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The local economic impacts of the oil and gas industry: Boom, bust and resilience to shocks☆

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ABSTRACT

In this paper, we study the impact of the oil and gas industry on county-level employment and wage earnings across not only the boom, but also the bust cycle. Our paper is among the first to estimate wage and employment impacts of the bust cycle for the U.S. oil and gas industry and directly compare these employment and wage impacts for the boom. We then evaluate spillovers into other sectors in the economy, comparing impacts on tradable and non-tradable industries for three distinct geographic regions and estimate separate models for rural and urban areas. We find variation across geographic context, but in general the oil and gas bust was associated with a significant decrease in overall employment, with the effect most notable in non-tradable industries in rural counties. Finally, we investigate the differential impact of the 2008 financial crisis on labor in producing and non-producing counties. We find that, employment and wages in oil and gas producing counties were impacted by the financial crisis less than non-oil and gas counties and recovery in oil and gas counties started earlier.

1. Introduction

The U.S. energy sector has experienced a dramatic transformation in the past fifteen years due in large part to the innovation of hydraulic fracturing in combination with horizontal drilling. Historically an energy importer, the U.S. became a net oil exporter in 2018, and natural gas imports decreased by half. Not only did total energy production increase, but the number of places that became significant oil and gas producers expanded considerably. Traditionally, energy extraction was concentrated in the U.S. in offshore fields in Alaska, California and the Gulf of Mexico, with limited conventional oil production (vertical wells) in some states. However, hydraulic fracturing allowed the energy industry to expand into 34 states, bringing oil and gas jobs to mostly rural areas.

The local economic impact of this energy boom has been well-studied (Weinstein et al., 2018; Freyrer et al., 2017; Hoy et al., 2017; Jacobsen and Parker, 2016; Komarek, 2016; Tsvetkova and Partridge, 2016; Munasib and Rickman, 2015; Weber, 2012), however little work has been done to evaluate the bust phase that is typical of many extractive industries. One recent paper Rickman and Wang (2020) investigate the impact of the bust on local economies in four states, but more work is needed to understand how the bust phase compares to the boom in local economies. We address the study of both the boom and bust phases of oil and gas production in the United States and appraise the net economic impact. Additionally, we use an event study framework to evaluate whether the oil and gas boom helped communities weather the broader economic shock from the Great Recession.

Given the oil and gas industry's emergence as an economic cornerstone in many rural communities, it is important to understand the industry's impact over the entire course of the boom and bust cycle. This work is closely related to the existing natural resource curse literature that assesses medium- to long-run outcomes of resource extraction communities. In the U.S., previous studies have examined resource extraction impacts in other contexts, namely coal mining (Betz et al., 2016; Deaton and Niman, 2012; Papyrakis and Gerlagh, 2007; Black et al., 2005) and conventional oil and gas production (Bjornland and Thorsrud, 2016; Marchand, 2012; Michaels, 2011) with mixed evidence for a resource curse. However, since unconventional shale oil and gas extraction has only recently experienced a bust, little has been done to examine how the boom and bust cycles compare in the contemporary U.S. context.

Additionally, the recent shale oil and gas boom is fundamentally different than previous American resource booms in coal mining or conventional oil and gas extraction. Many coal mining communities in Appalachia have had a centuries-long relationship with the coal industry, which has created a cultural institutionalization of the industry in those communities. Conversely, although some places—like in Texas

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and Oklahoma—had experience with oil extraction, many communities like those that experienced an unprecedented natural gas boom in Pennsylvania had little prior experience with natural resource extraction. Investigating how such different contexts experience the life cycle of oil and gas extraction has important policy implications.

Often resource booms have disparate impacts on local tradable and non-tradable sectors (Maniloff and Mastromonaco, 2017; Black et al., 2005), which in turn have important implications for the long-run net impact on local economies. There are several channels through which the oil and gas industry can impact both tradable and non-tradable sectors in the short run. First, wage and employment growth in the oil and gas sector can induce positive income shocks, thereby increasing demand for local goods and services and employment and wages in local non-traded sectors. Income also flows into the community through land leases and royalty payments, further increasing demand in the non-tradable sector. Conversely, oil and gas activity can compete with other industries for resources (land, water, and labor) increasing production costs for competing industries. This competition effect can disproportionately impact tradable sector industries that do not benefit from the local demand shock associated with local oil and gas production.

Finally, we employ an event study strategy to investigate the differential impact of the 2008 financial crisis on producing and non-producing counties, focusing on non-tradable industries in rural counties. Noting that the financial crisis took place in the midst of the boom phase, we limit our study to the period of 2001 to 2014. We find that prior to the crisis, there were no differential trends in employment and labor earnings between producing and non-producing counties. Once the crisis took place, we observe a positive differential trend in favor of producing counties, indicating that oil and gas activity buffeted the crisis.

We find significant impacts of the boom and bust on employment and labor earnings in oil and gas producing counties, especially for rural counties. While the results across regions are heterogeneous in magnitude, the general trend shows an increase in total employment and wages during the boom that is reversed during the bust. Moreover, we find these changes in employment and labor earnings are mostly due to the impact of the boom and bust on industries in the non-tradable sector, most notably the construction industry and the transportation industry. Our results suggest that the oil and gas industry has a substantial impact on local labor markets. A boom in oil and gas mining led to significant gains in employment and faster growth in labor earnings, and a portion of these gains are later lost as a result of the bust. These results concur with earlier work on the impact of natural resource extraction on local economies (Black et al., 2005). Moreover, the event study suggests the mining industry fostered local economic resilience during the global economic crises.

In the next section, we start with a descriptive overview of the oil and gas industry in the United States between 2000 and 2018. We document a clear trend of industry growth from 2005 to 2014 in which oil and gas production – as well as employment– in the industry increased at a persistent rate. Industry revenues had a general positive trend during the period 2005–2014 with short-term fluctuations that correlated with price fluctuations. From 2015 to 2017, there was a substantial bust in the industry characterized by a slowdown in production, and a significant decrease in revenues and employment. Based on these observations, we distinguish three phases: a pre-boom phase from 2001 to 2004, a boom phase that takes place from 2005 and 2014, and finally a bust phase from 2015 to 2017. It's worth noting that the bust period was relatively short in comparison to the nearly decade-long boom period. Unlike the coal bust of the 1980s that resulted in a dramatic production decrease, the oil and gas "bust" that we analyze can be considered a temporary downturn that reversed a decade of fast growth in the oil and gas industry. Indeed in 2018, oil and gas employment and production capacity still far exceed 2005 levels. We then explore the impact of the boom and bust on total employment and labor earnings in three geographic regions, regrouping multiple states that were at the center of the dramatic increase in U.S. oil and gas activity.

The rest of this paper is organized as follows: in Section 2, we present the main data sets used along with a discussion of national trends. In Section 3, we discuss regional changes in the oil and gas sector. Section 4, contains our main empirical analysis of the boom and bust. An event study investigating the differential effect of the 2008 recession on producing and non-producing counties is presented in Section 5. The last section concludes.

2. Data

In this section, we provide a detailed description of the data sets we used to construct the main variables in our empirical analysis. We also present stylized facts and trends in the oil and gas industry in the United States from 2000 to 2018. For this study, we assemble multiple data sources on oil and gas production and prices, well drilling, and oil and gas employment. We conduct our main empirical analysis using two proprietary data sets. The first is an oil and gas production data set compiled by Enverus that allows us to construct monthly and yearly oil and gas production by county. Combined with historic monthly average prices of oil and gas, we are able to calculate monthly and yearly oil and gas revenues by county between 2000 and 2018. Second, we use data on county-level employment and labor earnings by detailed 4-digit NAICS[1] industries from Economic Modeling Specialists International (EMSI).

2.1. Oil and gas production data

Enverus[2] collects detailed information on every oil and gas production unit (well) in the United States. This data set contains a wealth of information on drilling leases, drilling start dates, reservoir characteristics and production quantities. We use variables measuring monthly oil production, monthly gas production, spud date and the date each well began production. We exclude all offshore drilling and production from our sample and limit our observations to drilling and production for the years 2000–2018. We then aggregate the raw measures to obtain county level (monthly and yearly) observations for the period of interest.

The evolution of average daily[3] crude oil and natural gas extraction in the United States is presented in Fig. 1. Oil production remained fairly stable until around 2009 before rising sharply from 2010 to 2014, where average daily production reached 7 million barrels a day. Over the next three years, oil production growth slowed but continued to climb to a peak of 7.3 million barrels a day in 2015. In 2018, oil production increases sharply again to reach a new peak of 8.6 million barrels a day on average. Natural gas extraction presents a similar trend, but with production growth starting earlier than oil, before accelerating more quickly around 2010. Similar to the oil production trend, gas production growth slowed between 2015 and 2017 before rising sharply again in 2018 to reach an average daily production of 92.8 million McF.

Quantities of oil and gas produced offer a good measure of extraction activity, but in order to capture the full scope of economic activity generated by the industry we use prices to compute the total yearly revenue generated in a given county oil and gas industry. We use West Texas Intermediate (WTI) for oil price and the Henry Hub price for natural gas[4] in combination with the production data to calculate revenues. WTI is in dollars per barrel and the Henry Hub price is in dollar per

[1] North American Industry Classification System

[2] Further information about Enverus and access to data can be found on https://www.enverus.com/

[3] Per day production is obtained by dividing total production in a year by 365. Therefore the plot presents the average daily production for a specific year.

[4] Prices are obtained from U.S. Energy Information Administration https://www.eia.gov/

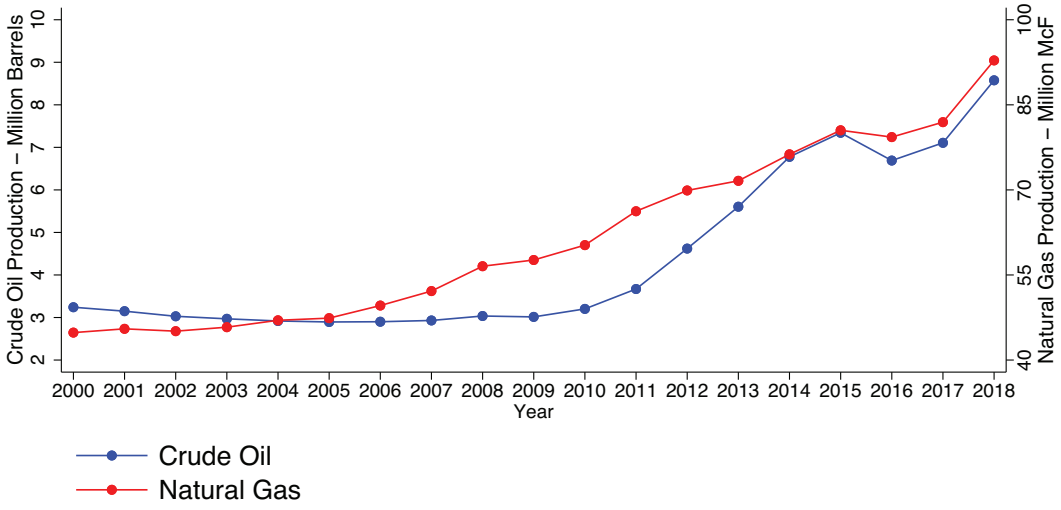


Fig. 1. Oil and Gas Production in the United States. Note: This figure plots the average daily production of crude oil and natural gas in the United States for the period 2000–2018. The measurements are based on total yearly production divided over 365 days. Average daily crude oil production can be read on the left y-axis, and the average natural gas production can be read on the right y-axis.

million British Thermal Units (MMBtu[5]). Since 2011, a small portion of the oil produced in the U.S. is priced using the Brent crude oil price. For most of the period of interest, the spread[6] between both prices is negligible with the exception of the 2011–2013 period where the spread was larger than the historic trend in favor of the Brent. However, fluctuations in both prices were positively correlated. Using monthly prices and quantities produced, we compute monthly revenues by county, which are then summed to obtain yearly oil and gas revenues by county. Using average monthly prices rather than average yearly prices allows for a more precise estimation of revenues, since yearly measures might mask large price fluctuations that could occur in a given year. It should be noted that the average prices used do not necessarily match the prices that producers obtained. Therefore, our revenue measure is not exact, but nevertheless, a good approximation. More importantly, this approximation allows us to observe the revenue trends, which is most important to our study.

Fig. 2 plots the time series of the average monthly price of a barrel of oil. Over the entire period oil prices fluctuated quite a bit. The price was relatively stable at around $30 until around January 2004 where it began to steadily increase. Around 2007, prices rose even faster before reaching a record high of $133 per barrel in June 2008. In the 10 years between mid 2008 and end of 2018, oil prices are marked by two significant declines, first, during the Great Recession and then, between July 2014 and January 2015. The phase between the shocks was characterized by a quick recovery until the first half of 2009, after which oil prices remained relatively stable.

Gas prices (Fig. 2) exhibit a different pattern, characterized by two significant phases. The first from 2000 until mid 2009 was highly volatile, where prices went as low as $2.3 per MMBtu and spiked as high as $13 per MMBtu on multiple occasions. This period was followed by a less volatile period, where prices were concentrated around $3.4 per MMBtu. Also of note is the trend reversal that took place in 2008. From 2000 until mid-2008, prices trended upward. After the sharp decline in gas prices in mid-2008, a declining trend followed through 2018.

It is important to note that both prices and production respond to global economic trends. For instance, the large drop in both oil and gas prices in mid 2008 coincide with the global financial crisis and the recession that ensued. The slow-down in natural gas production also coincides with the recession. Between 2014 and 2017 there was a simultaneous downturn in production and a drop in prices of oil and gas. There are several factors affecting supply and demand of oil and gas that could explain these observations. On one hand the expansion of production by US-based producers led to an increase in total supply. Moreover, during that period a slowing in Chinese and other emerging economies took place which reduced global demand.

Fig. 3 shows oil and gas revenues together for the entire U.S. to provide a composite picture of Figs. 1 and 2. The price and production variation discussed above are pronounced in total revenues. The early increase in gas production and both oil and gas prices led to steady revenue growth between 2000 and 2008. Total oil and gas revenues dipped to around $148 billion in 2009, a 48% reduction from the previous year. This large loss in revenue was primarily due to the simultaneous sharp decreases in oil and gas prices associated with the recession. The quick resurgence of prices and production led to revenue growth that reached a historic peek of $347 billion in 2014, before falling over the next three years as a result of both lower prices and production.

2.2. Employment and labor earnings data

Oil and gas industry employment is another measure of economic activity associated with oil and gas production. EMSI compiles data from the Bureau of Labor Statistics Quarterly Census of Employment and Wages (QCEW), supplemented by the Bureau of Economic Analysis (BEA) Regional Economic Accounts and the US Census Bureau's County Business Patterns to produce county-level employment and earnings per worker data for 323 4-digit NAICS industries. The value of this data is that we are able to distinguish oil and gas employment from all other mining employment, which cannot be done at the country level in publicly available datasets. Using this data, we are able to observe employment and wages for workers in the oil and gas industry in every county in the US, thus providing an additional measure of oil and gas activity. Employment and average yearly labor earnings in the oil and gas industry in the whole U.S. is plotted in Fig. 4. Oil and gas industry employment positively correlates with the production trends documented above, however they diverge toward the end of the series when oil and gas employment steadily declines after 2014.

[5] The rate of conversion of MMBtu to McF is 1.034.

