zero (Table 7A). On the other hand, the findings for college-going rate appear to be robust to changes in year fixed effects specification as all specifications, except full year fixed effects, yield positive and statistically significant results of roughly the same magnitude (Table 7B). The point estimates for high school graduation are very close to zero and not consistent in sign or statistical significance.

We also run models using pre-recession property tax revenue share as the instrument. The estimates generated by these models are provided in Tables 8A-C. Using property tax revenue share to instrument for PPE produces similar estimates to those generated using state revenue share. For NAEP, the results using the JWX year grouping produces positive significant results; however, the other year groupings produce negative point estimates with inconsistent statistical significance. College-going estimates again appear relatively robust to different specifications for year-specific controls. Estimates for high school graduation rates are close to zero and not consistent in sign or statistical significance.

These findings indicate that the NAEP results are highly sensitive to different specifications of the year fixed effects. Estimates generated using the specific year grouping employed in JWX are relatively robust to dropping Washington D.C. from the analysis and using property tax share for the instrument. However, all other reasonable year fixed effect specifications we test yield point estimates that are either negative or zero. The weakness of the first-stage is a likely driver of this result - F statistics from the first stage of alternate year fixed effect specifications

indicate a weak instrument.[28] Given there is not a strong theoretical reason to group years in the specific way JWX implements, and since we find many other reasonable specifications yield a weak first stage and null results, we conclude that the JWX linear IV model is unlikely to identify a systematic relationship between NAEP scores and spending cuts following the Great Recession.

While the college-going results appear more robust, the sensitivity of the NAEP results and lack of statistically significant effects on high school graduation rates call into question the pathway by which PPE affects college-going. If PPE did not have a consistent effect on student achievement and did not impact graduation rates, then how did it affect the college-going rate? The next section provides one potential answer to that question.

Higher Education Confounding

While the JWX college-going results appears to be somewhat robust in models presented above, there is reason to believe that the finding may be confounded with contemporaneous higher education trends. Section III describes why we believe this is the case and section IV lays out our three-pronged approach for empirically demonstrating that confounding likely exists between K-12 and higher education spending.

First, we replace the K-12 state share instrument with pre-recession state share of higher education revenue. Table 9 presents the results of this exercise for both NAEP and college-going rates. The first two columns in each panel provide the original JWX findings and our replicated findings from Table 7. Results using the higher education state share instrument are found in the final two columns of Table 9. Our findings indicate that replacing the K-12 state share instrument with higher

[28] Recent analysis (Lee et al. 2020) suggests that second-stage t-statistic critical values may be more sensitive to the strength of the first stage than previously thought, and as a result, the statistical significance of many IV results may be overstated.

education revenue yields point estimates that are of similar magnitude and significance to those obtained using K-12 state share. This indicates that state shares of K-12 and higher education revenue are likely confounded.

Next, we estimate linear IV models replacing the dependent variable with state and local higher education appropriations per FTE and tuition and fees per FTE. Tables 10A and 10B present the results of those models. As in the linear IV section we provide results across all year fixed effect specifications outlined in Table 5. For all 16 specifications, except the model including full year fixed effects for tuition and fees, we find that instrumented PPE is statistically significant and positively related to state and local higher education appropriations per FTE and tuition and fees per FTE. The ability of instrumented PPE to predict higher education funding variables indicates that the IV exclusion restriction may be violated in the JWX college-going model.

Finally, we estimate JWX-style IV models to predict college-going rates using pre-recession state share of higher education revenue to instrument for state and local higher education appropriations per FTE and tuition and fees per FTE. We also estimate these models substituting K-12 state share as the instrument in place of higher education revenue. This investigates whether the confounding of the instrument is also apparent when higher education spending is treated as the endogenous variable. We estimate these models using the natural log of appropriations and tuition and fees per FTE. Table 11 provides the results for these models. All specifications yield statistically significant, positive point estimates, indicating that higher education spending is a viable alternative pathway for impacting college-going rates.

Based on the results of the three tests, we believe that the college-going finding is confounded with contemporaneous higher education trends. While it may be feasible that both K-12 spending and higher education spending impact college-

going, we do not think it is possible to disentangle those impacts using a JWX-style IV approach.

VI. Conclusions

As states face looming budget shortfalls and schools grapple with the effects of COVID-19, it has become increasingly important to understand the potential impact of education funding reductions on student outcomes. Using data from the years around the Great Recession, JWX suggests that K-12 spending reductions have widespread negative impacts on both student achievement and attainment.

While we believe that spending reductions may have negative impacts on student outcomes, our results suggest that there is not a clear and compelling story about the impact of school spending reductions related to the Great Recession on student achievement. Moreover, we find that the relationship between K-12 spending and college-going rates is likely confounded with contemporaneous higher education funding trends. Specifically, we find:

- the JWX group IV model categorizes very few states as having low-reliance (***three states***) or high-reliance (***four states***) on state revenue to fund K-12 education, and while there may be an effect at the extremes of the distribution, the results are sensitive to relatively small changes in group composition;
- the JWX linear IV uses a non-standard specification for year fixed effects, and the results are sensitive to using other reasonable specifications to control for year-specific shocks; and
- post-recession K-12 and higher education funding trends are related, and as a result, the JWX finding that K-12 spending reductions impacted state college-going rates is likely confounded with contemporaneous higher education funding trends.

Our results highlight the challenges of estimating causal effects for loosely defined interventions (e.g., funding changes) at the level of states and the importance in exercising caution when making policy recommendations based on such studies. It is not surprising that it is difficult to empirically estimate the impact of school funding on student outcomes. K-12 education is a complex system and how schools deal with funding changes varies widely both within and across states. Unless those changes are substantial and have a direct, sizeable impact on classrooms, student outcomes are unlikely to respond quickly enough to be captured in short timeframes. Therefore, it is questionable whether rigorous research can consistently show that school spending matters for educational outcomes on such a broad scale.

