How the Shale Boom Has Transformed the US Oil and Gas Industry

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Introduction

The United States has experienced dramatic increases in oil and natural gas production since 2005, underpinned by new technological developments such as hydraulic fracturing and horizontal drilling and supported initially by high prices for natural gas and oil. Combined with advancements in seismic imaging and surveying technologies, these breakthroughs brought about the US shale revolution—unlocking vast reserves of "tight" oil and gas found in geologic formations previously thought to be inaccessible and nonviable for conventional development and production. These advances have allowed drillers to extract from significantly larger subsurface acreage using fewer wellbores and with much higher production per well.

These changes have propelled the resulting shale gas boom along with the most rapid and largest surge in oil production in US history. The shale revolution has fundamentally changed how oil and gas are produced in the United States and has potentially profound implications for policy and business decisionmaking. Do these shifts in US fossil fuel production mean that the United States has entered a new era of stable oil and gas prices?

Background

In the words of one industry expert, conventional oil and gas investments resemble high-risk/high-reward "big game trophy hunting," which involves drilling many dry holes in search of a few highly productive ones. This stands in stark contrast to modern unconventional extraction from shale, which is commonly said to resemble a "manufacturing process" in that operators have much more flexible and certain control over their production levels.

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KEY POINTS

- To assess changes in the supply responsiveness of the US oil and gas sectors, we analyzed 2000–2015 drilling and production data from approximately 62,000 gas wells in Texas and 164,000 oil wells in the five major oil-producing states.
- For both oil and gas, unconventional wells take somewhat longer than conventional wells to begin production after drilling begins—but they produce much more per well, compensating for the lag time.
- The increased productivity of unconventional wells makes production from shale resources much more sensitive to price.
- Decreased price volatility for natural gas appears to reflect these fundamental market changes, reducing the risk of policy and business decisions dependent on future gas prices.
- Our results point to a significantly larger role for the US incremental supply of oil than before the shale revolution—as well as continued relevance for the US Strategic Petroleum Reserve to respond to short-term market imbalances.

Generally speaking, industry operators have better information about the location and scale of shale resources than they do for conventional formations—the challenge with shale has been extracting them. Advances in drilling technology that have allowed access to these previously unexplored shale resources have resulted in significant jumps in production—and in shorter order, suggesting a tighter relationship between drilling effort from unconventional sources and realized production. Unconventional wells take somewhat longer to drill and reach production initially, but they produce much more per well than conventional sources and have less risk associated with variation in well productivity. Experts have suggested that taken together these factors make unconventional oil and gas more responsive to market prices. We tackle the question head on in this issue brief, which summarizes findings discussed more fully in two recent analyses of changes in the supply responsiveness of the US oil and gas sectors.[1]

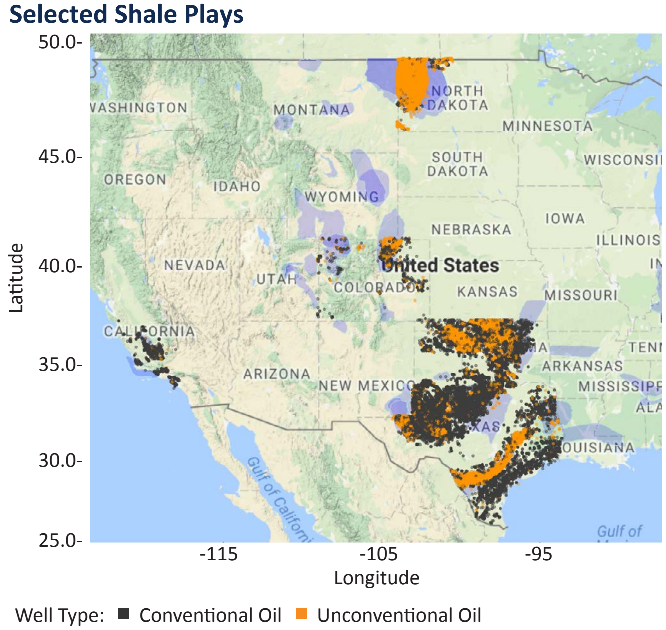
To the extent that unconventional oil and gas is more price responsive, the shale boom has likely "flattened out" the US oil and gas natural gas supply curves, meaning that producers can respond more readily to price changes. In turn, we would expect a reduction in price volatility in the market for natural gas (which is primarily North American), as suppliers can now respond more rapidly to market signals. However, because oil is a global market, it has typically been assumed that incremental production from the United States has a very small impact on prices.