[6] Time series of both price can be found on https://fredblog.stlouisfed.org/2016/09/friction-in-oil-markets/?utm_source=series_page utm_medium = related_content utm_term = related_resources utm_campaign = fredblog

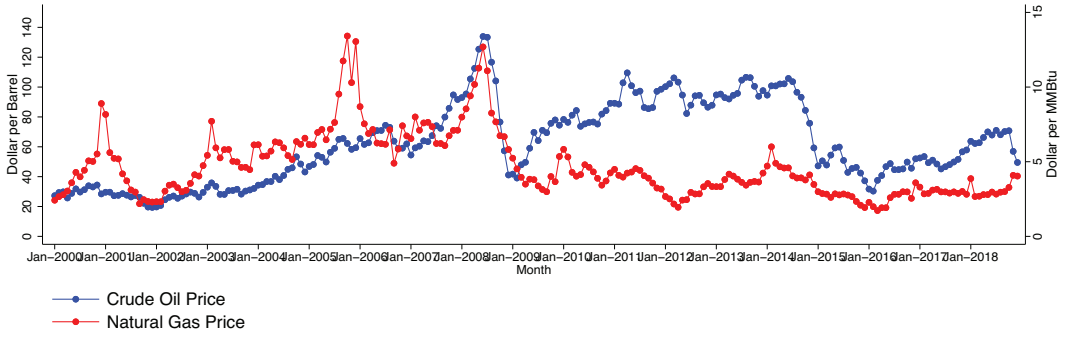


Fig. 2. Monthly Market Prices of Oil and Gas. Note: This figure plots the average monthly prices of crude oil and natural gas. The WTI oil price is represented on the left y-axis and the Henry Hub natural gas price is represented on the right y-axis.

It should be noted that while employment and production positively correlate at the two major trend changes (i.e. the beginning of the boom and the bust), employment changes lead the changes in production. Moreover, because of variation in labor intensity in each of the phases of oil and gas extraction (Brown, 2015), the recession's impact on employment extends beyond its impact on production. During the development phase more labor intensive activities –like drilling, fracking, and pipeline construction– take place. Workers also engage in complementary tasks during this phase, including infrastructure building, transportation, and heavy machinery operation. In earlier phases of exploration and appraisal, limited crews of specialized professionals evaluate potential drilling sites, negotiate procurement leases, and drill exploratory wells to better estimate the oil and gas field's size and value. In the final phase, oil and gas production is done by a limited number of rig operators.

Various economic factors affect the initiation and progress of each stage, and therefore employment and production levels. For instance, growth in the overall economy and sanguine expectations about future fossil fuel demand can lead to further exploration and field development, and an employment surge. Alternatively, when fossil fuel demand slows, production in currently operating fields might persist for a period of time at the same level, while future development might be put on hold, slowing down future employment growth.

It is also worth noting the average yearly earnings of a worker in the oil and gas industry increased steadily throughout the observation period. The average yearly wage doubled in less than 20 years, increasing from slightly higher than $100,000 in 2000 to $220,000 in 2018. Wage growth positively correlates with production growth, accelerating during production booms and nearing zero during busts.

The main objective of this paper is to study spillovers from the oil and gas industry into other sectors of the local economy. Outcome variables of interest are obtained from the EMSI data and they include county level measures of overall employment and labor earnings as well as county level measures of these outcomes for two Tradable industries (Agriculture and Manufacturing) and four non-Tradable industries (Construction, Retail, Food Services and Transportation). We compute average yearly growth rate in overall employment and labor earnings for counties with no oil and gas production and for those that had any oil and gas production, the trends are presented in Fig. 5. Until 2006 trends in employment growth rate for producing and non-producing counties were parallel being slightly larger in the non-producing counties. Between 2007 and 2009 both group of counties experienced a progressive drop in employment growth, however this decrease in growth was faster in the non-producing counties. In the period 2010 to 2014 employment growth rate in producing counties was larger than counties who did not have oil and gas production. For the last three years of the observation period, the order is inverted with growth rate in non-producing counties being higher. To sum up the observation about employment growth, we note that in the period where oil and gas activity was booming

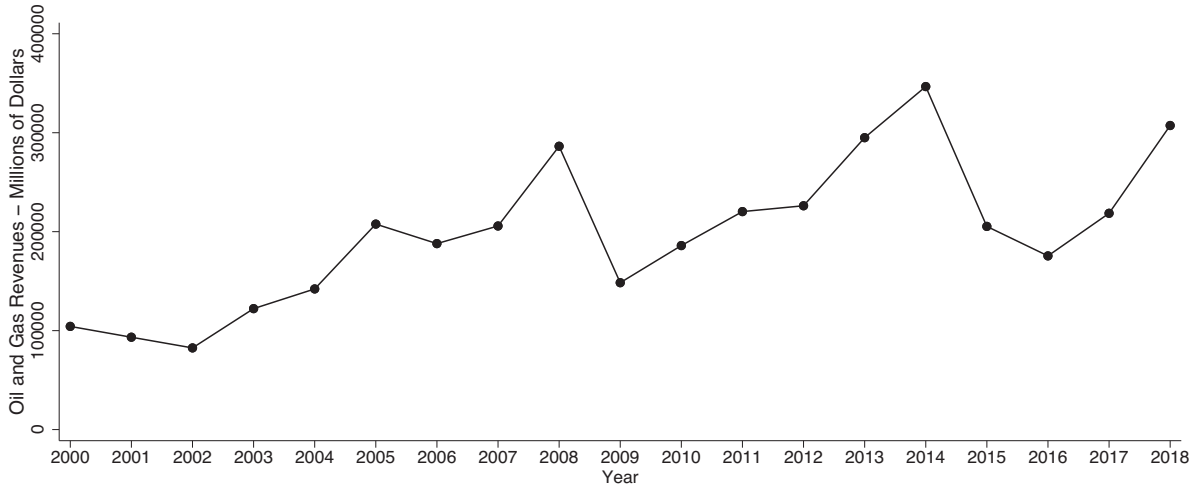


Fig. 3. Oil and Gas Revenue in the United States. Note: This figure plots total revenues in the oil and gas industry. Revenues were computed using average monthly prices and quantities produced of oil and gas.

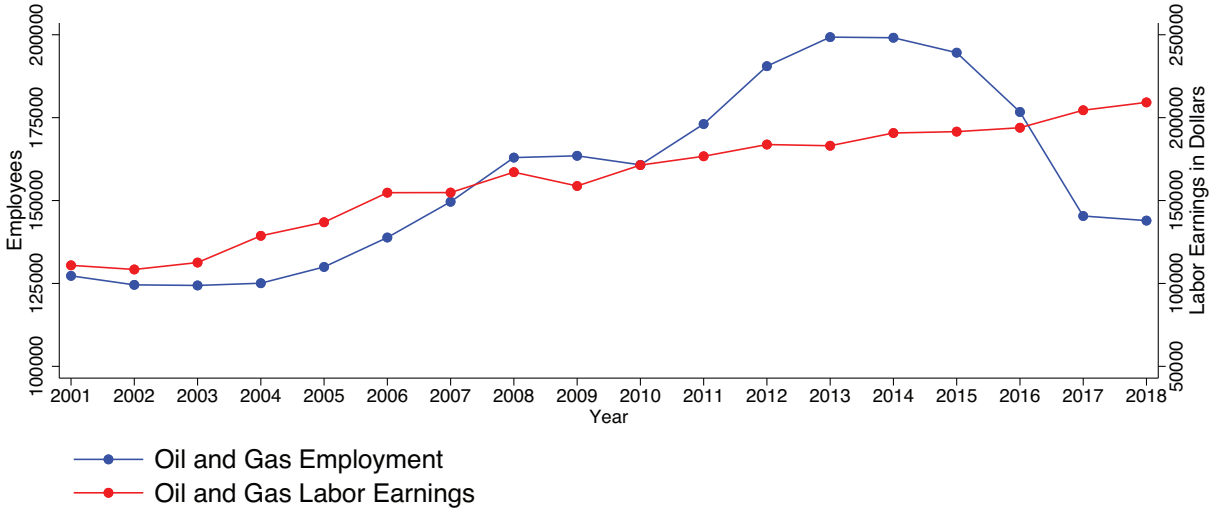
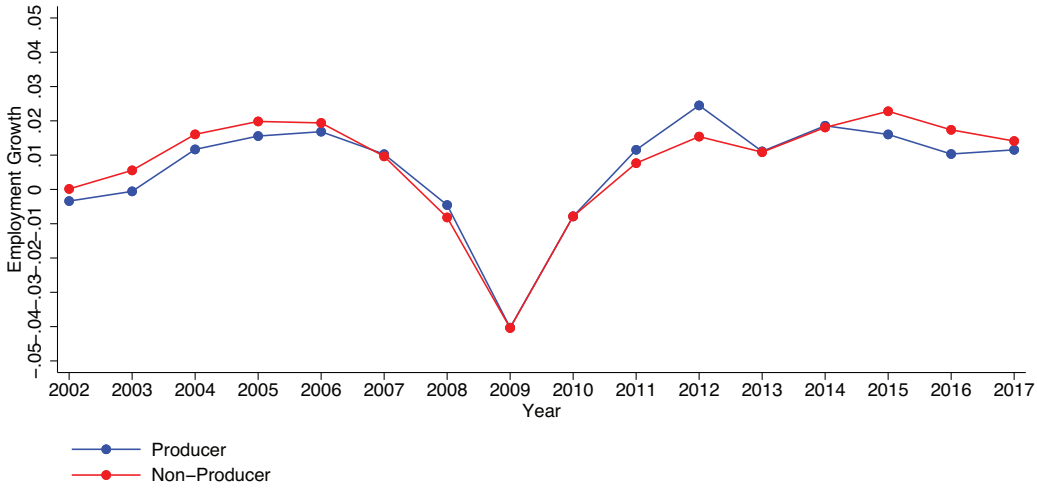
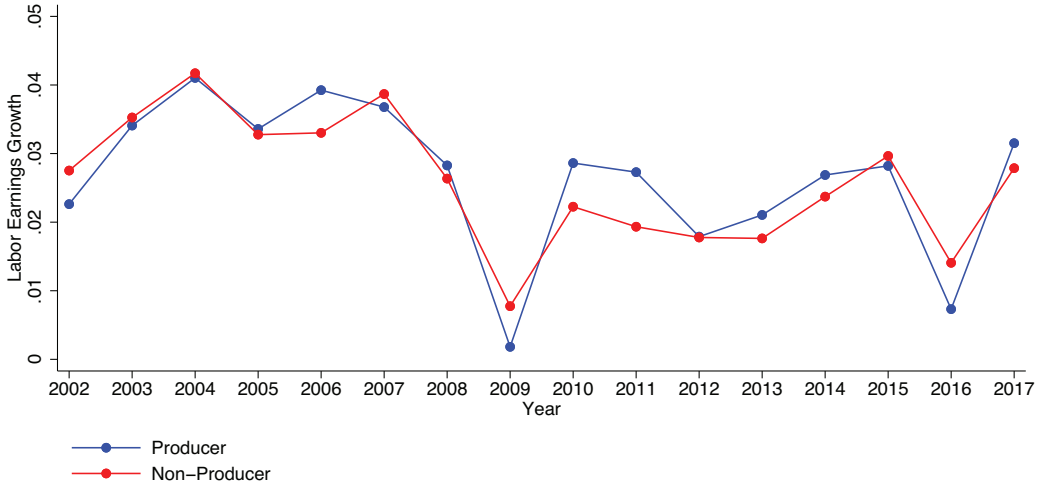


Fig. 4. Oil and Gas Employment and Earnings in the United States. Note: This figure plots employment and labor earnings in the oil and gas industry. Employment numbers can be read on the left y-axis, and labor earnings can be read on the right y-axis.



(a) Employment Growth Rate



(b) Labor Earnings Growth Rate

Fig. 5. Trends in Labor Market. Note: The figure plots (a) yearly average growth in total employment, and (b) yearly average growth in labor earnings in counties that had oil and gas production versus those that had no production.

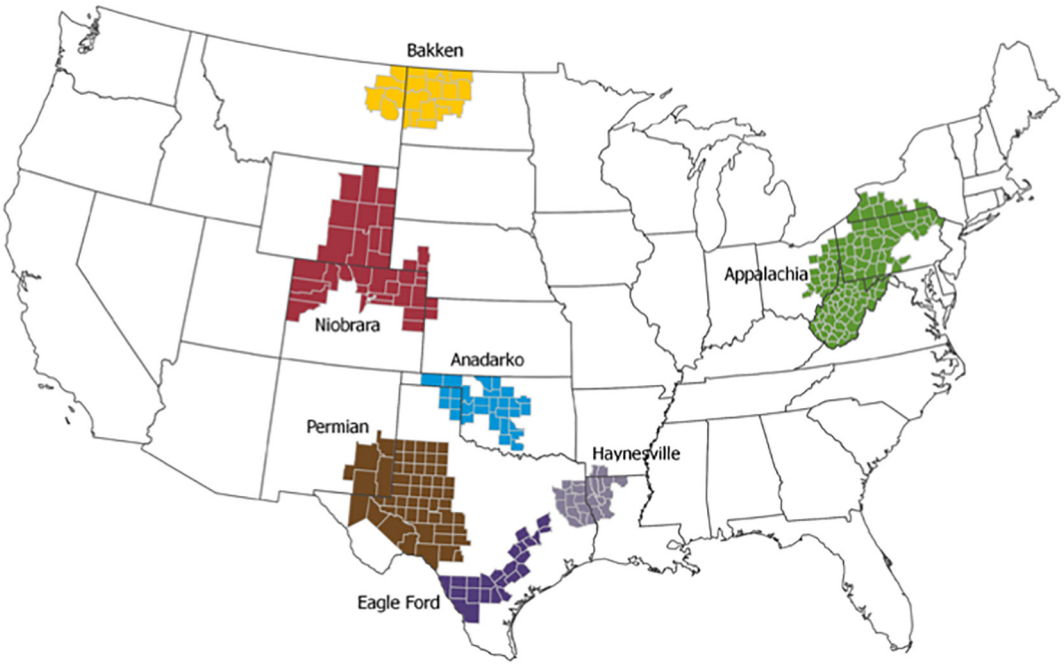


Fig. 6. Major Shale Plays in the United States. Source: U.S. Energy Information Administration

(2005–2014) total employment in producing counties increased at a faster rate (excluding the recession period where employment in all counties dropped at a similar rate), then in the period where oil and gas activity slowed down non-producing counties experienced a faster growth in employment. The trends in wage growth are not as clear as those of employment, while we can see a faster growth in labor earnings in producing counties during the period 2010–2014 no clear ordering of earning growth between producing and non-producing counties can be detected for the period preceding the recession or the period of downturn in oil and gas activity.

3. Regional variation in oil and gas development

3.1. Boom and bust timing

An interesting aspect of oil and gas development in the United States over the past decade and a half is the substantial variation in commodity extracted and timing of booms and bust across shale plays. While a mix of oil and natural gas are extracted in every region, there are substantial differences in proportion of each across regions. For instance, the Bakken play in North Dakota and Montana primarily produces oil, where the Marcellus play produces mostly natural gas. These differences, coupled with other regional economic factor and policy differences, have led to differences in the timing of production. In our study, we focus on three geographic clusters of states 1) Marcellus (Ohio, Pennsylvania and West Virginia); 2) South (Louisiana, Oklahoma and Texas); 3) West (Colorado, Montana, North Dakota and Wyoming). Individually, these 10 states are the largest oil and gas producers in the country, excluding Alaska and California. More importantly, these states had the largest growth in oil production as a result of the fracking revolution.

Fig. 6 shows the major oil and gas shale plays in the contingent 48 states. The map marks the counties that lay on top of these major basins. Almost all of them lay within the three geographic regions we focus on in this paper.[7]

The Appalachia basin, also known as the Marcellus play, is currently the largest natural gas producing basin in the United States. This basin covers the entirety of West Virginia, the north and west of Pennsylvania, and the eastern counties of Ohio, and a few counties in south west New York. Oil and gas activity from this basin coincide with our definition of Marcellus region.[8]

This region had the most rapid increase in fossil fuel production in the past 20 years. There was virtually no oil and gas production in the region until 2009 when production increased rapidly to reach 30 million McF per day by 2018 (Fig. 7b). Currently, 30% of total daily production in the United States originates from the Marcellus play. Additionally, there was an increase in oil production in the region around the same time (Fig. 7b). Fig. 7a shows that employment and labor earnings growth in the oil and gas sector preceded production by about three years, demonstrating the differences between the exploration, appraisal, and development phases between 2006 and 2009.