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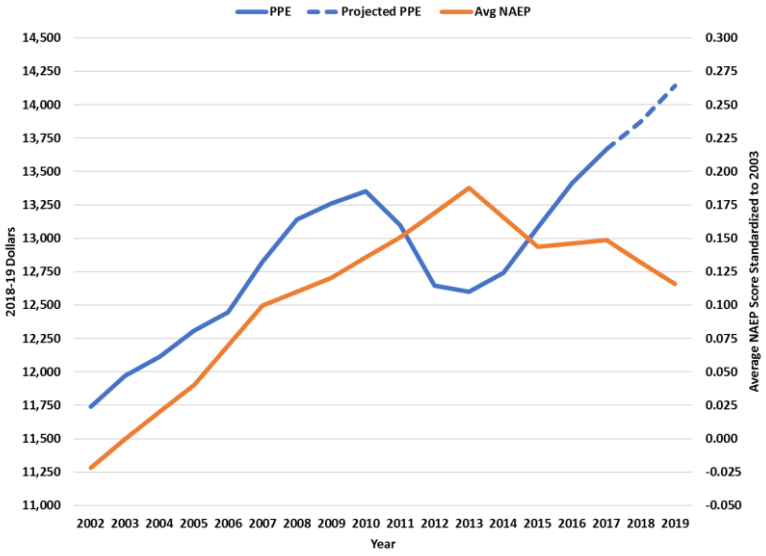
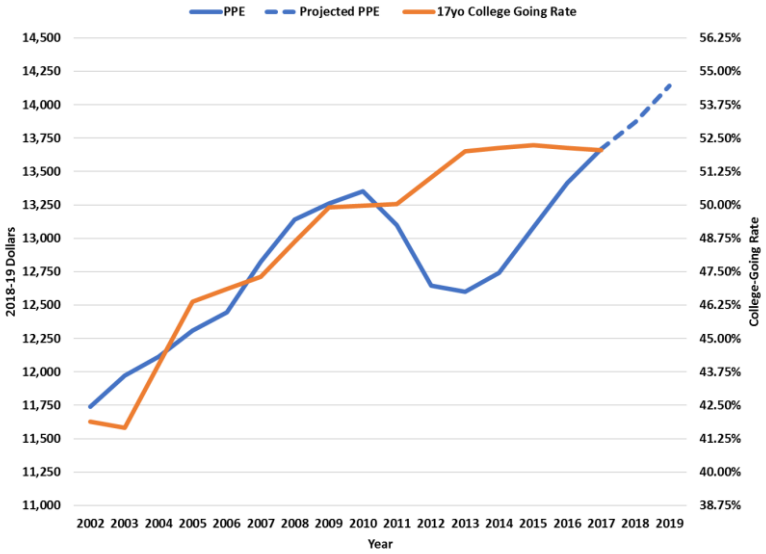
Tables and Figures

Figure 1: Per-Pupil Current Expenditures (PPE) and Average NAEP Scores



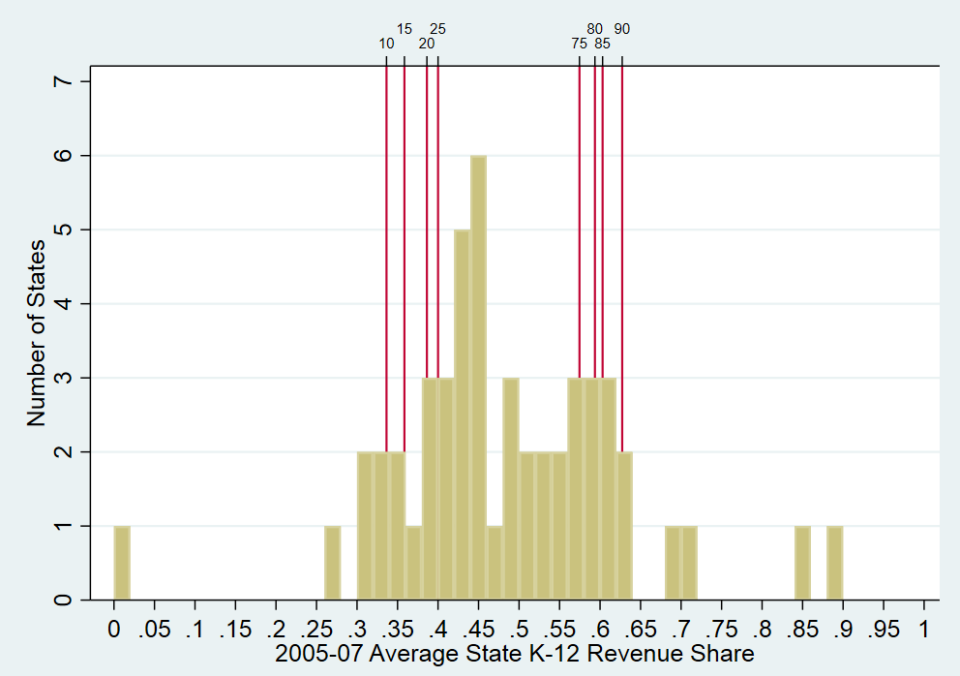
Notes: PPE was collected from the 2019 NCES Digest of Education Statistics table 236.55. Average NAEP is the national public average score on reading and mathematics tests standardized to 2003. NAEP data were collected from the NAEP Data Explorer. Only the reading test was administered in 2002. Mathematics test scores for that year were imputed using linear interpolation

Figure 2: Per-Pupil Current Expenditures (PPE) and College-Going Rate



Notes: PPE was collected from the 2019 NCES Digest of Education Statistics table 236.55. The college-going rate is the number of first-time enrollees in the fall semester who graduated high school in the past 12 months divided by the Census estimate for the number of 17-year-olds in the previous year. The national rate was calculated by summing the numerator and denominator across states in each year. See the Data section for more details on the data and calculation.

Figure 3: Histogram of 2005-07 Average State K-12 Revenue Share



Notes: The red lines represent the percentile labeled at the top of the figure. For illustrative purposes, Washington D.C. is included in the figure with a value of zero despite being listed as N/A in the NCES data.

