The Response of Employment to Changes in Oil and Gas Exploration and Drilling

By Jason P. Brown

During early summer of 2014, oil prices exceeded $100 per barrel, and many industry analysts expected prices to remain at that level for some time. However, oil prices began to decline in July, and were down more than 50 percent by the beginning of 2015. Although the response was delayed by a few months, exploration and drilling for oil and gas dropped significantly, with rig counts down 49 percent by the end of April 2015. Exploration and drilling may decline further depending on when oil prices settle and for how long.

In energy-producing states, exploration and drilling in the oil and gas sector—and economic activity more broadly—are vulnerable to energy price declines, with smaller and less-diversified states expected to be the most exposed. The net effects of price declines are not obvious. When oil prices fall, consumers likely have more money to spend on other goods and services. However, oil- and gas-producing states have a larger share of employment in the oil and gas sector, and falling oil prices can thus directly decrease employment. For example, when energy prices collapsed in 2008-09, employment in energy-producing states fell, partially reversing the strong performance of those states through the early stages of the Great Recession. In subsequent years of the recovery, growth in the global oil supply—mostly from U.S. production—coupled with

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declining global demand for oil, led to the price of oil falling by over 50 percent in the second half of 2014, with potential negative effects on oil- and gas-producing states.

Despite the growth of the oil and gas sector over the past decade, energy-producing states appear to now rely less on the sector than in the early and mid-1980s, but more than in the late 1990s. Given the technological changes the sector has experienced, it is unclear how the recent decline in crude oil prices will affect energy-producing states. Prior research has shown that employment in oil- and gas-producing states is more responsive to changes in exploration and drilling, measured by rig counts, than to oil prices directly. As a result, changes in oil prices could affect total employment in producing states through changes in rig counts.

This article estimates the response of total employment in oil- and gas-producing states to changes in rig activity caused by changes in oil prices. Results indicate that removing an active rig eliminates 28 jobs in the first month, 82 jobs after six months, and 171 jobs in the long run. Given the decline in rigs from September 2014 to April 2015, total employment is expected to fall as much as 4 percent in some energy-producing states but as little as 0.1 percent in others.

Section I highlights past boom and bust cycles in the oil and gas sector. Section II discusses the various phases of oil and gas development and the changing nature of the employment footprint associated with each phase. Section III introduces a model to estimate how total employment responds to changes in rig counts.

I. Boom and Bust Cycles of Oil Prices, Exploration, and Drilling

Over the last five years, the oil and gas sector underwent a boom, with rigs more than doubling, and then a bust, with rigs falling over 50 percent in the last six months. Such boom and bust cycles are not uncommon in energy-producing states. Steep oil price declines have occurred several times in the last 30 years. Each of these declines induced a large decline in exploration and drilling as measured by rig counts. Yet each cycle had unique circumstances due to changes in supply and demand factors. Over the same time period, the share of economic output and labor compensation from oil and gas declined in most energy-producing states, potentially making them less vulnerable to the current drop in rig counts.

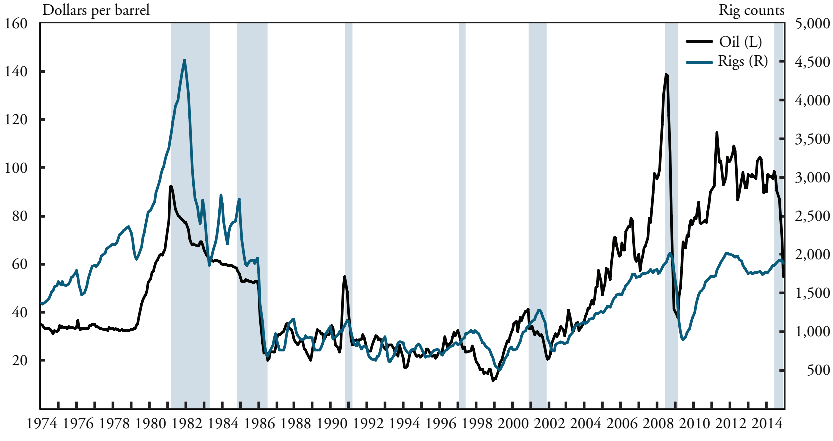
A rapid decline in crude oil prices and subsequent decline in rigs is not a rare event. Crude oil prices dropped sharply six times from 1981 to 2009 (Chart 1). Wilkerson summarized these episodes to contextualize the most recent decline and found differences in the speed of the price decline, the path of prices prior to the decline, the duration of low oil prices, and the state of the U.S. economy at the time of the decline (Table 1).

The 1985-86 period appears to be most similar to the present situation. Real oil prices fell by more than 50 percent, rigs declined by 60 percent, and the United States was not in a recession—all similar to the second half of 2014 and beginning of 2015. The role of the Organization of the Petroleum Exporting Countries (OPEC) was also similar to today. From 1981 to 1985, Saudi Arabia, the largest OPEC member, reduced its production by 75 percent in the wake of falling oil prices (Hamilton). When the price of oil continued to decline in 1986, Saudi Arabia abandoned this strategy and began increasing production. With the increase in supply, the price of oil declined further to $20 per barrel, spurring a further decline in rigs. Similarly, in November 2014, OPEC announced it would not cut production despite the price of oil declining in each of the prior four months. In the past, OPEC would often cut production to boost prices. However, in the face of growing supply from U.S. producers, OPEC was unwilling to cut production, perhaps to protect their market share of global oil sales. Their unwillingness to cut production was an additional shock to oil prices, and West Texas Intermediate (WTI) futures prices declined nearly 20 percent in both December 2014 and January 2015. Futures prices averaged about $49 per barrel through March 2015, with a significant reduction in rig activity.