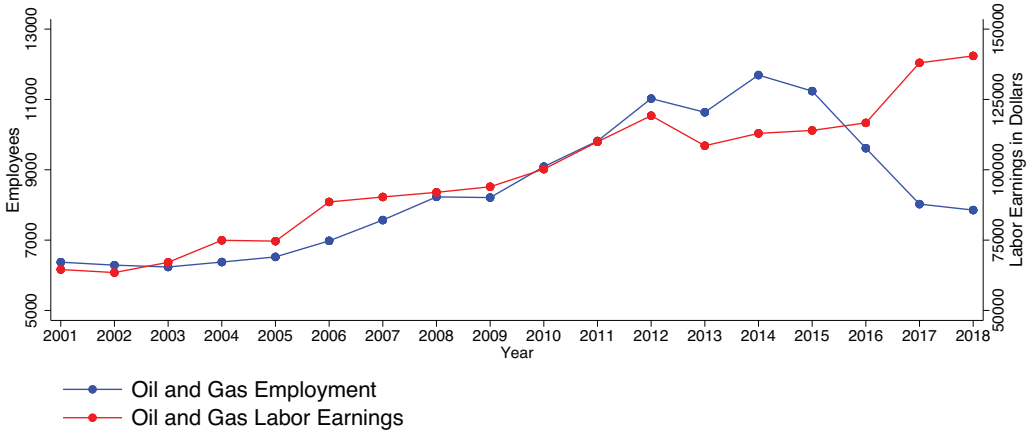
The plots show that between 2015 and 2017 there was a large decrease in oil and gas employment in Marcellus region, while labor earnings growth abated. Meanwhile, growth in both oil and gas production slowed. These boom and bust patterns are reflected clearly in the oil and gas revenues generated in the region (Fig. 7c). Revenue growth started in 2009, then accelerated after 2012, before peaking in 2014 and declining in the next two years.

The second geographic region (South) we focus on incorporates four shale plays across Louisiana, Oklahoma, and Texas. The Permian in Texas is one of the largest oil and gas basins in the US, producing the largest daily quantity of oil and the second largest quantity of gas in the U.S. The Eagle Ford basin, which also produces large quantities of both oil and gas, lays entirely within Texas. Haynesville basin, the third largest natural gas producing basin in the U.S., is split between north western Louisiana and eastern Texas. Finally, the Anadarko basin in the western and central parts of the state of Oklahoma produces both oil and gas.

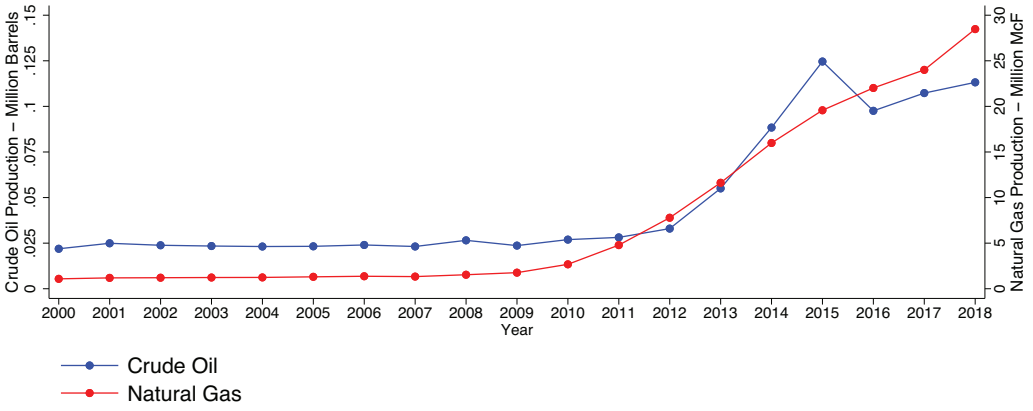
Louisiana and Texas have historically been major oil and gas producers. A large portion of their production is extracted offshore in the

[7] We do not include the few oil and gas producing counties in Kansas and Nebraska in our Western region or New York in the Appalachia basin also.

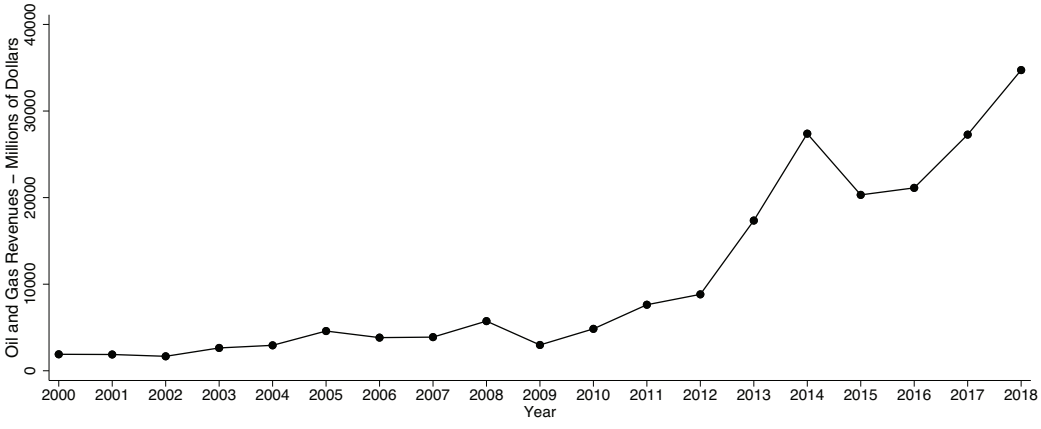
[8] New York state production of oil and gas is negligible as a result of various state-wide bans and restrictions on hydrofracking.



(a) Labor and Earnings



(b) Production

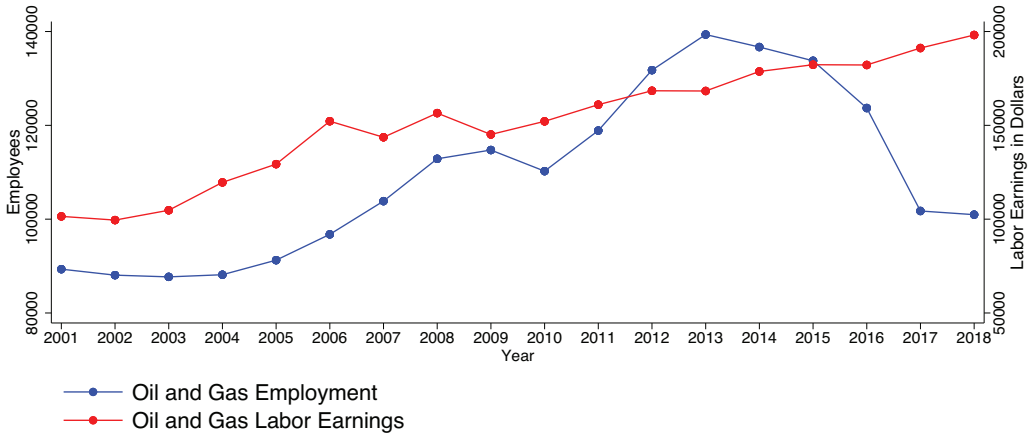


(c) Revenues

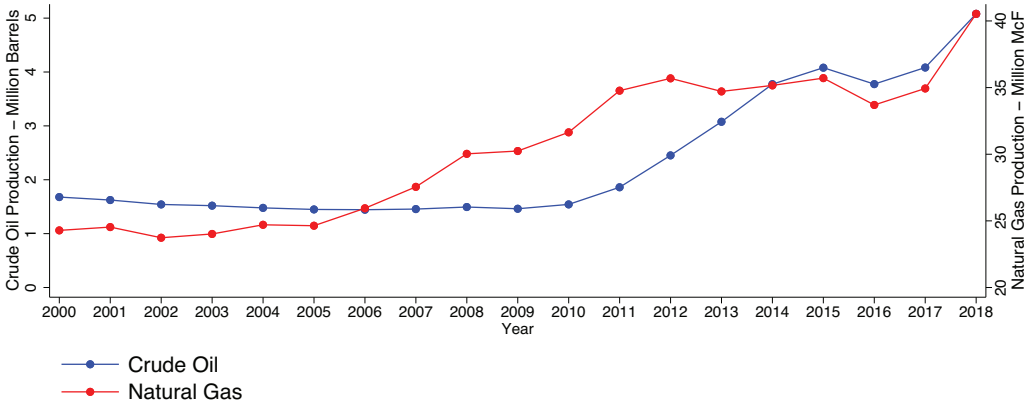
Fig. 7. Oil and Gas Activity in Marcellus Region. Note: The figure plots (a) yearly employment and labor earnings in oil and gas industry, (b) total yearly production of crude oil and natural gas, and (c) total yearly revenues of the oil and gas industry in the states of Ohio, Pennsylvania and West Virginia.

Gulf of Mexico. Both these states, along with Oklahoma, experienced production growth after modern fracking was introduced. Plot 8b shows that quantities of oil and gas produced (excluding offshore production) in this region in 2018 are almost three fold that of those in 2001. Similar to region 1, oil production began increasing in 2010. However, natural gas production started slightly earlier.

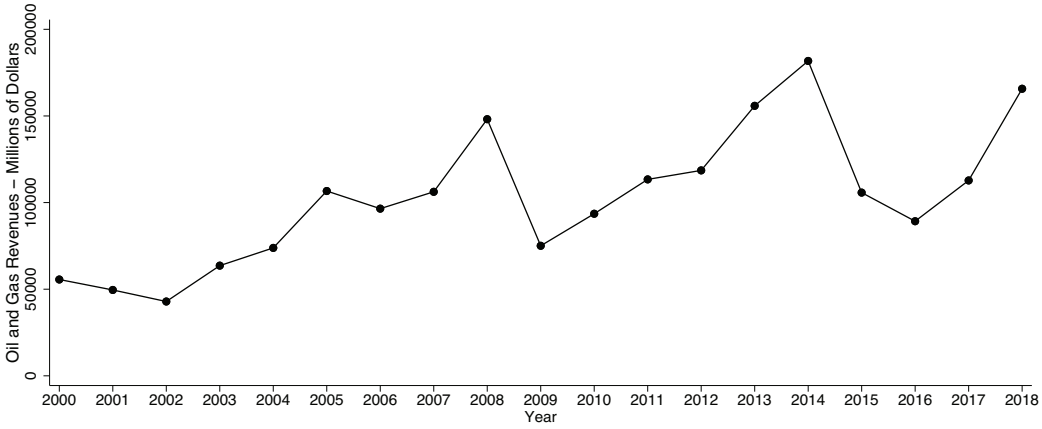
Fig. 8a shows a substantial increase in employment starting in 2004 that peaked in 2013, with a short dip during the 2009 recession. After 2013, employment in the oil and gas sector shrank by almost a third. Labor earnings, on the other hand, increased steadily until 2012, after which they flattened for the next four years (Fig. 8a). Revenues generated by the oil and gas sector in



(a) Labor and Earnings



(b) Production



(c) Revenues

Fig. 8. Oil and Gas Activity in South Region. Note: The figure plots (a) yearly employment and labor earnings in oil and gas industry, (b) total yearly production of crude oil and natural gas, and (c) total yearly revenues of the oil and gas industry in the states of Louisiana, Oklahoma and Texas.

the region increased between 2002 and 2014, with the exception of the year following the 2008 recession. In 2015, oil and gas revenues dropped by 40%, persisting at this lower level until 2017.

In the third region (West) there are two major shale plays. The Bakken, which is located in the border region of Montana and North Dakota is the second largest oil producing basin in continental US. The Niobrara basin is mostly located in the eastern part of Wyoming and northern counties of Colorado as well as a couple of counties in each of Nebraska and Kansas.

The main variables in the oil and gas sector in the west region follow similar trends as in the other two regions. Fig. 9 shows increase in production, employment, labor earnings and revenues until 2014, followed by declining production, revenues and employment and a slow down in labor earnings growth.

In summary, all three regions witnessed a common cycle of oil and gas activity: a boom characterized by increased employment, production, and revenues, followed by a 3-year bust characterized by a rapid drop in oil and gas employment. The increase in oil and gas employment started around the year 2005 in all three regions, peaking around 2014, and followed by a bust that reduced employment extensively by the year 2017.

3.2. Employment and labor earnings changes

Next we quantify employment and labor earnings unconditional changes over the pre-boom and, boom, and bust periods in each region. The first challenge to our empirical work is determining the precise periods of boom and bust. The graphical evidence presented above, at both national and regional levels, seem to suggest that the bust period lasted from 2015 to 2017. The start of the boom period is less evident. There are differences in terms of the beginning of the upward trends in employment and production, with increase in oil and gas employment preceding increase in production. Moreover, there are geographic differences in the timing of the start of the growth between regions. We choose to set the start date of the boom in 2005, as it coincides with the start of growth in national level employment in the oil and gas sector (Fig. 4) as well as the start of the upward trend in crude oil price. This is also consistent with previous studies investigating the boom.

In Table 1 we report the average county-level annual change in log employment and log labor earnings in the oil and gas industry for the different periods in each region. We only include counties with positive oil or gas production in the peak year (2014) in these calculations. The table reports the mean change and the standard deviation, as well as the p-value for a t-test of mean differences over two consecutive phases (pre-boom vs boom and boom vs bust). The table highlights the strong employment growth during the boom period, especially in the Marcellus region, where oil and gas employment grew by 9% on average every year. During the bust years, oil and gas employment declined at a much faster rate than the growth in the boom years, particularly in the South region. However, since the boom period was 3 times longer than the bust period, overall oil and gas employment grew from 2005 to 2017. One thing to note is that in both the South and West regions, there was statistically significant positive oil and gas employment growth in the pre-boom period. Moreover this growth is not statistically different in the boom period in these regions, signifying that the booms in South and West regions might have started before the national aggregate boom.

The second part of Table 1 presents annual oil and gas labor earnings growth. During the boom period, we observe oil and gas sector wage growth in all three regions, though the changes across periods are not statistically significant in the Marcellus and West regions. There are two possible explanations for these unexpected findings. First, wages in the oil and gas sector might be downward sticky. As such, when the sector is growing wages increase, however they remain constant when the sector is stagnant. The second explanation is selection in lost employment. As we discussed above there are four phases in the extraction process, the labor employed in these different phases varies by quantity and skill. Moving from one phase to the next depends on how oil companies asses current and future market conditions. If market prices are high, producers increase production and develop new fields. If prices low or expected to fall, production and development slow, while exploration continues. Our data report average county salary within the entire oil and gas industry, so phase changes impact the average industry salary in the county. If higher wage exploration phase workers replace lower wage drilling workers in a time of low prices, average earnings reported might be increasing as a result of this selection.

4. Impact of the boom and bust on the rest of the economy

In this section, we estimate the separate effects of the boom and bust on employment and labor earnings in producing counties. We adapt the specification below from Black et al. (2005) to compare producing and non-producing counties in the phases of pre-boom, boom and bust for each of the three regions of interest.

$$\Delta \log(y_{ist}) = \sum_{j=1}^{3} \beta_j (Phase_{jt} * Producer_i) + (State_s Year_t)\phi + \epsilon_{ist} \quad (1)$$

where $Producer_i$ is a dummy variable that takes value 1 if county i is a producer[9] of oil or gas and 0 otherwise and $Phase_{jt}$ are indicators of the pre-boom "1", boom "2" and bust "3" periods, taking value 1 if year t is in the corresponding phase. The outcome variable y_{ist} is employment or labor earnings in county i of state s in year t. We include year by state fixed effects in all our estimations to control for state specific macroeconomic trends. Eq. (1) is estimated separately for each of the three different regions to capture possible regional heterogeneity in the impact of the boom and bust.

The coefficients β_j in Eq. (1) are the average difference in percentage change of variable y between treatment and control counties in phase j. We are particularly interested in coefficients β_2 and β_3 as they show the average yearly difference during the boom and bust years respectively. The coefficient β_1 is the baseline difference in the outcome variables between treatment and control counties prior to any shock from the oil and gas sector. A statistically insignificant β_1 would allow us to attribute the differences we observe in the later phases to the effect of the boom and the bust in the oil and gas sector.

