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What Goes Up Must Come Down? A Case Study of the Recent Oil and Gas Employment Cycle in Louisiana, North Dakota and Oklahoma

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Abstract: The recent boom and bust in the oil and natural gas sector provide a unique opportunity to assess whether the employment impacts of energy development are symmetric across the differing phases of the energy cycle. This study uses the synthetic control method to examine the boom and bust effects for three key oil and natural gas producing states: Louisiana, North Dakota, and Oklahoma. The three states are chosen as case studies because of their relative intensity in oil production in addition to their production of natural gas. Because of Hurricane Katrina, we examine Louisiana sans New Orleans. The three states also most closely match each other in cyclic movements relative to other energy producing states. The results reveal differing employment impacts across the three states in both the short and long run, with the differences at least in part suggested to be connected to state and local government education expenditure responses to the boom and bust, particularly in terms of their effects on public school teacher salaries.

Keywords: Energy Boom; Resource Curse; Synthetic Control Method

JEL Codes: Q33; R12; R23

1. Introduction

After bottoming out during 2002-2004, US employment involved in oil and natural gas extraction dramatically increased with the rise in energy prices and technological advances in horizontal drilling and hydraulic fracturing. National employment in oil and gas extraction, and support activities combined, more than doubled from 2004 to 2014. Oil and gas employment then declined by nearly thirty percent from 2014-2016 following the dramatic drop in oil prices the second half of 2014, in which natural gas prices had peaked years earlier.[1] The decline returned national oil and gas employment to about its 2008 level. Although there is a burgeoning literature on the regional economic impacts of energy extraction, there have been few studies on busts after booms (Marchand and Weber, 2017); especially lacking is analysis at the US state level, including the employment impacts of state and local fiscal policy responses over the energy cycle on short- and long-run growth.

With few exceptions, studies of the US regional economic impacts of energy extraction have been at the county level (Weber, 2012; 2014; Brown, 2014; Haggerty et al., 2014; Jacobsen and Parker, 2014; Weinstein 2014; Paredes et al., 2015; Bartik et al., 2016; Komarek, 2016; Tsvetkova and Partridge, 2016; Maniloff and Mastromonaco, 2017; and Allcott and Keniston, 2017).[2] The estimated economic impacts of energy extraction though could be expected to vary with the level of geographic aggregation used in the analysis. Use of states would reduce concerns of ignoring geographic spillovers that extend beyond county boundaries (Munasib and Rickman, 2015; Agerton et al., 2017). Besides inter-industry and income-consumption linkages across counties, likely significant sources of spillovers occur through the effects on state government expenditures and taxes (Weber et al., 2015) and on royalty payments (Brown et al., 2016). Feyrer et al. (2017) find that the broader regional economic impacts of the oil and gas

[1] US Bureau of Labor Statistics Current Employment Statistics, https://www.bls.gov/ces/data.htm, last accessed May 9, 2018.

[2] Exceptions include Miljkovic and Ripplinger (2016) who estimate the employment and wage effects of the oil boom, as represented by the number of rigs, from 1992 to 2014 in North Dakota. Agerton et al. (2017) pool data for the lower 48 states over the 1992-2014 period to estimate the average relationship between land-based oil and gas rig counts and employment.

extracted from fracking are several times that in the county of extraction; about one-third of the new jobs occur within the county of extraction and two-thirds occur within a 100-mile radius.

Yet, identifying the inter-industry spillover effects of energy extraction may be more problematic at the state level. Machinery and fabricated metals produced for oil and natural gas development may be both a response to local energy activity and to that outside the region. The co-location of export-based energy-related manufacturing and energy activity is more likely at broader levels of geographic aggregation. To be sure, the linkage between key manufacturing sectors and energy activity may be why studies have failed to find significant crowding out of manufacturing employment in energy boom areas (Marchand, 2012; Brown, 2014; Bartik et al., 2016; Komarek, 2016; Tsvetkova and Partridge 2016).

In one of the few studies of both boom and bust periods, Marchand (2012) found significant positive labor market effects of energy booms in Western Canada Census divisions but did not find significant effects during the period of bust. In an analysis of the local labor market effects of the coal boom and bust in Kentucky, Ohio, Pennsylvania, and West Virginia, Black et al. (2005) report that the bust was modestly stronger than the preceding boom suggesting the existence of a resource curse. In their study of the western US energy boom and bust counties during the 1970s and 1980s, Jacobsen and Parker (2014) similarly found per capita income to be lower and unemployment compensation to be higher after the bust than they would have been had the energy boom not occurred. Studying energy counties in six western states over a longer time-period, 1980 to 2011, Haggerty et al. (2014) found a negative effect on per capita income for counties heavily involved in the early 1980s energy boom. Allcott and Keniston (2017) conclude that the post-1960 resource booms in the US increased welfare in oil and gas rich counties.

As Marchand and Weber (2017) note, the negative labor demand effect during an energy bust need not precisely match the positive labor demand during the boom. There may be asymmetry in spillover effects such as in state fiscal policy responses to energy sector shocks (James, 2015). The growth achieved during the energy boom also may create agglomeration economies that permanently increase the size of the local economy (Michaels, 2011). Alternatively, natural resource extraction may produce lower growth in the longer run by increasing regional input prices and crowding out activity in other sectors, or because of constraints on capital and labor adjustment (Sachs and Warner, 2001; Papyrakis and Gerlagh, 2007; Jacobsen and Parker, 2014, Tsvetkova and Partridge, 2016). There also may be longer term negative growth feedback effects if the environment is damaged by the energy activity (Rickman and Rickman, 2011; Mason et al., 2015). Educational attainment may fall during energy booms because of the increased opportunity cost of education, reducing human capital-based growth (Rickman et al., 2017a), though James (2017) reports higher spending on public education in resource rich states.

To the best of our knowledge, there have not been any studies that have examined both the energy boom and the bust at the US state level. Therefore, this paper estimates the total employment effects of the energy boom and bust in the key oil producing states of Louisiana (minus New Orleans because of Hurricane Katrina), North Dakota and Oklahoma as case studies for the period 2004-2016. The three areas have higher than average nonmetropolitan shares of employment and population, making it easier to empirically detect the energy impacts (Munasib and Rickman, 2015). The three areas also most closely match each other in employment growth prior to 2004 relative to the other energy producing states. An additional contribution of the study is the accounting of other energy-based export employment responses, namely in manufacturing and pipeline transportation services, in calculating the energy sector employment multipliers.

We use the synthetic control method (SCM) (Abadie and Gardeazabal, 2003; Abadie et al., 2010) to construct a control or comparison unit for each state. SCM constructs a control unit as a composite of non-oil (gas) states based on affinities and outcomes between it and the energy state. The control units are composites of states and provide estimates of what total employment would have been in the energy states had there not been an energy boom. We use the period of 1992-2004, a period absent an energy boom, in constructing the synthetic control states. The differences between the outcomes of the control state and the energy state post-2004 are the estimated effects of the energy sector. The time frame allows for estimation of both the potential positive short-run total employment effects during the increases in oil and gas employment and the potential negative short-run effects during the corresponding declines. Analysis of the entire period allows us to assess the longer run impacts.

We then calculate employment multipliers for each state for the entire treatment period and for the boom and bust sub-periods. We calculate multipliers under alternative assumptions about how much of the energy-related manufacturing/pipeline transportation responses are endogenous responses to energy extraction in the state versus increased export demand outside the state. A key advantage of the SCM case study approach is the allowance for heterogeneous outcomes (Munasib and Rickman, 2015).

In the next section, we discuss the areas and periods of study. Section 3 discusses our empirical approach. The results follow in Section 4. We find differing employment impacts across the three states in both the short and long run and find that they are in part suggestive of a connection to state and local government expenditures, particularly to public school teacher salaries. The patterns for the entire 2004-2016 period suggest long-run growth benefits of energy development for North Dakota either through agglomeration economies and/or benefits of increased education funding, slight long-run growth benefits in Louisiana, but more likely a slight resource curse effect in Oklahoma. For Louisiana and Oklahoma, we also find that it is important to account for exports of energy-related manufacturing and pipeline transportation services in the estimation of oil and gas employment multipliers. Section 5 concludes the paper and offers suggestions for further research.