Figure 4: College-Going IV Directed Acyclic Graphs (DAGs)

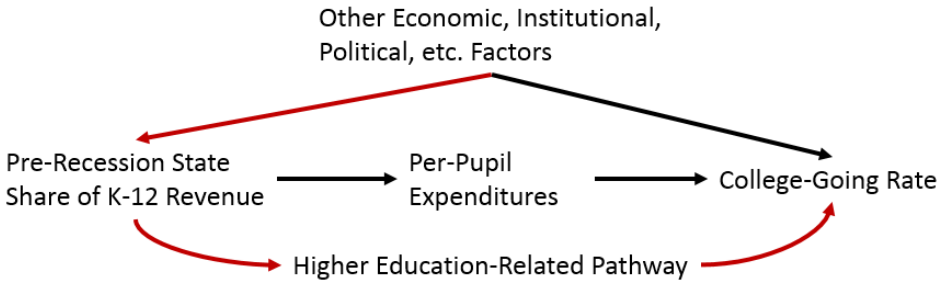
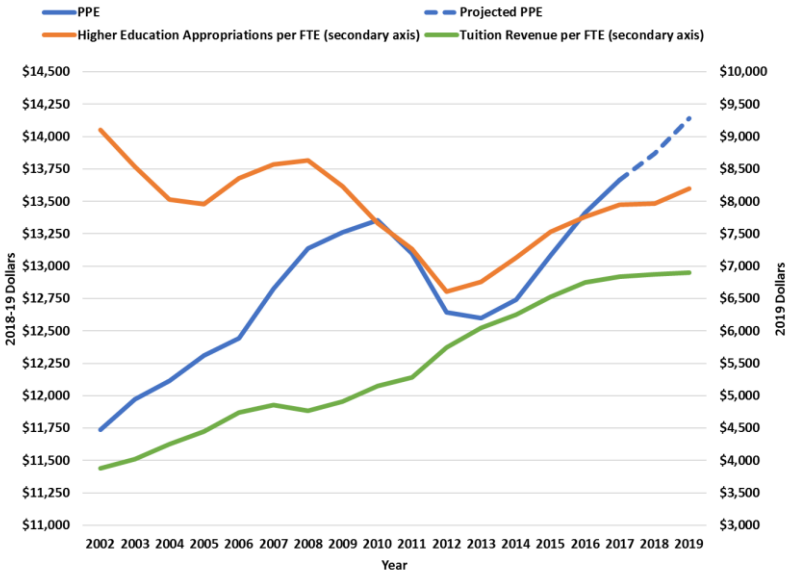
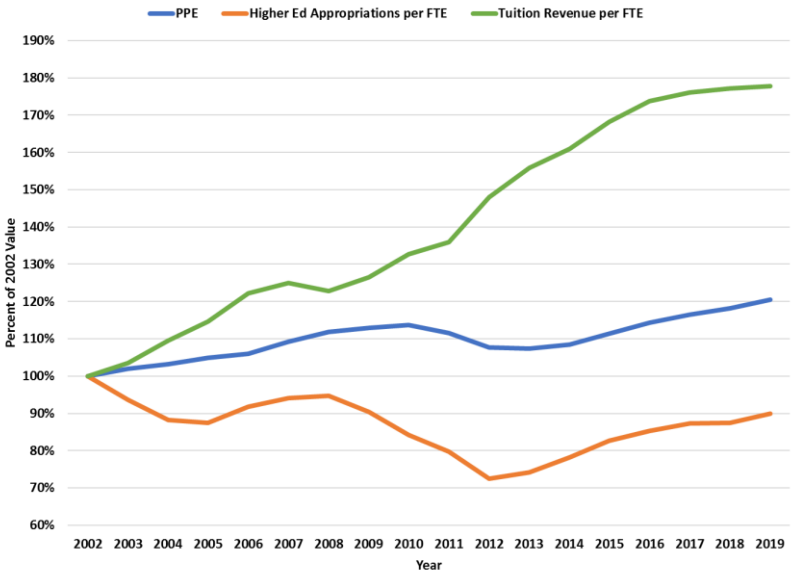


Figure 5: Per-Pupil Current Expenditures (PPE) and Higher Education Funding Trends



Notes: PPE was collected from the 2019 NCES Digest of Education Statistics table 236.55. State and local appropriations per FTE and tuition and fees per FTE are obtained from the State Higher Education Executive Officers Association (SHEEO, 2019).

Figure 6: 2002 Indexed Per-Pupil Current Expenditures (PPE) and Higher Education Funding Trends



Notes: PPE was collected from the 2019 NCES Digest of Education Statistics table 236.55. State and local appropriations per FTE and tuition and fees per FTE are obtained from the State Higher Education Executive Officers Association (SHEEO, 2019).

Figure 7: Per-Pupil Expenditures Event Study Graph
Using 48 Percent Threshold for High-Reliance

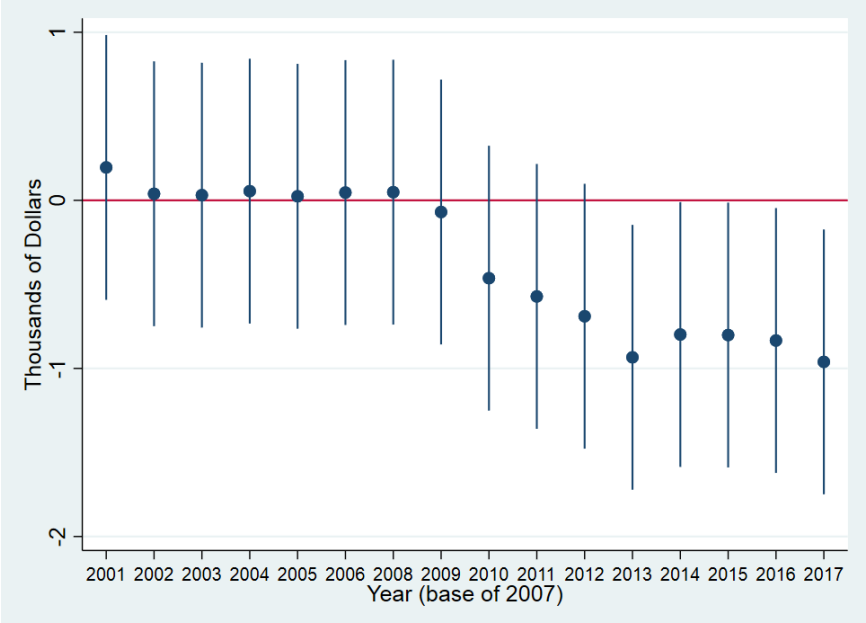


Figure 8: NAEP Scores Event Study Graph
Using 48 Percent Threshold for High-Reliance