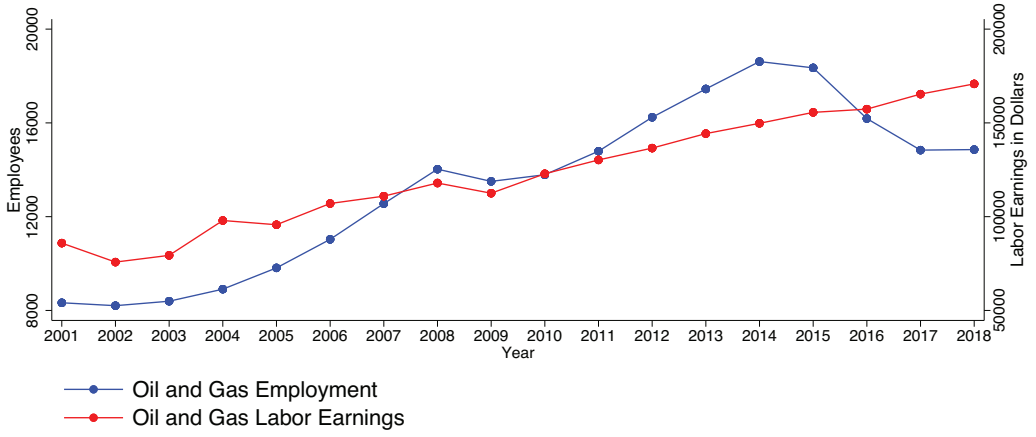
A challenge to the estimation strategy is to determine oil and gas producing counties and the appropriate control counties. In appendix A, Figs. 14 to 19 show oil and gas production levels by county for each region at several points in time during the study period. We note two distinctive features that are common to the three regions of interest. First, during the boom there was both an increase in the number of producing counties as well as an increase in production by producing counties. Second, during the bust there was a decrease in production across many areas in each region, but no county reverted back to pre-boom production levels. These observations confirm that a boom is characterized by an increase in exploration and extraction, while during bust there is no or little development of new fields and a decrease in extraction.

While the visual evidence suggest the production status of certain counties changed from non-producer to producer during the boom, the production status in our specification is not time dependent.

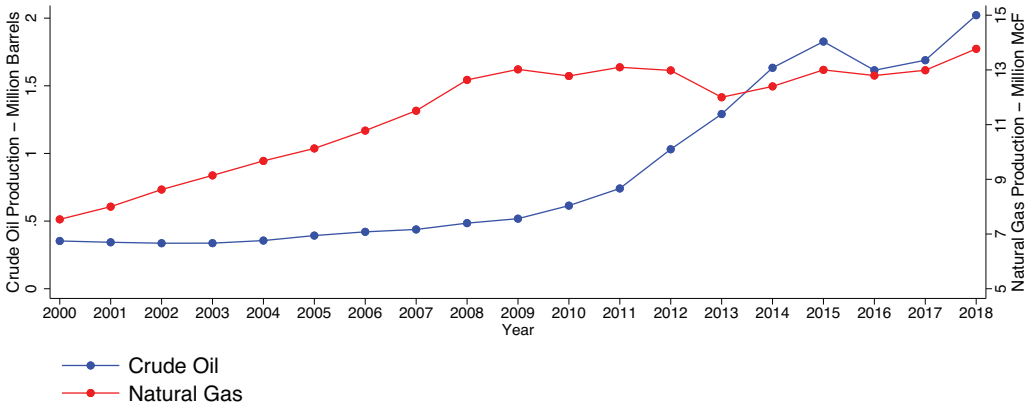
Appendix B provides descriptive information on yearly oil and gas production and county population for counties that had positive oil and gas production in the peak production year (2014). Table 5 show the counties percentile of production of both oil and gas. The numbers show considerable variance in quantities produced of both commodities. Most importantly we note that the counties in the lowest 10% of production percentile, in all three regions,[10] produce such small

[9] We give a formal definition of production counties below.

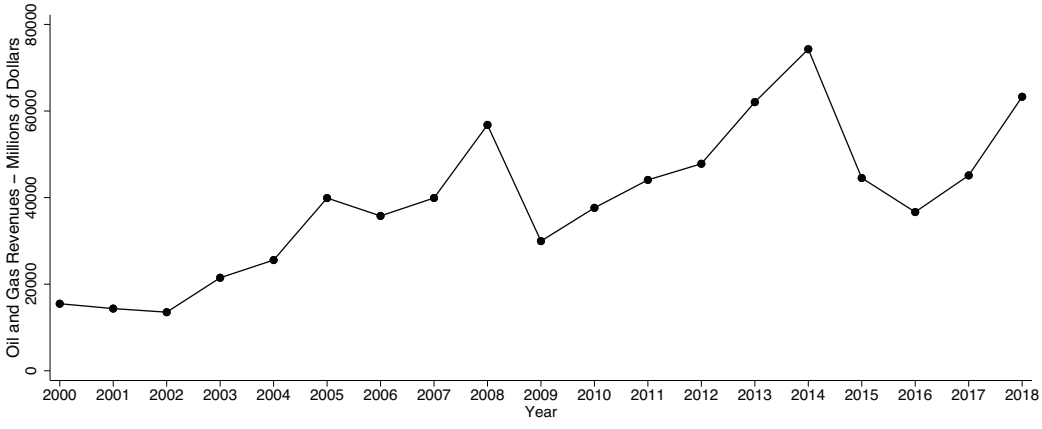
[10] With the exception of the lowest 10th percentile of gas production in the South region.



(a) Labor and Earnings



(b) Production



(c) Revenues

Fig. 9. Oil and Gas Activity in West Region. Note: The figure plots (a) yearly employment and labor earnings in oil and gas industry, (b) total yearly production of crude oil and natural gas, and (c) total yearly revenues of the oil and gas industry in the states of Colorado, Montana, North Dakota and Wyoming.

quantities it's unlikely production had any significant effect on the local economy. We therefore classify a producing county to be a county that had a production of at least 50,000 barrel of oil or 700,000 Mbtu of natural gas in 2014. We use counties with no oil or gas production in 2014 as control counties. Table 6 shows the population percentile of producing and non-producing counties. There are notable differences in population distribution across regions and between producing and non-producing counties. To ensure that our treatment and control counties are of similar size we restrict our observations to counties with population between the 10^{th} and 90^{th} percentile of population of

Table 1
Changes in Oil and Gas Employment and Labor Earnings.

Average annual growth in	Marcellus		South		West	
	(1)		(2)		(3)	
Oil and Gas employment						
Pre-boom period	−0.060		0.043		0.079	
2001–2004	(0.033)		(0.021)		(0.039)	
		[0.001]		[0.374]		[0.710]
Boom period	0.090		0.063		0.060	
2005–2014	(0.022)		(0.011)		(0.026)	
		[0.000]		[0.000]		[0.002]
Bust period 2015–2017	−0.127		−0.162		−0.106	
	(0.033)		(0.022)		(0.044)	
Oil and Gas Labor earnings						
Pre-boom period	0.047		−0.029		0.080	
2001–2004	(0.034)		(0.020)		(0.040)	
		[0.784]		[0.000]		[0.451]
Boom period	0.034		0.040		0.041	
2005–2014	(0.022)		(0.010)		(0.025)	
		[0.670]		[0.023]		[0.966]
Bust period 2015–2017	0.016		−0.003		0.044	
	(0.026)		(0.014)		(0.034)	

Note: Standard errors are reported in parenthesis. The values between brackets are the p-value for the test if statistical difference between the mean of two successive periods. Marcellus region is composed of the states of Pennsylvania, Ohio and West Virginia. South region is composed of the states of Louisiana, Oklahoma and Texas. West region is composed of the states of Colorado, Montana, North Dakota and Wyoming.

the producing counties in each region. Table 8 summarize county distribution by region between producing and control counties. In the Marcellus and West regions, we have a balanced distribution of counties between the two groups. In the South region however, the majority of counties are classified as producing counties, with around 10% of counties classified as control counties.

4.1. Impact on global employment and labor earnings

We start our analysis by investigating the effect of the boom and bust on total employment and average yearly labor earnings in producing counties. Table 2 present estimates of Eq. (1) for percentage change in total employment and average labor earnings in the county. For each region the estimates are reported for the full sample and for urban and rural counties separately.

The upper half of Table 2 shows the results for the percentage change in employment models. The coefficients from the full sample models (columns (1, 4, 7)) show there was little-if any- significant difference in annual employment growth between producing and non-producing counties during the pre-boom period. The pre-boom coefficient is insignificant in the West region and although the pre-boom coefficients for Marcellus and South are statistically significant, their magnitude is small suggesting no major economic significance. This provides us some measure of confidence that we can interpret the boom and bust period coefficient as causal. Moreover during the boom period, in the Marcellus and South regions there was no statistically significant difference in change in employment between producing and non-producing counties. However, in the West region employment in oil and gas producing counties grew at a faster rate than the employment in control counties, with a 1.8 percent average yearly difference. Finally during the bust period, the percentage change in employment in producing counties was much lower than that of control counties, the difference being 1.5 percent, 2.2 percent and 3.5 percent in the Marcellus, South and West regions, respectively.

These findings mask important differences between rural and urban counties. In all three regions, there was no difference in employment growth between treatment and control rural counties in the pre-boom period. During the boom, employment in rural producing counties grew by 2 percentage points more than employment growth in rural control counties in region West. The difference was only 0.7 percent in the South region, and statistically insignificant in Marcellus region. During the bust, rural producing counties saw employment decline by 1.6, 1.9 and 3.9 percent more than control counties in the Marcellus, South and West regions, respectively. Urban producer counties in the Marcellus and South regions had steeper employment declines across all three periods, however the absolute value of the difference in growth is smaller during the boom period, signifying that the boom allowed producing counties to decrease the gap in employment growth with control counties. In the West region, there was no significant difference between urban treatment and control counties. We should note that the statitiscally significant β_1 coefficients in multiple regressions using the sample of urban counties suggest that the estimation of the impact of the boom and bust on employment and earnings for this subsample is inconsistent.

The estimated coefficients show the average yearly effect of each phase on employment. While in all three regions the average yearly impact on employment during the bust is larger than the average yearly impact of the boom,[11] it should be noted that the boom lasted for 10 years while the bust lasted for only 3 years. In the west region, for instance the average employment in rural counties before 2005 was 5,924, a 2% average yearly gain in employment during the boom led to the creation of an average of 1,297 jobs per county. The three years of bust in the region led to an average loss of 832 jobs, which net an average gain of 465 jobs. Rural counties in south region netted 103 jobs on average over the boom and bust, while in Marcellus region the average rural county had a net loss of 874 jobs.

Similarly, results for yearly labor earnings reported in the bottom half of Table 2 show that the during the boom labor earnings grew faster in producing counties compared to control counties. During the bust, this is reversed, with earnings growing at a slower rate in the producing counties. Moreover, coefficients are generally larger during the bust for all three regions. This trend is most notable in the West region where labor earnings grew 1.3 percent faster in treatment counties during the boom and at 1.7 percent slower during the bust. Similar to employment, the effects we observe on labor earnings in the full sample reflect mostly what took place in rural counties.

In summary, the findings in this section suggest that in oil and gas producing counties total employment and average labor earnings grew faster than the non-producing counties during the boom, but during the bust the differential in yearly growth is reversed. Moreover, the results are more pronounced in rural counties. Our results concur with the findings in Rickman and Wang (2020), which evaluates the impact of the boom and bust in the oil and gas industry in four states using synthetic control methods.

4.2. Spillovers into other sectors of the local economy

The earlier findings suggest a significant relationship between the boom and bust in the oil and gas industry and changes in total county employment and average county yearly labor earnings. We now turn to investigate possible spillovers into specific industries in the local economy. We examine multiple industries in the tradable and non-tradable sectors. Tradable industries are those whose output could be traded outside the geographic unit of production (county), the demand for these goods should not be affected much by demand shocks within the county, such as those created by an influx of labor and land lease earnings from oil and gas development. Changes in the oil and gas industry could, however, affect tradable industries through competition

[11] For the estimations using the sample of rural counties we perform the following test $H_o: \beta_2 + \beta_3 = 0$; $H_a: \beta_2 + \beta_3 > 0$. We reject the null hypothesis for all employment regressions and we fail to reject it for all earnings regressions.

Table 2
Impact of Boom and Bust on Total Employment and Earnings.

	Marcellus			South			West		
	All Counties	Urban	Rural	All Counties	Urban	Rural	All Counties	Urban	Rural
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
% Change in employment									
Pre-boom period 2001–2004	−0.008 ***	−0.017 ***	−0.003	−0.008 **	−0.024 ***	−0.004	0.001	−0.003	0.003
	(0.003)	(0.003)	(0.004)	(0.003)	(0.005)	(0.004)	(0.004)	(0.008)	(0.004)
Boom period 2005–2014	−0.002	−0.006 ***	0.001	0.002	−0.016 ***	0.007 ***	0.018 ***	0.008	0.020 ***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.004)	(0.005)	(0.004)
Bust period 2015–2017	−0.015 ***	−0.015 ***	−0.016 ***	−0.022 ***	−0.039 ***	−0.019 ***	−0.035 ***	0.007	−0.039 ***
	(0.002)	(0.003)	(0.003)	(0.004)	(0.006)	(0.004)	(0.005)	(0.007)	(0.006)
% Change in labor earnings									
Pre-boom period 2001–2004	−0.002	−0.004 **	0.000	−0.003	−0.007	−0.001	0.014 ***	−0.003	0.015 ***
	(0.002)	(0.002)	(0.004)	(0.003)	(0.005)	(0.003)	(0.005)	(0.005)	(0.006)
Boom period 2005–2014	0.004 ***	0.003 **	0.005 **	0.008 ***	0.0004	0.011 ***	0.016 ***	0.007	0.017 ***
	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.005)	(0.003)
Bust period 2015–2017	−0.005 *	−0.004	−0.006	−0.017 ***	−0.019 ***	−0.017 ***	−0.018 ***	0.013	−0.020 ***
	(0.003)	(0.004)	(0.004)	(0.003)	(0.006)	(0.004)	(0.005)	(0.013)	(0.005)

The table report OLS estimation results of Eq. (1) for the effect of the oil and gas boom and bust on global employment and wages at the county level. For each geographic region we estimate the equation for all counties as well as for urban and rural counties separately.
Note: Marcellus region is composed of the states of Pennsylvania, Ohio and West Virginia. South region is composed of the states of Louisiana, Oklahoma and Texas. West region is composed of the states of Colorado, Montana, North Dakota and Wyoming.
All regressions include state by year fixed effects. Robust standard errors are reported in parenthesis.
* – $p < 0.1$; ** – $p < 0.05$; *** – $p < 0.01$.

over resources (land, labor, water). Non-tradable industries are those whose outputs are traded within the county and consumed by local residents. We expect additional income earned by local residents from the oil and gas boom increases demand for non-tradable goods and services, therefore increasing employment and labor earnings in these industries. Conversely, we expect the opposite to take place during the bust. We estimate Eq. (1) for employment and earnings in each industry and consider rural areas separately.

We consider two tradable sectors (agriculture and manufacturing) and four non-tradable sectors (construction, retail, food services, and transportation). Early in the oil and gas boom, many farmers worried that fracking would negatively impact agriculture by competing for resources and migrant labor (Hitaj et al., 2017; Ong, 2014). Conversely, anecdotal evidence suggests the oil and gas industry had positive spillovers into local services that directly support the industry (construction and transportation) and indirectly (retail and food service). Estimation results for tradable sector industries are presented in Table 3 and non-tradable sector industries are reported in Table 4. Table 3 shows a weak relationship between changes in the oil and gas industry and employment and earnings in manufacturing. With the exception of a negative association between the bust period and manufacturing employment changes in the Marcellus region, all other coefficients are insignificant. These results are not surprising since as we have discussed earlier, a small portion of manufacturing goods are consumed within the county where they are produced, therefore the effect of income shocks within the region of production would not have a large effect on the demand for these goods. Moreover, although manufacturing and fossil fuel production compete for labor within the same demographic (typically lower educated males), each industry requires distinct skills and expertise.

Evidence from the Marcellus and South regions suggest agriculture and resource extraction compete for workers. In those regions, agricultural sector employment grew 2.5 percent slower in producing counties during the boom. As in the main overall results, the effect is driven primarily by rural areas. This is intuitive given the thinner labor markets in rural areas. During the bust there was no significant difference in agriculture employment growth between producing and control counties across all regions. We also document no significant difference in labor earnings between control and producing counties associated with the various phases. These findings confirm our hypothesis of a weak link between the oil and gas industry and tradable sector. Neither boom nor bust lead to substantial changes in employment or labor earnings in the agriculture or manufacturing sectors.