Throughout these boom and bust cycles, the effect on oil- and gas-producing states has differed from the effect on the national economy. Oil- and gas-producing states are typically the first to experience the effects of boom and bust cycles in energy activity and may, as a result, face different outcomes compared with the nation as a whole.

Chart 1

Real Price of Oil and Rig Counts, 1974 to 2014



Note: Blue bars denote periods of oil price declines of 30 percent or higher.
Sources: Energy Information Administration and Baker Hughes.

Table 1

Past Episodes of Declining Real Oil Prices

Period	Months of price decline	Real oil price change (percent)	Prior six months price change (percent)	Rig counts change (percent)	Prior six months rig counts change (percent)	U.S. recession	Months before price recovered by half
1981-83	25	-31	38	-48	14	Yes	412
1985-86	7	-58	-1	-60	14	No	50
1990-91	5	-47	85	-19	27	Yes	159
1997-98	17	-50	20	-21	9	No	7
2000-01	13	-47	20	-16	25	Yes	7
2008-09	7	-71	42	-33	2	Yes	22
2014-15	7	-54	6	-49	5	No	?

Note: Rig counts data for 2014-15 are through April 2015.
Source: Wilkerson.

Hamilton and Owyang found U.S. oil-producing states experienced their own regional recession in the mid-1980s when oil prices declined even while the U.S. economy grew strongly.

Despite the growing importance of the oil and gas sector in recent years, most oil and gas states rely less on the sector now than in prior decades. For example, in 1982, the average share of economic output from oil and gas extraction in energy-producing states was 17 percent. The share was as high as 35 percent in Wyoming and Louisiana compared with just 4 percent for the United States as a whole (Chart 2, Panel A). The relative size of the sector decreased in the late 1990s, as oil and gas shrank in energy-producing states on average to around 3 percent of total output. By 2012, the average share had increased to 9.5 percent but was still only 2 percent of total U.S. output. A similar trend occurred in the share of total labor compensation from the oil and gas sector: the share declined from 1982 to 1997 and was higher by 2012, though still below its 1980s level (Chart 2, Panel B). One exception to this trend is North Dakota, which saw labor compensation from the sector increase from 1982 to 2012.

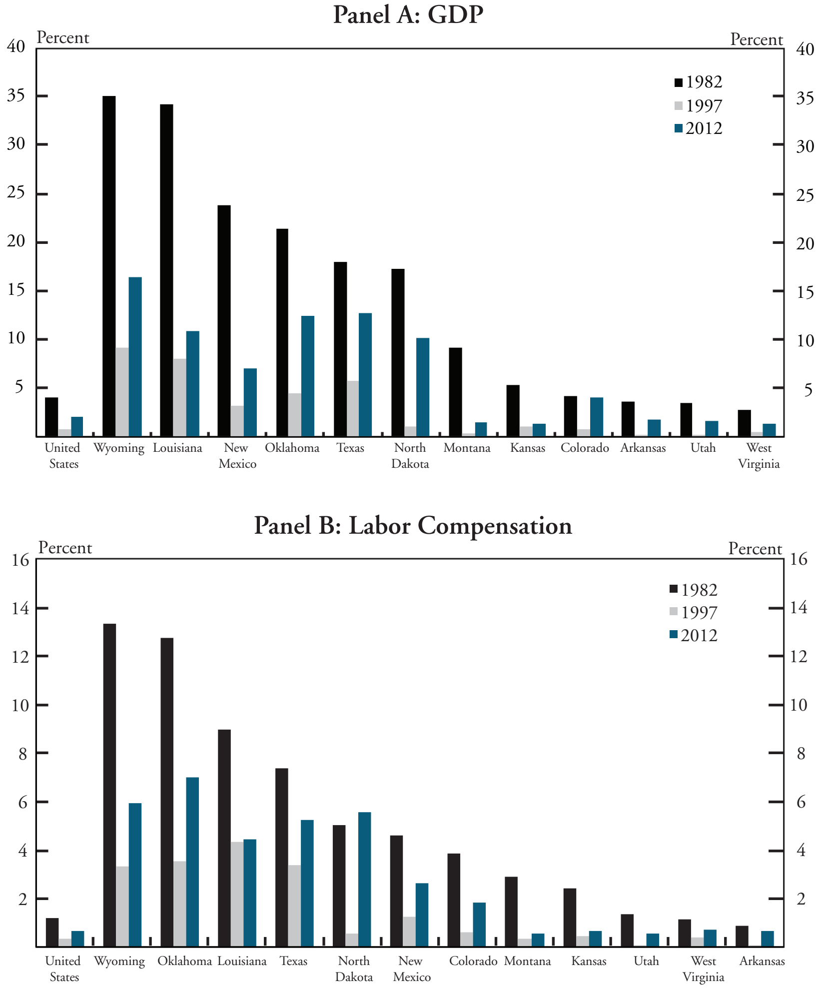
Since the relative importance of oil and gas differs among the states, it is not surprising that the effect of changes in oil prices or rigs would also differ. For example, recent work by Murphy, Plante, and Yücel shows that the cost and benefits of the recent oil price decline are unevenly distributed across the 50 states. They estimate a 50 percent decline in crude oil prices could reduce total employment from 0 to 1 percent in Alaska, Louisiana, New Mexico, Texas, and West Virginia. The authors expect larger declines of more than 2 percent in Oklahoma, North Dakota, and Wyoming, but expect employment in the remaining states to increase modestly.[1]