The magnitude of the shale revolution as well as the significant drop in oil prices in 2014 and 2015 make the US global market position worth reexamining. In particular, it is worth assessing whether the United States is now a "swing oil producer," a role historically played by Saudi Arabia and a small number of other OPEC countries who alter the amount of spare production capacity they hold to help moderate shocks to oil supply and demand. Here we answer that question in short and give an overview of the how changes in US production from unconventional extraction technologies have affected the ability of oil and gas producers to respond to price changes.

Study Area and Data

Our two studies analyzed 2000–2015 drilling and production data from approximately 62,000 gas wells in Texas and 164,000 oil wells in the five major oil-producing states of Texas, North Dakota, California, Oklahoma, and Colorado (Figures 1 and 2). We distinguish carefully between conventional wells and unconventional wells drilled in 2005 or later, when the shale gas revolution began in earnest. The data analyzed describe multiple characteristics of each well. The characteristics include each well's dates of drilling and first production, location, drilling direction, and reservoir, among other features. In addition, we also use monthly time series data of each well's oil and gas production. We developed a simulation model based on three stages of the production process: (1) drilling (or "spudding") activity; (2) spud-to-production time; and (3) production from existing wells.

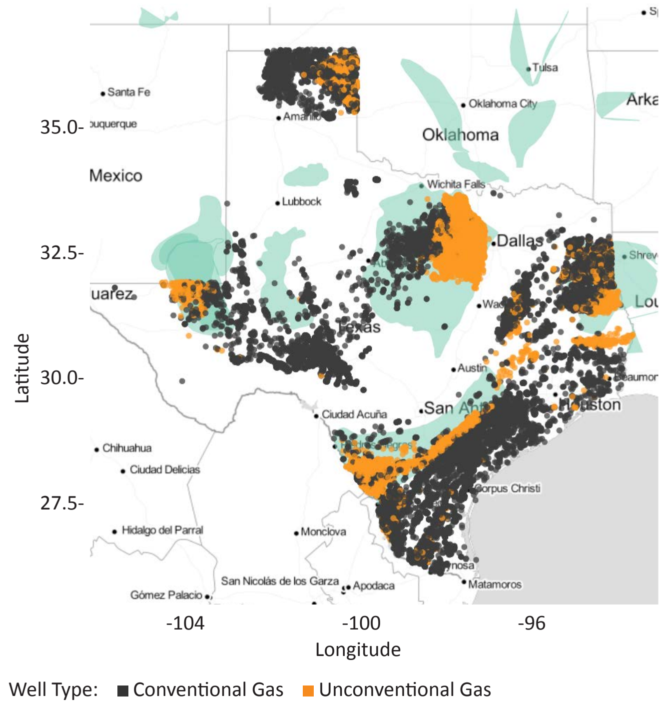
Figure 1. Location of Oil Wells in Data by Well Type and Selected Shale Plays



[1] Newell, Richard G., and Brian C. Prest. 2017. Is the US the New Swing Producer? The Price-Responsiveness of Tight Oil. Working paper 17-15. Washington, DC: Resources for the Future.

Newell, Richard G., Brian C. Prest, and Ashley Vissing. 2016. Trophy Hunting vs. Manufacturing Energy: The Price-Responsiveness of Shale Gas. Discussion paper 16-32. Washington, DC: Resources for the Future.

Figure 2. Location of Gas Wells in Data by Well Type and Selected Shale Plays



Characteristics of Conventional and Unconventional Oil and Gas Production

An analysis of the data confirms some important conjectures about conventional versus unconventional production.

The decision to drill is quite sensitive to price changes. We find drilling activity to be the important margin for the price response. In the case of oil, we estimate a price elasticity for drilling of 1.6 for unconventional oil wells compared to 1.2 for conventional wells, meaning that unconventional oil drilling reacts more to price changes. In contrast, the price response of gas drilling is similar for conventional and unconventional technologies, with an elasticity of about 0.9.