Next we consider four non-tradable sector industries mentioned above. There is a strong relationship between changes in the oil and gas sector and construction employment and earnings. Both employment growth and labor earnings growth are positively associated with the boom and negatively associated with the bust across all three regions, though the coefficients are only statistically significant in the South and West regions. During the boom the difference in construction employment growth between producing and non-producing counties is 1.5, 1.9 and 4.7 percent in the Marcellus, South and West regions, respectively. During the bust, construction employment declined by 3.1 percentage points faster in producing counties in South and 9.1 percentage point lower in West, while the difference is insignificant in Marcellus. The difference in employment between producing and non-producing counties are larger when we restrict the estimation to rural areas. There were also significant effects on labor earnings in the construction industry associated with the boom and bust. This is intuitive given that construction and resource extraction compete for the same pool of workers. In Marcellus, average labor earnings in construction grew by 1.1 percentage point faster in producing counties during the boom, while during the bust there was no significant difference between producing and control counties. Similarly, in the South and West regions, yearly growth in employment was 2 percentage point higher during the boom. However, during the bust growth in employment in construction sector was 4 percentage point lower in the producing counties.

The results show substantial effects on the local transportation sector as well. In the South and West regions, yearly employment growth was 1.7 and 6.4 percentage points faster in producing counties during the boom and 7.2 and 7.9 percentage point slower during the bust. The boom also had positive impacts on labor earnings growth in producing counties, where yearly labor earnings growth

Table 3
Impact of Boom and Bust on Labor and Earnings in Tradable Sectors.

	Marcellus			
	Agriculture		Manufacturing	
	All counties	Rural	All counties	Rural
	(1)	(2)	(3)	(4)
% Change in employment				
Pre-boom period 2001–2004	−0.033	−0.053	0.004	0.004
	(0.025)	(0.037)	(0.010)	(0.014)
Boom period 2005–2014	−0.025 **	−0.036 **	−0.011 *	−0.017
	(0.012)	(0.017)	(0.006)	(0.011)
Bust period 2015–2017	−0.019	−0.033	−0.027 ***	−0.032 **
	(0.015)	(0.021)	(0.009)	(0.014)
% Change in labor earnings				
Pre-boom period 2001–2004	−0.005	−0.003	−0.004	−0.002
	(0.008)	(0.013)	(0.005)	(0.006)
Boom period 2005–2014	0.007	0.007	0.003	0.005
	(0.005)	(0.009)	(0.003)	(0.005)
Bust period 2015–2017	−0.027 *	−0.029	−0.003	−0.011
	(0.014)	(0.019)	(0.006)	(0.010)
	South			
	Agriculture		Manufacturing	
	All Counties	Rural	All Counties	Rural
	(1)	(2)	(3)	(4)
% Change in employment				
Pre-boom period 2001–2004	0.012	0.029	0.036	0.035
	(0.018)	(0.022)	(0.023)	(0.030)
Boom period 2005–2014	−0.025 ***	−0.030 ***	−0.017	−0.011
	(0.007)	(0.009)	(0.013)	(0.016)
Bust period 2015–2017	0.002	0.011	−0.017	0.0001
	(0.013)	(0.016)	(0.036)	(0.045)
% Change in labor earnings				
Pre-boom period 2001–2004	0.010	0.007	−0.015	−0.012
	(0.007)	(0.008)	(0.013)	(0.016)
Boom period 2005–2014	0.0004	0.001	0.003	0.001
	(0.004)	(0.005)	(0.010)	(0.012)
Bust period 2015–2017	−0.009	−0.008	−0.006	0.008
	(0.007)	(0.006)	(0.013)	(0.015)
	West			
	Agriculture		Manufacturing	
	All Counties	Rural	All Counties	Rural
	(1)	(2)	(3)	(4)
% Change in employment				
Pre-boom period 2001–2004	0.006	0.022	0.020	0.022
	(0.034)	(0.034)	(0.032)	(0.034)
Boom period 2005–2014	0.025	0.026	−0.012	−0.012
	(0.019)	(0.019)	(0.016)	(0.017)
Bust period 2015–2017	−0.029	−0.016	−0.041	−0.045
	(0.020)	(0.017)	(0.026)	(0.028)
% Change in labor earnings				
Pre-boom period 2001–2004	−0.002	−0.005	0.012	0.007
	(0.013)	(0.014)	(0.023)	(0.025)
Boom period 2005–2014	0.003	0.002	0.016	0.015
	(0.007)	(0.007)	(0.014)	(0.015)
Bust period 2015–2017	0.001	0.002	−0.024	−0.025
	(0.011)	(0.008)	(0.022)	(0.024)

Note: All regressions include state by year fixed effects.
Robust standard errors are reported in parenthesis.
* – $p < 0.1$; ** – $p < 0.05$; *** – $p < 0.01$.

was 1.4 percentage points higher than control counties in the West region, though statistically insignificant in the South region. Results for Marcellus show that in both boom and bust yearly employment growth was lower in producing counties, however the estimates are only significant at the 10% significance level. We also document a faster increase in transportation industry yearly labor earnings for producing counties in Marcellus, however the magnitude of the difference is small.

Finally, we see similar effects on both the retail and food services industries, but the magnitude of the coefficients are smaller. In the Marcellus region, the boom was associated with a small yet statistically significant increase in earnings growth in both sectors, but little to no effect on employment growth. The bust had a negative effect on employment growth in both sectors, but no effect on earnings growth. In the South region, the boom had no effect on either employment or earnings in either sector. However, during the bust yearly employment growth in producing counties was 2 and 3 percentage points lower in the retail and food service industries respectively. We see the largest impact on these two industries in the West region. Where the bust led to a 1 percent increase in both employment and labor earnings in each industry. Moreover, the bust lowered employment in food services industry by 3% and labor earnings by 5%. In general, we find oil and gas production to be complementary to non-tradable industries and competitors to tradable industries. While the results are somewhat stronger for rural areas, the rural coefficients are not dramatically larger than the overall coefficient, spillovers into the rest of the local economy from the oil and gas industry are similarly impactful in urban areas.

5. Event study: the 2008 recession

An interesting aspect of the U.S. oil and gas boom is that it occurred in the midst of the 2008 financial crisis and the recession that ensued. The trends described in Section 2 show that the recession occurred during the oil and gas boom, interrupting the growth of the industry for a period of time. We exploit that event to explore whether counties with oil and gas production were affected differently that those who do not produce. The aim of this exercise is to explore whether counties rich with natural resources were more resilient or susceptible to dramatic international economic shocks like the global financial crisis.

The results in the previous sections show the impact of the oil and gas industry has been most pronounced in rural areas, likely due to higher concentrations of oil and gas workers as a share of the overall economy, lower overall industry diversity, and less labor market flexibility in rural areas. We therefore restrict our focus to rural counties hereafter. We also restrict our sample to the period extending from 2001 to 2014, excluding the bust period since the above analysis suggest it produced disparate results compared to the boom. We study the effect on all three regions combined, using the same definition for producing and control counties.

Fig. 10 plots average total employment in producing and control counties between 2001 and 2014, normalized to their respective 2008 level of employment. Prior to the crisis both producing and control counties had similar employment growth trends. Between 2008 and 2009 employment in producing counties drops by 3 percent, while in control counties the drop was around 5 percent. Employment growth rebounded in producing counties earlier than control counties. With employment growth starting in 2010, reaching the pre-crisis employment level by 2012 and continuing to grow for the two years after. Conversely, employment stagnates in control counties, with minimal growth for the next three years post crisis. By 2014, it was still 3 percent lower than the 2008 average employment level.

Similarly we plot average labor earning trends for producing and control counties in Fig. 11. The earnings data show the average yearly earnings among those who are employed and does not reflect the average prevalent wage in the market, due to selection into the labor market. Indeed what we observe may reflect employers laying off less productive workers rather than a growth in average wages.The plot

Table 4
Impact of Boom and Bust on Employment and Earnings in Non-Tradable Sectors.

	Marcellus							
	Construction		Retail		Food services		Transportation	
	All Counties	Rural	All Counties	Rural	All Counties	Rural	All Counties	Rural
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
% Change in employment								
Pre-boom period 2001–2004	−0.019 *	−0.020	−0.003	0.008	−0.010	−0.005	−0.016	−0.003
	(0.010)	(0.018)	(0.005)	(0.007)	(0.006)	(0.010)	(0.012)	(0.019)
Boom period 2005–2014	0.015 ***	0.023 ***	−0.001	−0.001	0.003	0.009 *	−0.012 *	−0.002
	(0.005)	(0.009)	(0.002)	(0.003)	(0.004)	(0.005)	(0.007)	(0.009)
Bust period 2015–2017	−0.011	−0.031	−0.016 ***	−0.020 ***	−0.012 *	−0.017 **	−0.019 *	−0.024
	(0.013)	(0.020)	(0.004)	(0.005)	(0.006)	(0.008)	(0.011)	(0.017)
% Change in labor earnings								
Pre-boom period 2001–2004	−0.007	−0.010	−0.004	0.0001	0.002	0.003	−0.005	−0.003
	(0.009)	(0.017)	(0.003)	(0.004)	(0.004)	(0.006)	(0.006)	(0.010)
Boom period 2005–2014	0.011 **	0.016 *	0.005 ***	0.004 *	0.004 *	0.006 *	0.007 **	0.006
	(0.005)	(0.008)	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)	(0.005)
Bust period 2015–2017	−0.001	−0.016	0.00004	−0.0002	−0.001	−0.004	0.009	0.010
	(0.014)	(0.021)	(0.002)	(0.004)	(0.003)	(0.005)	(0.007)	(0.009)
	South							
	Construction		Retail		Food services		Transportation	
	All Counties	Rural	All Counties	Rural	All Counties	Rural	All Counties	Rural
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
% Change in employment								
Pre-boom period 2001–2004	−0.014	−0.020	−0.012	−0.018 *	−0.007	0.005	0.007	0.027
	(0.012)	(0.015)	(0.010)	(0.011)	(0.015)	(0.018)	(0.025)	(0.027)
Boom period 2005–2014	0.019 **	0.023 **	0.002	0.007	0.005	0.012	0.017 *	0.022 **
	(0.008)	(0.009)	(0.006)	(0.007)	(0.009)	(0.010)	(0.009)	(0.011)
Bust period 2015–2017	−0.031 **	−0.032 *	−0.020 **	−0.017 *	−0.030 ***	−0.036 **	−0.072 ***	−0.054 **
	(0.013)	(0.017)	(0.008)	(0.009)	(0.012)	(0.014)	(0.024)	(0.024)
% Change in labor earnings								
Pre-boom period 2001–2004	−0.005	−0.003	−0.009	−0.001	−0.016	−0.016	0.003	0.002
	(0.009)	(0.010)	(0.006)	(0.007)	(0.014)	(0.018)	(0.012)	(0.014)
Boom period 2005–2014	0.020 ***	0.023 ***	0.005	0.003	0.009	0.010	0.003	0.004
	(0.006)	(0.007)	(0.003)	(0.004)	(0.006)	(0.008)	(0.006)	(0.007)
Bust period 2015–2017	−0.038 ***	−0.046 ***	−0.005	−0.005	−0.017 **	−0.013	0.003	0.001
	(0.009)	(0.011)	(0.006)	(0.007)	(0.007)	(0.008)	(0.010)	(0.012)
	West							
	Construction		Retail		Food Services		Transportation	
	All Counties	Rural	All Counties	Rural	All Counties	Rural	All Counties	Rural
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
% Change in employment								
Pre-boom period 2001–2004	−0.004	−0.003	−0.005	−0.004	−0.017	−0.011	0.004	0.011
	(0.015)	(0.016)	(0.007)	(0.007)	(0.012)	(0.012)	(0.016)	(0.016)
Boom period 2005–2014	0.047 ***	0.047 ***	0.011 **	0.013 ***	0.010	0.014 *	0.064 ***	0.068 ***
	(0.011)	(0.012)	(0.005)	(0.005)	(0.007)	(0.008)	(0.011)	(0.011)
Bust period 2015–2017	−0.091 ***	−0.099 ***	−0.012	−0.014	−0.028 **	−0.029 **	−0.079 ***	−0.076 ***
	(0.019)	(0.020)	(0.009)	(0.009)	(0.012)	(0.013)	(0.019)	(0.019)
% Change in Labor Earnings								
Pre-boom period 2001–2004	0.004	0.004	0.004	0.004	0.001	0.006	0.008	0.012
	(0.009)	(0.010)	(0.005)	(0.006)	(0.009)	(0.010)	(0.011)	(0.011)
Boom period 2005–2014	0.018 **	0.019 **	0.009 **	0.010 **	0.015 ***	0.016 **	0.014 **	0.015 **
	(0.008)	(0.008)	(0.004)	(0.004)	(0.006)	(0.006)	(0.007)	(0.007)
Bust period 2015–2017	−0.041 ***	−0.048 ***	−0.002	−0.003	−0.044 ***	−0.050 ***	−0.007	−0.007
	(0.014)	(0.015)	(0.007)	(0.007)	(0.010)	(0.011)	(0.011)	(0.013)

Note: All regressions include state by year fixed effects.
Robust standard errors are reported in parenthesis.
* – $p < 0.1$; ** – $p < 0.05$; *** – $p < 0.01$.

shows that prior to the crisis yearly labor earning were growing in a similar fashion in both producing and control counties. It remains flat between 2008 and 2009. After which, yearly labor earning growth starts growing at a faster in producing counties.

Next we investigate the differential impact of the recession on non-tradable sector employment. To that purpose we employ an event study design. We estimate the following equation

$$z_{ist} = \sum_{j=-7}^{6} \alpha_j \mathbb{1}\{t = 2008 + j\} + \sum_{j=-7}^{6} \beta_j \mathbb{1}\{t = 2008 + j\} * Producer_i + \epsilon_{ist} \quad (2)$$

where the outcome variable z_{ist} is the normalized employment or labor earnings of an industry in county i of state s at year t. We normalize

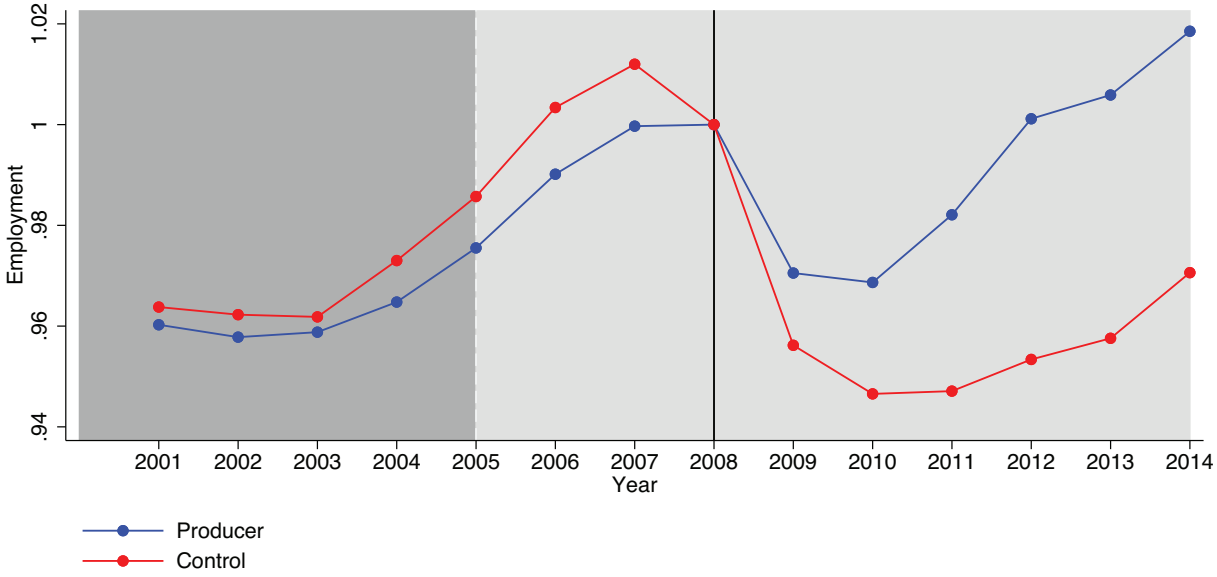


Fig. 10. Employment Trend.

employment and labor earnings relative to their value in 2008. The $j < 0$ are the time periods that occurred prior to the recession and the $j > 0$ are after the recession. The β_j coefficients show the difference between producing and non-producing counties at every period. In particular, we are interested in the coefficients post-recession as they should reflect the differential impact of the event on producing counties.