II. Employment in Phases of Oil and Gas Extraction

Oil and natural gas extraction involves four main phases: exploration, appraisal, development, and production. The number and type of workers involved in each phase varies. Development in a region often takes place over several years. Workers as well as goods and services may be sourced throughout a state to directly and indirectly support

Chart 2

Oil and Gas Sector Share of GDP and Labor Compensation



Sources: Bureau of Economic Analysis and author's calculations.

development, all of which potentially influence total employment as a result of oil and gas activity.

In the first phase (exploration), teams of geologists, geophysicists, and engineers identify, characterize, and examine geologic prospects that hold the most promise of yielding commercial quantities of oil and natural gas. Before drilling can occur, procurement specialists negotiate oil and gas leases with public or private mineral owners (Fitzgerald). These leases give energy companies the legal right to access public and private land and negotiate what mineral owners will be paid if oil and gas is found. Workers then drill exploratory wells to determine whether a reservoir has sufficient oil and gas to make development profitable (Dahl and Duggan).

In the second phase (appraisal), workers drill additional wells in smaller areas of the reservoir to confirm earlier estimates of the amount of oil and gas that can be extracted profitably. The purpose of this phase is to reduce uncertainty about the size of the oil or gas field and its properties (Stoneburner). Petroleum geologists, geophysicists, and reservoir engineers evaluate samples and information collected from the reservoir to determine how much oil or gas might be in the reservoir and how fast oil or gas will move through it. The appraisal phase helps a company decide whether the oil or gas field can be developed. Employment associated with the exploration and appraisal phases mostly occurs within the oil and gas sector and in professional and business services, such as legal services to negotiate the terms of leasing contracts or engineering services to conduct environmental assessment studies.

The third phase (development) takes place after successful appraisal and before full-scale production. The development stage is the most labor intensive. Workers must prepare the drilling site, drill and case the well, perform hydraulic fracturing ("fracking"), and construct the needed pipeline infrastructure (Jacquet). Additional workers are also often needed to build access roads to reach new development areas. Jobs in the development phase include drilling rig operators, excavation crews, truck drivers, heavy equipment operators, fracking equipment operators, and semiskilled general laborers. These workers come not only from the oil and gas sector but also from the manufacturing, construction, and transportation sectors. Once workers finish drilling wells in one area, crews and rigs typically move on to other areas in the same region to drill more wells. During this phase, areas of development experience the largest influx of oil and gas workers and the highest demand for goods and services from the sector.

In the fourth phase (production), rig operators extract hydrocarbons from oil or gas fields and see the first revenue from selling the oil or gas. Production can last from a few years to several decades depending on the size of the oil or gas field and the cost of running the wells and production facilities. Compared with the development stage, fewer workers are needed during production, and most jobs are within the oil and gas sector (Jacquet).

As most development phases involve jobs in multiple sectors, net employment effects are best measured as the change in total employment in each state. Oil and gas extraction directly increases employment and the income of those working in the industry, particularly during exploration and drilling but also during production. Expenditures on constructing and operating oil and gas wells may also indirectly increase demand for other goods and services such as gravel, water, concrete, vehicles, fuel, hardware, consumables, food services, and housing. As a result, other industries producing or selling these goods and services in an area with large-scale development may also increase employment to meet demand.

III. Employment Response to Changes in Exploration and Drilling

The increase in U.S. oil and gas production over the past decade has renewed interest in the sector's influence on economic outcomes, especially employment. Prior studies of the employment effects of oil and gas activity principally use simulation or empirical methods that identify differences in outcomes between energy-producing and non-producing areas. Empirical studies mostly rely on variations across regions to identify any changes in total employment from changes in oil and gas employment or changes in oil and gas production (see the Box for more details on these studies). Most of these studies, however, do not account for the dynamic effects of oil and gas development and changes in the employment response as the sector changes over time. The dynamic portion is potentially important to understand the complete effect on employment in the short- and long-run.

Measures of oil and gas drilling and exploration

One of the most timely and frequent measures of oil and gas activity are rig counts. Many firms and industry analysts use rig counts as a measure of exploration and drilling in the oil and gas sector. Baker Hughes, a large supplier of oil- and gas-field services, surveys rig operators in North America and publishes a weekly, state-level count of rigs actively exploring, drilling, or developing oil or natural gas.[2]

Chart 3 shows rig counts vary significantly from month to month across major oil- and gas-producing states. The level and variation over time are also quite different across states. For example, the level of rig counts is significantly higher in Texas, Oklahoma, and Louisiana; North Dakota and Kansas, however, have experienced larger variations in rig counts. North Dakota has experienced recent sharp increases, but Kansas has experienced a large and long-lasting decline in the number of rigs. Much of the recent variation is explained by activity in states with large shale plays such as the Fayetteville in Arkansas; the Woodford in Oklahoma; the Bakken in North Dakota; the Niobrara in Colorado; and the Barnett, Eagle Ford, and Permian Basin in Texas.

