Business Cycles and Innovation Cycles in the U.S. Upstream Oil & Gas Industry

BY ROBERT L. KLEINBERG AND MARIE N. FAGAN

Introduction

When oil and gas prices are declining and low, "innovation" is frequently invoked as the key to continued petroleum industry viability and profitability. But what kind of innovation can be expected on the short time scales – on the order of a year – invoked by industry executives, analysts, and the press?

Efficiency, process, and technical improvements, which do not require significant research and development investments, continue independent of business cycles. These classes of improvements can indeed increase production and reduce costs over relatively short time scales. On the other hand, major technological innovations that require sustained investments of human and financial resources can take a decade or more to mature. In this research, we develop insights that can help the upstream oil and gas industry—exploration and production (E&P) companies as well as service companies—better understand oil price and innovation cycles. Our approach combines a top-down econometric analysis of innovation efforts, and bottom-up case studies of innovation results. An extended treatment of this work is published elsewhere [Kleinberg & Fagan, 2019].

Econometric Analysis

How does innovation effort respond to changes in the business cycle? Do service companies and exploration and production companies behave in the same way? In this section, we use company-level data and an econometric model to shed light on these questions. R&D spending is an input into the innovation process, not an output, so it serves as an appropriate metric for innovation effort, though it is not a measure of innovation itself. Details and quantitative results of our econometric analysis are presented elsewhere [Kleinberg & Fagan, 2019]. We summarize our methods and findings here.

We examined R&D spending across two long oil price cycles. Exploration and production (E&P) companies are represented by the set of companies which have reported to the Energy Information Administration's Financial Reporting System (FRS). This data set encompasses U.S.-based energy companies and the U.S.-based subsidiaries of public foreign oil and gas companies that had at least 1% of U.S. oil or gas production or reserves in a given year. For this reason, the data set is focused on R&D spending in the United States. The companies which comprise the FRS data set have changed over time as energy companies have been involved in mergers, acquisitions, and spinoffs. The oilfield service companies are represented by Schlumberger, which is a very large presence in the service industry, with R&D spending (on a global basis) often equal to or greater than the combined R&D expenditures of its major competitors, far larger than all but the largest global oil companies, and at a level which has sometimes even exceeded R&D spending of the FRS companies as a group.

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A shown in Figure 1, the surge in oil prices in the late 1970s seems to have supported interest in innovation by both U.S.-based E&P companies and oilfield service companies (represented by Schlumberger). For the E&P

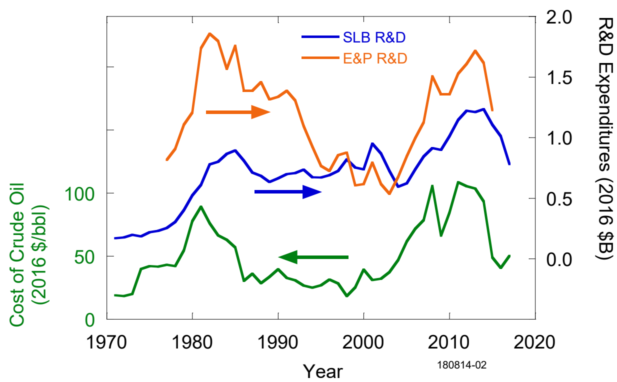

Figure 1. R&D expenditures and oil prices. Green line: Refiner acquisition cost of crude oil [EIA, 2018]; Blue line: Schlumberger R&D spending, [Schlumberger, 2018]; Orange line: E&P R&D spending [IHS Markit, 2017]. All data are in real (2016) dollars [Census Bureau, 2017]. The complete list of FRS companies is available at [EIA, 2010].

companies, R&D spending on oil and gas recovery surged immediately with rising oil prices in the late 1970s; then declined along with weakening oil prices. The same pattern emerged in a second upswing, during the oil price surge of 2000-2007. And, as in the 1980s, when oil prices later collapsed, the E&P companies cut back R&D precipitously.

Schlumberger's R&D spending showed a different pattern. It increased much more gradually, and with a lag during the first oil price boom. Compared to the E&P companies, its subsequent decline was much smaller. It sustained its R&D spending during the low-price years of the 1990s. When prices boomed in 2000-2007, it raised spending, but again, much less dramatically, and again with a lag compared to oil prices and to E&P companies' R&D spending. However, since 2014, Schlumberger R&D spending has followed falling oil prices more closely.