2. Areas and Periods of Study

We examine the oil rich states of Louisiana, North Dakota and Oklahoma from 1992 to 2016. We remove New Orleans from Louisiana in the analysis because of the occurrence of Hurricane Katrina in 2005. The three states also experienced periods of increasing natural gas production during the post-2004 period. The time-period is divided into two sub-periods of equal length and compared: 1992-2004 and 2004-2016. The first sub-period is one of lower inflation-adjusted oil and natural gas prices and lower energy employment intensity in the three states relative to the 1980s boom period. The second sub-period is one of booms and busts of oil and natural gas prices and energy sector employment.

All three states rank in the top ten among all states for oil production in both 2004 and 2016.[3] As shown in Figure 1, the three states also closely match each other in terms of employment growth during 1992-2004. Post-2004, the three states follow one another in the patterns of responses to the changes in oil prices, though by differing scales.[4] Other top oil producing states exhibited differing employment growth patterns prior to 2004. Factors likely contributing to similarity in patterns among the three states include having higher shares of oil and gas sector employment and higher nonmetropolitan shares of wage and salary employment. The effects of changes in oil and gas sector employment are more likely to be evident where it comprises a larger share of total economic activity and where the energy economic cycle is the more dominant force such as in nonmetropolitan areas (Munasib and Rickman, 2015).

Among the other states considered, mining employment comprised less than one percent of total US Census County Business Patterns employment in 2004 in California, Colorado and Utah. Only Alaska, New Mexico and Wyoming had comparable or higher nonmetropolitan shares of state employment.[5] Employment in coal mining (including support for coal mining), which exhibits a different economic cycle, comprised over twenty-seven percent of total mining employment in Wyoming. Colorado, New Mexico and Utah had the next three largest number of jobs in coal mining among the oil and gas states considered.[6] Alaska experienced a continual

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[3] US Energy Information Administration https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbblpd_a.htm, accessed August 27, 2017.
[4] Because the QCEW series begins in 2001, we rely on CES data for the pre-treatment period and use QCEW data post-2004; each series is normalized to its 2004 level. The average correlation between the CES and QCEW total nonfarm wage and salary employment from 2001-2016 for the three states is 0.984.
[5] US Bureau of Economic Analysis Local Area Personal Income, https://www.bea.gov/regional/index.htm, accessed August 26, 2017.
[6] US Census Bureau, County Business Patterns, https://www.census.gov/programs-surveys/cbp/data/datasets.html, accessed June 19, 2017.

steady decline in oil production, including during the post-2000 boom in oil prices, and experienced post-2004 declines in natural gas production.

From 2004-2008, US Bureau of Labor Statistics QCEW mining employment increased by 31, 92, and 68 percent, respectively, in Louisiana (sans New Orleans), North Dakota and Oklahoma. Louisiana mining employment includes that in offshore operations and is reported by place of establishment onshore.[7] Based on US Census County Business Patterns data for 2004 and 2008, non-oil and gas employment in mining was responsible for only three percent of total mining employment growth for North Dakota, less than one percent of the growth for Oklahoma and was a negative 1.7 percent for Louisiana. Scaled by the mining employment shares in 2004, the direct growth rate effects on total nonfarm employment of increased mining employment over 2004-2008 are 0.8, 1.0 and 1.5 percent for Louisiana, North Dakota and Oklahoma, respectively.

Mining employment reached its peak in 2012 for Louisiana, and in 2014 for both North Dakota and Oklahoma. At the peak, mining employment had increased by 33.4 percent for Louisiana, nearly doubled in Oklahoma and increased by over eight times in North Dakota. The decline in mining employment from its peak in each state following the bust in energy prices left mining employment below the 2004 level by 3.4 percent in Louisiana. But in North Dakota mining employment in 2016 remained over four times the 2004 level, while the increase for Oklahoma over the period was 42.4 percent. Peaks in total nonfarm employment in Figure 1 correspond to the peaks for mining employment in Louisiana and North Dakota, while total nonfarm employment in Oklahoma peaked in 2015, slightly above the 2014 level.

The differences in magnitudes and peaks of mining employment in the three states corresponded to differing oil and natural gas production cycles. The growth in mining employment from 2004-2008 was associated with a doubling of oil production in North Dakota, and nearly a five percent decline in natural gas production over the period.[8] North Dakota oil

[7] US Bureau of Labor Statistics, accessed at https://www.bls.gov/cew/oil_gas_drilling.htm on August 30, 2017.
[8] The US Energy Information Administration is the source of both state oil production (https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_m.htm) and state natural gas production

production peaked in 2015 at nearly fourteen times the 2004 level, while natural gas production only began to dramatically increase in 2010, increasing through 2016 to nine times its 2004 level. In Oklahoma, natural gas production increased over twelve percent and oil production increased by five percent from 2004-2008. Both peaked in 2015, with natural gas production forty-nine percent above its 2004 level and oil production nearly one and one-half times greater after beginning a rapid ascent in 2011. Field production and offshore production of natural gas in Louisiana together began increasing in 2009, peaking in 2011, and began significantly declining in 2013. While field production of oil in Louisiana declined over entire period, Gulf of Mexico offshore production of oil increased from 2004 to 2009, dropped after 2010 with the BP oil spill, and rebounded to finish nine percent above the 2004 level in 2016.

The three states then likely match well in terms of employment growth prior to 2004 because of their stable patterns of production of oil and gas production until the middle of the decade. Subsequently, the three states were subjected to differing energy shocks in terms of oil vs natural gas, magnitude and timing. A comparison of three states post-2004 then provides insights into the varied possible impacts of energy shocks across boom and bust periods.

3. Empirical Approach

We apply the synthetic control method (SCM) (Abadie and Gardeazabal, 2003; Abadie et al., 2010) individually to Louisiana, North Dakota and Oklahoma. The three states are the treatment units and other (thirty) non-energy states serve as potential donors in the construction of control units for comparison.[9] Using Bureau of Labor Statistics annual total nonfarm wage and salary employment data, we specify 1992-2004 as the pre-treatment period and 2004-2016 as the post-treatment period.[10] The pre-treatment period is used to establish baseline estimates of post-2004 employment growth in the three states in the absence of the energy boom.

(https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_VGM_mmcf_a.htm), in which data for both were last accessed August 30, 2017.

[9] We use the program package Synth in STATA to perform the SCM analysis (http://web.stanford.edu/~jhain/synthpage.html).

[10] See footnote 4.

We examine the effects of the variation in mining employment (NAICs 21) in the three oil and gas states on total nonfarm wage and salary employment growth. The 2004-2016 period provides a longer run assessment of the impacts of the energy boom. The boom sub-period of 2004-2008 can be compared to the 2014-2016 bust sub-period to assess whether there are symmetric responses across short-run boom and bust periods. The nearly equal absolute value percentage changes in national oil and gas employment in the two periods makes them useful for the boom-bust comparison. The 2008-2014 period includes the national recession, which can make it more difficult to empirically isolate the short-run effects of the energy cycle.

An advantage of SCM is the use of a weighted average of other states as the control for comparison rather than having to match to a single state that may not be sufficiently similar to the treatment state; SCM also does not require the parallel trends assumption of standard difference-in-differences. The control represents a composite state that establishes the baseline for the oil and gas state in the absence of the post-2004 energy cycle. The weights applied to the donor states in creating the composite state are obtained through bi-level optimization in matching the pre-treatment trends and pre-intervention characteristics between the treatment state and composite state (Abadie and Gardeazabal, 2003). The difference between the post-2004 total nonfarm employment growth for the treatment state and the composite state is the impact of the energy sector. We exclude other energy (and mining) states and Hawaii from consideration in the construction of the synthetic control for each state.[11] We select 2004 as the treatment year because of the increase that year in US oil and gas employment after bottoming out in 2003. SCM results have been reported not to be sensitive to minor changes in the treatment year (e.g., Munasib and Rickman, 2015; Rickman et al., 2017a). [12]

[11] The energy and mining states excluded are: Alaska, Arizona, Arkansas, Colorado, Idaho, Kansas, Kentucky, Mississippi, Montana, Nevada, New Mexico, Pennsylvania, Texas, Utah, West Virginia, Wyoming. Not all states are traditional energy states, but they experienced increased mining employment during the fracking boom (e.g., Arkansas, Mississippi and Pennsylvania) (Munasib and Rickman, 2015).