Recent work by Agerton and others shows employment in oil- and gas-producing states is more responsive to changes in rig counts than changes in oil prices. This result is intuitive, as oil and gas companies typically change future investment decisions first when faced with an oil price shock. When oil prices decline, firms often cut their planned capital spending, including exploration and drilling. In 2015, for example, exploration and production companies are expected to cut capital expenditures by 32 percent on average (Oil & Gas Journal). The reduction in exploration and drilling would mean fewer oil and gas workers. Depending on the initial intensity of activity, the size of the development area, and the length of the oil-price drop, employment in other sectors could also decline.

Box

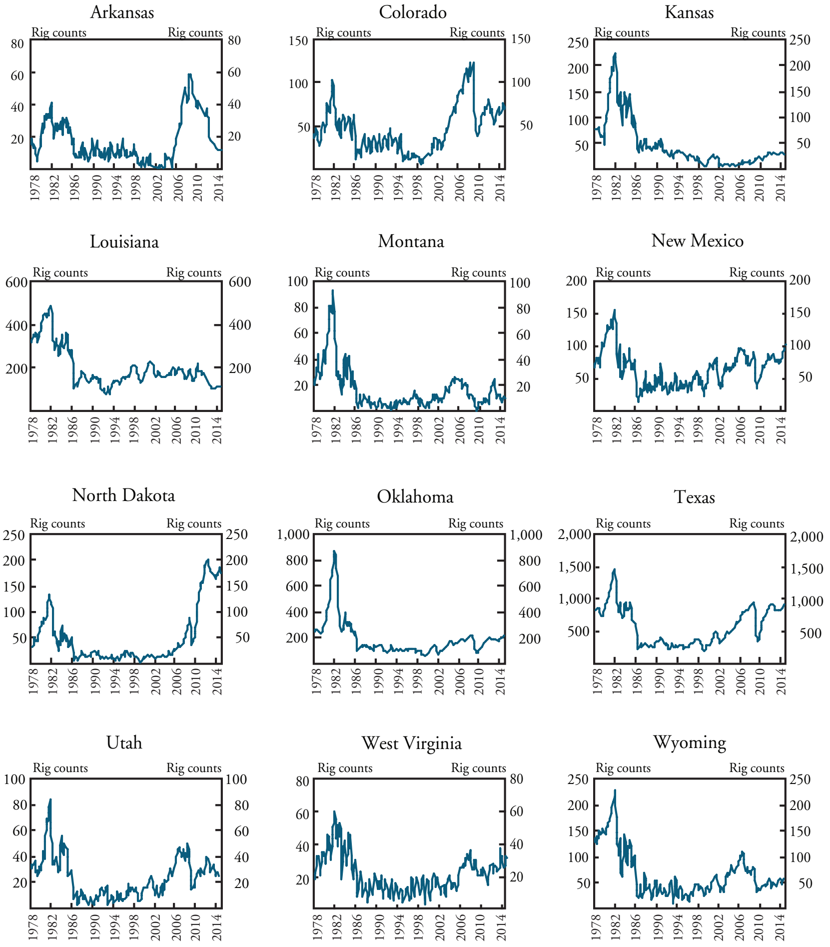
Previous Studies of the Employment Response to Oil and Gas Activity

Previous studies have used simulation models, principally input-output models such as the Impact Analysis for Planning (IMPLAN), to project the economic effects of expanding unconventional oil and gas drilling. The input-output approach creates a mathematical representation of an economy by specifying linkages between sectors. When combined with region-specific industry information, the relationships between sectors permit projections of how the expansion or contraction of one industry would affect output in the entire economy. Most importantly, they can provide projections before much industry growth has happened. However, input-output approaches often assume that input prices such as wages are not affected by changes in demand and, therefore, that increased demand in one sector does not crowd out inputs in other sectors (Kilkenny and Partridge). Kinnaman suggests recent studies on the oil and gas sector using input-output models likely overstate spillover effects from oil and gas because of this same assumption.

Thus far, most empirical approaches test for differences in outcomes between oil- and gas-producing areas and non-producing areas. Despite different methods, measures of oil and gas activity (for example, employment or production), areas of study, and time frames, these studies consistently find modest effects from the oil and gas sector on total employment (for example, Weinstein and Partridge; Weber (2012, 2014); Brown (2014); Munasib and Rickman). Compared with the simulation studies, these studies are able to capture potential crowding-out effects from the oil and gas sector. However, one common and potentially limiting feature of these studies is that outcomes are usually measured on an annual frequency and over a limited number of years.

Chart 3

Oil and Gas Rig Counts by State



Source: Baker Hughes.