Figs. 12 and 13 shows the β_j coefficients for the employment outcome in each of the four non-tradable sectors. All estimations show that for the time periods prior to the beginning of the crisis there were no statistically significant differences between producing and non-producing counties. We then see a statistically significant positive difference in each of the sectors in the aftermath of the recession, indicating that these industries in producing counties experienced less adverse effects from the crisis and recovered faster. The magnitude of the difference is largest for the construction and transportation industries, both of which show significant differences in employment between the producing and control counties as early as 2009. These differences grew to reach a 23 and a 27 percentage points in construction and transportation, respectively. The effect on employment in retail and food services are comparatively smaller, but still positive. Moreover, the differential impact does not start until 2011 for both industries.

The findings for labor earnings are more or less similar to the employment results, with the exception of the transportation industry. There, we observe no difference prior to the financial crisis and a positive significant difference that grow overtime in the aftermath of the crisis. Labor earnings in the food services and retail industries show an average 2 to 4%age point yearly difference between producing and control counties. The construction industry shows a much larger difference reaching 14%age point by the year 2014.

These results are important for local policy makers considering how to react to global economic shocks. Oil and gas producing counties

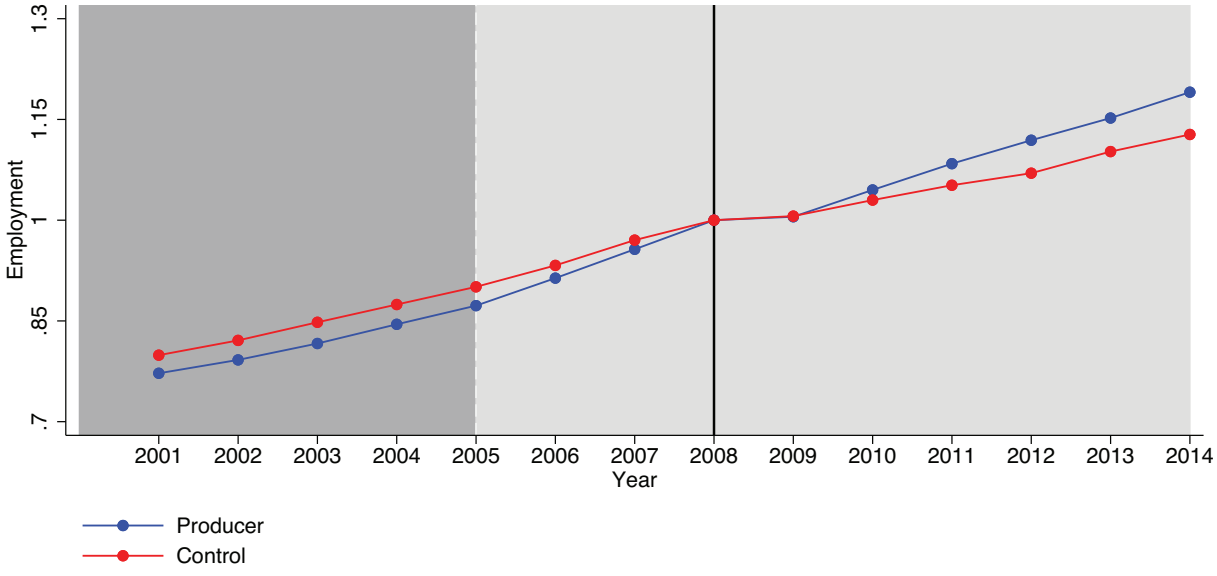


Fig. 11. Labor Earnings Trend.

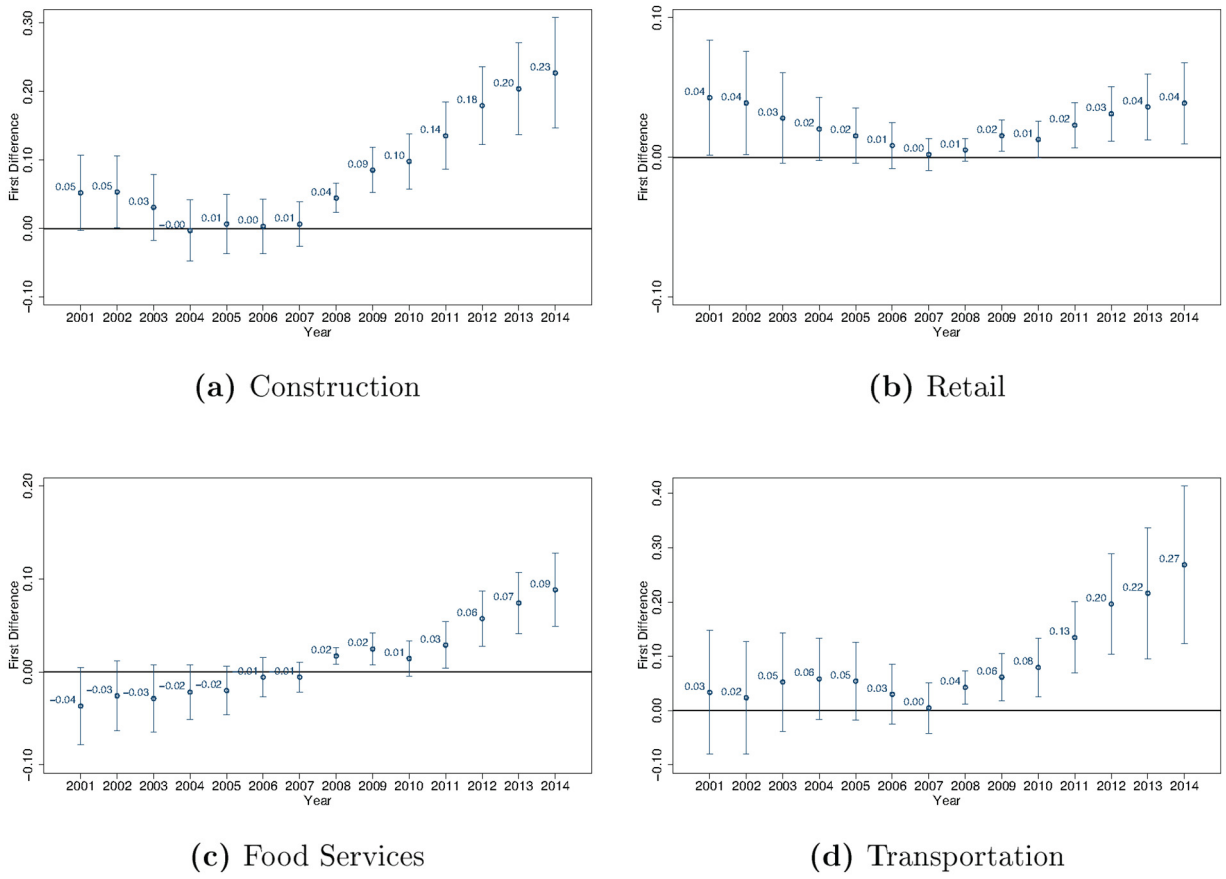


Fig. 12. Event Study: Employment in Non-Tradable Sector. Note: This figure presents the coefficients β_j and associated 95% confidence intervals.

seems to have weathered the shock better than non-producing counties. This even considering oil prices fell dramatically from record highs and still remain at decadal lows. Furthermore, these results are particularly relevant given the current global economic crisis induced by COVID-19. Early estimates suggest that the decline in oil demand will be substantial. The Energy Information Agency released a report in early 2021 estimating that in 2020 global consumption of liquid fuels experienced the largest decline in the last forty years EIA (2021). The drop in domestic and international travel has sent the US oil and gas industry in decline, a decline similar to the one from 2015 to 2017 examined in this paper. This suggests oil and gas reliant communities may have experienced employment and wage declines as large as those estimated here. However, at the time of writing there is reason for industry optimism. As vaccination continue to roll out, some economic forecasts expect a strong recover Torry and DeBarros (2021), as pent up demand for travel and in-person entertainment push oil demand to pre-COVID levels.

6. Conclusion

In this paper, we study the regional impact of the oil and gas industry changes resulting from the fracking revolution in the past 20 years. In particular, we focus on how regional employment and labor earnings were affected in the presence of that industry. A novel contribution of our paper is to compare the oil and gas industry's impact on local employment and labor earnings during the boom with those during the bust.

Our results show that the oil and gas industry had a positive impact on the local economy, most notably in rural counties, consistent with previous findings. The oil and gas boom had a significant positive effect on employment and labor earnings. This effect is mostly due to additional jobs in non-tradable industries, in particular in the construction and transportation industries. We are unable to investigate the exact channels through which the expansions in the oil and as industry benefit the transportation and construction sectors, but there are a few plausible explanations. The most likely is that additional infrastructure (road, pipelines, processing facilities) is needed to support oil and gas activities. It is also possible that higher local wages push demand for new housing or additions on existing homes higher. Future research determining the specific channels through which oil and gas raises the prospects of other industries would help policy makers better understand these dynamics. Ultimately, these gains are dependent on the persistence of growth in the oil and gas industry, since our results show that annual employment and earnings declines during the bust were larger in some industries than their respective increase during the boom.

We also evaluate the differential impact the 2008 financial crisis had on counties that produced these natural resources. We find that oil and gas producing counties were less adversely affected in terms of employment and labor earnings than those who were not producers. Moreover, they rebounded faster from the crisis and reached their pre-recession level of employment by 2014, unlike the non-producing counties who at the same time were still lower than their respective 2008 level of employment.

These results are important for several reasons. First, although the positive impacts of the oil and gas boom have been well documented, policy makers have little information about what happens in the local economy when the industry slows. Understanding the bust phase is

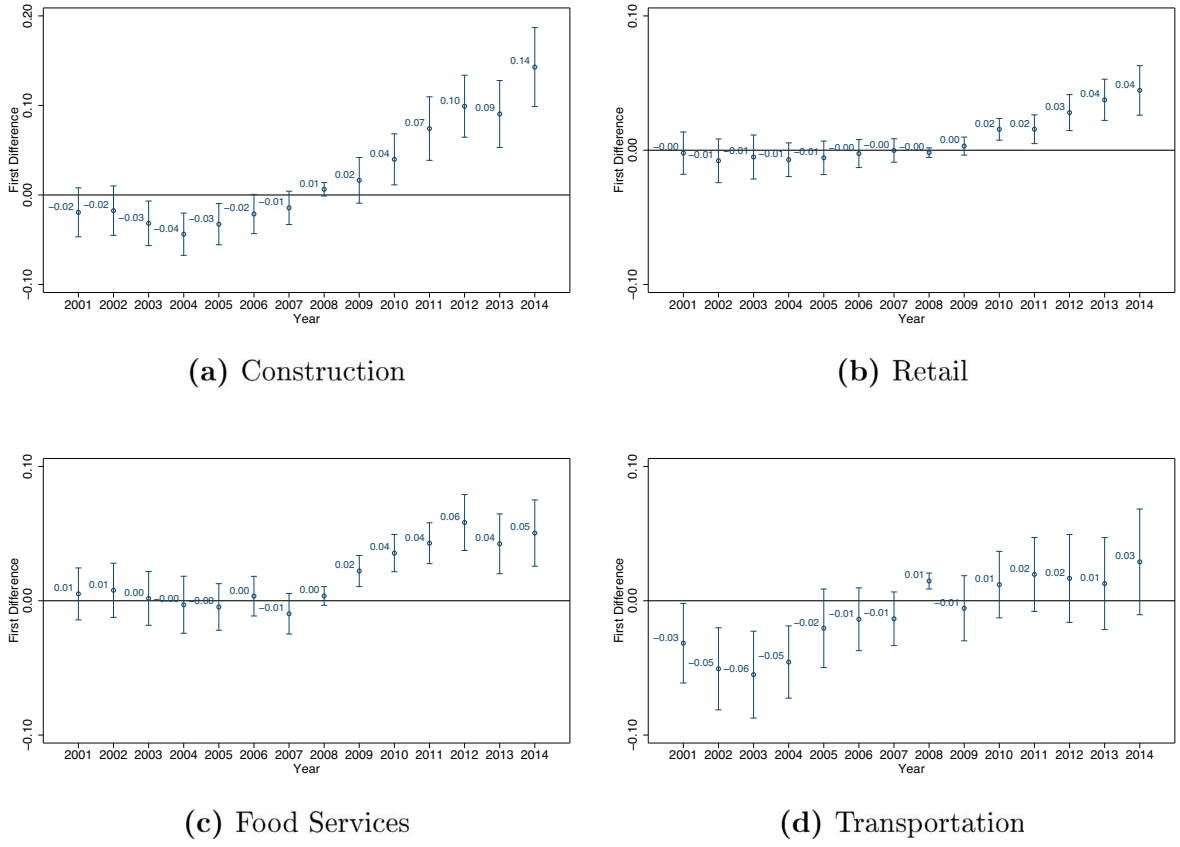


Fig. 13. Event Study: Labor Earnings in Non-Tradable Sector. Note: This figure presents the coefficients β_j and associated 95% confidence intervals.

important for local economic planning efforts just as much as understanding the benefits forecasted in a boom.

Second, understanding an oil and gas downturn provides some sense of the long-run effects of an oil and gas bust. Black et al. (2005) found that with coal mining, the bust can sometimes be erase all benefits of the boom and even leave mining communities worse off in the long run. While we did find the boom led to extended improved employment growth in all regions, the bust led to larger employment declines when compared to the pre-boom trend, at least in the short term. While the U.S. EIA predicts oil and gas resources to last for decades to come in many communities, these results are particularly important for some communities with smaller resource endowments who would like to begin to plan for the exhaustion of local oil and gas reserves and what their local economy may look like when that happens.

Last we provide evidence that the oil and gas industry was protective against a global economic shock. The negative impact of the global financial crisis was dampened in oil and gas counties, and likely played a role in their faster recovery. This is particularly salient given the current COVID-19 induced economic crisis. While the current economic shock may prove exceptional, resource extraction communities will likely face other global economic shocks and understanding their differential effects on producing and non-producing counties will be important. As a final note, its important to recognize the diversity of experiences that communities experience with the oil and gas industry. This is clear from the range of estimates we see across the three regions in our empirical investigation. This is important for policy makers to understand with regard to longer-term outcomes in their communities. Other studies provide cause for concern about U.S. extraction communities experiencing a resource curse over the long run (Black et al., 2005; Deaton and Niman, 2012). Yet extraction communities are not fated to worse long-run economic outcomes. Proactive policy strategies that aim to diversify the local economy and use mining-related resources to increase local human capital will allow communities the flexibility they need to successfully navigate the inevitable future downturns in shocks to the oil and gas industry, including long-term moves away from fossil fuels.

Appendix A. Geographic distribution of production over time

In what follows, we present maps describing the geographic dispersion of oil and gas production and it's evolution over time. Using Enverus production data, we plot the aggregate yearly county production of oil and gas for the three regions of interest at different points in time. The maps below show production in the pre-boom era (2000), early phase of the boom (2008), the peak year (2014) and during the bust (2016).