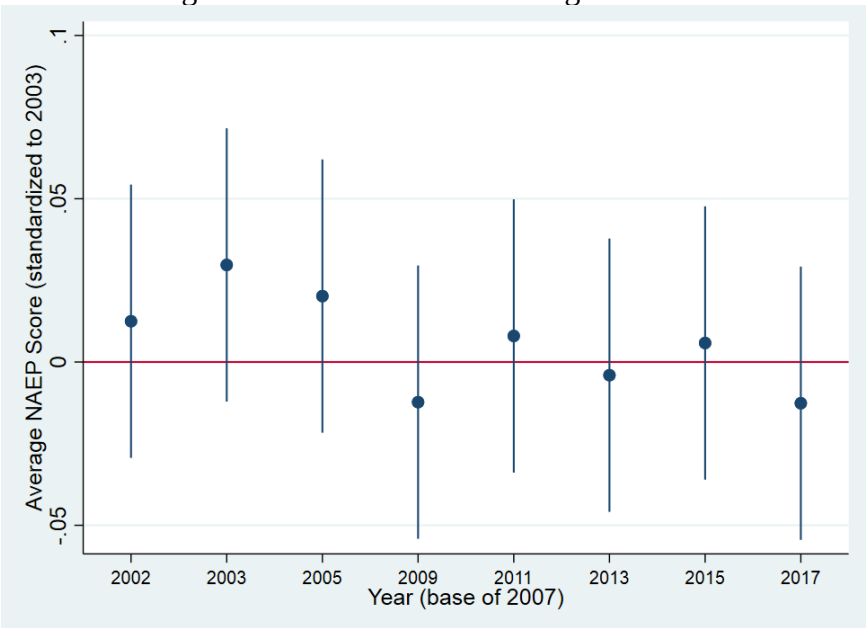


Figure 9: College-Going Rate Event Study Graph
Using 48 Percent Threshold for High-Reliance

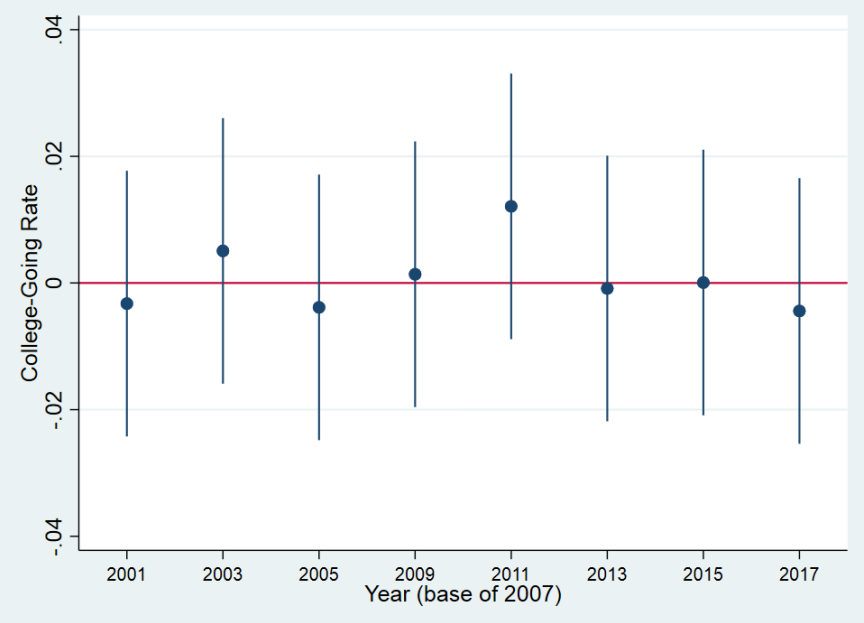


Figure 10: High School Graduation Rate Event Study Graph
Using 48 Percent Threshold for High-Reliance

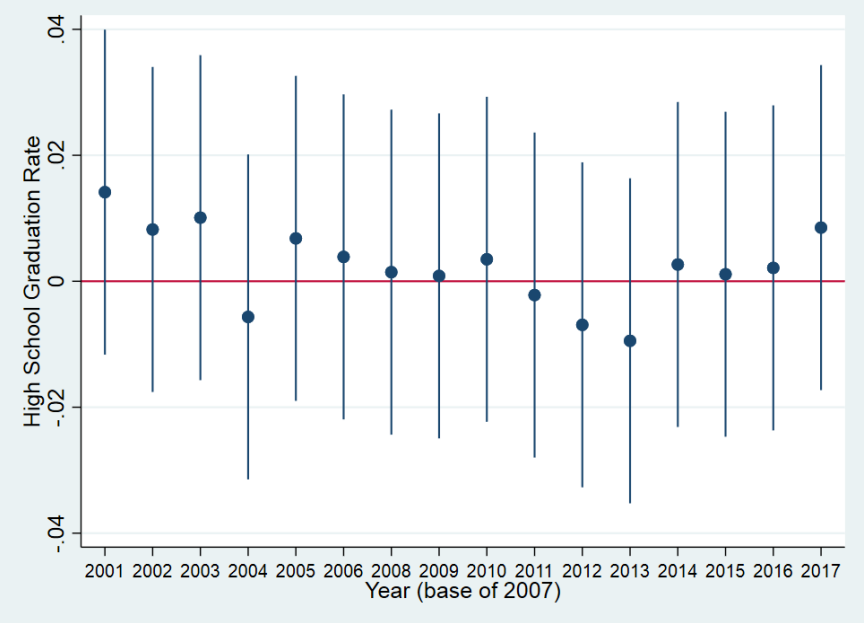


Table 1: Study Data Summary Statistics

	JWX Values			Replication Values			P-Value for t-test of Difference in Means
	N	Mean	SD	N	Mean	SD	
Per-pupil spending (2015 dollars)	510	13,208	3,807	510	13,203	3,699	0.98
Share of revenue from state sources in 2008 (JWX)	51	0.493	0.137	51	0.493	0.137	
Share of revenue from state sources in 2008 (Census)				51	0.502	0.144	
Share of revenue from state sources in 2008 (NCES)				51	0.496	0.144	
Share of revenue from property taxes in 2008 (NCES)				51	0.300	0.131	
Average NAEP Z-Score (standardized to 2003)	459	0.125	0.211	459	0.120	0.200	0.71
College Enrollment Rate (17-year-olds)	459	0.475	0.078	459	0.480	0.079	0.33
High School Graduation Rate				510	0.773	0.081	
Unemployment Rate	510	5.777	1.965	510	5.742	1.955	0.78
Annual Average Employment (thousands)	510	2,603.81	2,820.57	510	2,600.10	2,822.63	0.98
Average Annual Wage (2015 dollars)				510	53,052.66	10,744.91	
Bartik Unemployment Rate				510	5.972	1.659	
Bartik Average Annual Wage (2015 dollars)				510	46,807.09	1,496.35	