[12] Other advantages and technical presentations of SCM can be found in (Abadie and Gardeazabal, 2003; Abadie et al., 2010; Munasib and Rickman, 2015).

We perform placebo analysis to assess whether the estimated treatment effects for the three states can be attributed to the energy sector cycle. Each state in the donor pool is assumed to be treated with the energy boom, in which the remaining states serve as potential donors to the synthetic control. Given the absence of oil and natural gas resources in the donor states, we expect either no difference between employment growth in the placebo state and its synthetic control, or we expect differences not to correspond to fluctuations in the oil and gas cycle; rather, differences that might exist would be attributable to factors such as non-energy-based idiosyncratic industry shocks or changes in state policy.

The predictor variables we use are from Munasib and Rickman (2015) and Rickman et al. (2017a). The variables include a series of county-level variables produced by the Economic Research Service (ERS) of the US Department of Agriculture (USDA, 2015) that are aggregated to the state level: the state composition of counties dependent on labor earnings from farming, manufacturing and mining; the natural amenity attractiveness of the state; the state composition of counties that are a retirement destination; the state composition of nonmetropolitan counties that were recreation dependent; the state composition of industries that lost population during 1980-1990 and 1990 and 2000; the state composition of counties that had a poverty rate of 20 percent or higher in each of the 1970, 1980, 1990 and 2000 censuses; and the state composition of rural-urban continuum code values. Other predictor variables include: the state population density in year 2000; variables reflecting the educational attainment shares of the adult population 25 years and older from the 2000 Census of Housing and Population; and Fraser Institute's Economic Freedom Index for the beginning of the decade (Goetz et al., 2011). Following convention, (e.g., Abadie et al., 2010), we also include the first, mid, and last years of the pre-treatment periods.

4. Results

We first report and discuss the base results from the application of SCM to each of Louisiana, North Dakota and Oklahoma for total nonfarm wage and salary employment. Included is a comparison to the unweighted-average of the 30 non-energy donor states, where the difference between the treated state and the 30-state average is akin to a standard difference-in-differences estimate. This is followed by presentation and discussion of calculated total employment multipliers for oil and gas-related exogenous employment using difference-in-differences between the treated state and its synthetic control post- and pre-treatment. Multipliers are calculated for the entire post-treatment period of 2004-2016, as well as for the sub-periods of 2004-2008 and 2014-2016. Placebo analysis then follows, where each donor state is separately specified as a treatment state with the remaining states serving as the pool of potential donor states. The section concludes with a comparison of state and local expenditures in each treated state relative to that of its respective comparison unit to assess their effects on short-run multipliers and on potential longer run outcomes of the oil and gas boom; in particular, the potential roles of education expenditures and public school teacher salaries are assessed.

4.1 Synthetic Control Results

The SCM results for total nonfarm wage and salary employment are shown in Figures 2-4. The figures show the close pre-treatment period matching of employment growth between each oil and gas (treated) state and its synthetic control. The three oil and gas states also generally follow the average of the thirty non-energy states during the pre-treatment period.

The state weights in the construction of the synthetic controls are shown in Table 1. From largest to smallest, the states with by far the largest weights in forming the composite state for Louisiana are Alabama and South Dakota. These are followed by Missouri, Georgia and Florida. For North Dakota's control, the states with the largest weights are South Dakota, Illinois and Nebraska. The remaining state forming the synthetic control is Iowa, with only slight weight in the control. The states with largest weights in the construction of the composite state for Oklahoma in order are, Missouri, Washington, Georgia, and Minnesota. California and South Dakota are slightly weighted.

The values for the predictor variables for each energy state generally more closely match those of the respective synthetic control than those of the other two energy states (not shown). North Dakota's synthetic control values are closer to North Dakota's values than are the average values for Oklahoma and Louisiana for fifteen of the seventeen variables (including the three lagged outcome variables); the corresponding numbers for Louisiana and Oklahoma are twelve and ten, respectively, each compared to the other two energy states.

The predictor variable values for each synthetic control also are closer to those for the respective treated state than are those for the average of the thirty donor states (not shown). Of the seventeen predictor variables, the synthetic control is closer to Louisiana for thirteen of the variables, where the comparable numbers for North Dakota and Oklahoma are twelve and ten. In terms of standard deviations in the predictor variables across states, the synthetic control for Louisiana particularly better matches in terms its share of counties with persistent poverty and its education shares among adult population, especially for the share with a bachelor's degree. For North Dakota, its synthetic control particularly better matches in terms of farm dependence of the economy, classification along the rural-urban continuum and the state share of counties with persistent population loss. Oklahoma's synthetic control is particularly a better match for the state share of counties with persistent poverty and population density.

For each of three treatment states, the initial oil and gas boom causes total nonfarm employment to grow faster than that of the corresponding synthetic control post-2004 (Figures 2-4). Employment in each synthetic control grew faster than the average of the thirty non-energy states, suggesting the importance of comparing the oil and gas states to their synthetic controls; i.e., the estimated employment effects of the initial oil and gas boom would be biased upwards if the thirty-state average was used for comparison instead of the synthetic controls.

Corresponding to the Great Recession, total nonfarm employment declined for all three synthetic controls. In Louisiana and Oklahoma, total nonfarm employment peaked in 2008, with that of each of their synthetic controls peaking in 2007. Louisiana and Oklahoma only followed the nation into the recession after oil and gas prices fell from their 2008 peak. Both North Dakota and its synthetic control peaked in 2008; despite the fall in oil prices in 2008, North Dakota's total nonfarm employment only slightly dropped in 2009.

With the dramatic turnaround in energy prices during the rebound of the national economy from the recession, growth of total nonfarm wage and salary employment in the three states once again began to exceed that of the synthetic controls for three oil and gas states. Louisiana and North Dakota peaked in 2014, while despite a contraction in the energy sector in 2014, Oklahoma peaked in 2015. All three state registered employment declines from 2014-2016.

At the end of the bust in 2016, total nonfarm wage and salary employment in Louisiana finished above that of its synthetic control, despite mining employment dropping below its 2004 level by 3.4 percent. North Dakota's total employment finished far above its synthetic control in 2016, corresponding to the over fourfold increase in mining employment. Despite the over forty-percent increase in mining employment from 2004-2016 in Oklahoma, its total employment dropped slightly below that of its synthetic control in 2016.

4.2 Calculated Oil and Gas Employment Multipliers

We next calculate oil and gas nonfarm wage and salary employment multipliers for each treated state for the full period of 2004 through 2016 and the sub-periods of 2004-2008 and 2014-2016. We first calculate the difference-in-differences (DID) in total nonfarm wage and salary employment for 2004-2016 versus 1992-2004 for each treated state versus its synthetic control. We then calculate the same for mining wage and salary employment. For the sub-period calculations, the 1992-2004 differences are prorated based on the number of years in the sub-period, i.e., one-third for 2004-2008 and one-sixth for 2014-2016.

A first set of multipliers is calculated as the synthetic control DID estimate of total wage and salary nonfarm employment divided by the DID estimate of mining wage and salary employment. This approach implicitly assumes the same multiplier effects of mining employment changes in the composite state and treated state.[13] As discussed above, the change in

[13] The difference estimate for mining employment in the synthetic control is weighted by the ratio of mining employment to total employment in the synthetic unit divided by the corresponding ratio for the treated (oil and gas) state in calculating the DID mining employment estimate. As non-energy states, mining employment in the synthetic controls as shares of total employment are small fractions relative to those for the three energy states.

mining employment in the three treated states can be attributed to oil and gas employment in the sector.

