SPE 135555: Shale Gas Production Decline Trend Comparison over Time and Basins

Jason Baihly, Raphael Altman, Raj Malpani & Fang Luo, Schlumberger

Overview

• Objectives
• Motivation
• Formations Analyzed
• Methodology
• Horizontal Shale Basin Results
• Vertical to Horizontal Well Comparison
• Sandstone and Shale Horizontal Well Comparison
• Economic Analysis
• Conclusions
Objectives

- Examine production trends in horizontal shale gas wells over time in a given basin
- Compare the production profiles between shale basins
- Compare historical production of vertical and horizontal Barnett Shale wells
- Compare the production profiles of horizontal tight gas sandstone and shale formations
- Perform a basic economic analysis of the average shale basin horizontal well

Motivation

- Disagreement within the industry in shale plays over
  - Long term viability
    - Decline trends
    - Time to abandonment rate
    - EUR
    - Resultant economics
Formations Selected for Analysis

Methodology for Production Analysis

- Core area was chosen in each shale basin based upon
  - Limit the number of wells for analysis
    - Perform proper QA/QC on a well by well basis
  - Wells not on the periphery of the play
  - Horizontal wells drilled since the inception of the basin
  - Better producing area in the play
- Eagle Ford gas area was analyzed and due to low well count, the entire play was analyzed
- Hundreds of horizontal wells chosen in each play
- Each play was analyzed individually
Methodology for Production Analysis

- Monthly production broken down into daily rates
- All wells not exhibiting a normal decline trend were excluded
- Wells were grouped by date of first production
- Data sets with less than eight wells were ignored
- Wells falling an order of magnitude or more outside of the trend were scrutinized further
- Data normalization
  – Shift all well production data to a specific ‘time zero’
- Once the well count fell drastically, the analysis was stopped

Data Quality Control

<table>
<thead>
<tr>
<th>Number of Producing Wells</th>
<th>Gas Production Rate (MSCF/D)</th>
</tr>
</thead>
</table>

Sudden drop in well count representing wells that started production in latter stages of 2007.
Number of Wells Analyzed

<table>
<thead>
<tr>
<th>Case</th>
<th>Total Wells #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnett</td>
<td>731</td>
</tr>
<tr>
<td>Fayetteville</td>
<td>467</td>
</tr>
<tr>
<td>Woodford</td>
<td>305</td>
</tr>
<tr>
<td>Haynesville</td>
<td>275</td>
</tr>
<tr>
<td>Eagle Ford</td>
<td>59</td>
</tr>
</tbody>
</table>

Forecast Method

- Decline curve analysis (DCA)
  - Determine Arps’ b exponent from regression of historical production data for each group
- Forecast analysis
  - Formulate a production type curve for each shale gas basin from DCA
**Barnett Shale Maximum Time Decline Trend**

**Barnett Shale Summary**

- IP’s and decline trends are similar over time
  - Open natural fractures
  - Low stress anisotropy
  - Pipeline capacity maxed out
- Wells are not interfering with one another
  - Some wells have frac’d into one another
- Increasing from two to six frac stages over time
- Proppant per stage decreasing as number of stages increased
- One study found that proppant amount correlated well to production results
Fayetteville Shale
Maximum Time Decline Trend

Fayetteville Shale Summary

• IP’s and production increase over time
  – Lateral length increased from 1,800 to 4,300 ft
  – Frac stages per lateral went from 3-4 to 6-8
  – Fluid volume per lateral has doubled
  – Proppant amount per lateral has tripled
• Production decline trends are fairly parallel over time
• Increase in production appears to be sustained
Woodford Shale Summary

- IP’s and production increase over time
  - Lateral length increased 1,800 to 4,800 ft
  - Frac stages per lateral went from 3 to 10
  - Fluid volume has increased, but not proportionately
  - Proppant amount per lateral has remained constant
- Production decline trends are somewhat parallel over time
- Increase in production may be sustained, more production is needed
- Decline profile similar to the Fayetteville
Haynesville Shale Summary

- IP’s have increased by 18% year on year
  - Completion trends have rapidly evolved
  - Lateral length increased 2,200 to 4,800 ft
  - Frac stages per lateral increased from 6 to 14
  - Stimulation volumes have increased proportionately to the number of stages
  - Fluid volume per stage ~12,000 bbl
  - Proppant amount per stage ~300,000 lbs
- Production decline trends are fairly parallel over a short timeframe
Eagle Ford Shale Decline Trend

![Eagle Ford Shale Decline Trend](image)

Eagle Ford Shale Summary

- IP is second highest over shale plays analyzed
  - Lateral length is ~5,000 ft
  - Frac stages per lateral are 12 to 14
  - Frac designs are comparable to the Haynesville Shale
- More time needed to perform additional analysis
2009 DOFP Inter Shale Basin Comparison

Absolute Gas Production Rate for Barnett Horizontal and Vertical Wells
IP-Normalized Gas Production Rate for Barnett Shale Horizontal and Vertical Wells

Overlay of IP-Normalized Production Type Curves for Horizontal and Vertical Sandstones
Overlay of IP-Normalized Production Type Curves for Horizontal Sandstone and Shale Plays

Overlay of Absolute Production Type Curves for Horizontal Sandstone and Shale Plays
## Comparison of DCA for Various Plays