Notes: Variables were collected for each state and the District of Columbia for the following years: 2001, 2002, 2003, 2005, 2007, 2009, 2011, 2013, 2015, and 2017. College-going variables are available for odd numbered years starting in 2001. We use NAEP from 2002 matching JWX.

NAEP test scores are standardized to 2003, and then averaged for each state and year. Only the reading test was administered in 2002, and five states do not have 2002 NAEP scores: AK, CO, NH, NJ, and SD. We used 2003 average reading z-score as the 2002 value for these five states.

We model the college-going rate as the number of first-time college enrollees divided by the number of 17-year-olds in a state.

Data from 2001-2013 represent Average Freshman Graduation Rate (AFGR) values and data from 2014-2019 are Adjusted Cohort Graduation Rates (ACGR).

Table 2: Data on State and Property Tax K-12 Revenue Share

State	(1) JWX Categorization	(2) 2007-10 (3yr) Real Per-Pupil Expenditure Change	(3) 2007-12 (5yr) Real Per-Pupil Expenditure Change	(4) 2007-17 (10yr) Real Per-Pupil Expenditure Change
Alabama	M	317	-912	-242
Alaska	M	3,515	4,536	3,646
Arizona	M	260	-819	-717
Arkansas	H	607	216	93
California	M	109	-510	2,084
Colorado	M	88	-824	122
Connecticut	M	1,305	1,899	4,090
Delaware	M	-540	215	868
District of Columbia	L	2,185	17	1,979
Florida	M	-293	-1,413	-1,245
Georgia	M	-412	-1,365	-737
Hawaii	H	-281	-1,166	655
Idaho	M	-34	-939	-402
Illinois	L	1,870	1,560	4,671
Indiana	M	-195	-693	-1,138
Iowa	M	1,394	1,058	1,795
Kansas	M	-64	-831	-1,107
Kentucky	M	583	367	141
Louisiana	M	1,456	661	605
Maine	M	798	-85	1,140
Maryland	M	1,530	487	757
Massachusetts	M	644	915	3,223
Michigan	M	64	-807	-570
Minnesota	M	646	79	1,451
Mississippi	M	221	-313	-29
Missouri	M	736	45	535
Montana	M	686	-144	326
Nebraska	L	641	193	1,388
Nevada	M	-23	-730	-346
New Hampshire	M	1,609	1,743	2,998
New Jersey	M	447	-404	985
New Mexico	H	342	-919	-597
New York	M	2,014	1,923	4,234
North Carolina	M	47	-563	-256
North Dakota	M	1,408	1,540	3,657
Ohio	M	992	268	199
Oklahoma	M	60	-669	-1,047
Oregon	M	130	-552	747
Pennsylvania	M	1,102	669	2,682
Rhode Island	M	775	155	507
South Carolina	M	106	-515	353
South Dakota	M	762	-430	829
Tennessee	M	564	547	817
Texas	M	609	-662	188
Utah	M	448	-34	649
Vermont	H	1,741	1,919	4,203
Virginia	M	-238	-868	-456
Washington	M	512	133	2,217
West Virginia	M	1,958	828	695
Wisconsin	M	834	-338	-144
Wyoming	M	1,681	1,534	1,094

Note: In column 1, green is used to highlight states are categorized as low-reliance in JWX and red is used to highlight states that are categorized as high-reliance in JWX. Constant dollar change in per-pupil expenditures was collected from the NCES Digest of Education Statistics Table 236.70.