A second set of multipliers is calculated by recognizing that other energy-linked industries produce for exports in addition to local demand. This is particularly important when calculating multipliers at the state level; the greater the level of geographic aggregation the more likely there is co-location of direct energy employment and export employment in energy-linked industries. Using the US total requirements matrix provided by the US Bureau of Economic Analysis, we identify four industries as candidates to produce for exports related to energy production in other states: Primary Metals Manufacturing (NAICS 331), Fabricated Metals Manufacturing (NAICS 332), Machinery Manufacturing (NAICS 333) and Pipeline Transportation (NAICS 486). Among sectors traditionally not considered as local, the four sectors have the largest coefficients in the 2004 US total requirements matrix averaged across Oil and Gas Extraction and Mining Support Activities.[14] Changes in non-energy related exports are assumed to be captured in the synthetic control and no additional adjustments are required.

For each of the four sectors, the 2004 QCEW employment location quotient (LQ) is applied to the relative change in employment for each period. A DID estimate of wage and salary employment in each sector is then calculated in the same manner as for mining employment discussed above. Applying the 2004 LQs to changes in employment implicitly assumes constant shares of employment for local demand versus export demand, equal to the initial shares implied by the 2004 LQ.[15] The LQ has two notable limitations (Swanson et al., 1999), which in this case

[14] The industry by industry total requirements matrix is available from 1997-2015 for 71 industries at https://www.bea.gov/industry/io_annual.htm, last accessed September 13, 2017. The coefficients remain the largest after adjusting for relative differences in 2004 US Bureau of Labor Statistics employment to output ratios), https://www.bls.gov/emp/ep_table_207.htm, last accessed September 13, 2017. Each coefficient in the total requirements matrix represents the total change in dollar demand for the row industry for a one-dollar change in purchases by the column industry. This accounts for all interindustry changes that affect the row industry from the change in purchases by the column industry.

[15] The LQ values for Louisiana, North Dakota and Oklahoma for Primary Metals Manufacturing, Fabricated Metal Manufacturing, Machinery Manufacturing are Pipeline Transportation Services are as follows. Primary Metals Manufacturing: 0.38, 0.15, 1.02. Fabricated Metal Manufacturing: 0.93, 0.50, 1.49. Machinery Manufacturing: 0.58, 1.93, 1.80. Pipeline Transportation Services: 3.65, 2.50, 3.62. Cushing, Oklahoma is a major oil trading hub for the US and is the largest oil storage field, while Louisiana has two of the five largest storage fields in the US (http://www.nola.com/business/index.ssf/2015/03/largest_us_crude_oil_storage_s.html). North Dakota has a

leads to an unknown effect on estimated exports. First, a sector is only assumed to export when it has a higher than national average employment share; i.e., a state with a higher than national share is assumed a net exporter, but never an importer of a good, potentially under estimating exports. Second, the method assumes identical national and regional demands for the sector. But an oil and gas rich state likely has higher local demand for the four industries than the nation, which would lead to over estimates of exports.

Both sets of multipliers are reported in Table 2, arranged by period and state. The multiplier results for Louisiana (sans New Orleans) are shown in the first column of Table 2. The two multipliers for 2004-2008 are 4.47 and 3.34. The multipliers for 2014-2016 are larger in magnitude at 5.85 and 4.22. This suggests stronger multiplier effects during the bust phase. The DID estimate for total nonfarm wage and salary employment is slightly positive for 2004-2016, despite a slightly negative DID estimate of mining employment, which produces the negative long-run multiplier when considering mining employment alone as the exogenous change. The full- period estimate suggests there were long-run growth benefits of the energy boom in Louisiana through agglomeration economies and/or public education spending, despite mining employment eventually falling below its 2004 level in 2016.[16] Although the sign switches, the

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pipeline system that connects to Canada. When we further investigated the sub-sectors of machinery manufacturing and fabricated metals, we found that the changes in the aggregates for North Dakota and Oklahoma could be attributed to those producing specifically for the oil and gas sector. But for Louisiana the sub-sectors producing for oil and gas exhibited different patterns than the aggregates. Therefore, for Louisiana the calculations for the second set of multipliers used QCEW employment in the following sub-sectors rather than the aggregate sectors: Mining and Oil and Gas Field Machinery Manufacturing (LQ=5.7); Plate Work and Fabricated Structural Products (LQ=5.4); and Fabricated Pipe and Pipe Fitting Manufacturing (LQ=3.1).

[16] Hurricane Katrina in 2005 is not likely driving the results. First, we removed New Orleans from all the data for Louisiana because of Hurricane Katrina. Other parts of Louisiana and neighboring states were directly and indirectly affected but the multiplier calculated for the 2006-2008 sub-period is approximately the same as for 2004-2006. According to RAND Corporation Gulf States Policy Institute (2010) eighty four percent of evacuees from Alabama, Florida, Louisiana, and Mississippi returned to their home state within one year of initial displacement. Except Mississippi, by the end of 2016 labor force participation and employment in the affected states rebounded to pre-Katrina rates, with Louisiana's rising to higher rates. Those that did not return reported significantly increased self-employment rates, which is not part of the QCEW wage and salary employment used in the analysis. In addition, only twelve percent of displaced New Orleans residents initially relocated elsewhere in Louisiana (Sastry and Gregory, 2014).

large positive multiplier when also considering manufacturing and pipeline services over the entire period also supports an interpretation of long-run growth benefits.

From column (2), we see that the multipliers range from 4.63 to 4.34 for North Dakota over the period 2004-2008. The values are larger than the comparable total nonfarm wage and salary employment multiplier of 3.37 estimated by Munasib and Rickman (2015) for the nonmetropolitan portion of North Dakota. The larger multipliers may in part be attributable to the inclusion of the metropolitan areas, which may capture the effects of additional royalty payments and state government taxes and expenditures. The multipliers during the 2014-2016 period of falling oil and gas employment range between 3.23 and 3.13. The smaller multipliers during the decline help produce long-run multipliers for the 2004-2016 period of 6.19 and 6.77. The larger multipliers in the long run are suggestive of agglomeration effects or growth benefits of increased education spending rather than resource curse effects, though it also could reflect expectations of future growth in oil and gas development in the state.

The third column of results in Table 2 show smaller multiplier values for Oklahoma, 2.95 and 2.52. The simple mining employment multiplier value fits the county-based multipliers reported by Tsvetkova and Partridge (2016), who report a value of 3 over a six-year period. Weber (2014) reports an employment multiplier of 2.4 associated with natural gas extraction for counties in Arkansas, Louisiana, Oklahoma and Texas over a ten-year period. In examining 647 nonmetropolitan counties mostly in the 10th Federal Reserve District 2001 to 2011 over a ten-year period, Brown (2014) finds an employment multiplier of 1.7 from natural gas exploration and extraction. The much larger multipliers for the 2014-2016 period of decline for Oklahoma contrasts with the smaller multipliers for North Dakota but fit those for Louisiana. The negative DID estimate for total nonfarm wage and salary employment despite the long-run increase in oil and gas employment suggests a slight resource curse result.

4.3 Sensitivity Analysis

We compare the results for Louisiana, North Dakota and Oklahoma with those for the thirty donor states and their synthetic controls. This follows the procedure for placebo analysis in the SCM method where each donor state is specified as a treated state and compared to a corresponding synthetic control. Any difference between the treated donor state in employment growth relative to the corresponding synthetic control would not be expected to follow the pattern of oil and gas states; the differences could be attributable to other idiosyncratic industry shocks or changes in state policy.

Figure 5 shows the differences in total nonfarm wage and salary employment between each treated state in the placebo analysis and its synthetic control.[17] The three oil and gas states peak in relative employment in 2009 compared to the donor states during the initial boom. Louisiana, North Dakota and Oklahoma are ranked fifth, third and tenth, respectively, in 2009. The three states reached absolute peaks in 2008, ranking fifth, first, and third respectively in 2008. Relative to their synthetic controls, North Dakota rises to first place by 2014, with Oklahoma fourth and Louisiana fifth. Despite significant employment losses from 2014-2016, North Dakota remains in first place in 2016 in terms of relative employment growth from 2004-2016. Louisiana and Oklahoma fall to fourteenth and twenty-third place respectively.