Modeling the dynamic nature of oil and gas activity

Since several sectors of a state economy may be involved in various phases of oil and gas development, changes in rig activity likely take time to work through the economies of energy-producing states. To capture these potentially dynamic effects, the model assumes changes in total employment in a particular state are a function of past changes in employment and current and past changes in rig counts, and may be correlated with changes in employment in other states. A reduction of one rig in a large state like Texas, with nearly 1,000 active rigs, would be a much smaller shock to the state economy than would a reduction of one rig in North Dakota, a state with less than 200 rigs. To account for this, the model scales rig counts and employment by population.[3] Seasonally adjusted employment data are from the Current Employment Survey produced by the Bureau of Labor Statistics. Monthly data from January 1976 to December 2014 are used for 12 oil and gas states.[4]

The base model estimated is:

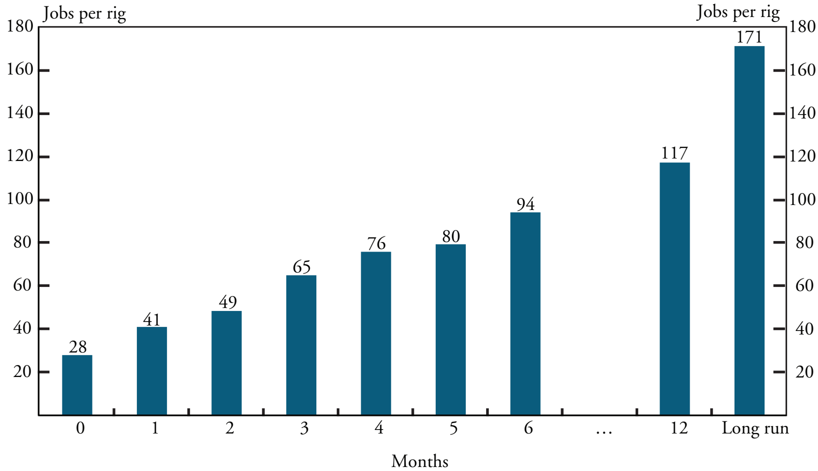
$$\Delta emp_{it} = \sum_{m=1}^{12} \alpha_m \Delta emp_{it-m} + \sum_{k=0}^{6} \beta_k \Delta rigs_{it-k} + \gamma_t + \varepsilon_{it},$$

where Δemp_{it} is the change in employment per capita in state i at time t, $\Delta rigs_{it}$ is the change in rig counts per capita in state i at time t, γ is a time-fixed effect to control for seasonal factors, and ε_{it} is an error term.[5] Goodness-of-fit measures determined the number of lags (12 for employment and six for rigs) in the model. The immediate employment response from a change in rig counts is estimated by β_0, which is the number of jobs added per rig in the same month the rig is deployed. The other coefficients, $\beta_1, \beta_2, \ldots, \beta_6$, estimate the employment response in months one to six following a change in rig counts. The main estimate of interest is the long-run multiplier (LRM), the long-run effect of a change in rig counts on employment. The LRM is estimated by:

$$LRM = \frac{\sum_{k=0}^{6} \beta_k}{1 - \sum_{m=1}^{12} \alpha_m}.$$

Chart 4

Estimated Cumulative Employment Response to an Additional Rig



Source: Author's calculations.

The estimated employment response from changes in rig counts is significant and grows over time. Chart 4 shows the cumulative response increases over time, with an additional rig adding 28 jobs in the first month, 94 jobs after six months, and 171 jobs in the long run. The full set of model results is reported in the Appendix (Table A-1). A significant employment response occurs in the same month as the change in rig counts and in months one, three, and six following the addition of a new rig.[6]

The initial change in employment is likely related to the installation of the rig itself and the oil and gas sector more broadly. Over time, however, the employment response likely spills over to other sectors in the economy that directly and indirectly support oil and gas. The cumulative employment response in the first six months is used as a proxy for the short-run employment response, in which most of the change in employment is associated with workers operating and servicing the rig. The long-run response is a combination of those workers and employment that spills over into other sectors. Following this logic, a rough approximation of the employment multiplier for the oil and gas sector would be the ratio of the LRM to the short-run (first six months) cumulative response. The implicit multiplier is 1.8 (171/94), suggesting 0.8 jobs added outside the oil and gas sector for every job in the sector. This number is similar to some previous estimates, which range from 0.7 to 1.4 additional jobs (Brown (2014); Weber; Munasib and Rickman).

Employment response from the recent decline in rig counts

Oil- and gas-producing states may feel the recent decline in rigs differently depending on the timing and pace of the decline in each state. The rig counts began to fall in most states in September 2014. The employment response from the observed decline in rig counts from September 2014 to April 2015 is forecast using the base model results. The first two columns in Table 2 report the observed decline in rig counts in each state over the time period in level and percentage terms. The table also reports the estimated short-run and long-run job losses as well as the long-run job losses as a percentage of total employment in each state in September 2014. The predicted job losses are larger in the long run, as the dynamic effect of the reduction in rig counts works its way through the state economy. The states with the largest decreases in rigs—Texas, North Dakota, and Oklahoma—had the largest predicted reduction in employment: nearly 82,000 fewer jobs in Texas, 17,000 in North Dakota, and 16,000 in Oklahoma.

Although Texas saw the largest level of employment losses, less-diversified states may feel the decline in rig counts more severely. For example, the predicted job reduction in North Dakota and Wyoming represented 3.8 percent and 1.9 percent of total employment, respectively, compared with 1 percent in Oklahoma and 0.7 percent in Texas. These estimates are in line with the predictions of Murphy, Plante, and Yücel, but estimates for other states show a smaller employment reduction than the authors predict.[7] While these results suggest only modest employment effects thus far, they may not capture the full effect, as the recent decline in energy activity is still unfolding.

