

# Technological and Institutional Interaction in the Shale Oil [R]evolution

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## Abstract:

A decade ago, peak oil was widely discussed. By early 2015, US oil production reached 9.7 million barrels per day, a figure not seen since the nation's previous peak production in 1971. The dramatic increase in US production is commonly referred to as the shale oil revolution. It is often alleged that the shale oil revolution was the result of technological change, particularly horizontal drilling and fracking. Technological change contributed to the increase in production but such change involved much more than horizontal drilling and fracking. Institutional changes also contributed to the shale oil revolution. Besides market changes, new mechanisms of financing exploration and production were facilitated by low interest rates and quantitative easing. The political and regulatory environments changed as well. This paper will investigate the peculiar interaction of institutions and technology in the shale oil industry between 2010 and 2015.

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## Introduction:

A decade ago, peak oil was a widely discussed topic. In 1970, U.S. crude oil production averaged 9.6 million barrels per day. Production peaked in November 1970 reaching 10.04 million barrels per day (bpd) (EIA, 2016). By 2009, US oil production had decreased to 5.3 million bpd and many analysts thought that this nearly four decade downward trend was a permanent feature of the US oil industry (Schumaker and Bookchin 2008; Goodchild 2009; Forbes and Maxwell 2010). Hubbert's peak seemed clearly upon us (Hubbert 1949, 1956) yet by April 2015, US oil production reached 9.627 million barrels per day, a figure not seen since 1971 (EIA 2016). The dramatic increase in US production is commonly referred to as the shale oil revolution.

It is often alleged that the shale oil revolution was the result of technological change, particularly horizontal drilling and hydraulic fracturing (fracking). Technological change was an important contributing factor to the increase in production but such change involved much more than horizontal drilling and fracking. Institutional changes also contributed in a major way to the shale oil revolution. Upstream, midstream and downstream markets changed dramatically. Global markets changed in surprising ways. New mechanisms of financing exploration and production were facilitated by low interest rates and quantitative easing. The political and regulatory environments changed dramatically as well. Oil and gas markets, like other markets, consist of more than simple supply and demand. Markets are a set of rules (institutions) that govern transactions (Commons 1924; Atkinson and Paschall 2016). This paper will investigate

the peculiar interaction of institutional and technological change in the shale oil industry between 2010 and 2015.

## Technological Change

Horizontal drilling and fracking are the shale oil production technologies most likely to be known by the general public. Neither is a new technology. The first horizontal well was drilled in Texas in 1929 (EIA 1993). Fracking was a known technique in the 1860s and was put to commercial use in 1949 (AOGHS, ND). During the 1990s, George Mitchell successfully combined the two techniques in drilling for natural gas in the Barnett Shale in Texas.

Other technological advances facilitated the shale oil boom as well. Many of these had long histories and, not surprisingly, some were simply incremental improvements on existing technologies. Among recently adopted technologies are: (1) new drilling rigs, (2) new drilling bits, (3) 3D seismic sensing, (4) 4D seismic sensing, (5) new proppants, (6) measurement while drilling (MWD), (7) GPS tracking of rigs, (8) Rotary Steerable Systems (RSS), (9) generators powered by raw unprocessed natural gas, (10) coiled tubing and several more. A brief description of a few of these technologies follows.

New drilling rigs “. . . can walk, rotate, be operated with a remote control, and load pipe automatically” (Scheyder 2014). A few years ago, rig counts were reliable indicators of both current activity and future production, but this is no longer the case. The new rigs are so

productive that the Energy Information Administration now issues a quarterly drilling productivity report that attempts to explain what rigs actually do.

Along with new drilling rig technology, new drilling bits have contributed to increasing exploration and production productivity. The new bits do more and last longer than traditional bits. Several firms now offer to build bits customized for a particular well.

Both 3D and 4D seismic sensing are now common features of exploration and production. During the shale oil boom, these technologies were improved and became much more common. 3D seismic surveys have been in use since the 1980s, while 4D seismic surveys were in use in the 1990s. McFarland (2009) suggested that “3D seismic surveys have lowered finding costs and allowed exploration for reserves not locatable by other means, revolutionizing the industry.” 4D seismic surveys allow monitoring of oil flows in a reservoir over time.

Fracking requires proppants, mixtures of sand, chemicals, water or other fluids, to be injected to keep fissures open and oil or gas flowing. Proppants have been around for a long time, at least since the 1940s. In the last several years, there have been major improvements in proppants. Roach (2014) referred to the new proppants as “The greatest oilfield innovation of the 21<sup>st</sup> Century.”