4.4 Public Spending Over the Boom-Bust Cycle

We next explore whether differences in state and local spending responses to the oil and gas boom and bust affected the short-run and long-run multipliers. Negative impacts on state employment from reduced state and local government spending have been reported by Rickman and Wang (2018). Of particular relevance to possible resource curse outcomes, negative relationships have been found between resource dependence and public education spending (Gylfason, 2001; Papyrakis and Reyer, 2007; Walker, 2013). Contrarily, based on a panel of the lower 48 US states from 1970 to 2008, James (2017) reports that resource rich states spend more on public education, particularly during times of high energy prices.[18] Marchand and Weber (2018) found though that greater spending in Texas school districts experiencing an increase in their tax base from the recent shale boom accrued to capital projects and debt servicing rather

[17] Florida is removed from the comparison because of a poor pre-treatment fit in the outcome variable.
[18] James (2017) also reports that the result holds when only considering the top five oil and gas producing states, either in terms of total production or per capita production.

than to teachers, which may have contributed to the observed greater teacher turnover and decline in student test scores.

Figure 6 shows a comparison of the changes in real per capita total state and local general expenditures in the three oil and gas states compared to their respective synthetic controls using the weights for each synthetic control shown in Table 1.[19] Figure 7 similarly shows the same for changes in real per capita state and local education expenditures in the three oil and gas boom states compared to those of the corresponding synthetic controls. Panels A and B of Table 3 show the differences in growth between the oil and gas state and their synthetic controls. Because of data availability, we report expenditures for the entire state of Louisiana.

Figures 6 and 7 show that during the 1992-2004 pre-treatment period, the pre-treatment paths of the synthetic controls generally follow those of their respective oil and gas states; this is notable considering that the weights for the synthetic controls were obtained from matching of total nonfarm wage and salary employment, not public expenditures. But real per capita total state and local expenditures grew slower in all three states relative to their synthetic controls (Figure 6 and Panel A of Table 3) during the pre-treatment period, approximately one-half of a percentage point per year or less. The same was true for Louisiana and North Dakota for growth in real per capita education expenditures (Figure 7 and Panel B of Table 3); whereas, Oklahoma's pre-treatment growth closely matched that of its synthetic control.

During the initial boom period beginning in 2004, growth in real per capita total general expenditures began to exceed those of the synthetic controls for Louisiana and Oklahoma (Figures 6 and Panel A of Table 3). North Dakota's growth matched that of its synthetic control. During the 2008-2015 period, Louisiana's real per capita general expenditures dramatically declined relative to its synthetic control, North Dakota's dramatically rose, while Oklahoma's slightly increased. Consistent with James (2017) expenditures grew in all three states relative to their synthetic control over the entire 2004-2015 period.

[19] State expenditures are from the Annual Survey of Government Finances: Urban Institute-http://slfdqs.taxpolicycenter.org/pages.cfm.

Real per capita state and local education expenditures also rose during the initial 2004-2008 boom period in Louisiana and Oklahoma and were likewise flat in North Dakota (Figure 7 and Panel B of Table 3). From 2008-2015, North Dakota's expenditures dramatically rose, while they declined in both Louisiana and Oklahoma, particularly during 2014-2015 for Oklahoma. The increases over the 2004-2015 period were smaller than those for total general expenditures.

To address more specifically the potential effects on the quality of primary and secondary education, we also examine public school teacher salaries.[20] Increased education spending can accrue to non-instructional uses such as capital projects and debt servicing rather than teacher salaries, which can affect turnover and quality of instruction (Marchand and Weber, 2018). Total education spending also includes that on higher education.

Panel C of Table 3 shows larger relative increases in real teacher salaries during 2004-2008 in Louisiana and North Dakota than in Oklahoma. Relative teacher salaries then declined from 2008-2016 in Louisiana and Oklahoma, producing only a slight increase over the entire 2004-2016 period for Louisiana and a decline in Oklahoma. North Dakota experienced nearly a fourteen percent increase in real teacher salaries over the entire post-treatment period. In fact, Oklahoma's teacher salaries ranked forty-eight among the fifty states in both 2004 and 2016. [21] Louisiana improved its ranking from forty-third to thirty-third, while North Dakota improved its ranking from forty-ninth to twenty-eighth. Besides the reduction in real teacher salaries in Oklahoma, increased classroom crowding, the move by some schools to four-day weeks, and the statewide shortage of teachers (Wendler, 2015) that resulted from reduced spending may have adversely affected educational outcomes and business recruiting (Hardiman, 2017).[22]

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[20] Public school teacher salaries are from various years of the Digest of Education Statistics by the National Center for Education Statistics, https://nces.ed.gov/programs/digest/.

[21] Using the 2009-2011 3-year microdata sample of the American Community Survey, Rickman et al. (2017b) report Oklahoma near the bottom in teacher salaries among all states, regardless of adjusting for teaching conditions, cost-of-living and household amenity-attractiveness.

[22] Earthquakes in Oklahoma associated with the disposal of wastewater from hydraulic fracking of oil and gas began to increase after 2010, with the number of 3.0 magnitude or higher earthquakes exceeding the number in California by 2014, creating a new household disamenity in Oklahoma (Cheung et al., 2016). But because the number of earthquakes did not peak until near the end of the period, earthquakes less likely influenced the outcomes during the entire period. Earthquakes though could become another source of a resource curse in Oklahoma if they reduce the natural amenity attractiveness of the state.

The larger boom in energy production in North Dakota likely is the dominant factor in explaining its relative increase in state and local expenditures. But Oklahoma also is reported to have had the lowest effective tax rate (severance and ad valorem taxes combined) on oil and gas production among nine states.[23] Louisiana had the second highest rate, while North Dakota had the fifth highest rate. Louisiana also was the only one of the three states not to reduce its top personal income tax rate between the tax years of 2004 and 2016 (Tax Policy Center, 2017). As is more typical during energy booms (James, 2017), Oklahoma cut its top personal income tax rate from 6.75 to 5 percent from 2004 to 2016, while North Dakota cut its top personal income tax rate from 5.54 to 2.9 percent from 2008 to 2016. The personal income tax rate for Louisiana remained at 6 percent throughout the 2004-2016 period. All three states have low personal income shares of property taxes, which make them less likely a source of increased education spending from rising property values during an energy boom as in Texas (Marchand and Weber, 2018). The higher rate of taxation of oil and gas production and the absence of cuts in the rate of personal income taxation could plausibly explain Louisiana's surge in real per capita education spending and estimated (slight) long-run growth benefits from the oil and gas cycle during the 2004 to 2016 period relative to Oklahoma.

5. Conclusion

Addressing understudied aspects of the energy cycle, this paper examines the employment impacts of the oil and gas boom and bust for the US states of Louisiana, North Dakota and Oklahoma over the period 2004-2016. The period includes an initial boom, a decline that includes the Great Recession, a subsequent boom, and then a bust in energy prices and energy sector employment during a period of national growth. The three states are intensive in the production of oil and generally match each other prior to the energy boom and in the timing of the ups and downs in the energy cycle during the post-2004 period. With New Orleans removed

[23] The nine states in order of rate of taxation are Wyoming, Louisiana, Arkansas, Montana, North Dakota, Texas, Utah, Idaho and Oklahoma (Covenant Consulting Group, 2017, p.14).

from Louisiana because of Hurricane Katrina, the areas of study are relatively more nonmetropolitan than other states and absent strong trends in other mining employment.

The synthetic control method is applied to total nonfarm wage and salary employment from 1992 to 2004 to construct the counterfactuals for the three states for the post-2004 period. Employment multipliers are calculated during the initial boom period (2004-2008), a bust in the oil and gas sector that diverged from overall national economic trends (2014-2016) and the entire period (2004-2016). For all three states, increased oil and gas employment significantly increased relative total nonfarm employment during the initial boom period. The multipliers during the initial boom period are comparable or larger than employment multipliers reported in the literature, which almost exclusively have been estimated at the US county level.

For North Dakota, what went up did not completely come down. Possible agglomeration economies and benefits of increased education spending and increased teacher salaries may underlie the smaller multipliers during the bust phase of the energy cycle. Although Louisiana mining employment declined over the post-2004 period, relative total nonfarm employment remained above that of its synthetic control comparison unit; the outcome is suggestive of slight agglomeration economies or long-run benefits from improvement in education spending and teacher salaries. Only for Oklahoma is there evidence of a (slight) resource curse effect. Larger multiplier effects were estimated for the bust phase, producing a long-run reduction in total nonfarm employment, despite a long-run increase in mining employment in the state. Associated with the outcome was a decline in real public school teacher salaries in Oklahoma that left them ranked forty-eighth in the nation.

