Anatomy of a Shale Boom
The Case of the Eagle Ford Shale

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Enablers of US shale are unique

- Private ownership of mineral rights
- Low barriers to entry
- Robust services sector
Private ownership of mineral rights

- Aligns interests of landowners & firms
  - Rents go directly to landowners
  - Decreases political resistance

- Purchasing leases requires
  - Costly searching
  - Many bilateral negotiations

- Versus ownership by crown
Low barriers to entry in US shale

- Entire onshore upstream value chain is extremely competitive
- Common services purchased from third-party firms
- Smaller capex (not mega-projects)
Why worry about dynamics?


- Need to understand agents’ outside options to predict negotiated prices

- Landowner’s outside option is waiting for the next firm

- This is a non-stationary, dynamic problem (fewer acres each period)
Research question

- How does leasing-market evolve over time, accounting for
  - Equilibrium interactions of firms & landowners
  - Depletability of leases and resources
  - Forward looking agents

- How are rents distributed between E&P firms and landowners?
What the model tells us

▶ When is it best to be a landowner or a firm?
▶ How well do landowners monetize their assets?
▶ Implications for taxing authorities?
Eagle Ford Shale ($\approx 33k \text{ km}^2$)
**Competitive leasing market**

<table>
<thead>
<tr>
<th>Acreage share</th>
<th>Firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>5–6.5%</td>
<td>2</td>
</tr>
<tr>
<td>2–4.99%</td>
<td>9</td>
</tr>
<tr>
<td>1–1.99%</td>
<td>13</td>
</tr>
<tr>
<td>&lt;1%</td>
<td>1365</td>
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</tbody>
</table>
Leasing is rapid
Most surface area is leased
Leasing precedes drilling

Oil

Wet Gas

Dry Gas

Leases (sq km)

Wells

Agerton (Rice Univ) Eagle Ford context
Key ideas in model

- Lease value derived from depletable resource
- Forward-looking agents
- Depletability $\implies$ nonstationary world
- Decentralized lease-market
  - Costly random search
  - Many leases per firm
  - Bargaining
Key assumptions

- Continuous time, complete information
- Finite and homogenous land
- Competitive firms
- And firms are “big” while landowners are “small”
  - Match arrival is random for landowners
  - But deterministic for firms
  - Use Acemoglu and Hawkins (2014) labor-search model
Land and landowners

\[
\bar{A} = \bar{A}^N + \bar{A}^S
\]

Unleased acres

\[
u = \bar{A} - A
\]

can’t go below \(\bar{A}^N\) so

\[
u \in [\bar{A}^N, \bar{A}]
\]

Probability match is with seller (vs non-seller)

\[
\sigma \equiv \frac{u - \bar{A}^N}{u}
\]
Matching

Aggregate searching by firms

\[ \bar{v} = n \times v \]

Aggregate matching function

\[ M(u, \bar{v}) = \bar{m} u^\mu \bar{v}^{1-\mu} \]

Market tightness, match-rates for firms and landowners

\[ \theta \equiv \frac{\bar{v}}{u} \quad q(\theta) \equiv \frac{M(u, \bar{v})}{\bar{v}} \quad \theta q(\theta) = \frac{M(u, \bar{v})}{u} \]

Individual firms’ acreage acquisitions:

\[ \dot{A} = v \times \sigma \times q(\theta) \]
Nash Bargaining determines acreage price

Define

\[ \psi_a : \text{Marginal value of acres} \]
\[ V^u : \text{Value of being unmatched} \]

Acreage price

\[ p_a = \arg \max_{p_a} [p_a - V^u]^\tau [\psi_a - p_a]^{1-\tau} \]
\[ = \tau \psi_a + (1 - \tau)V^u \]

Match surplus

\[ S \equiv \max \{\psi_a - V^u, 0\} \]
Landowner dynamics

Equation of motion for landowners’ value of being unmatched

\[ \dot{V}^u = -\tau S \times \theta q(\theta) + \rho V^u \]

- \( \dot{V}^u \) is the change in the landowner's value of being unmatched.
- \( \tau S \times \theta q(\theta) \) represents the share of surplus multiplied by the match rate.
- \( \rho V^u \) is the continuation term.
Firm’s problem

Pick searching \((v)\) and drilling \((h)\) activity to

\[
\max_{v,h} \int_0^T e^{-\rho t} \left\{ ph - c(h) - \kappa(v) - p_a \dot{A} \right\} d\tau
\]

subject to

\[
\begin{align*}
A &\geq H & \text{Lease before drill} \\
\dot{A} &= v \sigma q(\theta) & \text{Lease-rates} \\
\dot{H} &= h & \text{Drilling} \\
v &\geq 0 & \text{No resale of acres} \\
h &\geq 0 & \text{Irreversible drilling}
\end{align*}
\]
Equilibrium

Unique equilibrium given transversality conditions

\[
\dot{A} = \varphi \sigma^\beta \left(\frac{u}{n}\right)^{1-\beta} S^\beta \\
p = c'\left(\dot{H}\right) + (-\psi_h) \\
\dot{\psi}_a = \rho \psi_a \\
\dot{\psi}_h = \rho \psi_h \\
\dot{V}^u = (-\tau S) \varphi \sigma^\beta \left(\frac{S}{u/n}\right)^\beta + \rho V^u
\]

Where

\[
\varphi = \overline{m}^{1+\beta} \left(\frac{1-\tau}{\kappa}\right)^\beta \\
\beta = \frac{1-\mu}{1+\mu}
\]
Cumulative drilling & leasing

![Graph showing cumulative drilling & leasing with two lines labeled A and H.](image-url)
Equilibrium-searching
Match surplus determinants
Real lease prices decline

\[ e^{-\rho t} \psi_a \]
\[ e^{-\rho t} p_a \]
\[ e^{-\rho t} V^u \]
Model predictions

- Search frictions and landowners’ outside options play a meaningful role in limiting rate of leasing
- Landowners always get $\tau$ or higher share of Hotelling rents
- Landowners’ share (acreage price) decreases over time
- Scarcity only limits rate of price decrease... scarcity $\not\Rightarrow$ price increase
- Leases are allocated optimally
Future directions for research

- Compare leasing allocation mechanisms in terms of
  1) Ability to match data
  2) Efficiency

- Modifications
  - Heterogeneity in firms’ productivity and landowners’ disutility of drilling
  - Principal–agent contracts
  - Directed search


Timmins, Christopher and Ashley Vissing (2014). Shale Gas Leases: Is bargaining efficient and what are the implications for homeowners if it is not? Duke University.