Technical Efficiency among Gas Producers in the Barnett Shale Play

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Outline

• Introduction
• Data
• Methodology: SFA and MLM
• Results
• Conclusion
Introduction

• Barnett shale play has the longest production history among US shale plays
• Drilling activities began in the early 1980s but only picked up significantly during mid-2000s
• Gas production increased as a consequence of increased number of wells and improvements in technology (horizontal drilling, longer lateral lengths)
• Variation in output among gas producers
• Given similar formation characteristics, producers differ in the amount of gas extracted
• This work in progress examines differences in technical efficiency among producers
Introduction

• Production frontier – maximum output that can be produced from a given set of inputs (output oriented def.)
• TE – ratio of a firm’s actual output relative to its potential output (production frontier)
• A firm on the frontier → fully efficient, below the frontier → inefficient
Data

- ~3,000 wells that began producing in 2009-2010
- More than 50 producers – five largest owned 75% of the wells. Devon (675), Chesapeake (607), XTO (501), EOG (336), Quicksilver (130)
- 17 counties – distribution of wells among counties also not uniform
- 90% of the wells drilled in 5 counties: Tarrant (934), Johnson (859), Wise (395), Denton (268), Parker (173)
- Output: natural gas produced during first 6 months
- Inputs: length, proppant (sand), fluid
- Geologic characteristics: thermal maturity, pressure, porosity, thickness
## Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev</th>
<th>P5</th>
<th>Median</th>
<th>P95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production (MMcf)</td>
<td>243.86</td>
<td>154.66</td>
<td>43.73</td>
<td>217.47</td>
<td>529.73</td>
</tr>
<tr>
<td>Length (ft)</td>
<td>3453</td>
<td>1108</td>
<td>1968</td>
<td>3323</td>
<td>5458</td>
</tr>
<tr>
<td>Fluid (bbl)</td>
<td>96383</td>
<td>114564</td>
<td>32012</td>
<td>85807</td>
<td>179831</td>
</tr>
<tr>
<td>Proppant (lbs)</td>
<td>2823295</td>
<td>2493480</td>
<td>647860</td>
<td>2204420</td>
<td>6554786</td>
</tr>
<tr>
<td>Thermal Maturity</td>
<td>1.312</td>
<td>0.131</td>
<td>1.100</td>
<td>1.287</td>
<td>1.534</td>
</tr>
<tr>
<td>Pressure</td>
<td>3488</td>
<td>395</td>
<td>2764</td>
<td>3521</td>
<td>4070</td>
</tr>
<tr>
<td>Porosity</td>
<td>0.059</td>
<td>0.006</td>
<td>0.050</td>
<td>0.060</td>
<td>0.069</td>
</tr>
<tr>
<td>Thickness</td>
<td>296.73</td>
<td>49.72</td>
<td>202.50</td>
<td>305.18</td>
<td>359.62</td>
</tr>
</tbody>
</table>
Methods

• Stochastic frontier analysis:
  • \( \ln(y_i) = \beta_0 + \beta_1 \ln(x_{i1}) + ... + \beta_k \ln(x_{ik}) + v_i - u_i \)
  • \( u_i \sim N^+(\alpha_i, \sigma^2) \)
  • \( \alpha_i = \delta_0 + \delta_1 z_{i1} + \delta_j z_{ij} \)
  • Each producer-well pair taken as a DMU
  • Producer-level efficiency scores calculated from efficiency estimates of the wells they own
  • Assumption: firms have the same production technology, environmental factors only affect distance from the production frontier
Methods

• Multilevel modeling:
  • not a frontier method but good for analyzing hierarchical data
  • wells are nested within producers, each well has its own unique geology
  • can estimate group (producer) effects directly
  • \( \ln(y_{ij}) = \beta_0 + \beta_1 \ln(x_{ij1}) + \ldots + \beta_k \ln(x_{ijk}) + \eta_i + e_{ij} \)
  • group effects: \( \eta_i \)
  • likelihood ratio test of the null hypothesis \( \eta_i = 0 \) rejected at the 1% level (basic MLM model)
  • between-group variance \( \sim 65\% \) of the total variance
  • MLM appropriate to use for the data
## Results - SFA

