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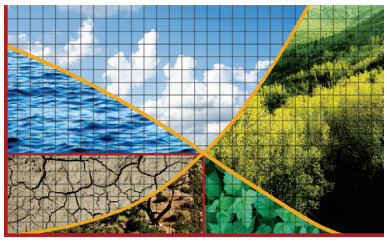

EXPERIENTIAL AND SOCIAL LEARNING IN FIRMS: THE CASE OF HYDRAULIC FRACTURING IN THE BAKKEN SHALE*

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Overview

How firms learn to use new technology is an important determinant of economic growth. Researchers, however, have difficulty observing what firms know about their production process—and therefore how they learn to use new technology.

Public reporting requirements that require firms to disclose information about their production functions are used in this study to examine whether firms change their production design over time to more closely approximate an optimal production design. Doing so would reduce the amount of money "left on the table" due to poor implementation of new technology and would increase profits.

The results suggest that firms *do* learn over time. However, they learn slowly and do not fully utilize information from other firms' experience.

Background

Any firm utilizing a new technology faces a tradeoff. The firm must either learn how to use new technology more efficiently through experimentation or try to maximize production with their current understanding of the technology. Experimentation may lead to increased profits, but it may also result in lower levels of production than current best practices. If the only result of experimentation is the latter, the firm will earn lower profits in the long run than if they did not experiment. Thus, experimentation offers the opportunity for higher profits, but with greater uncertainty about profits. Previous research has suggested that firms will do some experimentation and spend the rest of the time maximizing production based on their current understanding.

Hydraulic fracturing is a new technology that involves cracking oil-bearing shale rocks with high pressure water and then "propping" the cracks with sand to allow the oil to flow out of the wellbore. Firms must identify the best combination of sand and water to maximize the production of hydraulically fractured oil wells. Because of the unique reporting requirements in North Dakota, firms can learn from other firms' experimentation with various combinations of water and sand, as well as their own.

Using the information that firms report to regulators, an oil-production function is developed for wells, based on water, sand, and well-length inputs. The production function also considers well location to account for heterogeneity in the geological formation. With this location-specific production function, expected profits for all wells drilled in North Dakota's Bakken field from 2005 to 2011 are calculated based on the reported well design. Expected profit is

then calculated in two additional cases. In the first, expected profit is calculated using the well design the information available at the time of drilling suggests was optimal. Case two calculates the expected profit of the design that the full information set (2005-2011) suggests is optimal.

Comparing the expected profits with the actual design to the expected profits in these two cases over time offers a measure of how much firms learn about the best way to use hydraulic fracturing.

Key Findings

1. **Firms capture more profits over time.** From 2005 to 2011 firms increased captured profits from 21% of possible to 67% of possible. The biggest increases were from 2006-2007 (25.9% to 45.6%) and 2009-2010 (48.6% to 64.1%). In dollar terms that means firms left $7.7 million per well on the table in 2011 compared to $19.3 million in 2008.

2. **Firms capture this profit by learning to use the technology more efficiently.** Over time firms choose fracking designs that are closer to the observed optimal fracking design. For example, in 2005 the average well used 100 pounds less than the optimal amount of sand. But by 2011 this fell to 39 pounds less than optimal. The story is similar for water use.

3. **Firms become more profitable without getting more productive.** Well productivity (the amount of oil produced by a well with a set level of inputs) did grow slightly in the earliest years but there was no change in productivity from 2008-2011.

4. **Firms fail to choose the design the data available at drilling suggests is optimal.** While designs get closer to the optimal design over time, firms tend to choose fracking designs that are known to be suboptimal at the time the choice is made. However, these suboptimal choices tend to have more certain expected profits than the optimal designs.

5. **Firms learn more from their own experiences.** Despite having access to competitors' information, firms tend to overweight their own experience when making decisions.

Conclusions

The results of this study indicate that firms do learn how to use hydraulic fracturing technology better by experimenting over time. They capture an increasing share of profits by using the technology more optimally. However, they prioritize designs that are suboptimal but have lower uncertainty regarding expected profits. This is consistent with firms both experimenting and maximizing production when learning to use new technology. However, the research highlights that even in an industry with well-financed, technically-sophisticated leaders, firms are reluctant to experiment and do not trust data generated by their peers.

Full paper available at: http://heep.hks.harvard.edu/publications/experiential-and-social-learning-firms-case-hydraulic-fracturing-bakken-shale

About the Program

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