Once drilling has started, prices have little impact on the overall timing of a well's production. This is true for both the time from drilling to first production, as well as the production profile over time from producing wells. This is sensible, since once drilling has begun, much of the well development costs have been sunk. There also may be limited opportunities for cost-effectively speeding up completion or production from existing wells.

For both oil and gas, unconventional wells take somewhat longer than conventional wells to begin production after they have been "spudded" (i.e., after drilling has begun). We attribute this to the time needed to drill the longer wellbores and hydraulically fracture them. Figures 3 and 4 show the distribution of spud to production times across conventional and unconventional oil and gas wells.

Figure 3. Estimated Spud-to-Production Time Distribution, Oil Wells

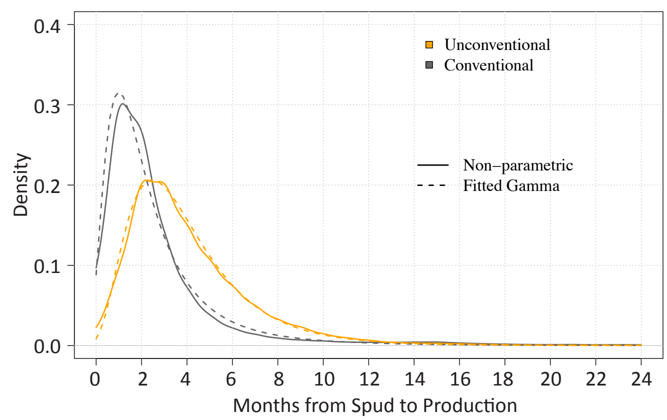
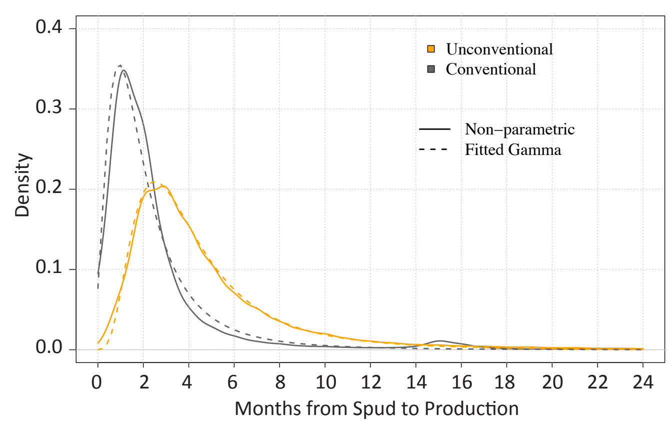


Figure 4. Estimated Spud-to-Production Time Distribution, Gas Wells



Although unconventional wells tend to take longer to reach production, they produce much more per well than conventional wells. They also have much lower percent variation in production, consistent with the notion of a less-uncertain manufacturing process. A well's flow rate depends on subsurface pressure, meaning that wells tend to produce at their highest rates immediately, followed by a quick decline. The average production profiles for unconventional and conventional wells in our data are shown in Figures 5 and 6.

Figure 5. Mean and Median Profile of Monthly Oil Production, Oil Wells

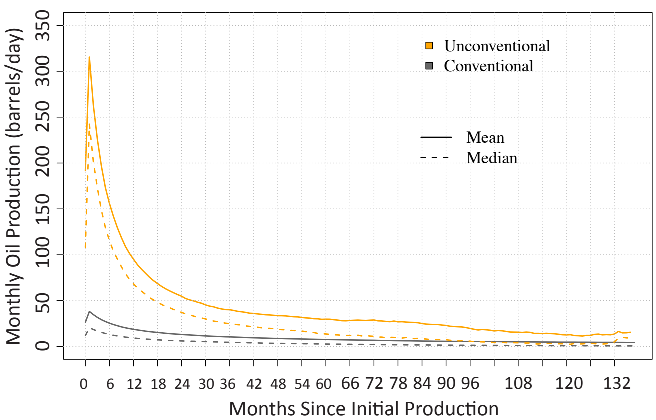
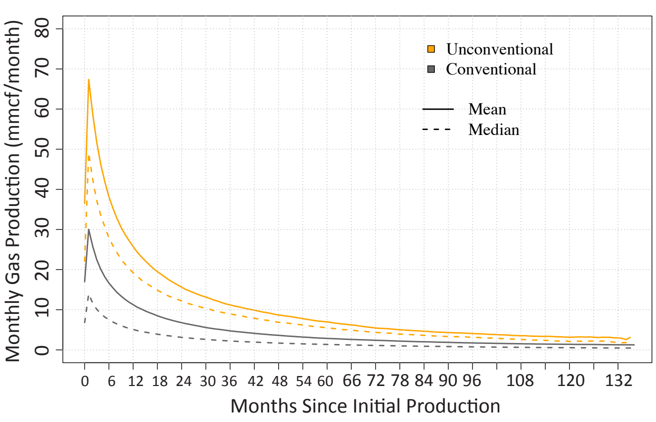