Future research could examine the distribution of impacts across sectors in assessing potential long-run growth benefits versus resource curse outcomes over even a longer time-period. The large estimated growth effects in North Dakota may in part relate to expectations of future energy development and continued investment in energy-related infrastructure. There also may be thresholds in public school funding levels and teacher salaries that produce resource curse outcomes that should be avoided. Further research also is needed on estimating state exports in other sectors related to the energy cycle. This issue was shown to be important for Louisiana and Oklahoma in this study and needs to be addressed in estimating the impacts of the energy sector at broader geographic scales.

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Table 1. Synthetic control state Weights

State	Louisiana Weights	North Dakota Weights	Oklahoma Weights
Alabama	0.588	0	0
California	0	0	0.088
Connecticut	0	0	0
Delaware	0	0	0
Florida	0.05	0	0
Georgia	0.06	0	0.107
Illinois	0	0.257	0
Indiana	0	0	0
Iowa	0	0.05	0
Maine	0	0	0
Maryland	0	0	0
Massachusetts	0	0	0
Michigan	0	0	0
Minnesota	0	0	0.107
Missouri	0.083	0	0.401
Nebraska	0	0.228	0
New Hampshire	0	0	0
New Jersey	0	0	0
New York	0	0	0
North Carolina	0	0	0
Ohio	0	0	0
Oregon	0	0	0
Rhode Island	0	0	0
South Carolina	0	0	0
South Dakota	0.218	0.464	0.03
Tennessee	0	0	0
Vermont	0	0	0
Virginia	0	0	0
Washington	0	0	0.268
Wisconsin	0	0	0

Table 2. Employment Results: Oil and Gas Boom State-Synthetic Control State

	LA	ND	OK
2004-2008			
Total Employment Change	45,875	14,080	62,832
Multiplier: Mining	4.47	4.63	2.95
Multiplier: Mining+Mft+Pipeline	3.34	4.34	2.52
2014-2016			
Total Employment Change	-72,505	-46,625	-86,644
Multiplier: Mining	5.85	3.23	5.01
Multiplier: Mining+Mft+Pipeline	4.22	3.13	4.00
2004-2016			
Total Employment Change	5,213	69,570	-7,639
Multiplier: Mining	-3.58	6.19	-0.54
Multiplier: Mining+Mft+Pipeline	42.95	6.77	-0.51

Notes: Total change in employment is calculated as the change in total nonfarm employment over the period in the energy boom state less that of the respective synthetic control state.

Table 3. Relative Growth of Real Per Capita Public Expenditures and Teacher Salaries

Panel A			
Real Per Capita Total Expenditures: Treated-Synthetic			
	LA	ND	OK
1992-2004	-6.3%	-5.5%	-4.4%
2004-2008	31.6%	0.4%	5.5%
2008-2015	-20.9%	35.4%	2.5%
2014-2015	-4.1%	8.1%	-3.2%
2004-2015	10.6%	35.7%	8.0%
Panel B			
Real Per Capita Education Expenditures: Treated-Synthetic			
	LA	ND	OK
1992-2004	-7.6%	-4.4%	-0.6%
2004-2008	10.2%	0.0%	4.4%
2008-2015	-1.6%	17.8%	-2.2%
2014-2015	0.7%	5.9%	-3.6%
2004-2015	8.6%	17.8%	2.1%
Panel C			
Real Teacher Salaries			
	LA	ND	OK
1992-2004	-1.6%	2.1%	8.6%
2004-2008	7.0%	5.3%	1.9%
2008-2016	-5.3%	8.5%	-4.4%
2014-2016	3.7%	-0.3%	-0.8%
2004-2016	1.7%	13.8%	-2.5%

Notes: Per capita state and local expenditures are in 2015 dollars, while teacher salaries are in 2016 dollars using the Bureau of Labor Statistics Consumer Price Index.

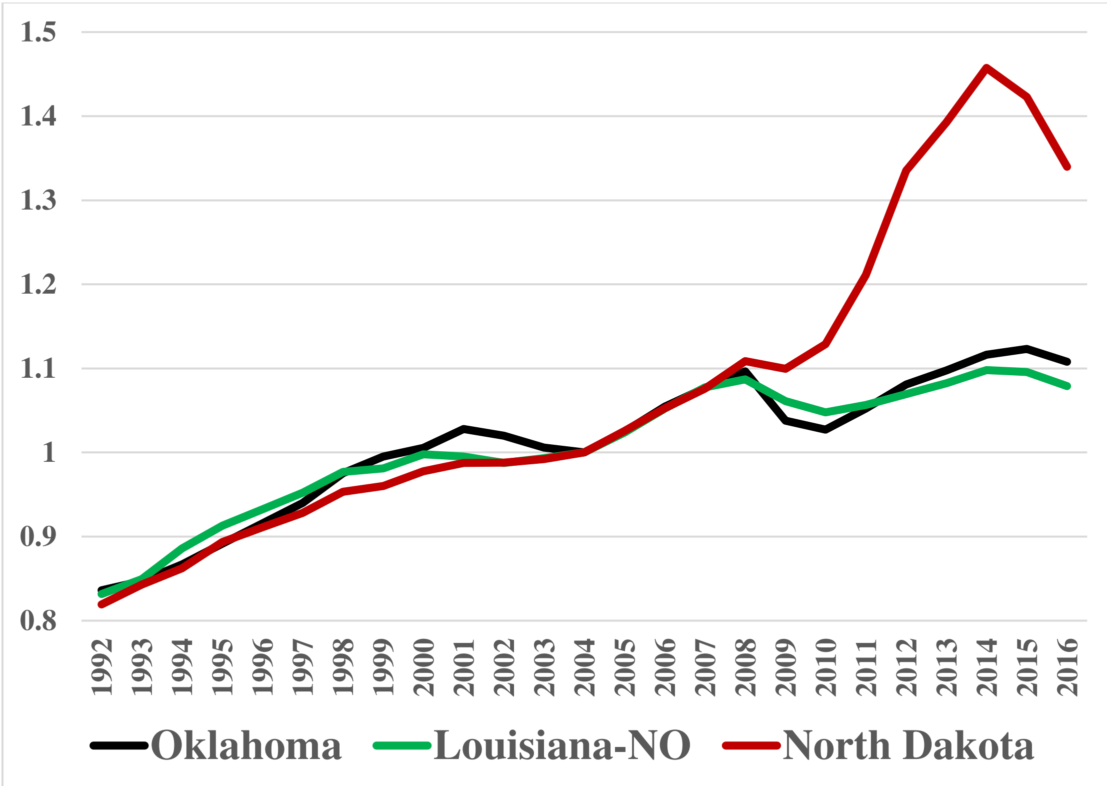

Figure 1. Total Nonfarm Wage and Salary Employment (2004=1)