Table 3: Data on State and Property Tax K-12 Revenue Share

		(1)	(2)	(3)	(4)	(5)
		JWX	Census	NCES	NCES	NCES
State	Abbreviation	2008 State Revenue Share			Avg. 2005-07 State Revenue Share	Avg. 2005-07 Property Tax Revenue Share
Alabama	AL	60.2%	60.2%	60.6%	56.2%	13.0%
Alaska	AK	64.9%	64.9%	66.3%	58.7%	9.8%
Arizona	AZ	48.1%	48.5%	51.7%	49.2%	29.8%
Arkansas	AR	75.7%	76.0%	56.7%	57.5%	25.1%
California	CA	57.9%	59.9%	61.3%	60.0%	21.6%
Colorado	CO	42.1%	42.4%	42.2%	42.8%	38.7%
Connecticut	CT	37.8%	38.5%	39.6%	38.5%	54.7%
Delaware	DE	61.2%	63.0%	62.0%	62.7%	23.3%
District of Columbia	DC	0.0%	0.0%	N/A	N/A	21.3%
Florida	FL	39.4%	39.4%	38.8%	40.8%	39.9%
Georgia	GA	45.1%	45.2%	45.4%	44.4%	31.3%
Hawaii	HI	84.8%	84.8%	84.8%	89.0%	0.0%
Idaho	ID	65.5%	65.5%	67.1%	60.3%	24.3%
Illinois	IL	32.9%	33.8%	31.2%	30.6%	51.7%
Indiana	IN	47.3%	48.5%	53.5%	49.8%	31.3%
Iowa	IA	44.8%	46.5%	46.5%	45.6%	31.7%
Kansas	KS	58.4%	58.4%	57.5%	55.6%	26.1%
Kentucky	KY	57.9%	57.9%	57.3%	56.9%	20.9%
Louisiana	LA	43.6%	43.9%	44.8%	44.5%	14.2%
Maine	ME	43.2%	44.5%	44.9%	42.9%	44.8%
Maryland	MD	42.0%	42.0%	42.1%	39.1%	25.3%
Massachusetts	MA	41.8%	42.1%	41.9%	45.4%	45.1%
Michigan	MI	54.6%	57.3%	57.5%	59.4%	27.0%
Minnesota	MN	64.4%	65.8%	65.9%	69.2%	13.7%
Mississippi	MS	53.7%	53.8%	54.5%	52.8%	22.8%
Missouri	MO	40.8%	41.1%	33.3%	33.6%	43.0%
Montana	MT	49.0%	49.4%	49.7%	46.5%	24.2%
Nebraska	NE	32.3%	33.0%	33.1%	31.6%	50.4%
Nevada	NV	57.5%	57.5%	30.8%	26.6%	28.4%
New Hampshire	NH	37.1%	38.6%	38.6%	38.6%	52.1%
New Jersey	NJ	40.0%	41.3%	42.1%	42.6%	49.2%
New Mexico	NM	71.2%	71.2%	70.8%	70.9%	10.2%
New York	NY	45.2%	45.4%	44.8%	43.0%	45.0%
North Carolina	NC	58.8%	58.8%	65.7%	62.9%	20.6%
North Dakota	ND	34.7%	36.1%	36.3%	36.2%	37.9%
Ohio	OH	43.0%	44.1%	45.6%	44.0%	39.5%
Oklahoma	OK	51.2%	51.2%	54.2%	53.5%	22.7%
Oregon	OR	52.4%	52.8%	52.3%	50.2%	29.2%
Pennsylvania	PA	34.3%	35.8%	36.5%	35.9%	41.7%
Rhode Island	RI	38.5%	38.7%	39.9%	40.0%	50.3%
South Carolina	SC	50.6%	50.7%	50.8%	44.9%	34.3%
South Dakota	SD	33.1%	33.2%	33.9%	33.1%	42.0%
Tennessee	TN	45.9%	46.1%	45.6%	43.0%	21.4%
Texas	TX	43.1%	43.2%	44.8%	35.8%	46.4%
Utah	UT	56.3%	56.3%	56.7%	55.3%	26.1%
Vermont	VT	68.3%	88.5%	85.9%	85.5%	00.2%
Virginia	VA	40.3%	41.0%	41.0%	40.6%	23.9%
Washington	WA	61.9%	62.4%	62.5%	60.9%	23.2%
West Virginia	WV	58.1%	58.1%	59.1%	60.0%	24.4%
Wisconsin	WI	49.2%	50.1%	50.0%	51.6%	37.8%
Wyoming	WY	52.8%	52.9%	52.8%	48.3%	28.7%

Note: Census values are provided because JWX differs from the Census data. Green is used to highlight states that have 2008 state revenue share less than 0.33 and red is used to highlight states that have 2008 state revenue share greater than 0.67.

Table 4: Categorizations for Group IV

	(1) JWX Groups	(2) 10th and 90th Percentiles	(3) 15th and 85th Percentiles	(4) 20th and 80th Percentiles	(5) 25th and 75th Percentiles
Low-Reliance	**(3 States)** ***D.C.*** IL NE	**(5 States)** ***D.C.*** IL NE **NV** **SD**	**(7 States)** ***D.C.*** IL **MO** NE **NV** **SD** **TX**	**(11 States)** **CT** ***D.C.*** IL **MO** NE **NV** **NH** **ND** **PA** **SD** **TX**	**(13 States)** **CT** ***D.C.*** IL **MD** **MO** NE **NV** **NH** **ND** **PA** **RI** **SD** **TX**
High-Reliance	**(4 States)** AR ***HI*** NM VT	**(5 States)** ***HI*** **MN** NM **NC** VT	**(7 States)** **DE** ***HI*** **MN** NM **NC** VT **WA**	**(10 States)** **CA** **DE** ***HI*** **ID** **MN** NM **NC** VT **WA** **WV**	**(12 States)** **AK** **CA** **DE** ***HI*** **ID** **MI** **MN** NM **NC** VT **WA** **WV**

Notes: Percentile groups are determined using NCES average 2005-07 state revenue share. States that are highlighted in red are different from the JWX categorization (column 1). D.C. and Hawaii are in bold and italics because their education funding systems are fundamentally different from other states. We drop D.C. from some analyses. Dropping D.C. results in MO moving into the bottom decile and PA into the bottom 15th percentile, otherwise the groups remain the same. Based on the text of JWX the group cutoffs are state share less than 1/3 for low reliance and state share greater than 2/3 for high reliance. When implementing these rules, JWX appears to have simplified to 0.33 and 0.66. If the 1/3 rule had been applied strictly, South Dakota should also have been included in the low-reliance group.

Table 5: Year Groupings for Fixed Effects

	Number of Year Fixed Effects	2001/2002	2003	2005	2007	2009	2011	2013	2015	2017
JWX Grouping	3	P	P	P	P	D	D	A	A	A
Grouping 2	3	P	P	P	D	D	A	A	A	A
Grouping 3	4	P	P	P	X	D	D	A	A	A
Grouping 4	5	P	P	P	X	D	X	A	A	A
Grouping 5	5	P	P	P	P	D	D	X	X	X
Grouping 6	6	P	P	P	P	D	X	X	X	X
Full Year Fixed Effects	9	X	X	X	X	X	X	X	X	X

Notes: Colors are used to indicate year groupings for fixed effects. P indicates pre-recession group. D indicates during recession group. A indicates after recession group. X indicates individual year fixed effect. The rows correspond to the different estimation results in columns 2-9 of tables 6A-C.