Measurement While Drilling (MWD) provides data collected from sensors in the well-hole (generally near the drilling bit). The data collected include information about the underground

geology, the location of the drilling, and more. The data can be used to facilitate directional drilling, identify problems, and to keep the traditional well-log, all in real time. (Rigzone 2016)

Drilling rigs require electrical power for a variety of uses. Since rigs are often located far from power lines, the traditional method of providing electrical power was to use portable diesel generators which are expensive, heavy polluters, and require frequent maintenance. There are now generators available that can use unprocessed natural gas which may be available from the well being drilled or a nearby well. These generators are claimed to reduce flaring of natural gas and the pollution from diesel generators (Mesa Natural Gas Solutions, 2015).

The discussion above includes only a small sample of the technological changes in the oil and gas industry that facilitated the shale oil boom. While many of these innovations came into widespread use only during the last few years, in all or almost all cases the technological innovation evolved over a period of many years.

The technological changes just discussed occurred in the context of major institutional changes which are discussed in the next section. The structure of the industry changed substantially. High oil prices from 2011 through June 2014 undoubtedly accelerated the development and deployment of oil industry technological innovations. Federal Reserve policies that created massive excess reserves in the banking system and historically low interest rates also contributed to these technological innovations. The regulatory environment at the federal, state, and local levels also changed considerably, partly in response to new drilling methods and production increases.

## Institutional Change

The oil industry is not what it used to be. The industry is no longer dominated by the so-called seven sisters: BP, Exxon, Chevron, Gulf Oil, Mobil, Shell, and Texaco. These were large vertically integrated companies that as recently as the 1970s dominated the industry. Their story was told in some detail by Sampson (1975). For all practical purposes, Texaco, Gulf and Mobil no longer exist. Texaco was taken over by Chevron in 2001 (Texaco 2016). Gulf oil was restructured into seven operating companies in 1975 and most of these assets are now owned by Chevron (Gulf Oil 2016). In 1998, Exxon and Mobil were merged into the Exxon-Mobil Corporation (Exxon-Mobil 2016).

While BP, Exxon-Mobil, Chevron, and Shell remain very large firms, their dominance in the oil industry has been challenged by the increasing importance of state monopolies (e.g., Saudi Arabia and Russia). More important for the shale oil revolution have been relatively new US firms who became the innovators and leading firms in the new oil game. Following a long tradition in the oil and gas industry, several of the new firms were created by colorful characters.

The new players include Chesapeake Energy, incorporated in 1996 and recently the 13<sup>th</sup> largest producer of natural gas and NGL liquids (Reuters 2016). Chesapeake is particularly fascinating because its founder, Aubrey McClendon, was an innovator in oil and gas leases and in using the now familiar combination of fracking and horizontal drilling.

An early entrant in the shale game was Mitchell Energy, headed by its legendary CEO George Mitchell. Mitchell energy had been a long time natural gas producer in Texas. Mitchell had drilled above and below the vast shale formations in the Barnett Shale in North Texas but had not attempted to extract natural gas directly from shale. After several years of mostly failed attempts, Mitchell was able to extract natural gas in commercial quantities from the Barnett shale using fracking and horizontal drilling. In short, Mitchell taught the industry how to make extraction from shale a viable option (Gertner, 2013).

Devon Energy was formed in 1971 and purchased Mitchell Energy in 2001 (Devon Energy 2016). In 2015 Devon was the second largest producer in Texas in 2015 at 148,700 barrels per day (DiLallo, 2016).

Continental Resources was founded in 1967 by 21-year-old Harold Hamm. While Continental is nearly fifty years old, it is best known for fracking and horizontal drilling in the Bakken formation in North Dakota which barely began decade ago. According to its website, Continental's lease holdings are the largest in the Bakken and it is one of the largest producers in the Bakken (Continental 2016). Harold Hamm, is frequently mentioned as a possible Secretary of Energy in a Trump administration.

Pioneer Resources (PXD) was formed in 1997 and is now a major oil and natural gas player in the Eagle Ford, Permian and Raton basins as well as the Gulf of Mexico (Pioneer Resources, 2016). Pioneer was widely known for its technological innovations in the exploration and production (E&P) end of the oil business. At his retirement in July 2015, Pioneer's chairman,

Scott Sheffield claimed that Pioneer could produce oil in the Permian Basin at \$2.25 per barrel (Brown, 2016)

EOG resources (previously Enron Oil and Gas) was formed in 1999 and has become one of the largest players in the Permian Basin but has operations in many parts of the world. It is one of the largest independent (non-integrated) oil companies. EOG produces both oil and natural gas. EOG claims 2.1 billion barrels of oil equivalent as proven reserves in 2015 and is the largest producer in Texas at 255,000 barrels per day (EOG 2016). EOG acquired Yates Petroleum in September 2016 for \$2.5 billion. Yates, a New Mexico firm had been producing oil and gas in the Permian since the 1920s.

