

# Adjustment Cost, Uncertainty, & the Proved Reserves of Crude Oil



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## Abstract:

Why do firms hold large amounts of proved reserves relative to crude oil productions? To answer this question, we build a simple deterministic and a stochastic model. In the deterministic model, we find a delayed response is necessary for the firm to hold proved reserves while adjustment costs govern the periods of delay. In the stochastic model, this result still holds. We find uncertainties from demand and exploration lower the firms' optimal productions and thus resources would be exhausted within a longer period. The stochastic model predicts that firms would hold larger proved reserves than productions either if the demand volatility is much smaller than the interest rate or if the exploration volatility is not noticeably larger than the interest rate. By using U.S. data, we verify that this prediction is empirically relevant.

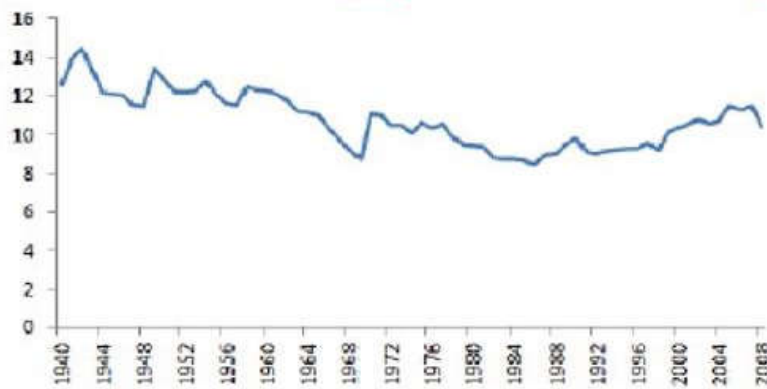


## Research Question

Why do firms hold large amounts of proved reserves relative to crude oil productions



Why does the ratio of proved reserves to productions remains relatively stable over time



— US Crude Oil Proved Reserve/Production

## Results

### Deterministic Model

- A delayed response is necessary for the firm to hold proved reserves while adjustment costs govern the periods of delay.
- However, the deterministic model solely relies on the periods of delay to explain the stylized facts.
- It fails to account for why the ratio of proved reserves to productions declines slowly or even remains stable.

### Stochastic Model

- Uncertainties from demand and exploration *lower* the firm's optimal productions.
- Thus the stock of oil in place would be exhausted within a *longer* period.
- The stochastic model predicts that a firm would hold larger proved reserves than productions
  - if the demand volatility is much *smaller* than the interest rate,
  - or if the exploration volatility is *not* noticeably larger than the interest rate.

## Method: Stochastic Optimal Control

### Basic setup

- We consider a representative firm that maximizes the lifetime profits by choosing an optimal plan of oil discoveries and production over time.
- Use the concept of adjustment cost and delayed response in a deterministic model.
- Due to the delay between resource discovery and production, a firm makes decisions on how fast the resources are moved to the proved and then production stage.
- Adjustment costs associated with the fact that moving discoveries quickly to the proved and then production stage is more costly than doing it slowly.

### Stochastic specification

- Examine how demand and exploration uncertainties affects the crude oil production and the accumulation of proved reserves.
- Demand and exploration uncertainties are added to the deterministic model.
- Explicitly solves the analytical solutions of expected productions and proved reserves.

## Conclusion

- There are important delays and adjustment costs in transferring resources from the oil-in-place stock to the production stage.
- The *larger* is the delayed periods, the *more* likely the firm will reach production quickly.
- The intuition behind the stochastic model suggests that proved reserves refer to *expected future productions* within the delayed period, different from the oil in place.
- Although uncertainties lower productions and leave more resources as oil in place, proved reserves may not necessarily increase.



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