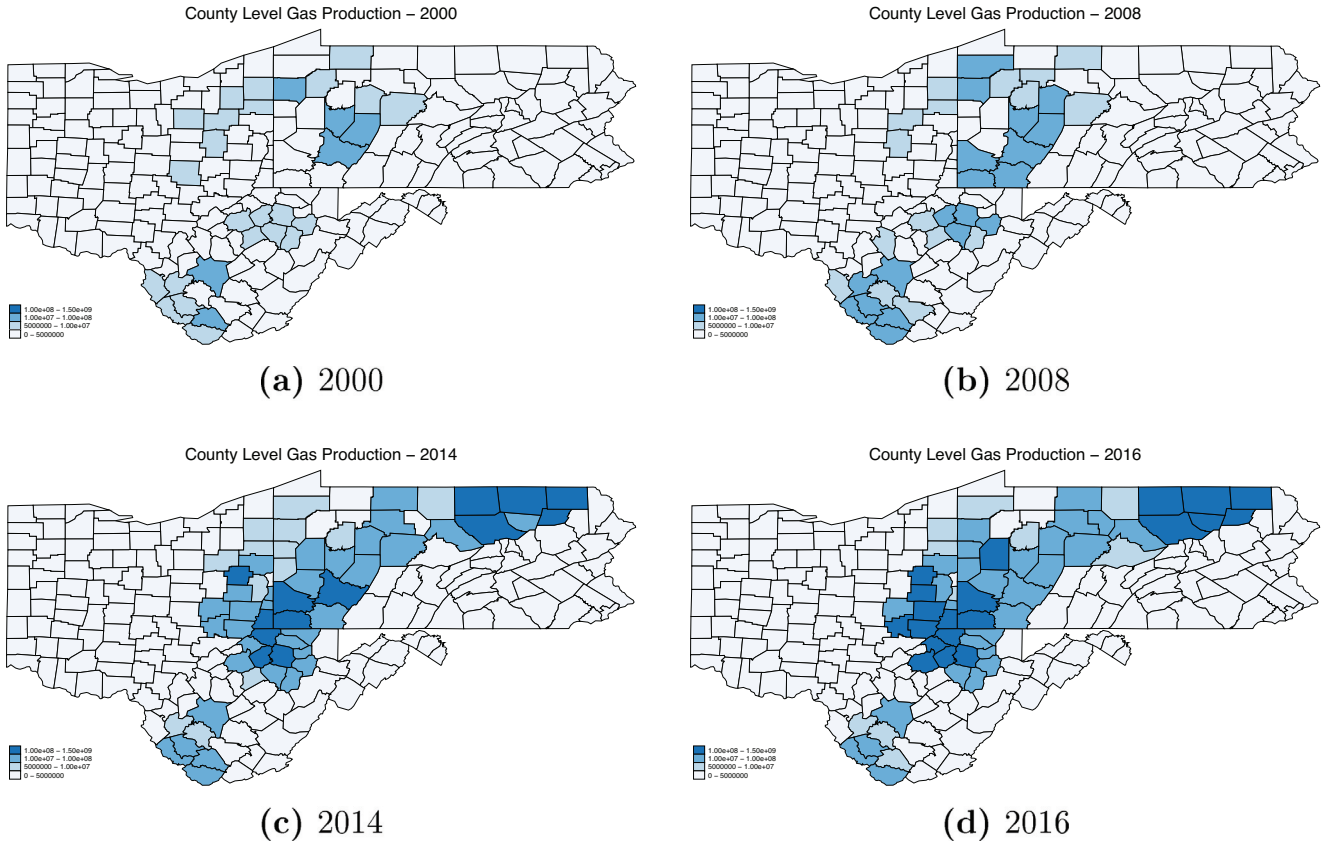


Fig. 14. Regional Distribution of Gas Production Over Time – Marcellus.

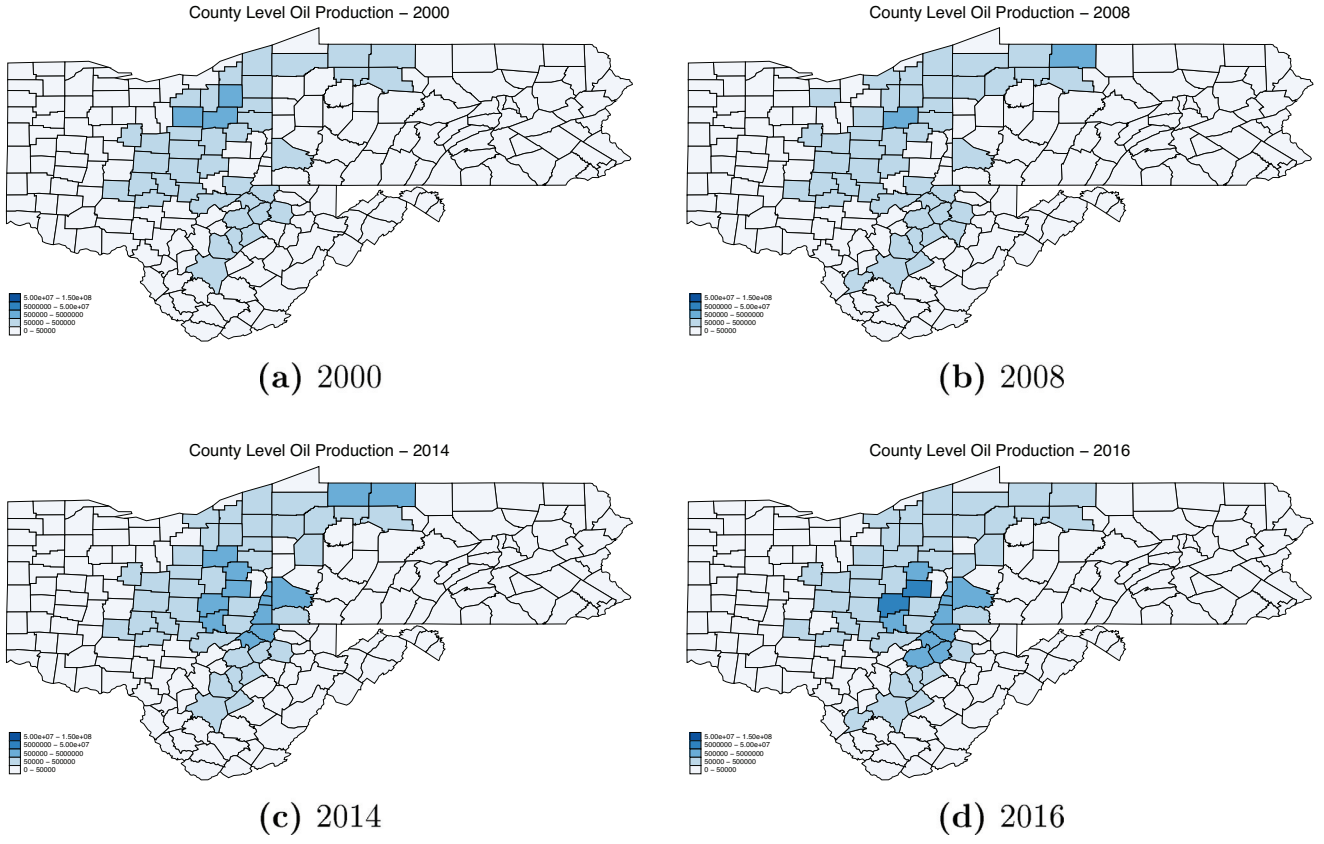


Fig. 15. Regional Distribution of Oil Production Over Time - Marcellus.

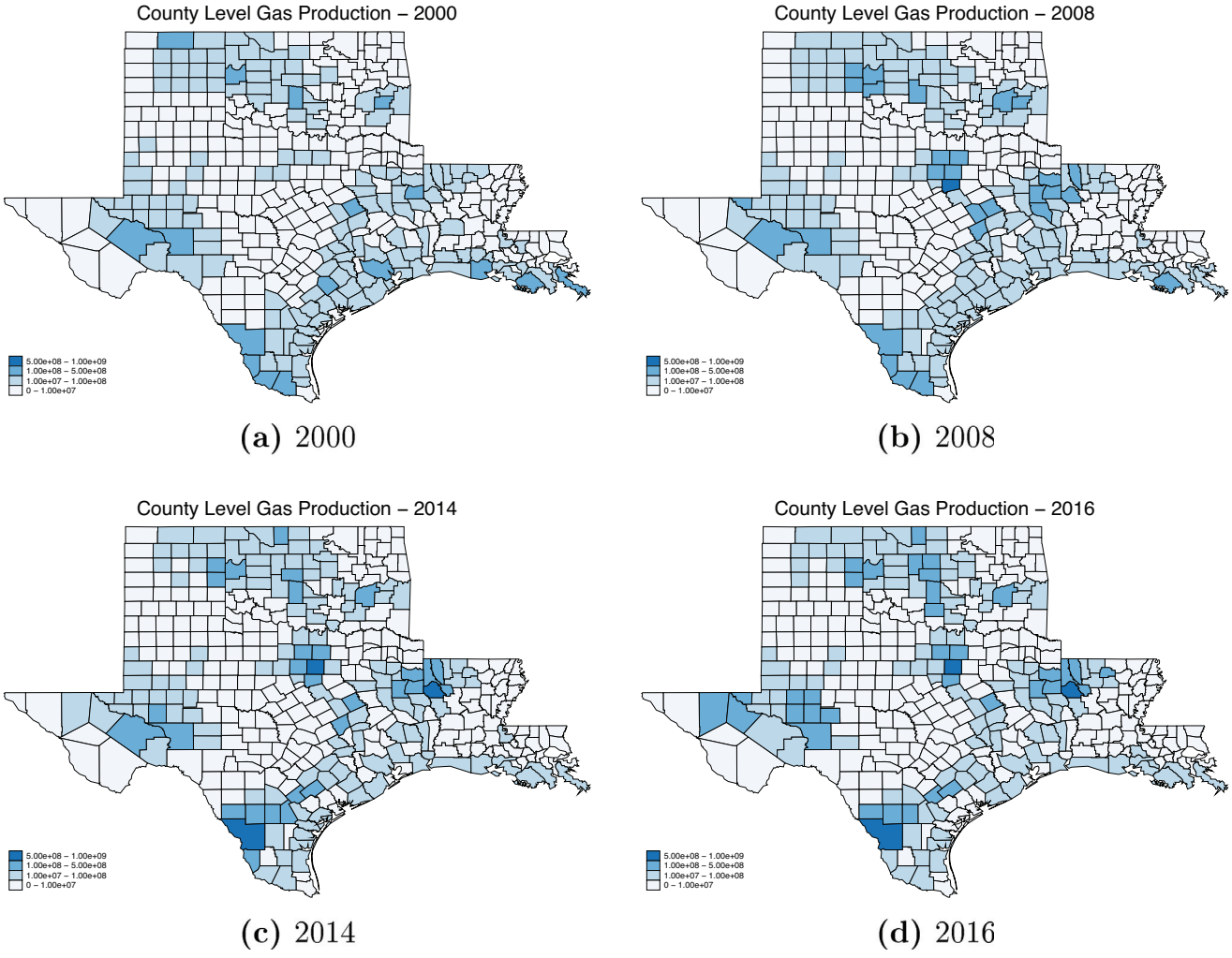


Fig. 16. Regional Distribution of Gas Production Over Time - South.

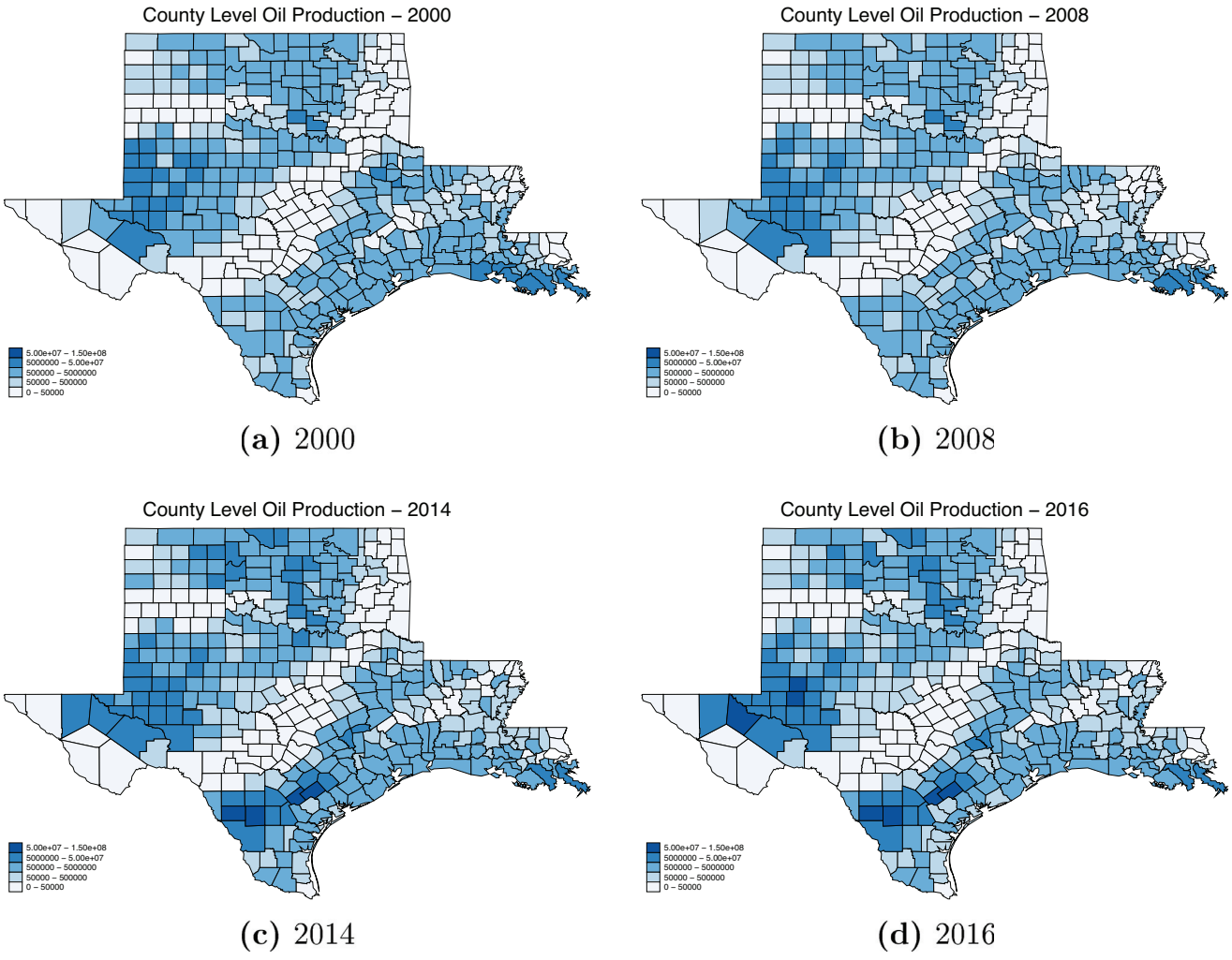


Fig. 17. Regional Distribution of Oil Production Over Time - South.