These new firms and many dozens of others were the innovators and leaders of the so-called shale revolution. But it is more than new firms that have created a new oil market. From its beginnings, the oil industry has been home to gamblers and speculators. The image of the wildcatter who risked everything to drill a hole in the ground with no assurance of an economic return immediately comes to mind. In the last ten or fifteen years, there has been a slow but easily recognizable change in oil market speculation. The oil futures market began in 1983 but recently large financial institutions, often with no direct ties or knowledge of the oil industry, have become major players in oil futures. Juvenal and Petrella (2012, 2) describe this phenomenon as follows:

One striking characteristic of the oil market over the past decade is that large financial institutions, hedge funds, and other investment funds have invested



billions of dollars in the futures market to take advantage of oil price changes.

Evidence suggests that commodities have become a recognized asset class within the investment portfolios of financial institutions. . .

Whether or not these institutions ever take physical possession of the oil they buy and sell is not the key issue. Many do not but there has been a parallel expansion in the purchase of oil for storage. “In the old market, oil for consumption was purchased and stored. This market is characterized by a new player: opportunistic buyers of oil for storage” (Verleger 2016)

Low interest rates and excess reserves in the banking system after 2008 also contributed greatly to the financialization of the industry and to expansion of the shale industry. One industry expert described it as follows:

The quantitative easing program pursued by the Fed from 2009 to 2014 has prompted a flood of cash into the oil industry. The money in turn sparked the expansion of master limited partnerships and the activity of independent drilling firms bent on boosting oil and gas output quickly with fracking technology. (Verleger 56-57).

A BP analyst stated that:

It seems quite likely that the scale of funding that enabled the US shale revolution to expand at the pace it did over the past 4 or 5 years would not have been available had global interest rates not been close to zero, with central banks using

large-scale quantitative easing to encourage investors to invest in riskier forms of assets (Dale 2016, 11-12).

Others have argued that the increased drilling enabled by quantitative easing (QE) led to increases in supply, storage capacity, and ultimately the oil price collapse that started in June 2014. “The end of QE would suggest stronger economic growth and higher oil demand, which would remove one of the major bearish factors driving oil prices lower this year” (Lynch 2015). Lynch continued “. . . the Fed rate rise will unleash countervailing forces on the price of oil, but almost certainly so minor as to be overwhelmed by market conditions (record high global oil inventories) and geopolitical instability (Venezuelan elections).”

Despite dramatic increases in oil production since 2010, many industry insiders argue that changes in the regulatory environment impose severe restrictions that constrain production (Prandoni 2014). At the federal level, the Obama administration has been accused of limiting exploration and production on federal land onshore, restricting permits for off-shore drilling, imposing “unnecessary” environmental restrictions, and refusing to allow construction of the Keystone pipeline. An Energy Information Administration report describes recent trends in drilling on federal lands as follows:

Overall fossil fuel production from federal lands generally declined between FY 2003 and FY 2014, down 21% in FY 2014 compared with FY 2003 [...]. This trend is primarily the result of a steady decline in federal offshore natural gas

production between FY 2003 and FY 2014 and the 9% drop in coal production from federal lands from FY 2012 to FY 2013 (EIA 2016).

The Environmental Protection Agency's (EPA) proposed rules on flaring of natural gas, methane emissions, and volatile organic compounds are also debated vigorously by environmentalists and those who oppose additional regulation (EPA 2016).

At the state level, environmental regulations and direct taxation are important industry issues. Pit rules requiring oil and gas operators to line the pits near wells that store produced water (and in some cases to haul off produced water in an effort to protect groundwater supplies) have been a particularly contentious issue (IPANM 2011). Pit rules with varying requirements have been established and challenged in several oil producing states including New Mexico, Texas, Oklahoma, Wyoming and Pennsylvania.

Both state and local governments have imposed limits on fracking and the injection of produced water near cities because of the increased earthquake activity (Phillips 2016).

The list of relatively new regulations at all levels of government is a long one. The few examples presented above are intended only to suggest that the regulatory environment in which the oil and gas industry operates has become vastly more complicated.

Concluding remarks

The definitive story of the shale revolution, complete with history and analysis has yet to be written. The focus of this paper is more modest, to demonstrate that the shale revolution is far more complex than the phrase ‘fracking and horizontal drilling’ suggests. The many technological changes that allowed the dramatic increase in U.S. oil and gas production may in total be regarded as revolutionary, but many of the advances were evolutionary. The technological changes were facilitated by institutional changes, relatively high and stable oil prices from 2011 to mid-2014, new firms doing things in different ways, expansive monetary policy, and the expansion of oil futures markets, among others. In turn, the shale revolution created new problems and concerns leading to a changing regulatory environment.

It should be no surprise that technological change and institutional change in the oil and gas industry are inter-twined and inter-related. That relationship is almost a definition of dynamic economic process.

No one knows what will happen to the oil and gas industry over the next several years. Some things are reasonably good bets. There is a lot of oil and gas in the ground and no reason to suppose that peak oil is just around the corner. Price volatility is an inherent part of the industry and will continue. Technological change related to the industry will continue, perhaps in surprising ways. The institutional environment (low interest rates, easy money, market conditions, and regulation) in which the industry operates will also change.

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