The Rise of the ManufRacturers[1]

Philip K. Verleger, Jr.
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man·u·frac·ture
man(y)əˈfrak(t)SHər/
verb
gerund or present participle: **manufracturing**
1. make (crude oil or natural gas) on a large scale from shale rocks using machinery.
"a company that manufractured light sweet crude oil"

In the past, observers and analysts viewed resource production as an extraction business in which costs and prices rise over time as the better low-cost prospects tap out. Fracking has changed the situation completely. Fracking is manufacturing or, perhaps better, "manufRacturing." It is not resource extraction. Historically, manufacturing is characterized by increasing productivity and falling costs. Furthermore, manufacturing typically begins in more advanced industrialized nations and then spreads over time to other countries. Cotton ginning started in the United States after Eli Whitney invented the first modern mechanical gin in 1793. The practice then spread to other countries. Advanced steel production began in the US after World War II and then took hold in Germany, Japan, South Korea, and China. Industrial revolutions move from high-cost countries to low-cost nations. We expect crude oil manufacturing to do the same.

To make the point clearer, we draw an analogy here between crude oil production's transition from extraction to manufacturing and the computer industry's shift from mainframe units to personal computers. The computer revolution began in 1979 with the introduction of the Apple II Plus. Prior to this event, PC development had been limited to hobbyists. The II Plus brought computing capacity to a much wider audience and quickly cut the umbilical cord that tied much of the population to bulky, centralized mainframe computers. The advent of faster minicomputers from Digital Equipment Corporation further reduced the need and demand for mainframes.

Following the technical revolution, the computer industry reorganized. IBM continued producing mainframes, as did Hitachi. The smaller suppliers operating at the time, affectionately called the BUNCH (Burrows, Univac, National Cash Register, Control Data, and Honeywell) seem to have exited the business through mergers or by turning themselves into service companies. A similar fate appears in store for many companies involved in mega development projects for crude oil and natural gas liquids.

We chose the PC to explain the upheaval occurring in oil and gas production because the former's transformation is familiar to many of our readers. Before the PC came along, those engaged in research

[1] Although the term "manufracturing" has appeared before in other contexts, its use with regard to fracking was suggested by Kim Pederson of EditHeads. We think the term is appropriate.
[2] Excerpted from "Implications of Applying the PC Analogy to Oil," *Notes at the Margin*, December 15, 2014.

or communication were tied to large institutions. Heavy computing was done at central locations. Information was transmitted by mail (again through large institutions) or by landline phone. Firms built large centers, some proprietary and some open to the public. The costs of these facilities rose steadily, at times exponentially, as larger and larger machines were acquired, even though the cost per calculation kept declining.

When the PC made its debut, the first machines were small and essentially toys. However, they evolved quickly into efficient competitors for many tasks as storage devices improved, processor capacity and speed increased, and memory grew. Moore's law, named for Intel co-founder Gordon Moore, ruled. Moore stated that the number of transistors that could be stored on a chip would double every two years, which is roughly what has happened. As a result, over three decades, mainframes and their supercomputer successors have been relegated to limited and specialized uses.

Recent experience with development in new oil and gas frontiers such as the Tengiz field in Kazakhstan or the Sakhalin field in Siberia precisely follow the trend in computing. These fields are like mainframes. They will produce great volumes at decreasing per-unit costs when and if they come on stream. The expense and time to complete such projects, though, seems to rise at an exponential rate.

Meantime, fracking, a disruptive technology, makes low-cost manufacturing of oil and gas possible. The process began on a small scale. Over time, the technology's application evolved in the same way as PC use. Productivity has increased sharply as per-unit output costs declined, which is what happens in all manufacturing process. The relatively modest investment required to build a crude oil manufacturing plant (otherwise known as a fracking rig) guarantees that fracking will be a permanent and ubiquitous feature of the oil and gas business just as the PC is in the computing world.[3]

For those who might doubt this, Harvard researcher Leonardo Maugeri offers a chilling story. In a short paper titled "Why US Shale Keeps Booming," Maugeri cites developments in gas production from the Marcellus shale. He writes that falling drilling and development expenses have increased productivity in the Marcellus and Haynesville shale plays. Drilling has continued despite the collapse of natural gas prices thanks to "Draconian cost reductions."

