

Learning Where to Drill

Drilling Decisions and Geological Quality in the Haynesville Shale

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Learning has increased shale productivity

- ▶ Production process: *how* to drill
 - How does output respond to inputs, experience?
 - Improve well drilling, design

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 - Which locations produce more?
 - Focus drilling on “sweet spots”

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 - *Learning hastens depletion*

How vs where matters for supply

	How	Where
Increasing output/well in SR	technology	targeting
All locations produce more	yes	no
LR depletion	delayed	accelerated

- ▶ Ignoring that firms choose where to drill \implies biased forecasts
 - 1) Underestimate depletion: drill best first
 - 2) Overstate technology: confound where & how

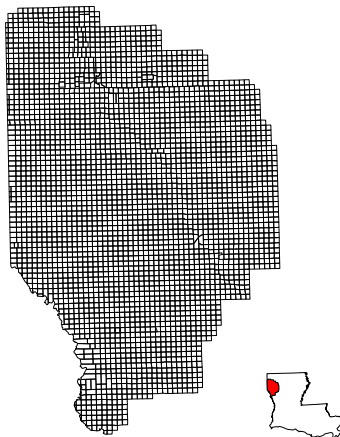
Research question: How bad could it be?

- 1) What do firms know about quality of locations they drill?
 - How does this affect their drilling decisions?
 - What do they learn by drilling?

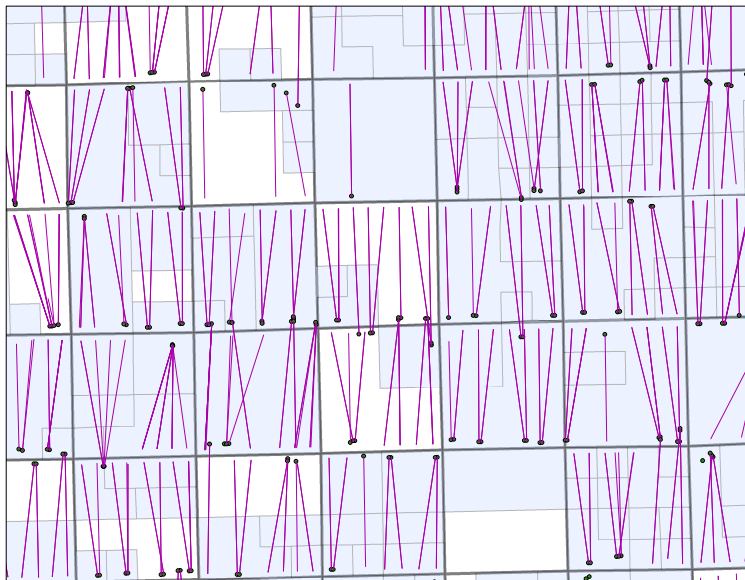
- 2) Quantitative implications for supply
 - Short run: is learning sufficient to increase average output/well?
 - Long run: how severe are depletion effects?

Unit of observation: 1 sq mi section

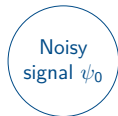
- ▶ Louisiana's Haynesville shale (2003–2016)
- ▶ Unit of observation: 1 sq. mile section
- ▶ All parties in a section must participate in each well



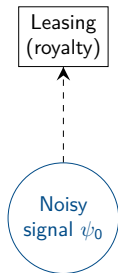
Join data to form investment history



What firms know & learn affects 3 outcomes



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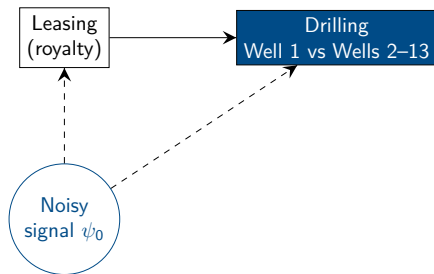


Avg royalty rate

r_i

section i

What firms know & learn affects 3 outcomes



Avg royalty rate

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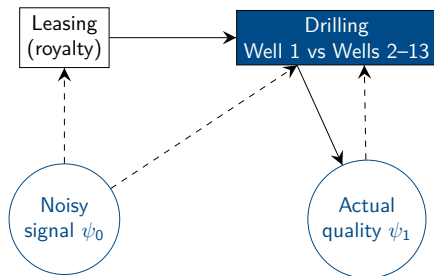
section i

