FROM HOTELLING TO DCDP MODEL: A NEW APPROACH FOR MICROECONOMIC EMPIRICAL WORK IN OIL AND GAS EXTRACTION

Jinmahn Jo, University of California – Davis, +1 7347809282, jmjo@ucdavis.edu
Mark Agerton, University of California – Davis, +1 5307528490, mjagerton@ucdavis.edu

Overview

How useful is economic theory model in understanding the decisions of fracking firms in the oil and gas industry? Anderson, Kellogg, and Salant (2018) (AKS) was successful in understanding the observed facts that for oil and gas extraction, drilling activity covaries with oil prices, while production from existing wells does not respond to price shocks. They reframe the Hotelling model of the optimal extraction of a nonrenewable resource as a drilling problem. However, the model is limited in its ability to rationalize why firms extract simultaneously from low and high quality deposits. In this research project, we rationalize the observed behavior by reformulating the Hotelling/AKS model to 1) incorporate resource quality and 2) combine it with Rust-style discrete choice dynamic programming (DCDP). We then use data from North Dakota to empirically test our model.

Methods

The three main goals of this research project are:

- to construct a model of drilling behavior for how geological features affect which wells and how fast wells are developed;
- to study the model's predictions; and
- to validate the model empirically

We modify the AKS model in two ways. First, we introduce heterogeneity in resource quality. Second, we allow firms to experience deposit-specific cost shocks. These modifications lend themselves to a Rust-style DCDP framework. The cost shocks serve to rationalize observed behavior without explicitly modeling capacity constraints or unrealistic cost functions to the model.

The model predicts that:

- firms will drill low- and high-quality resources at the same time;
- the probability of a particular location being drilled is increasing in resource quality; and
- negative price shocks like one during the second half of 2014 will cause firms to halt drilling of low-quality resources

We estimate the DCDP model of extraction conditional on resource quality and oil price.

It is essential to estimate the geological characteristics of each well site to validate the theory-based predictions. However, in general, such properties are unobservable. We employ Robinson's partially linear model that deals with the spatial distribution of geological properties nonparametrically to overcome this obstacle.

Results

We analytically show that the AKS framework cannot rationalize the first prediction without needing capacity constraints or unrealistic cost functions. In addition, we demonstrate the model's properties using simulation. We also show how the model accommodates both exogenous and endogenous prices.

Leaning on the model, data on drilling and production in North Dakota's Bakken shale reveal three things:

- As the model predicts, firms have not drilled their well locations in decreasing order of geological quality (i.e., they have drilled low- and high-quality resources simultaneously).
- The probability of a deposit being drilled is increasing in resource quality.
- Drilling of low-quality resources responded more to the negative price shock in 2014.

Conclusions

This paper represents an advance in the theory of nonrenewable resource extraction. While the dynamic nonrenewable resource models discussed in the literature can make general predictions, they are not well suited for empirical work, and they cannot rationalize some of the behavior we see in practice. The rise in availability of detailed data on extraction has allowed the profession to study the sector in new ways. We show how to marry theory and data in a unique approach that can leverage the new data and still make predictions based on the theory of nonrenewable resources.

References

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