Because it is clear from Figure 1, above, that the E&P companies' R&D spending has a different relationship to oil prices than Schlumberger's, we estimate separate models for Schlumberger and for the E&P companies. Quantitative results show that Schlumberger was less sensitive than the E&P companies to both ups and downs of the oil price cycle, and its response was symmetrical, i.e., about the same for an upturn or a downturn in prices. In contrast, the E&P companies' R&D spending was more cyclical. R&D spending responded more strongly to both increases in oil prices and oil price declines. This response was somewhat asymmetrical, as there was a larger impact on R&D spending from a decline in oil prices. Long-term elasticity estimates were larger than short-term estimates, as expected. For Schlumberger, these were about 3-4 times larger than the short-term estimates and were nearly symmetrical. For the E&P companies, the long-term elasticities were also substantially larger than the short-term elasticities, and they were asymmetrical with a larger response to an oil price downturn.

Case Studies

The econometric analysis helped to quantify the impact of the oil price cycle on innovation effort. What about innovation results? We turn now to case studies of specific technologies to illustrate the relationship of each stage of innovation to the oil price cycle, to help discover whether high and rising oil prices give birth to major innovations, or whether low or falling oil prices speed up innovations.

We partition innovation into four classes.

- Process and efficiency improvements. These are routine and continue through the life of an oil or gas field independently of business cycles.
- Technical improvements. These are innovative but do not require significant R&D investment. These too typically continue irrespective of business cycles.
- Major technological inventions. These require substantial R&D resources in order to be brought to market.
- Industry-changing innovations that profoundly affect oil or gas supply. An example from the twentieth century is secondary oil recovery by water flood or reservoir pressure maintenance. A more recent example is the combination of horizontal well construction and staged, massive hydraulic fracturing.

Process and efficiency improvements. The business cycle is not the only driver of oil and gas industry development. Each newly discovered resource poses challenges that must be overcome in the course of its development. Early in the development cycle of these emergent resources, costs increase rapidly. Later, costs decline due to process and efficiency improvements. In some circles this has been called innovative, and there is no doubt a great deal of practical ingenuity involved, but such developments are widespread, generally predictable, and do not rely on research and development investments.

Technical improvements. We define technical innovation as activities that require new, adopted, or adapted engineering solutions, but not necessarily requiring substantial research and development efforts. Pad drilling and super fracks are examples of technical innovations that reflect good engineering practice and optimization. They do not require substantial R&D expenditures and, like process and efficiency improvements, they are unaffected by business cycles.

Major technological inventions. Elsewhere [Kleinberg & Fagan, 2019] we present five case studies illustrating the course of technology development in the oil and gas industry. All required significant research and development investments. The case studies reveal a general pattern of development, superimposed upon which are variations specific to individual technologies. We observe that in many cases technologists lay the scientific ground work and perform proof-of-principle demonstrations independently of the business cycle. When energy prices are rising and high, R&D is accelerated by financial and human resources that pour into oilfield research and development. Nonetheless, major technological developments in the petroleum industry tend to mature slowly. The development of sophisticated geophysical technology is difficult; many problems of measurement physics, electrical engineering, and mechanical engineering must be overcome. Another barrier is inherent in the structure of the industry. Rig time is a major expense of drillers and the risk of losing a well to borehole collapse is an ever-present danger. Thus, there is significant resistance to innovators who wish to test prototype equipment in wells. These factors combine to lengthen the upstream oil and gas technology development cycle; ten years or more from concept to commercialization is the norm. It is frequently the case that by the time innovations are widely deployed, resource prices and business activity have declined, and return on investment is delayed.

The role of government and academic institutions

Research in government laboratories, government support for external research, and academic research have played important roles in oil and gas industry technology development. The public is sensitive to changes in energy prices, and officials respond by creating programs that address societal concerns. Similarly, university programs react to faculty and student interest in the problems of the day.