Rig counts could decline further through the second half of 2015 before leveling off. Thus far, oil and gas rigs combined have declined nearly 50 percent from September 2014 through April 2015 for the United States as a whole, consistent with the 50-percent drop in the

Table 2
Predicted Employment Response from Decline in Rig Counts

	Change in rig counts (Sept. 2014 to April 2015)	Percent change in rig counts (Sept. 2014 to April 2015)	Forecast short-run change in employment	Forecast long-run change in employment	Long-run percent change in employment (versus Sept. 2014)
Arkansas	-3	-25.0%	-81	-514	-0.04%
Colorado	-39	-51.3%	-1,114	-6,686	-0.3%
Kansas	-13	-52.0%	-366	-2,229	-0.2%
Louisiana	-45	-39.1%	-1,270	-7,714	-0.4%
Montana	-7	-87.5%	-194	-1,200	-0.3%
New Mexico	-50	-50.5%	-1,392	-8,571	-1.0%
North Dakota	-102	-54.5%	-2,924	-17,486	-3.8%
Oklahoma	-92	-43.0%	-2,603	-15,771	-1.0%
Texas	-480	-53.2%	-13,762	-82,285	-0.7%
Utah	-15	-65.2%	-438	-2,571	-0.2%
West Virginia	-6	-21.4%	-172	-1,029	-0.1%
Wyoming	-33	-56.9%	-928	-5,657	-1.9%

Note: The change and percent change in rig counts are calculated from September 2014 to April 2015.
Sources: Baker Hughes and author's calculations.

price of oil from its recent peak in June 2014. However, rigs have declined more than 50 percent in some states already, and it is unclear how many more rigs will be taken out of service. Table 3 shows the associated employment response in the long run if the rig counts decline by an additional 10 percent. Under this assumption, total employment in New Mexico, North Dakota, Oklahoma, and Wyoming would decline by over 1 percent, with even larger declines in North Dakota (4.4 percent) and Wyoming (2.3 percent).

Robustness checks

Additional specifications were estimated as robustness checks to the base model. These other models focused on possible non-linearity and variation in the employment response in different decades. Large changes in rig counts may have proportionally larger employment effects than small changes. To test for this, quadratic terms of changes in rig counts were added to the base model. The full results are shown in the Appendix (Table A-2). The quadratic terms were not jointly

Table 3

Employment Response from a 10 Percentage Point Larger Rig Decline in Each State

	Change in rig counts (versus Sept. 2014)	Percent change in rig counts (versus Sept. 2014)	Forecast long-run change in employment	Long-run percent change in employment (versus Sept. 2014)
Arkansas	-4	-35.0%	-720	-0.1%
Colorado	-47	-61.3%	-7,986	-0.3%
Kansas	-16	-62.0%	-2,657	-0.2%
Louisiana	-56	-49.1%	-9,680	-0.5%
Montana	-8	-97.5%	-1,337	-0.3%
New Mexico	-60	-60.5%	-10,268	-1.2%
North Dakota	-121	-64.5%	-20,677	-4.4%
Oklahoma	-113	-53.0%	-19,443	-1.2%
Texas	-570	-63.2%	-97,724	-0.8%
Utah	-17	-75.2%	-2,965	-0.2%
West Virginia	-9	-31.4%	-1,507	-0.2%
Wyoming	-39	-66.9%	-6,652	-2.3%

Note: The forecast for Montana suggests that all rigs would be taken out of service, which may not be a likely scenario.
Sources: Baker Hughes and author's calculations.

statistically significant, suggesting the employment response was not different for large and small changes in rig counts.

Over the past few decades, the oil and gas sector has experienced several technological advances that could alter the employment response over time. Some evidence suggests the sector has recently become more capital intensive and more productive (Melek). As a result, the sector may use less labor than it once did, and rigs may be associated with fewer jobs. To test this hypothesis, the base model is estimated restricting the sample from 1985 to 1989 and, separately, from 2010 to 2014. In the mid- to late 1980s, one new rig added 37 jobs in the same month, 141 jobs after six months, and 242 jobs in the long run (Table A-3). From 2010 to 2014, however, one new rig added only 20 jobs in the initial month, 62 jobs after six months, and 100 jobs in the long run (Table A-4). Combined, these results indicate the employment response to oil and gas activity may be on the decline, with further declines possible if the sector continues to become more capital intensive. However, additional hypothesis testing revealed that the employment response to the change in rig counts and six monthly lags was not jointly statistically different in the 1985-89 period compared with 2010-14. Furthermore, results for the more recent time period were less precise, making the full sample model preferable due to greater precision in the estimates.[8]

The results suggest a modest employment response to changes in rig counts overall, but a more substantial response in states where the oil and gas sector is a larger share of the economy. The modest response overall is not surprising, since oil and gas is still a relatively small share of overall economic activity. The employment response is dynamic in nature, with significant effects several months after an initial change in rig activity. The cumulative response increases over time as it spreads to other sectors of the economy beyond oil and gas. However, some evidence suggests the employment response has diminished in more recent years, perhaps because the sector has become more capital intensive.