<table>
<thead>
<tr>
<th>Case</th>
<th>Reservoir Type</th>
<th>Well Type</th>
<th>b</th>
<th>Current Cumulative Gas Production MMScf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnett</td>
<td>Shale Gas</td>
<td>Horizontal</td>
<td>1.5933</td>
<td>1,415</td>
</tr>
<tr>
<td>Fayetteville</td>
<td></td>
<td></td>
<td>0.6377</td>
<td>883</td>
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<tr>
<td>Woodford</td>
<td></td>
<td></td>
<td>0.8436</td>
<td>996</td>
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<td>Haynesville</td>
<td></td>
<td></td>
<td>1.1852</td>
<td>1,740</td>
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<tr>
<td>Eagle Ford</td>
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<td>1.6940</td>
<td>548</td>
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<tr>
<td>Cotton Valley</td>
<td>Tight Gas Sandstone</td>
<td>Vertical</td>
<td>0.7259</td>
<td>1,341</td>
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<tr>
<td>Cleveland</td>
<td></td>
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<td>1.0000</td>
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<tr>
<td>Cotton Valley (1980)</td>
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<tr>
<td>Cleveland (1980s)</td>
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<td>Cotton Valley (&gt;2005)</td>
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<td>1.0000</td>
<td>469</td>
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<tr>
<td>Barnett (1980s)</td>
<td>Shale Gas</td>
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<td>1.9366</td>
<td>389</td>
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## Economic Inputs

<table>
<thead>
<tr>
<th>Play</th>
<th>Well Cost $MM</th>
<th>Royalty %</th>
<th>Operating Cost $/MScf</th>
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<tbody>
<tr>
<td>Barnett</td>
<td>3</td>
<td>22</td>
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<tr>
<td>Fayetteville</td>
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<td>17</td>
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<tr>
<td>Woodford</td>
<td>6.7</td>
<td>19</td>
<td>1.2</td>
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<tr>
<td>Haynesville</td>
<td>8</td>
<td>25</td>
<td>2.5</td>
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<tr>
<td>Eagle Ford</td>
<td>5.8</td>
<td>25</td>
<td>1.5</td>
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### Economic and Production Results

<table>
<thead>
<tr>
<th>Case</th>
<th>DPI@0%</th>
<th>DPI@10%</th>
<th>DPI@15%</th>
<th>ROR,%</th>
<th>EUR,Bcf</th>
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</thead>
<tbody>
<tr>
<td>Barnett_DOFP_2008</td>
<td>2.11</td>
<td>1.11</td>
<td>0.92</td>
<td>12.6</td>
<td>2.895</td>
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<td>Barnett_DOFP_2009</td>
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<td>1.1</td>
<td>0.92</td>
<td>12.3</td>
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<tr>
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<td>14.7</td>
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<td>3.401</td>
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<td>Haynesville_DOFP_2008</td>
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<td>Haynesville_DOFP_2009</td>
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<td>6.092</td>
</tr>
<tr>
<td>Eagle Ford_DOFP_2009</td>
<td>0.83</td>
<td>0.45</td>
<td>0.38</td>
<td>0</td>
<td>3.793</td>
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<tr>
<td>Cotton Valley_Horizontal</td>
<td>0.92</td>
<td>0.69</td>
<td>0.64</td>
<td>0</td>
<td>2.036</td>
</tr>
</tbody>
</table>

### Economic Break Even Price

<table>
<thead>
<tr>
<th>Case</th>
<th>EUR, Bcf</th>
<th>Gas Price (DPI @ 10% = 1) (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnett_DOFP_2008</td>
<td>2.895</td>
<td>$3.70</td>
</tr>
<tr>
<td>Barnett_DOFP_2009</td>
<td>2.867</td>
<td>$3.74</td>
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<tr>
<td>Fayetteville_DOFP_2008</td>
<td>2.463</td>
<td>$3.65</td>
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<td>3.401</td>
<td>$3.20</td>
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<td>Woodford_DOFP_2008</td>
<td>2.544</td>
<td>$7.35</td>
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<tr>
<td>Woodford_DOFP_2009</td>
<td>3.389</td>
<td>$6.22</td>
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<tr>
<td>Haynesville_DOFP_2008</td>
<td>4.579</td>
<td>$6.95</td>
</tr>
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<td>Haynesville_DOFP_2009</td>
<td>6.092</td>
<td>$6.10</td>
</tr>
<tr>
<td>Eagle Ford_DOFP_2009</td>
<td>3.793</td>
<td>$6.24</td>
</tr>
</tbody>
</table>
Conclusions

• Haynesville IP > Eagle Ford IP > Woodford IP > Fayetteville IP > Barnett IP
  – Haynesville Shale IP is considerably higher than other Shales due to
    • Higher reservoir pressure
    • Aggressive drilling and completion approach
  • Production increased with time across all shale gas basins analyzed
    – Barnett Shale is the exception
    – Due to improvements in drilling, completion practices, stimulation designs, and knowledge gain over time
  • Cotton Valley Sand has the steepest decline over time of all formations analyzed

Conclusions

• Barnett Shale had a flatter production decline trend
  – Barnett would not serve as an analog shale play for estimating production declines in other shale gas plays
  – Could be due to natural fractures, curvature, and stress
  – Vertical and horizontal wells exhibit similar decline profiles during first 2 years of production
• ‘b’ exponents greater than 1.0 are realistic in unconventional gas reservoirs
• Economics in our study areas
  – Barnett and Fayetteville are economical @ $4/MScf gas price at 10% discount rate
  – Haynesville, Eagle Ford, and Woodford are economical @ >$6/MScf at 10% discount rate
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