The closer a product or technique is to commercialization the more its success depends on closely following the evolving demands of the market. The research and development divisions of industry participants maintain a level of contact with their operating groups and clients that cannot be replicated in an academic environment. Thus, outside of narrowly targeted investigations with near-term deliverables, academic and government programs are best directed to long-range objectives beyond the scope of in-house industrial R&D [National Research Council, 2014].

Discussion

We have shown that upstream oil and gas innovation efforts grow during periods of rising and high product prices, and shrink during periods of falling and low prices. We have also shown that product development cycles that depend on significant research and development investments are typically a decade or more in length. Economic cycles can have similar lengths, but because human and financial investments in R&D inevitably lag price signals, substantial support for a project may not commence until the midpoint or even the end of a economic upturn. Bringing a project to a successful conclusion often requires continuation of support during industry downturns.

By the time a product has been tested and enters the market, commodity prices may have collapsed, client interest in the innovation may have waned, and the rate of market growth is stunted. As a result, net present value forecasts based on market conditions at the commencement of a project may considerably overestimate the actual value of the innovation to the investor. In rare instances, as in the example of horizontal drilling combined with staged hydraulic fracturing ("fracking"), the widespread adoption of the technology itself is responsible for falling commodity prices [Braziel, 2016]. Exploration and production companies at large benefit from better upstream technology, but the innovators themselves can fail to capture the full value of the innovation.

The response of the U.S. petroleum industry to the mismatch between price cycles and technology cycles has been to de-risk technology development by outsourcing it. In the 1980s and 1990s the major oil companies, which had historically been drivers of oilfield innovation, downsized or closed their research and development operations. They looked to the oilfield service sector to take up the slack. In a second wave of outsourcing, service companies purchased technology by consolidation and by devouring start-ups, rather than developing it by organic growth [Schlumberger, 2014].

Ironically, the strategy of de-risking R&D risks undermining future technological prowess. Oilfield technology is not like information technology, where expertise can be developed quickly by youthful entrepreneurs. It is more akin to defense contracting or heavy machinery design, which benefit from innovators with long experience in their fields, who have access to a deep infrastructure of skilled technicians and specialized prototyping and test equipment.

While not unique to the upstream oil and gas sector, the mismatch between business cycles and development cycles is unusually severe there. Petroleum markets are unusually volatile; this is the reason gasoline prices are excluded from the U.S. core consumer price index. Moreover, the combination of front-loaded capital expenditure and substantial geological risk discourages the use of untried innovations. By contrast, in the consumer electronics and software industries, development cycles are shorter and the customer population is biased toward novelty, which speeds testing and acceptance. In the pharmaceutical industry, development cycles are even longer than in the upstream oil and gas sector, but market conditions are fundamentally more predictable.

Conclusions

Our results show that research and development efforts often follow the boom-bust pattern of oil price cycles while research and development results have often reflected sustained technical effort through market cycles. We conclude that industrial organizations willing to continue support for research and development through market declines – even if at reduced levels – are best prepared to benefit from ensuing market upturns. They are also best able to benefit from technological innovations coming from competitors or from outside the industry. A competitor's first-mover advantage can be minimized or quickly overcome by a technically adept fast follower.

Government, government-sponsored, and academic research has an important but limited role in technology development. Government and academic programs work best when they are dealing with long-range problems industry is not yet tackling, and may seemingly be of little interest to it. Even more importantly, because we are unable to accurately forecast future commercial and technology needs, the training of the next generation of scientists and engineers should be a national priority.

The future of upstream oil and gas innovation is unclear. On one hand, the attention of governments, the public, and the capital markets, is on renewable energy sources and technologies that reduce the demand for fossil fuels, such as more efficient and battery powered vehicles. On the other hand, reference case [EIA 2018d] or stated policies [IEA, 2019] forecasts predict that oil consumption is likely to remain steady through 2040. The natural decline of hydrocarbon reservoirs averages 6% per year for conventional oil fields [IEA, 2013], and fields producing tight oil, which now accounts for about 5% of the global crude oil market, decline even faster [Kleinberg et al., 2018a]. With world oil production at 100 million barrels per day, this implies that at least 6 million barrels per day of new production will need to be developed every year. It remains to be seen whether major innovations in the upstream oil and gas industry will be required to meet this demand.

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