IV. Conclusion

Combining hydraulic fracturing with horizontal drilling has opened petroleum reserves in several parts of the United States. The rapid expansion in production has led the country to become a global leader in hydrocarbon production, with large increases in activity concentrated in a few states. Over the past several decades, oil and gas states have experienced boom and bust cycles in exploration and drilling. In general, these states appear to be less dependent on the oil and gas sector now than in the early to mid-1980s. Nonetheless, the recent sharp decline in the price of oil and drilling activity will likely have a sizeable effect in a few states.

This article finds that within the timeframe and region under consideration, an increase in one rig added 28 jobs in the same month, 94 jobs after six months, and 171 jobs in the long run. The overall employment response from the decline in oil and gas activity in energy states will depend upon how long oil prices remain low, how quickly the oil and gas sector responds to future changes in the price of oil, and how productivity within the sector changes in the near term. Thus far, the expected employment declines are modest, with an estimated decline in employment from 0.1 to 4 percent across oil and gas states. Further declines are possible in the second half of 2015. However, some evidence suggests the employment response to changes in rig activity has dampened relative to earlier decades. If the oil and gas sector continues to become more capital intensive, total employment in energy-producing states may be less responsive to future changes in oil and gas activity depending upon the relative size of the sector in each state.

Appendix

Table A-1

Employment Response to Changes in Oil and Gas Rigs, 1976 to 2014

	Coefficient	Robust standard errors	T-statistic
Δ emp$_{t-1}$	-0.016	0.031	-0.520
Δ emp$_{t-2}$	0.102***	0.027	3.780
Δ emp$_{t-3}$	0.156***	0.024	6.560
Δ emp$_{t-4}$	0.075***	0.021	3.570
Δ emp$_{t-5}$	0.037	0.025	1.480
Δ emp$_{t-6}$	0.043**	0.019	2.230
Δ emp$_{t-7}$	0.050***	0.015	3.310
Δ emp$_{t-8}$	0.030*	0.017	1.800
Δ emp$_{t-9}$	0.059**	0.024	2.490
Δ emp$_{t-10}$	0.049***	0.016	3.120
Δ emp$_{t-11}$	-0.009	0.023	-0.390
Δ emp$_{t-12}$	-0.054*	0.027	-2.020
Δ rig$_{t}$	27.826***	5.368	5.180
Δ rig$_{t-1}$	13.842*	6.380	2.170
Δ rig$_{t-2}$	6.321	8.898	0.710
Δ rig$_{t-3}$	14.423*	7.612	1.890
Δ rig$_{t-4}$	7.955	8.708	0.910
Δ rig$_{t-5}$	0.308	7.912	0.040
Δ rig$_{t-6}$	11.083*	5.711	1.940

LRM	171.43
F-statistic	13.12***
R^2	0.129
N=5,460	

* Significant at the 10 percent level.
** Significant at the 5 percent level.
*** Significant at the 1 percent level.
Source: Author's calculations.

Table A-2

Non-Linear Employment Response to Changes in Oil and Gas Rigs, 1976 to 2014

	Coefficient	Robust standard errors	T-statistic
Δ emp$_{t-1}$	-0.017	0.031	-0.560
Δ emp$_{t-2}$	0.105***	0.028	3.750
Δ emp$_{t-3}$	0.161***	0.024	6.580
Δ emp$_{t-4}$	0.077***	0.023	3.420
Δ emp$_{t-5}$	0.031	0.026	1.190
Δ emp$_{t-6}$	0.041*	0.020	2.070
Δ emp$_{t-7}$	0.049**	0.016	3.070
Δ emp$_{t-8}$	0.029	0.017	1.770
Δ emp$_{t-9}$	0.060**	0.023	2.580
Δ emp$_{t-10}$	0.045**	0.017	2.700
Δ emp$_{t-11}$	-0.011	0.023	-0.460
Δ emp$_{t-12}$	-0.050*	0.025	-2.000
Δ rig$_{t}$	28.304***	6.025	4.700
Δ rig$_{t-1}$	16.294**	6.705	2.430
Δ rig$_{t-2}$	2.865	8.029	0.360
Δ rig$_{t-3}$	8.378	6.496	1.290
Δ rig$_{t-4}$	7.819	8.699	0.900
Δ rig$_{t-5}$	1.486	7.574	0.200
Δ rig$_{t-6}$	12.806**	5.695	2.250
Δ rig$^2_{t}$	0.005	0.139	0.040
Δ rig$^2_{t-1}$	0.364**	0.150	2.420
Δ rig$^2_{t-2}$	-0.280	0.181	-1.550
Δ rig$^2_{t-3}$	-0.410*	0.194	-2.120
Δ rig$^2_{t-4}$	0.022	0.204	0.110
Δ rig$^2_{t-5}$	0.083	0.321	0.260
Δ rig$^2_{t-6}$	0.033	0.141	0.230

F-test	10.61***	F-test (quadratic terms)	0.370
R^2	0.134		

* Significant at the 10 percent level.
** Significant at the 5 percent level.
*** Significant at the 1 percent level.
Source: Author's calculations.