The effect of the ongoing drilling is evident in the natural gas price. Figure 1 (page 3) displays the price per million Btu (mmBtu) at the Henry Hub from 2005 to 2014. Prices have remained between $3 and $5 ($18 to $30 per barrel in oil equivalents) since 2009 after peaking at $13.50 in the summer of 2008 ($80 per barrel oil equivalent). Prices in the Marcellus shale have generally averaged $1 to $2 per mmBtu less than the Henry Hub prices.

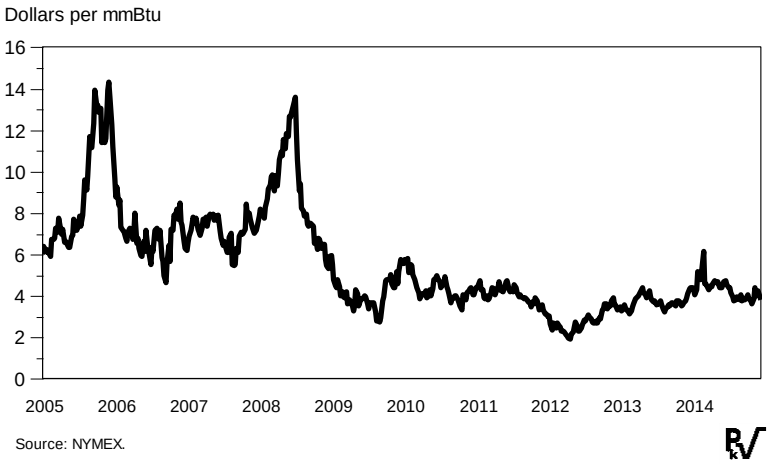
Perhaps more telling is the rig count in the Marcellus, which peaked at the end of 2011 at one hundred forty and has since declined to one hundred. The remaining rigs have become more productive, however, and as a result incremental output is still rising, even with the current low prices. Figure 2 (page 3) provides an illustration. This graph compares the active rig count in the Marcellus to the US Energy Information Administration's estimate of the wells' incremental gas production in their first month of operation. The latter data confirm Maugeri's comment that production has climbed even as the number of operating rigs has fallen.

[3] If the analogy continues, one must identify the oil and gas equivalent of the smartphone and tablet. The vexing problem, though, is that, whereas computer use has increased exponentially, consumption of hydrocarbons must decrease due to the constraints of increasing efforts to combat global warming.

Maugeri extends his analysis to shale oil, suggesting the results could apply there as well:

> For example, McKenzie County, North Dakota, is the most prolific area of the Bakken Three Forks formation, with an average output of almost 350,000 barrels per day, or more than one third of the total Bakken production of 1,132,000 bd as of August 2014. The McKenzie break-even point (including a 10 percent rate of return) is $28 per barrel.[4]

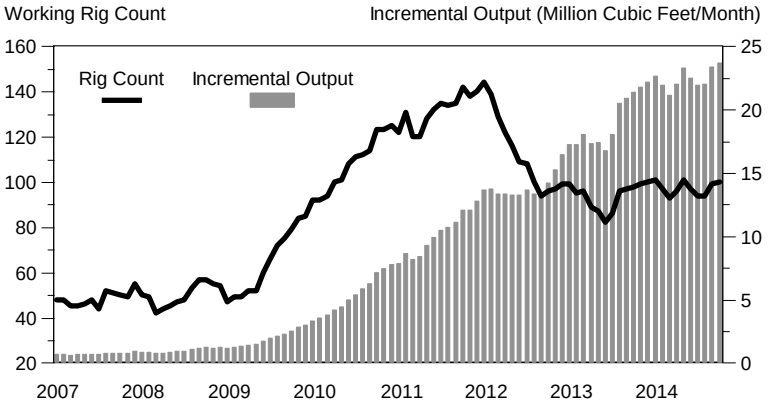
Figure 1
Weekly US Natural Gas Price at Henry Hub, 2005 to 2014



Source: NYMEX.

Maugeri adds that the breakeven point for oil produced in Divide County, North Dakota, is $85 per barrel. For the Bakken as a whole, he finds that eighty percent of the oil produced there now has a breakeven point below $42 per barrel.