Figure 6. Mean and Median Profile of Monthly Gas Production, Gas Wells



Note that the "decline curves" (i.e., the rate at which a well's production drops from its initial peak) are very similar for unconventional and conventional gas production, once we control for the peak. In the case of oil, unconventional wells decline much faster than conventional ones. For example, after 12 months, unconventional wells have declined by about 70 percent, compared to only about 50 percent for conventional wells. This highlights how steep decline curves are a distinguishing feature of shale oil wells, as has been commonly discussed.

Unconventional wells are much more productive than their conventional counterparts. On average, an unconventional gas well in our data produced nearly 70,000 thousand cubic feet (mcf) of natural gas in its first full month, compared to approximately 30,000 mcf from a conventional gas well—meaning on average over this sample period (2000–2015 for conventional and 2005–2015 for unconventional), unconventional gas wells were 2.3 times as productive. In the case of oil, while average initial production is approximately 9 times larger for unconventional wells, their much steeper decline rate means that the productivity advantage shrinks over time. As a result, they produce only about 6.5 times as much on average over the first 12 months (63,253 barrels versus 9,689 barrels). Over the longer run, the cumulative unconventional oil production advantage is about 4.6.

The Effect of the Shale Revolution on US Oil and Gas Supply Curves

The faster flow rate per well turns out to be the primary mechanism by which aggregate supply from unconventional production is more price responsive than conventional production. Although unconventional wells take longer to begin producing, the increased productivity of these wells more than compensates for the time lag. We simulated the responsiveness of US oil and gas production to a 10 percent increase in price.

Oil

The somewhat larger estimated drilling responsiveness of unconventional oil wells combined with the larger amount of oil produced per well leads to an estimated price response that is about 6 times greater from unconventional oil wells on a per-well basis. Further accounting for the sharp rise in unconventional drilling (compared to conventional drilling) and production per well over time makes this difference even larger, implying a price response for US oil supply that is 9 times larger when compared to the pre-shale era (Figure 7).

Figure 7a. Change in Oil Wells Beginning Production, following a 10% Price Shock

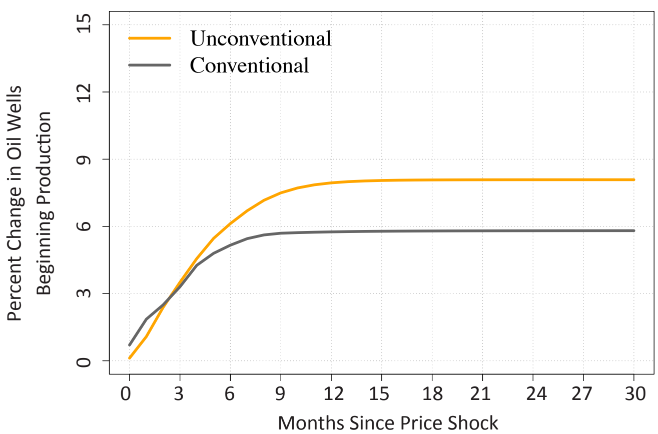
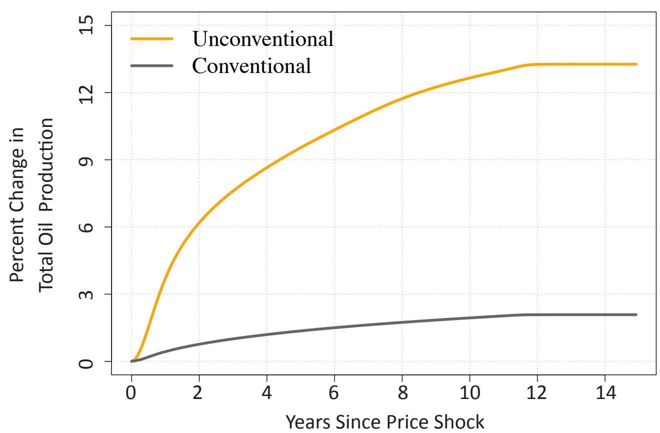


