Technical Session Agenda
2016 SPEE Annual Meeting

Tuesday, June 7, 2016  2016 SPEE Technical Session 2  Salon I/II

10:30 AM  Risky Business: Managing Uncertainty in Upstream Decision-Making  Tyler Schlosser

BIOGRAPHY
Tyler Schlosser – GLJ Petroleum Consultants

Tyler is GLJ’s Director of Commodities Research, focusing on economic modeling, risk analysis, commodity pricing and business development. Tyler is responsible for generating GLJ’s commodity price forecasts and modeling fiscal regimes across a broad range of international jurisdictions. With expertise in unconventional evaluations, probabilistic modeling and machine learning techniques, Tyler routinely tackles unique and complex problems for GLJ’s clients.
RISKY BUSINESS: MANAGING UNCERTAINTY IN UPSTREAM DECISION-MAKING

Tyler Schlosser, P.Eng.
June 2016
WHAT SMART PEOPLE SAY ABOUT UNCERTAINTY

• “We must become more comfortable with probability and uncertainty.”
  – Nate Silver (author and statistician, FiveThirtyEight.com)

• “Some people say, ‘How can you live without knowing?’ I do not know what they mean. I always live without knowing. That is easy. How you get to know is what I want to know.”
  – Richard Feynman (Nobel prize-winning physicist)

• “The world is noisy and messy. You need to deal with the noise and uncertainty.”
  – Daphne Koller (AI researcher, Stanford University)

• “Recognizing uncertainty is a sign of humility, and humility is just the ability or the willingness to learn.”
  – Charlie Sheen (Two and a Half Men)
NAVIGATING OUR NEW REALITY

“What will our earnings be?”

May 3, 2016

“Can we still make money?”
THE UPSTREAM INDUSTRY IS MORE ADAPTABLE THAN IT GETS CREDIT FOR

Source: RBN Energy, EOG
$55 IS THE NEW $80

- Technology
- Efficiency
- Cost deflation
- Quick payouts

High quality US shale acreage can sustain development at sub-$40 WTI

HOW CAN WE ACTIVELY MANAGE RISK?

• Optimize allocation of finite capital
  – Where can we spend the next dollar to receive maximum benefit?

• Define “optimal”
  – What are our criteria for success?
  – Are we only interested in maximizing the expected value?
  – Are we willing to give up some expected value to reduce our risk?

• Understand a broad range of plausible outcomes
  – Analyzing only the expected outcome ignores important information
  – What failure rate can we live with?

• Understand correlated uncertainties
  – Overall risk is greater when individual uncertainties are correlated
    than when they are independent
HOW CAN WE ANSWER THESE QUESTIONS?
EXAMPLE PLAY: KERROBERT VIKING OIL

1. What is the chance that WTI will average at least 60 USD/bbl in 2017?

2. What average 2017 WTI price are we 90% confident will be exceeded?

3. How likely is it that a single horizontal Kerrobert Viking well will pay out?

4. What is the chance of realizing a NPV$_{10}$ greater than zero for a 10-well drilling program spread across the Kerrobert area?
   - What if all 10 wells are drilled in the same section?

5. How many wells would need to be drilled to be 50% confident of a PI$_{10}$ greater than 1.2?
   - What if all wells are drilled within two miles of each other?
PROBABILISTIC ANALYSIS WORKFLOW

1. Identify analogous wells
2. Build probabilistic production forecasts
3. Generate parameter distributions
4. Calculate a correlation matrix
5. Run Monte Carlo simulation
6. Confirm Monte Carlo results
7. Use a stochastic price forecast?
   - Yes: Use Ornstein-Uhlenbeck process
   - No: Use deterministic price forecast
8. Generate revenues
9. Apply costs, royalties & other adjustments
10. Calculate final cash flows
11. Calculate performance metrics
12. Inform your decision
Components of a Half-Cycle Economic Analysis

- Prices
  - Market prices are hard to predict
  - Normally predictable to ±70% with 95% confidence one year out
  - Hedging can improve certainty

- Production & EUR
  - Well performance
  - Operational issues
  - Economic factors can limit

- Capital Costs
  - Usually predictable within 15%
  - Uncertainty largely tied to success/failure and experimentation