Num wells drilled

d_{it}

section-month it

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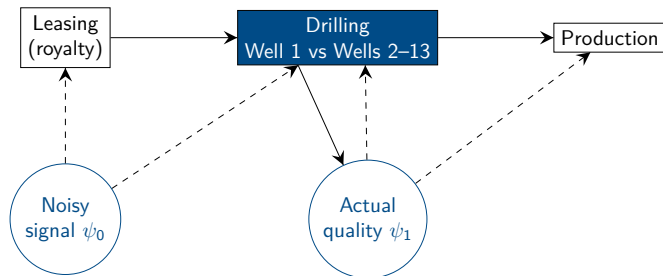
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Production

$\log q_{iwt}$

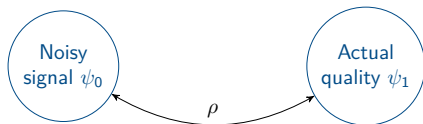
section-well-month iwt

What firms know & learn affects 3 outcomes

Leasing
(royalty)

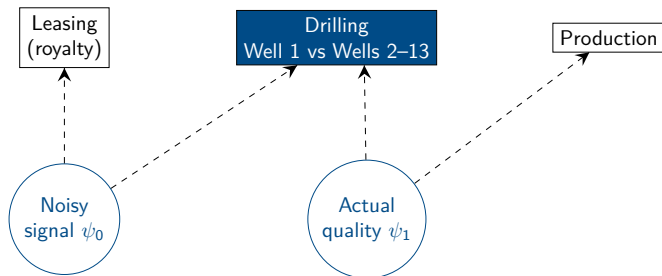
Drilling
Well 1 vs Wells 2-13

Production



1) **Informativeness of signal:** ρ

What firms know & learn affects 3 outcomes



- 1) Informativeness of signal: ρ
- 2) **Effects of information:** ψ_0, ψ_1

Econometric model: features & estimation

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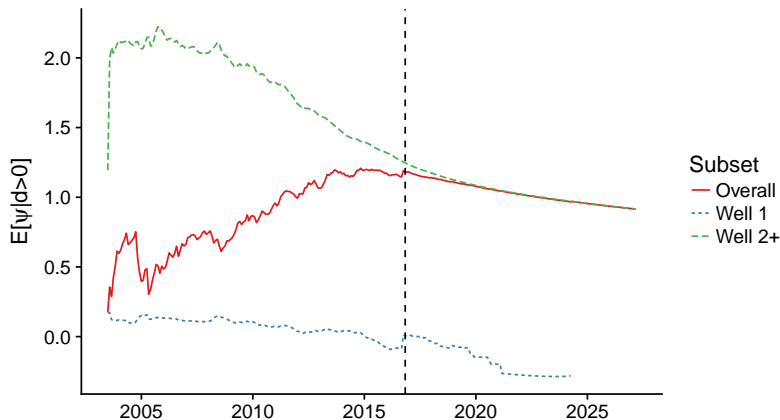
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- ▶ Royalty rate & Production
 - Help measure unobserved information

Econometric model: features & estimation

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- ▶ Drilling
 - Dynamic discrete choice: # wells to drill/month
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- ▶ Royalty rate & Production
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- ▶ Estimation: Maximum Simulated Likelihood
 - Rust (1987) nested fixed point approach for drilling
 - 3 outcomes linked by information (unobserved)
 - Integrate out signal & quality to recover distribution

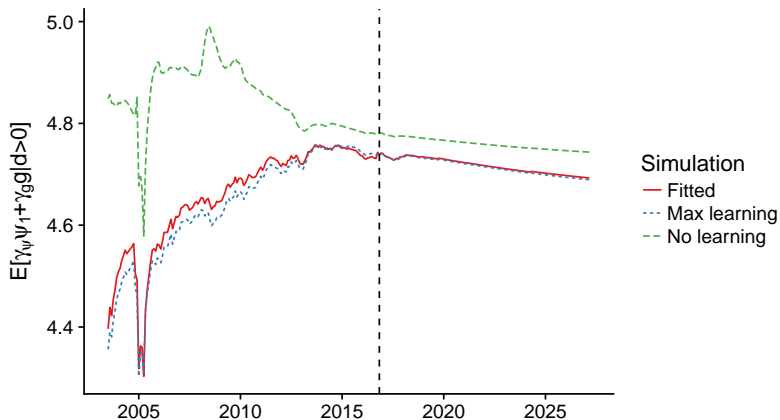
Simulation: mean productivity of wells drilled



► 2 phases

- 1) Learning: 15% growth over 2008–16
- 2) Depletion: -0.4%/yr decline over 2016–24

Simulation: well productivity with, without learning



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 - Are companies learning about *where* to drill? Yes!
 - They have noisy initial signals,
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 - Could this contribute to rising production/well? Yes!
 - How bad are depletion effects? Moderate.
 - Is Malthus slouching towards shale supply? No.