Figure 2
Marcellus Shale Operating Rig Count vs. New Incremental Natural Gas Output from Wells Drilled in a Month, 2007 to 2014



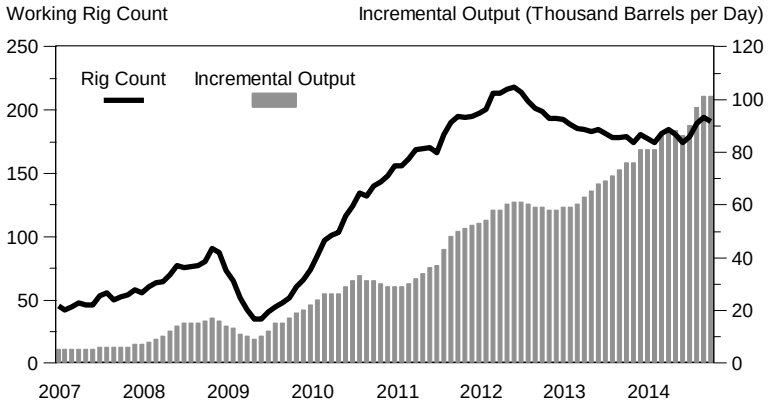
Note: The incremental output includes only the output from the well during its first month of production.
Source: US EIA.

While Maugeri's calculations cannot be independently verified, EIA data confirm his conclusion. Figure 3 (page 4) presents the same type of information as Figure 2 for the Bakken. The EIA data show that working rigs in that area peaked in June 2012 at two hundred sixteen. The aggregate daily production from the wells drilled by those rigs in June was sixty thousand barrels per day. This October, the working rig count fell to one hundred ninety-one as the aggregate incremental output rose sixty-seven percent to one hundred one thousand barrels per day. The productivity improvement per rig was ninety percent in just over two years.

[4] See Leonardo Maugeri, "Why US Shale Keeps Booming," *Global Energy Trends*, Briefing 2, November 19, 2014 [http://goo.gl/wpBu9I].

Mark Papa, the retired chairman of EOG Resources, one of the most successful developers of oil shale properties, provided further color on productivity improvement in a Wall Street Journal interview:

Figure 3
Bakken Operating Rig Count vs. New Incremental Crude Oil Output from Wells Drilled in a Month, 2007 to 2014



Note: The incremental output includes only the output from the well during its first month of production.
Source: US EIA.

> "Where we sit today with shale is the same place a petroleum engineer sat in the 1940s with a conventional sandstone reservoir," Mr. Papa says. The best recovery rate then was 10% to 15%, leaving the rest underground, much like shale now—but since has climbed to 40% or 50%. The technology doesn't yet exist for shale to yield similar shares, but Mr. Papa is confident that over the next 10 years it will emerge, "which basically means we're going to double or more the amount of oil we're going to recover. . . . Technology is always going to find a way to unlock each increment of resources."[5]

Papa, Maugeri, and others who have followed the fracking revolution closely make it clear that this is now a manufacturing business. Like all manufacturers, the frackers will record increasing output, falling unit costs, and declining fixed costs.

Papa and Maugeri also understand that the firms executing this business model will slow down but not stop as prices decline, even if the decrease is fifty percent or even greater. They also recognize that the technology changes and operational scale will enable these firms to restart operations quickly once prices recover. They know the equipment will not vanish. They realize that the labor force can be assembled rapidly, and they comprehend that the institutional knowledge will not be lost.

As yet, however, no observer has noted another development that will certainly follow: the migration of oil and gas manufacturing to countries where costs are lower. The oil volumes produced by fracking in other nations will almost surely surpass the US output within the next ten years and perhaps even the next five years. The cost associated with the new manufacturing plants will be low and the productivity will be higher. As with natural gas in the United States, the world will be awash in oil. The main Middle Eastern exporting nations will still be able to produce oil at lower prices, but their realizations will be in the $30 to $50 per barrel range at best.

The major integrated oil companies that have invested billions in large projects in difficult environments will face serious difficulties. Just as the BUNCH computing group had to transform or vanish, firms such as BP, ConocoPhillips, Eni, Petrobras, Shell, and Statoil will have to make drastic changes. Even the

[5] Joseph Rago, "The Oilman to Thank at Your Next Fill-Up," *The Wall Street Journal*, December 5, 2014 [http://goo.gl/6B5idz].

world's largest, most successful private companies, ExxonMobil and Chevron, will need to make radical adjustments.

Quite simply, the path for global oil and gas prices is down from here. Of course, we will see episodes of sharp increases caused by supply disruptions. The first will almost certainly come in 2015 when Venezuela's economy collapses and political unrest erupts. Other instances will follow. In the longer run, though, the price direction appears inevitable, especially given continued pressure across the globe to limit fossil fuel consumption.