# *INVESTMENT DECISIONS IN THE EAGLE FORD SHALE: REDUCED FORM EVIDENCE FROM A DYNAMIC GAME*

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## Overview

This paper presents descriptive statistics, visualizations and reduced-form evidence about what drives producers' upstream investment decisions in the Texas Eagle Ford Shale. The dataset is unique and comes from DrillingInfo's comprehensive databases, which cover all stages of upstream investment from leasing through last production.

Firms operate within a dynamic, strategic context and can observe one another's actions and production outcomes. They must balance the incentive to delay investment (at any stage) until competitors' actions provide information about nearby locations with the scarcity of leases and potential gains in productivity from learning. This means that in addition to prices and costs, spatial and temporal variation in firms' information sets influences their valuation of different investment opportunities. This translates into observable investment behavior. My paper is the initial stage of a larger project to estimate a dynamic, game-theoretic model of producers' investment behavior in a shale play.

The Eagle Ford Shale in Texas is one of the newest areas (historically speaking) for oil and gas development in North America. It is also one of the most active plays, which makes it highly interesting to industry players. The Eagle Ford is an ideal place to study shale investment since I can observe the complete life-cycle of investment decisions. First, since the vast majority of leases have been signed in recent years, they are recorded in my dataset (in contrast with other areas). Second, since the play is divided into gas and oil-bearing regions, I am able to observe firms make exit decisions in regions with dry-gas when gas prices drop. Third, I can leverage a large quantity of detailed microeconomic data on the four stages of investment in my dynamic game: 1) leasing and land-grabs, 2) initial development to hold a field with production and gain information, 3) further development with infill drilling, and 4) exit if the lease expires before development occurs.

My reduced form analysis measures the degree to which firms' investments at each stage respond to temporal and spatial variation in prices, costs, competitors' actions and new information about geologic productivity. The insights from this analysis will shape an econometric model of the dynamic investment game that upstream firms play. Because they are empirical and account for the multi-stage nature of upstream investment, my results should provide a more nuanced understanding of the elasticity of shale production with respect to prices than standard estimates based on calculation of break-even costs.

## Methods

I use data from DrillingInfo. These include detailed data on leasing, production units, wells, permits and production outcomes.

To inform empirical analysis, I outline a dynamic, game-theoretic model of shale investment in which producers use information on competitors' actions and outcomes to evaluate their own portfolios of investment opportunities. This builds on Lin (2013), who estimated a simple dynamic investment game for single pairs of offshore wildcat tracts. Recent advances in empirical games by Fox (2010) and Bajari, Benkard and Levin (2007) have shown it is possible to estimate much more complex games with multiple equilibria without the computational burden of explicitly solving the game.

Finally, I estimate a series of reduced-form discrete choice models concerning each stage of investment—leasing, initial drilling, infill development and exit—using data on prices, costs, competitors' actions and nearby production outcomes.

## Results

First, I motivate my analysis by outlining a dynamic upstream investment game. This brief section provides a framework that guides my analysis.

Second, in addition to descriptive statistics, I create sophisticated visualizations of each stage of investment to understand the broader spatial and temporal patterns of activity for each stage of investment. I relate these to my model and show how the game I propose has been realized.

Third, I estimate a number of discrete choice models to see how producers' decisions vary with the addition of new information, competitors' actions, prices, costs and the volatilities of the latter.

Fourth, I relate my reduced-form results back to the dynamic game I outline and, in particular, the following questions: How do prices and costs impact the value of each stage of upstream investment? What information about potential well productivity is available to firms, and how do updates to the information influence decisions to invest? Which stages of the investment involve learning-by-doing or strategic interactions?

## Conclusions

My analysis, though not fully complete, will help readers in industry, policy and academic circles get a comprehensive understanding of the temporal and spatial pace of multi-stage upstream investments within the Eagle Ford Shale. Results from the reduced form models will provide further insight on how firms respond to prices and costs, as well as new information on nearby competitors. Understanding the price, cost and productivity thresholds for each stage of investment will be of use to industry and policy analysts interested in forecasting production and understanding how future plays may develop.

## References

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