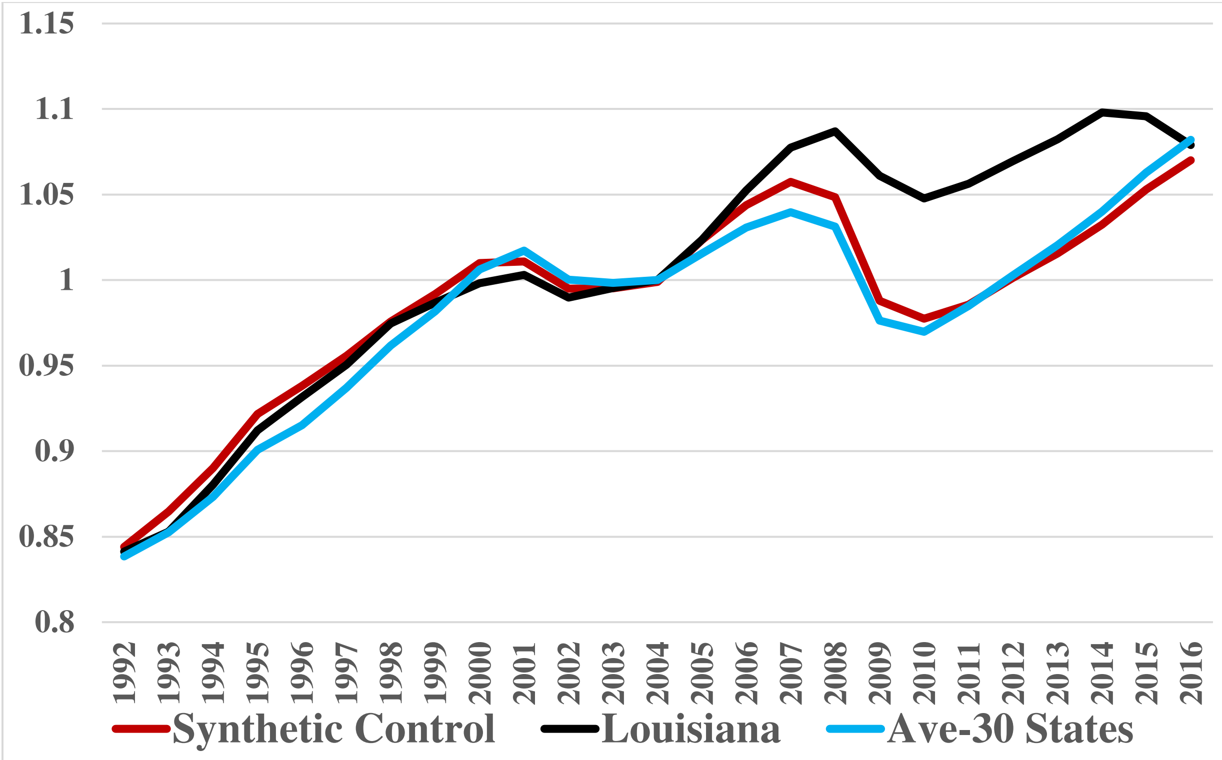

Figure 2. Louisiana Synthetic Control Results (2004=1)

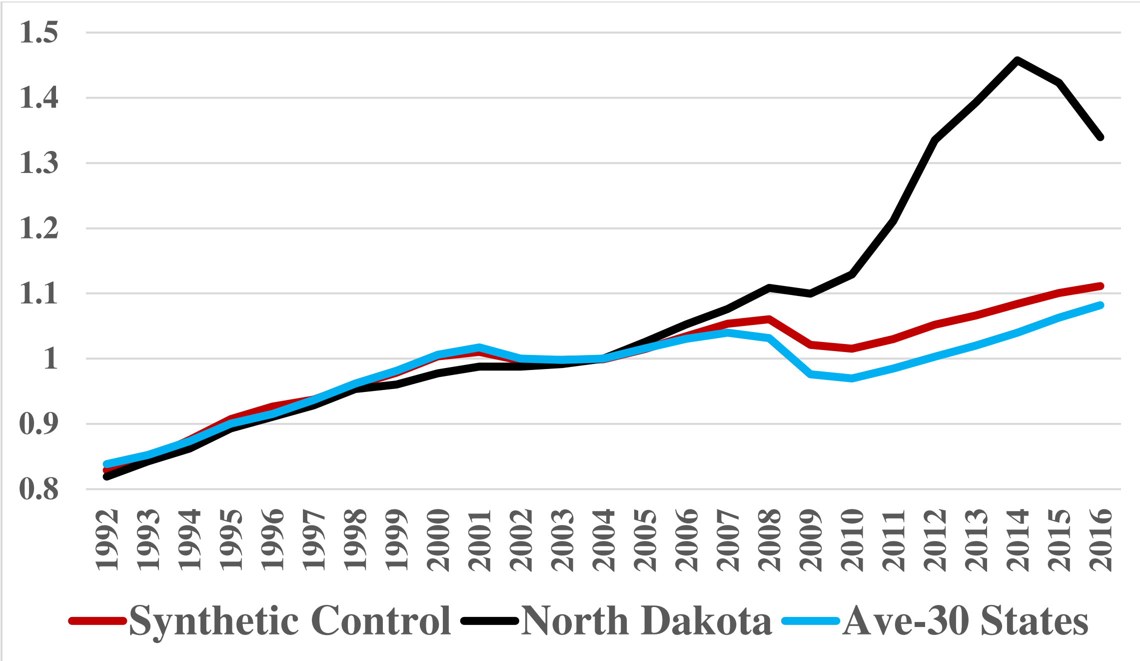

Figure 3. North Dakota Synthetic Control Results (2004=1)

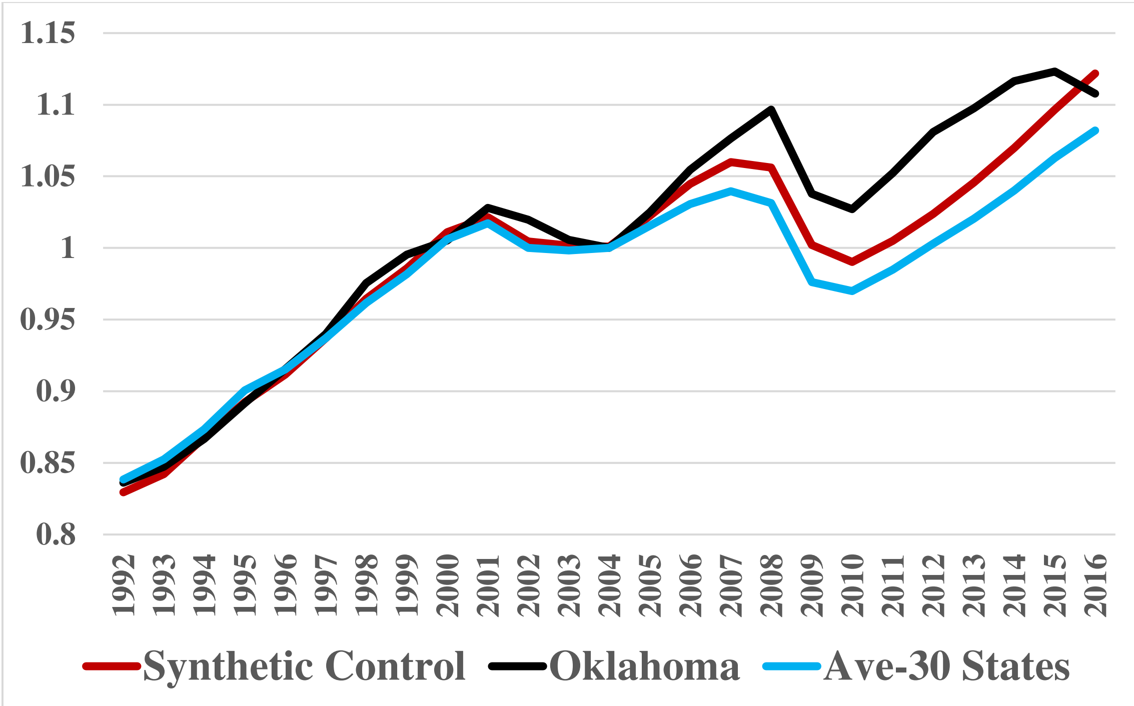

Figure 4. Oklahoma Synthetic Control Results (2004=1)