Table A-3

Employment Response from Changes in Oil and Gas Rigs, 1985 to 1989

	Coefficient	Robust standard errors	T-statistic
Δ emp_{t-1}	-0.076	0.063	-1.190
Δ emp_{t-2}	0.117**	0.046	2.570
Δ emp_{t-3}	0.187***	0.032	5.790
Δ emp_{t-4}	0.067	0.043	1.560
Δ emp_{t-5}	0.099	0.056	1.770
Δ emp_{t-6}	-0.034	0.046	-0.740
Δ emp_{t-7}	0.062	0.040	1.560
Δ emp_{t-8}	0.082	0.062	1.330
Δ emp_{t-9}	0.099**	0.043	2.280
Δ emp_{t-10}	0.029	0.031	0.940
Δ emp_{t-11}	-0.059	0.040	-1.480
Δ emp_{t-12}	-0.120**	0.047	-2.590
Δ rig_{t}	37.108***	8.886	4.180
Δ rig_{t-1}	41.454***	9.731	4.260
Δ rig_{t-2}	-7.306	18.754	-0.390
Δ rig_{t-3}	14.901	11.045	1.350
Δ rig_{t-4}	18.293	11.144	1.640
Δ rig_{t-5}	-10.999	23.362	-0.470
Δ rig_{t-6}	38.665***	6.781	5.700

LRM	242.03
F-statistic	55.69***
R^2	0.234
N=720	

* Significant at the 10 percent level.
** Significant at the 5 percent level.
*** Significant at the 1 percent level.
Source: Author's calculations.

Table A-4

Estimated Employment Response, 2010 to 2014

	Coefficient	Robust standard errors	T-statistic
Δ emp_{t-1}	-0.085**	0.035	-2.410
Δ emp_{t-2}	0.025	0.033	0.740
Δ emp_{t-3}	0.116***	0.025	4.660
Δ emp_{t-4}	0.015	0.065	0.230
Δ emp_{t-5}	0.050*	0.024	2.070
Δ emp_{t-6}	0.001	0.038	0.020
Δ emp_{t-7}	0.075**	0.025	2.990
Δ emp_{t-8}	-0.047**	0.020	-2.320
Δ emp_{t-9}	0.132***	0.037	3.520
Δ emp_{t-10}	0.023	0.017	1.350
Δ emp_{t-11}	-0.086	0.075	-1.140
Δ emp_{t-12}	0.063	0.067	0.940
Δ rig_{t}	20.939*	10.366	2.020
Δ rig_{t-1}	24.811	20.969	1.180
Δ rig_{t-2}	-12.253	43.102	-0.280
Δ rig_{t-3}	46.883*	24.411	1.920
Δ rig_{t-4}	7.849	37.597	0.210
Δ rig_{t-5}	5.747	17.089	0.340
Δ rig_{t-6}	-21.562	16.645	-1.300

LRM	100.79
F-statistic	28.39***
R^2	0.083
N=720	

* Significant at the 10 percent level.
** Significant at the 5 percent level.
*** Significant at the 1 percent level.
Source: Author's calculations.

Endnotes

[1]Murphy, Plante, and Yücel estimate positive employment effects from 0 to 1 percent in eight states, with employment in the remaining states increasing by more than 1 percent.

[2]Rig counts data are available at *http://phx.corporate-ir.net/phoenix.zhtml?c=79687&p=irol-reportsother*.

[3]Monthly population estimates are from the Bureau of Labor Statistics, Local Area Unemployment Statistics.

[4]The states chosen are major oil and gas producers with a history of development but also recent activity in shale plays. The states are Arkansas, Colorado, Kansas, Louisiana, Montana, New Mexico, North Dakota, Oklahoma, Texas, Utah, West Virginia, and Wyoming.

[5]The error term, ε_{it}, is adjusted for autocorrelation and heteroscedasticity using Driscoll-Kraay standard errors. Driscoll-Kraay standard errors are a Newey-West estimator applied to cross-sectional averages of the model's moments. The number of lags was chosen from the model with the minimum Akaike Information Criterion.

[6]The results are smaller in magnitude than those of Agerton and others, who estimate 37 jobs per rig in the month the rig was added and 224 jobs in the long run. One possible explanation for the difference is their study includes all 50 states in the United States and uses data beginning in 1990, while the present study uses data beginning in 1976 and only focuses on the major oil- and gas-producing states. Restricting the sample to the same time frame as Agerton and others resulted in a slightly larger employment response compared with the full sample, but still smaller compared with their results, suggesting some employment response may occur from neighboring non-energy producing states.

[7]They estimate that a 50 percent decline in the price of oil would reduce total employment in seven continental states: Wyoming (-4.3 percent), Oklahoma (-2.3 percent), North Dakota (-2.0 percent), Louisiana (-1.6 percent), Texas (-1.2 percent), New Mexico (-0.7 percent), and West Virginia (-0.7 percent).

[8]Models were also estimated allowing the employment response from changes in rigs to vary across the 12 states in the analysis. Hypothesis testing was done two different ways: by testing individual state coefficients against a global coefficient using Arkansas as the reference category or by dropping the global variables ($\Delta\ rig_t, \ldots, \Delta\ rig_{t-6}$) and including all the state coefficients. In both cases, a joint test was used to determine if the varying state coefficients were different from the global coefficient or if the state coefficients were different from each other. In both setups, only the $\Delta\ rig_{t-1}$ was statistically different across states. The other variables ($\Delta\ rig_t$, $\Delta\ rig_{t-2}, \ldots, \Delta\ rig_{t-6}$) were not statistically different. As a result, the simpler model was preferred.

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