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>0.309*** (0.0337)</td>
<td>0.325*** (0.0345)</td>
<td>0.312*** (0.0336)</td>
<td>0.289*** (0.0347)</td>
</tr>
<tr>
<td>Fluid</td>
<td>0.0659*** (0.0176)</td>
<td>0.0695*** (0.0176)</td>
<td>0.0642*** (0.0176)</td>
<td>0.0677*** (0.0172)</td>
</tr>
<tr>
<td>Proppant</td>
<td>0.177*** (0.0168)</td>
<td>0.165*** (0.0197)</td>
<td>0.179*** (0.0168)</td>
<td>0.178*** (0.0212)</td>
</tr>
<tr>
<td>County dummy</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Sand size dummy</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Oil dummy</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Avg. Eff.</td>
<td>0.6718</td>
<td>0.6729</td>
<td>0.6751</td>
<td>0.6678</td>
</tr>
</tbody>
</table>
Results – SFA efficiency est.
Results - SFA

- Estimates from Model 4 used to rank producers
- **Mean:** highest positions occupied by small producers – Vargas, Adkins, Eagleridge, Crown, Bagby, Frost, Finley, Western Chief, Cumming, Wilson
- **Median:** Vargas, Adkins, Bagby, Cumming, Eagleridge, Finley, Crown, Frost, J-W Operating, Titan
- **Max:** EOG, Vargas, Devon, XTO, Range, Quicksilver, Chesapeake, Grand Operating, Cumming, Encana
Results – SFA (>100 wells)
SFA Results (50,100)
Results – SFA (10,50)
Results – SFA (<10)
# Results - MLM

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 5</th>
<th>Model 6</th>
<th>Model 7</th>
<th>Model 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>0.374*** (0.0508)</td>
<td>0.366*** (0.0518)</td>
<td>0.377*** (0.0509)</td>
<td>0.359*** (0.0521)</td>
</tr>
<tr>
<td>Fluid</td>
<td>0.0846*** (0.0292)</td>
<td>0.0793*** (0.0295)</td>
<td>0.0847*** (0.0292)</td>
<td>0.0758** (0.0295)</td>
</tr>
<tr>
<td>Proppant</td>
<td>0.165*** (0.0322)</td>
<td>0.174*** (0.0338)</td>
<td>0.166*** (0.0322)</td>
<td>0.170*** (0.0344)</td>
</tr>
<tr>
<td>County dummy</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Sand size dummy</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Oil dummy</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>
Results - MLM

- Group effects estimate $\eta_j$ is used to rank producers.
- A positive value for $\eta_j$ implies that operator is above overall mean (negative, below).
- **Group effects ranking (model 8):** XTO, EOG, Adkins, Carrizo, J-W Operating, Wilson, Western Prod, Grand Operating, Range, Crow Creek.
Revenue approach

• Alternative approach – the decline in natural gas prices that followed the surge in shale gas production made liquids more valuable
• Increased drilling activity in the wet gas parts of the Barnett
• Producers choose to maximize revenue and not necessarily gas production
• Ran the same SFA and MLM regressions but replaced gas output with revenue from gas and oil produced from each well as the dependent variable
• Gas price: NGPL Mid-Con
• Oil price: WTI
## Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>SFA</th>
<th>MLM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>0.315*** (0.0362)</td>
<td>0.365*** (0.0506)</td>
</tr>
<tr>
<td>Fluid</td>
<td>0.0483** (0.0193)</td>
<td>0.0701** (0.0291)</td>
</tr>
<tr>
<td>Proppant</td>
<td>0.196*** (0.0178)</td>
<td>0.187*** (0.0320)</td>
</tr>
<tr>
<td>County dummy</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>
Results – Rev

• SFA
  • **Mean:** Vargas, Adkins, Cumming, Eagleridge, Western Chief, Newark, Crown, Frost, Wilson, Bagby
  • **Median:** Vargas, Cumming, Adkins, Bagby, Western Chief, Newark, Eagleridge, Crown, Richey Ray, Hillwood
  • **Max:** EOG, Cumming, Eagleridge, XTO, Range, Devon, Burlington, Williams, DTE, Vargas

• **MLM:**
  • **Group effects:** XTO, Western Chief, Range, Denbury, Carrizo, Adkins, Western Prod, Wilson, Crow Creek, Grand
Conclusion

• Preliminary attempt to estimate TE among gas producers in the Barnett
• A handful of small producers ranked highly in the different models
• Data still needs further analysis
Thank you!