Table 6A: Group IV – NAEP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Including Washington D.C.						Excluding Washington D.C.			
	Original JWX Result	JWX Replication	10th and 90th Percentiles	15th and 85th Percentiles	20th and 80th Percentiles	25th and 75th Percentiles	10th and 90th Percentiles	15th and 85th Percentiles	20th and 80th Percentiles	25th and 75th Percentiles
Per-Pupil Spending (thousands)	0.0385***	0.0472**	0.0389	0.0266	-0.0037	-0.0197	0.0197	-0.0064	-0.0190	-0.0363
	(0.0110)	(0.0172)	(0.0218)	(0.0226)	(0.0221)	(0.0327)	(0.0215)	(0.0257)	(0.0226)	(0.0369)
Pre-Recession State Trends	X	X	X	X	X	X	X	X	X	X
Year Fixed Effects	X	X	X	X	X	X	X	X	X	X
Bartik Economic Controls	X	X	X	X	X	X	X	X	X	X
States	51	51	51	51	51	51	50	50	50	50
State-Year Observations	459	459	459	459	459	459	450	450	450	450

Notes: The Original JWX Result is from Table 3 column 4 of JWX (2020a). *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 6B: Group IV – College-Going Rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Including Washington D.C.						Excluding Washington D.C.			
	Original JWX Result	JWX Replication	10th and 90th Percentiles	15th and 85th Percentiles	20th and 80th Percentiles	25th and 75th Percentiles	10th and 90th Percentiles	15th and 85th Percentiles	20th and 80th Percentiles	25th and 75th Percentiles
Per-Pupil Spending (thousands)	0.0124***	0.0203**	0.0212	0.0179	0.0147	0.0148	0.0089	0.0132	0.0086	0.0080
	(0.00387)	(0.0066)	(0.0122)	(0.0122)	(0.0112)	(0.0137)	(0.0132)	(0.0122)	(0.0114)	(0.0132)
Pre-Recession State Trends	X	X	X	X	X	X	X	X	X	X
Year Fixed Effects	X	X	X	X	X	X	X	X	X	X
Bartik Economic Controls	X	X	X	X	X	X	X	X	X	X
States	51	51	51	51	51	51	50	50	50	50
State-Year Observations	459	459	459	459	459	459	450	450	450	450

Notes: The Original JWX Result is from Table 3 column 8 of JWX (2020a). *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 6C: Group IV – High School Graduation Rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Including Washington D.C.						Excluding Washington D.C.			
	Original JWX Result	JWX Replication	10th and 90th Percentiles	15th and 85th Percentiles	20th and 80th Percentiles	25th and 75th Percentiles	10th and 90th Percentiles	15th and 85th Percentiles	20th and 80th Percentiles	25th and 75th Percentiles
Per-Pupil Spending (thousands)	-	0.0132	0.0424	0.0323	0.0144	0.0081	0.0335	0.0243	0.0093	0.0008
	-	(0.0094)	(0.0345)	(0.0287)	(0.0220)	(0.0258)	(0.0377)	(0.0314)	(0.0216)	(0.0239)
Pre-Recession State Trends	-	X	X	X	X	X	X	X	X	X
Year Fixed Effects	-	X	X	X	X	X	X	X	X	X
Bartik Economic Controls	-	X	X	X	X	X	X	X	X	X
States	-	51	51	51	51	51	50	50	50	50
State-Year Observations	-	867	867	867	867	867	850	850	850	850

Notes: *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 7A: Linear IV – NAEP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Including Washington D.C.		Excluding Washington D.C.						
	Original JWX Results	JWX Grouping	JWX Grouping	Grouping 2	Grouping 3	Grouping 4	Grouping 5	Grouping 6	Full Year Fixed Effects
Per-Pupil Spending (thousands)	0.0316***	0.0304***	0.0192***	-0.0082	-0.0340***	-0.0380*	-0.0088	-0.0215	0.0000
	(0.0127)	(0.0095)	(0.0060)	(0.0337)	(0.0129)	(0.0211)	(0.0096)	(0.0200)	(0.0337)
F-Statistic	41.61	33.77	31.88	1.16	17.55	7.92	16.78	6.86	1.68
Pre-Recession State Trends	X	X	X	X	X	X	X	X	X
Bartik Economic Controls	X	X	X	X	X	X	X	X	X
States	51	51	50	50	50	50	50	50	50
State-Year Observations	459	459	450	450	450	450	450	450	450

Notes: The Original JWX Result is from Table A23 column 4 of JWX (2020a). *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 7B: Linear IV – College-Going Rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Including Washington D.C.		Excluding Washington D.C.						
	Original JWX Results	JWX Grouping	JWX Grouping	Grouping 2	Grouping 3	Grouping 4	Grouping 5	Grouping 6	Full Year Fixed Effects
Per-Pupil Spending (thousands)	0.0240***	0.0146***	0.0145***	0.0386***	0.0227***	0.0136***	0.0137***	0.0085***	0.0145
	(0.00621)	(0.0020)	(0.0022)	(0.0119)	(0.0044)	(0.0044)	(0.0022)	(0.0023)	(0.0131)
F-Statistic	34.13	36.22	32.42	6.11	18.05	11.10	34.12	27.11	1.59
Pre-Recession State Trends	X	X	X	X	X	X	X	X	X
Bartik Economic Controls	X	X	X	X	X	X	X	X	X
States	51	51	50	50	50	50	50	50	50
State-Year Observations	459	459	450	450	450	450	450	450	450

Notes: The Original JWX Result is from Table A23 column 8 of JWX (2020a). *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 7C: Linear IV – High School Graduation Rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Including Washington D.C.		Excluding Washington D.C.						
	Original JWX Results	JWX Grouping	JWX Grouping	Grouping 2	Grouping 3	Grouping 4	Grouping 5	Grouping 6	Full Year Fixed Effects
Per-Pupil Spending (thousands)	-	-0.0054	-0.0078*	0.0134*	-0.0007	0.0055	-0.0075*	-0.0040	-0.0102
	-	(0.0045)	(0.0046)	(0.0070)	(0.0069)	(0.0072)	(0.0046)	(0.0046)	(0.0221)
F-Statistic		47.09	37.53	12.68	18.19	15.62	39.48	35.48	1.84
Pre-Recession State Trends	-	X	X	X	X	X	X	X	X
Bartik Economic Controls	-	X	X	X	X	X	X	X	X
States	-	51	50	50	50	50	50	50	50
State-Year Observations	-	867	850	850	850	850	850	850	850