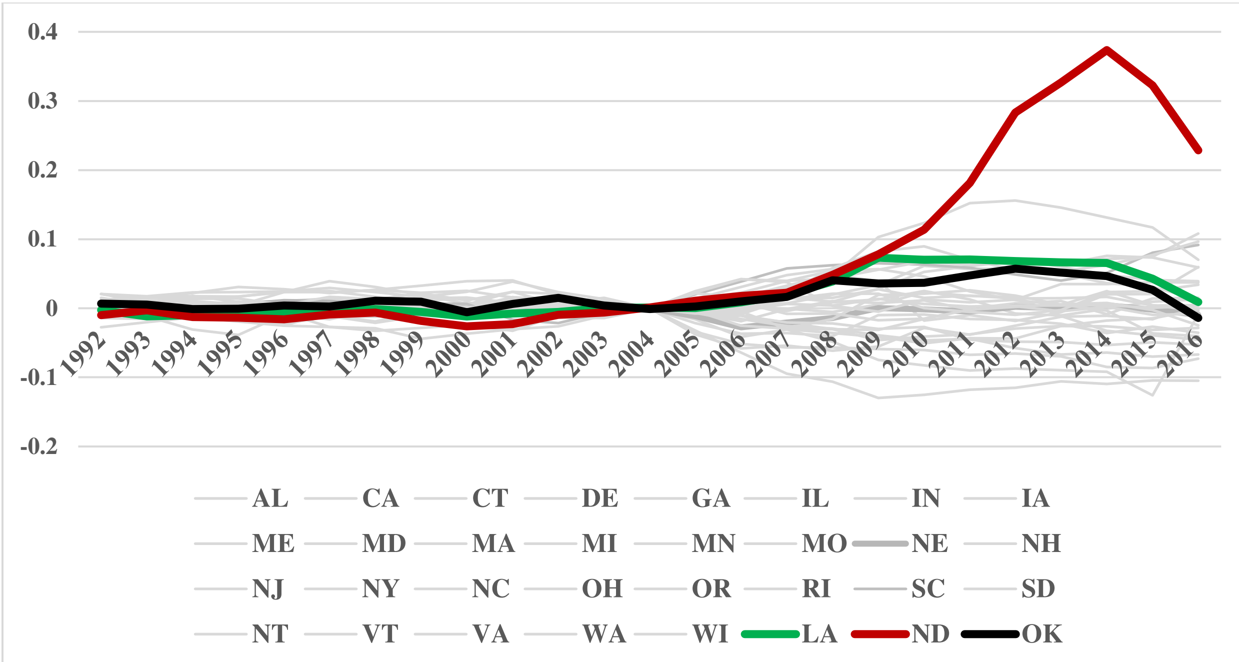

Figure 5. SCM Comparisons to Donor States (one eliminated-poor pre-treatment fit

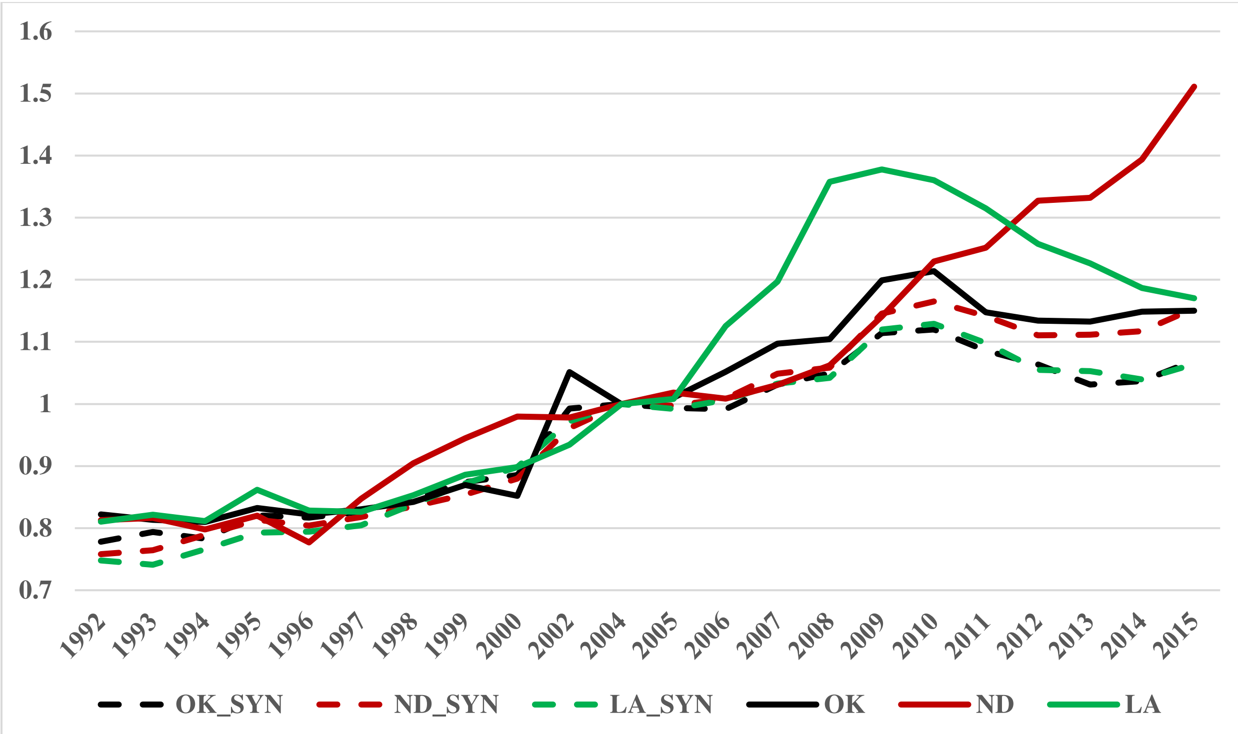

Figure 6. Real Per Capita Total State and Local General Expenditures: Treatment States and Synthetic Control States

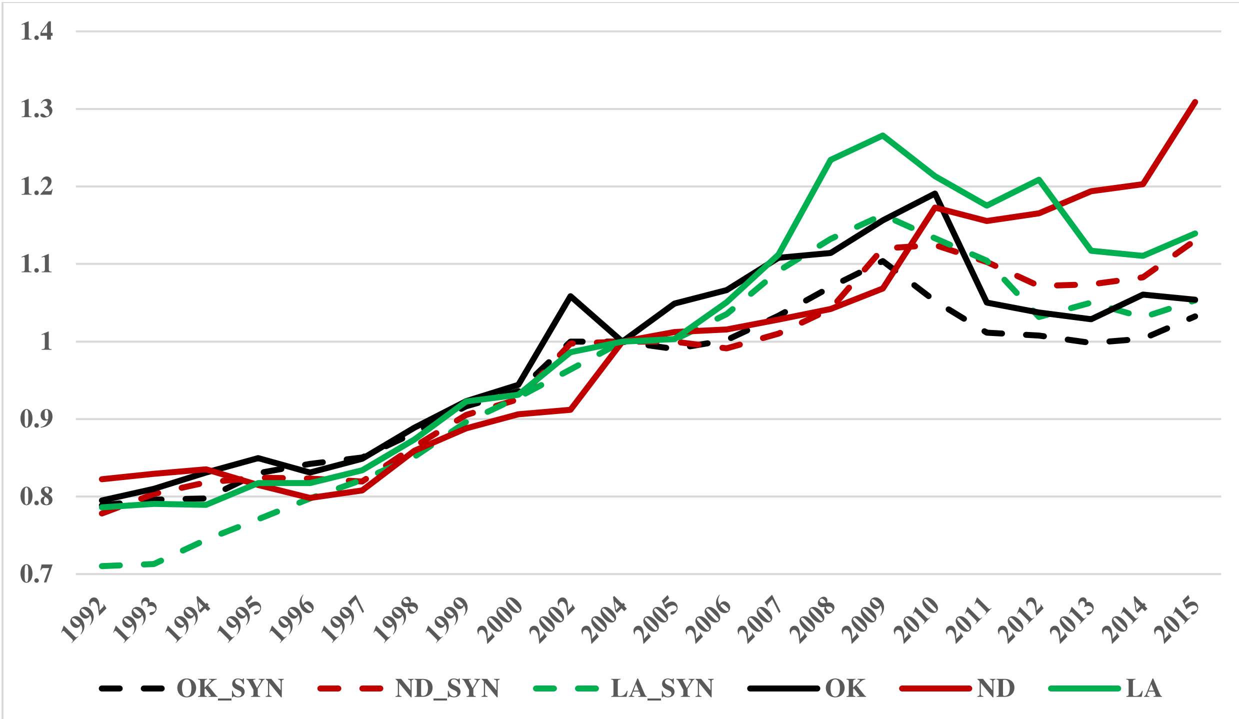

Figure 7. Real Per Capita State and Local Education Expenditures: Treatment States and Synthetic Control States