Figure 7b. Change in Oil Production from Oil Wells, following a 10% Price Shock



Over shorter time frames (3 to 6 months), the increases in supply from unconventional wells are restricted, as noted, due to the time it takes for drilling activity to ramp up and for drilled wells to begin production. Our simulations indicate that the response still takes more time to arise than is typically considered for a swing producer. This points to continued relevance for the US Strategic Petroleum Reserve to respond to short-term market imbalances.

Nonetheless, our analysis suggests that if oil prices were to rise from $50 to $80 per barrel, US suppliers could ramp up production by 0.5 million barrels per day in six months, 1.2 million in one year, 2 million in two years, and 3 million in five years. These represent substantial increases in the context of the global market—implying a significantly larger role for the US incremental supply than before the shale revolution, regardless of whether or not the nation currently fits the bill to act as a swing producer.

Natural Gas

Unconventional and conventional gas wells exhibit a similar drilling response to price changes but, as in the case of oil, the increased productivity of wells makes unconventional production much more sensitive to price. The right-hand panel of Figure 8 illustrates that, in the long run, the gas supply response to a 10 percent price increase by unconventional wells is about 2.7 times larger than that of conventional wells. This is entirely due to the fact that unconventional wells are about 2.7 times as productive as conventional wells, with initial production of approximately 80,000 mcf per month (the 2010–2014 average) compared to 30,000 mcf per month.

This heightened supply response has many implications for oil and gas price volatility and policymaking in general. Indeed, following the boom in shale gas,

Figure 8a. Change in Gas Wells Beginning Production, following a 10% Price Shock

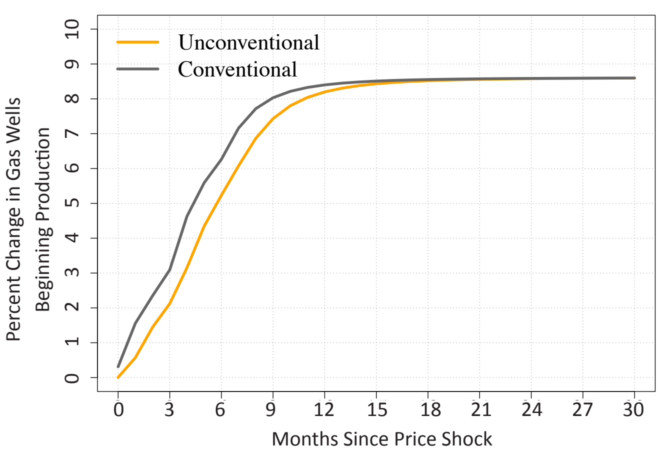


Figure 8b. Change in Gas Production from Gas Wells, following a 10% Price Shock

prices have been significantly less volatile compared to the early 2000s. To the extent that unconventional gas is responsible for this diminished volatility, continuation of this state of affairs would help reduce uncertainty for policymakers and businesses considering investments that are highly sensitive to gas prices. For example, compliance with regulations aimed at reducing carbon dioxide emissions from power plants would involve higher reliance on natural gas–fired generation, both as a subsitute for coal and as back-up for intermittent renewable power. The economic benefits of investments in export infrastructure for liquefied natural gas also depend on stable natural gas prices, as do the benefits of domestic investments in energy-intensive manufacturing and chemical production.

Conclusion

The shale revolution has dramatically changed the position of the United States as an energy producer, allowing the oil and gas sectors to more easily ramp up production in response to price changes. This has important implications for US policymakers and businesses. The recent reduction in price volatility in natural gas prices appears to reflect fundamental market changes reducing the risk of policy and business decisions dependent on the future price of gas. The US oil sector's increased production and responsiveness has global market implications, even if the United States is not at a point where it is a global swing producer. This indicates a continued relevance of the US Strategic Petroleum Reserve and strategic oil stock holdings by other countries, as well as the maintenance of spare production capacity by countries such as Saudi Arabia.