Notes: *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 8A: Linear IV using Property Tax Share – NAEP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Including Washington D.C.		Excluding Washington D.C.						
	Original JWX Results	JWX Grouping	JWX Grouping	Grouping 2	Grouping 3	Grouping 4	Grouping 5	Grouping 6	Full Year Fixed Effects
Per-Pupil Spending (thousands)	-	0.0306***	0.0197**	-0.0084	-0.0453**	-0.0294	-0.0239	-0.0224	-0.0060
	-	(0.0100)	(0.0084)	(0.0207)	(0.0181)	(0.0226)	(0.0147)	(0.0230)	(0.0315)
F-Statistic		18.95	49.44	5.42	17.06	14.67	17.19	11.41	1.46
Pre-Recession State Trends	-	X	X	X	X	X	X	X	X
Bartik Economic Controls	-	X	X	X	X	X	X	X	X
States	-	51	50	50	50	50	50	50	50
State-Year Observations	-	459	450	450	450	450	450	450	450

Notes: *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 8B: Linear IV using Property Tax Share – College-Going Rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Including Washington D.C.		Excluding Washington D.C.						
	Original JWX Results	JWX Grouping	JWX Grouping	Grouping 2	Grouping 3	Grouping 4	Grouping 5	Grouping 6	Full Year Fixed Effects
Per-Pupil Spending (thousands)	-	0.0116***	0.0138***	0.0085	0.0171**	0.0152**	0.0116***	0.0094***	0.0095
	-	(0.0026)	(0.0033)	(0.0061)	(0.0068)	(0.0066)	(0.0029)	(0.0031)	(0.0127)
F-Statistic		18.04	53.81	17.64	25.12	22.18	63.63	60.89	1.30
Pre-Recession State Trends	-	X	X	X	X	X	X	X	X
Bartik Economic Controls	-	X	X	X	X	X	X	X	X
States	-	51	50	50	50	50	50	50	50
State-Year Observations	-	459	450	450	450	450	450	450	450

Notes: *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 8C: Linear IV using Property Tax Share – High School Graduation Rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Including Washington D.C.		Excluding Washington D.C.						
	Original JWX Results	JWX Grouping	JWX Grouping	Grouping 2	Grouping 3	Grouping 4	Grouping 5	Grouping 6	Full Year Fixed Effects
Per-Pupil Spending (thousands)	-	0.0005	-0.0002	0.0150	0.0285**	0.0211*	-0.0001	0.0018	-0.0006
	-	(0.0032)	(0.0037)	(0.0108)	(0.0115)	(0.0116)	(0.0037)	(0.0042)	(0.0205)
F-Statistic		24.61	45.42	16.35	11.60	13.29	45.02	43.78	2.01
Pre-Recession State Trends	-	X	X	X	X	X	X	X	X
Bartik Economic Controls	-	X	X	X	X	X	X	X	X
States	-	51	50	50	50	50	50	50	50
State-Year Observations	-	867	850	850	850	850	850	850	850

Notes: *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 9: Replace Instrument with State Share of Higher Education Revenue

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	NAEP Scores				College-Going Rate			
	Original JWX Result	JWX Grouping from Table 6A	No Year Fixed Effects	JWX Grouping	Original JWX Result	JWX Grouping from Table 6B	No Year Fixed Effects	JWX Grouping
Per-Pupil Spending (thousands)	0.0316***	0.0304***	0.0325***	0.0293***	0.0240***	0.0146***	0.0196***	0.0116***
	(0.0127)	(0.0095)	(0.0123)	(0.0093)	(0.00621)	(0.0020)	(0.0040)	(0.0024)
Pre-Recession State Trends	X	X	X	X	X	X	X	X
Year-Group Fixed Effects	X	X	X	X	X	X	X	X
Bartik Economic Controls	X	X	X	X	X	X	X	X
States	51	51	51	51	51	51	51	51
State-Year Observations	459	459	459	459	459	459	459	459

Notes: The Original JWX Result for NAEP scores is from Table A23 column 4 of JWX (2020a). The Original JWX Result for college-going rate is from Table A23 column 8 of JWX (2020a).*** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 10A: Predict State Appropriations Per FTE for Higher Education

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	No Year Fixed Effects	JWX Grouping	Grouping 2	Grouping 3	Grouping 4	Grouping 5	Grouping 6	Full Year Fixed Effects
Per-Pupil Spending (thousands)	530.16***	399.46***	225.30	567.66***	332.17*	377.20***	255.56**	701.59**
	(136.71)	(109.28)	(254.78)	(164.12)	(181.94)	(111.81)	(119.91)	(326.25)
Pre-Recession State Trends	X	X	X	X	X	X	X	X
Bartik Economic Controls	X	X	X	X	X	X	X	X
States	50	50	50	50	50	50	50	50
State-Year Observations	850	850	850	850	850	850	850	850

Notes: *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 10B: Predict Tuition and Fees Per FTE for Higher Education

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	No Year Fixed Effects	JWX Grouping	Grouping 2	Grouping 3	Grouping 4	Grouping 5	Grouping 6	Full Year Fixed Effects
Per-Pupil Spending (thousands)	336.35***	257.58***	476.16**	227.28**	285.38**	258.02***	285.75***	199.13
	(104.69)	(71.29)	(236.66)	(112.03)	(144.14)	(75.31)	(86.84)	(281.88)
Pre-Recession State Trends	X	X	X	X	X	X	X	X
Bartik Economic Controls	X	X	X	X	X	X	X	X
States	50	50	50	50	50	50	50	50
State-Year Observations	850	850	850	850	850	850	850	850

Notes: *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 11: Linear IV for College-Going using Log State Appropriations Per FTE and Log Tuition Per FTE

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Higher Education Share				JWX K-12 State Share			
	State Appropriations		Tuition		State Appropriations		Tuition	
	No Year Fixed Effects	JWX Grouping	No Year Fixed Effects	JWX Grouping	No Year Fixed Effects	JWX Grouping	No Year Fixed Effects	JWX Grouping
Ln (State Approps or Tuition)	0.1831***	0.1185**	0.1884***	0.1321***	0.2441***	0.1883***	0.2269***	0.1596***
	(0.0616)	(0.0543)	(0.0587)	(0.0506)	(0.0589)	(0.0582)	(0.0630)	(0.0487)
Pre-Recession State Trends	X	X	X	X	X	X	X	X
Bartik Economic Controls	X	X	X	X	X	X	X	X
States	50	50	50	50	50	50	50	50
State-Year Observations	450	450	450	450	450	450	450	450

Notes: *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.