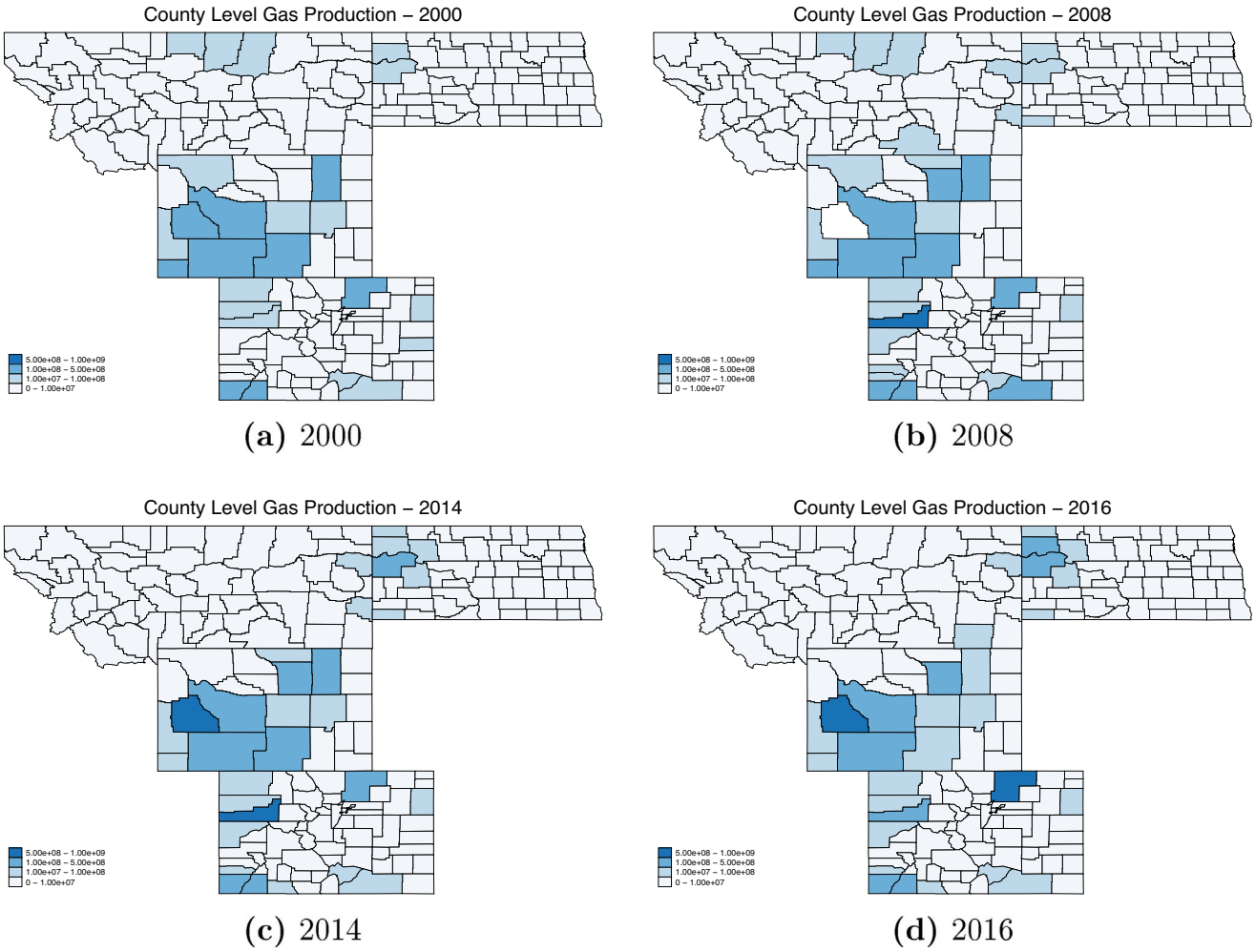


Fig. 18. Regional Distribution of Gas Production Over Time - West.

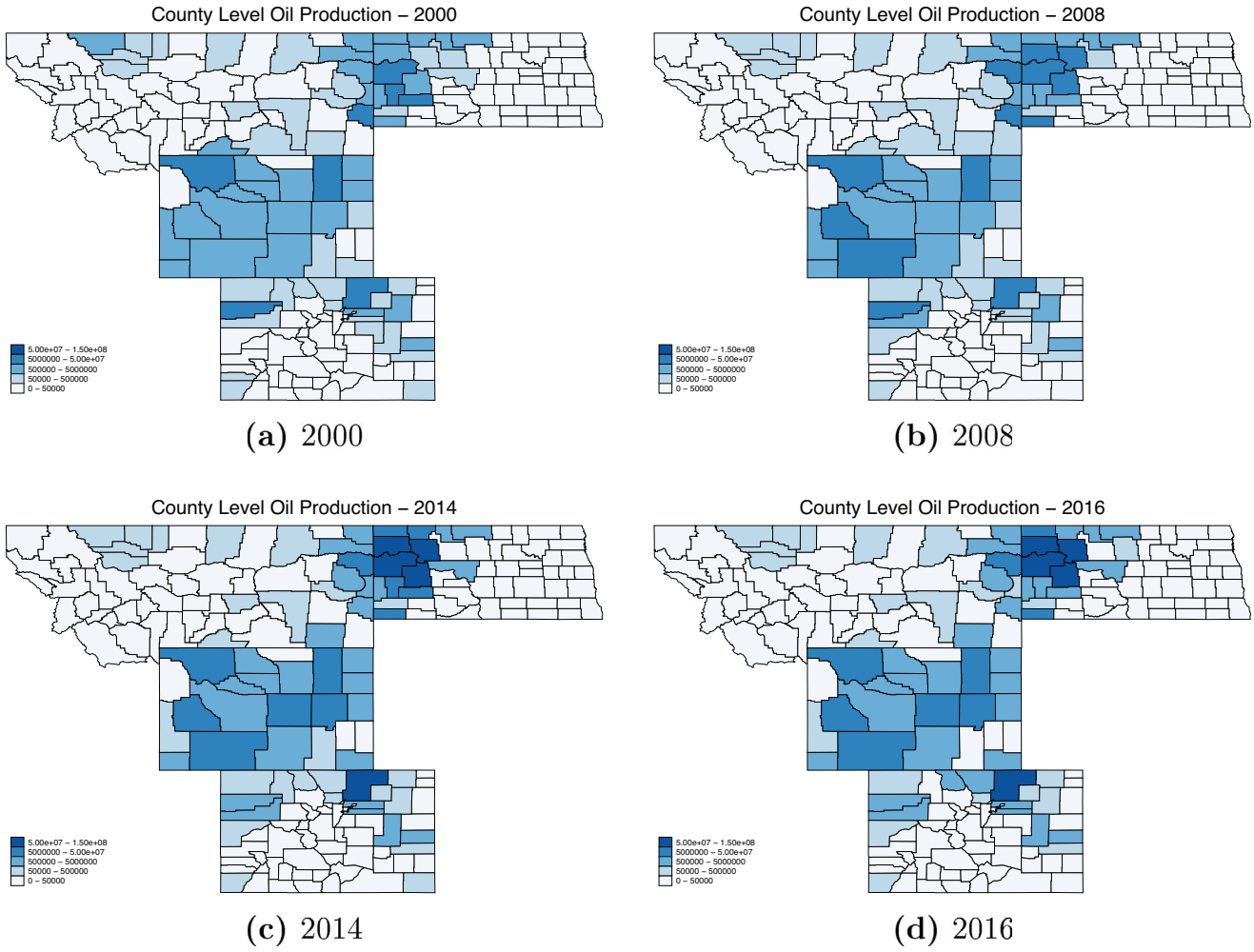


Fig. 19. Regional Distribution of Oil Production Over Time - West.

Appendix B. Production and control counties

Below we discuss counties assignment into treatment and control groups. We present descriptive statistics on counties oil and gas production, oil and gas employment and population size. Sample selection criteria and sample size are discussed in this section.

The year 2014 is the peak year of production in the United States during our period of study, we therefore use that year as our main reference point to determine assignment of counties into producing and non-producing counties. Table 5 present the production percentiles of oil and gas among counties that had any positive production in the year 2014. We make several observation about the production distribution. First, the percentiles confirm what we observe about aggregate production in terms of Marcellus being a major natural gas producer but a smaller producer of oil compared to the other two regions, who have considerable production of both oil and gas. Second, the distributions show large variance in production of both oil and natural gas between counties, with many counties having negligible production, while the top producing counties contribute large portion of their region's total production. Finally we note that production by county varies between region. For instance variance in natural gas production is much smaller in the South region compared to the other two regions. The variance in oil production is the largest in the West region, where the top 1 percentile oil production has the largest share of production we observe in the whole data. These distributions are most likely affected by the geography of the counties, especially the surface area of counties. As we noted in the maps of Appendix A, the South region is mostly composed of smaller counties and production is spread over many of them. While the West region has larger county size, and Marcellus region has a variation between small and large county size.

Given the observations noted above we limit our definition of producing counties to those that had a production of at least 50,000 barrels of oil or 700,000 Mbtu of natural gas in 2014. This threshold insure that the treatment (production) counties have large enough oil and gas industries to be impactful. Moreover, the threshold is not very restrictive, since the limits we set are around the 25th percentile of production in each of the three regions. Therefore only a limited number of counties with very low production are excluded from our sample. All counties with zero production of both oil and gas are assigned to the control group.

In addition to significant variation in production, the different counties of the three regions of interest have considerable variations in population size. In Table 6 we report counties population percentiles in the year 2014 in all three regions. The distribution is reported separately for producing and non-producing counties. We note stark differences in the counties population distribution across the three regions. When looking at the producing counties population distribution, Marcellus region has the smallest variance, with 70% of the producing counties having a population size between 17,000 and 205,000. The spread in the two other regions is larger. Similarly in the non-producing counties group distribution of counties

population varies between the three regions. The Marcellus region having more populated counties than the two other regions, in particular the West Region showing counties with very low population count. In the comparison we also note important differences in county population size between treatment and control counties within the same region. For the purpose of the estimation of the impact of oil and gas industry on labor markets we would like to ideally compare counties of similar population size.

Table 5
Distribution of Oil and Gas producing counties in peak year.

	Marcellus		South		West	
	Volume of Oil Production	Volume of Gas Production	Volume of Oil Production	Volume of Gas Production	Volume of Oil Production	Volume of Gas Production
			Production percentiles			
10^{th}	298	81,561	14,829	96,522	2705	9787
25^{th}	2752	751,664	181,901	1,216,908	32,903	176,981
50^{th}	34,353	4,572,622	695,327	8,907,888	341,374	1,286,214
75^{th}	158,241	22,000,000	2,444,709	34,300,000	1,903,280	13,700,000
90^{th}	624,113	102,000,000	8,871,775	97,100,000	7,678,547	102,000,000
95^{th}	1,778,032	239,000,000	22,800,000	165,000,000	37,300,000	251,000,000
99^{th}	4,124,806	818,000,000	58,800,000	365,000,000	113,000,000	613,000,000
Mean	275,720	46,300,000	4,027,947	38,300,000	5,961,035	42,700,000
std. Dev	716,522	135,000,000	10,800,000	83,400,000	19,600,000	129,000,000

Given the differences between three regions in county population distribution we impose different population size restriction by regions. In Marcellus we limit the sample to counties with population between 7,000 and 200,000. In South to counties with population between 2,000 and 210,000. Lastly, in West the population range of counties in sample is 1,000 to 210,000.

Table 6
Population Distribution in Producing and Non-Producing Counties.

	Module A: producing counties		
	Marcellus	South	West
Population percentiles			
10^{th}	6916	2334	1141
25^{th}	16,884	6189	2712
50^{th}	29,673	14,488	6371
75^{th}	61,767	33,881	17,428
90^{th}	127,183	89,886	55,467
95^{th}	205,436	212,498	220,410
99^{th}	858,898	1,228,357	424,002
	Module B: non producing counties		
	Marcellus	South	West
Population percentiles			
10^{th}	12,689	2143	1284
25^{th}	25,231	4465	2137
50^{th}	38,890	11,746	5182
75^{th}	146,278	32,838	13,692
90^{th}	344,933	165,688	55,522
95^{th}	431,074	276,971	80,902
99^{th}	1,080,029	591,763	446,781

Using the EMSI employment data we compute the county oil and gas employment share in the year 2014. We report the percentiles among producing counties in Table 7. There are important differences between regions in the counties distribution of labor force share of the oil and gas industry. Labor share is smaller in counties of Marcellus in comparison to those in the two other regions. The mean labor share of oil and gas industry in Marcellus is 0.55% compared to 1.48% and 1.35% in region South and West respectively. Moreover, in 75% of producing counties the oil and gas employment share is less than 0.63% of the total labor force in Marcellus, compared to 1.43% in South and 2.20% in West. The top 1% of oil and gas labor share is 4.84% in Marcellus which is half of that observed int he top percentile of counties in the West region and almost one quarter of that in the South region. This difference between the first region and the two other regions is most likely due to the large number of very low population counties in the South and West regions. Since in the selection criterion described above both these regions had counties with population size as low as 2,000 and 1,000 person for regions South and West respectively. Meaning that for even a small number of workers who are employed in the oil and gas industry that number will amount for a larger percentage of the workforce in that county.

Table 7
Distribution of Oil and Gas county employment share in peak year.

Oil and gas employment share of total employment	Marcellus	South	West
Percentiles			
25^{th}	0.02	0.11	0.15
50^{th}	0.16	0.51	0.79
75^{th}	0.63	1.43	2.20
90^{th}	2.16	4.09	4.07
95^{th}	2.40	6.08	4.31
99^{th}	4.84	15.74	8.92
Mean	0.55	1.48	1.35

Table 8
Treatment Assignment.

	Marcellus			South			West		
	All counties	Urban	Rural	All counties	Urban	Rural	All counties	Urban	Rural
Total number of counties	210	96	114	395	135	260	196	30	166
Producing counties	87	39	48	282	95	187	74	6	68
Control counties	56	24	32	37	8	29	81	14	67

Table 8 summarizes county treatment assignment by region. We can see that in both Marcellus and West regions there is a balanced number of producing and control counties. In the South region however, the number of producing counties is more than 7 times that of control counties, the imbalance is even larger for the subsample of urban counties in that region. As discussed earlier, the maps in Appendix A shows that in the south region oil and gas production are spread over a large number of small counties most notably in the state of Texas. This is due to the geography of the shale plays in the region.

Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2021.105285.

References

Betz, M.R., Partridge, M.D., Farren, M., Lobao, L.M., 2016. Coal mining, economic development, and the natural resources curse. Energy Econ. 50, 105–116.

Bjornland, H.C., Thorsrud, L.A., 2016. Boom or gloom? Examining the dutch disease in two-speed economies. Econ. J. 126 (598), 2219–2256.

Black, D., Mckinnish, T., Sanders, S., 2005. The economic impact of the coal boom and bust. Econ. J. 115 (503), 449–476.

Brown, J., 2015. The response of employment to changes in oil and gas exploration and drilling. Federal Reserve Bank of Kansas City Economic Review, pp. 57–81.

Deaton, J.B., Niman, E., 2012. An empirical examination of the relationship between mining employment and poverty in the appalachian region. Appl. Econ. 44 (3), 302–312.

EIA, 2021. Short-Term Energy Outlook Suppliment: Developments in Global Oil Consumption. Tech. rep., US Energy Information Agency.

Freyrer, J., Mansur, E.T., Sacerdote, B., 2017. Geographic dispersion of economic shocks: evidence from the fracking revolution. Am. Econ. Rev. 107 (4), 1313–1334.

Hitaj, C., Boslett, A., Weber, J., 2017. Fracking, farming, and water, uSAFE working paper no. 17-322.

Hoy, K.A., Kelsey, T.W., Shields, M., 2017. An economic impact report of shale gas extraction in Pennsylvania with stricter assumptions. Ecol. Econ. 138, 178–185.

Jacobsen, G.D., Parker, D.P., 2016. The economic aftermath of resource booms: evidence from boomtowns in the american west. Econ. J. 126 (593), 1092–1128.

Komarek, T.M., 2016. Labor market dynamics and the unconventional natural gas boom: evidence from the marcellus region. Res. Energt Econ. 45, 1–17.

Maniloff, P., Mastromonaco, R., 2017. The local employment impacts of fracking: a national study. Resour. Energy Econ. 49, 62–85.

Marchand, J., 2012. Local labor market impacts of energy boom-bust-boom in western Canada. J. Urban Econ. 71 (1), 165–174.

Michaels, G., 2011. The long term consequences of resource-based specialisation. Econ. J. 121 (551), 31–57.

Munasib, A., Rickman, D.S., 2015. Regional economic impacts of the shale gas and tight oil boom: a synthetic control analysis. Reg. Sci. Urban Econ. 50, 1–17.

Ong, B., 2014. The potential impacts of hydraulic fracturing on agriculture. Eur. J. Sustain. Dev. 3 (3), 63–72.

Papyrakis, E., Gerlagh, R., 2007. Resource abundance and economic growth in the United States. Eur. Econ. Rev. 51, 1011–1039.

Rickman, D., Wang, H., 2020. What goes up must come down? The recent economic cycles of the four most oil and gas dominated states in the us. Energy Econ. 86.

Torry, H., Debarros, A., 2021. U.s. economic growth will exceed 4 percent in 2021. WSJ https://www.wsj.com/articles/wsj-survey-u-s-economic-growth-will-exceed-4-in-2021-11610636401.

Tsvetkova, A., Partridge, M.D., 2016. Economics of modern energy boomtowns: do oil and gas shocks differ from shocks in the rest of the economy. Energy Econ. 59, 81–95.

Weber, J.G., 2012. The effects of a natural gas boom on employment and income in Colorado, Texas, and Wyoming. Energy Econ. 34 (5), 1580–1588.

Weinstein, A.L., Partridge, M.D., Tsvetkova, A., 2018. Follow the money: aggregate, sectoral and spatial effects of an energy boom on local earnings. Res. Policy 55, 196–209.