- Operating Costs
  - Transportation bottlenecks
  - Line pressures
  - Unexpected issues, maintenance
  - Competition, partnerships

- Royalties
  - Long term uncertainty in regulatory framework
  - Short term is usually quite certain
Choosing a sample area

- Geologically & operationally similar
- >30 wells is best
- Representative of your area of interest
PROBABILISTIC PRODUCTION FORECASTING

- Flow regime diagnostics
- Two-stage Arps hyperbolic declines
- Bootstrap resampling
MOST RELATIONSHIPS IN RESOURCE ANALYSIS ARE NONLINEAR

Spearman’s Rank Correlation vs. Pearson’s Correlation

Pearson’s Correlation
- Assumes constant variance
- Tests fit to straight line
- Is the ‘R’ in the familiar ‘$R^2$’

Spearman’s Rank Correlation
- Is the linear correlation of ranks
- Better for nonlinear relationships
- Less sensitive to extreme outliers

Pearson’s $R = -0.48$
Spearman’s $R = -1.00$
DECLINE CURVE PARAMETERS ARE NOT INDEPENDENT!

It is nearly always incorrect to move a type curve up or down proportionally to IP – the EUR to IP relationship is nonlinear

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<th>Spearman's Correlation Coefficients</th>
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<tr>
<td>qi</td>
</tr>
<tr>
<td>qi</td>
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<td>Di</td>
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<tr>
<td>bt</td>
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<tr>
<td>q1 (adj)</td>
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SAMPLING WITH DEPENDENCE - KERROBERT VIKING

Initial Rate

Initial Decline Rate

Transient Exponent

100,000 times
Could also analyze on a per-frac or per-length basis
CONFIRMING PRODUCTION FORECAST RESULTS

Model vs Real Data - IP365

Real Data
MC Sim Results

Looks good – P10/P90 ratios are within 4%
Each of the 100k production forecast realizations is paired with a unique stochastic price forecast realization.
STOCHASTIC PRICE FORECASTING: THE ORNSTEIN-UHLENBECK PROCESS

A modified random walk with a mean reversion tendency

Has four parameters:
- \( X_0 \): initial price
- \( \mu \): equilibrium price
- \( \sigma \): volatility
- \( \theta \): rate of shock dissipation

\[
dX_t = \theta(\mu - X_t)dt + \sigma dW_t
\]
CHOOSING SUITABLE O-U PARAMETERS

Equilibrium Price: 60 USD/bbl

Rate of shock dissipation: 5 years
(based on historical data, detailed in SPE-162629)
WTI EXPECTED TO BE BETWEEN $21/BBL AND $112/BBL THROUGH 2017

Implied volatility can be calculated from options prices.
HENRY HUB EXPECTED TO BE BETWEEN $1.55/MMBTU AND $6.00/MMBTU THROUGH 2017

Henry Hub with 2-Sigma Volatility Bounds

95% confidence
UNCERTAINTY = REALITY

Source: Carl Richards, New York Times
GENERATING FINAL CASH FLOWS

- Capital Costs
- Operating Costs

GLJ Database + Probabilistic Sampling

- Price Adjustments
- Byproduct Yields
- Surface Loss

$600k-$850k per well
SINGLE WELL NET PRESENT VALUE, 10% DISCOUNTING

Mean: $539k
P90: -$467k
P50: $140k
P10: $1908k
SINGLE WELL TIME TO PAYOUT

P90: DNPO
P50: 33 mo
P10: 7 mo

36% never pay out
SINGLE WELL PROFITABILITY INDEX, 10% DISCOUNTING

Mean: 1.75
P90: 0.36
P50: 1.19
P10: 3.65
EXPECTATIONS TIGHTEN WITH MORE WELLS

Here, every well drilled is geostatistically independent from every other well ("shotgun blast" scenario).

This is the “rolling a die multiple times” Monograph 3 aggregation method.

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<th># Wells</th>
<th>P50</th>
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<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>$288k</td>
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<td>$401k</td>
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<td>10</td>
<td>$461k</td>
</tr>
<tr>
<td>20</td>
<td>$497k</td>
</tr>
<tr>
<td>50</td>
<td>$518k</td>
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Kerrobert Area Viking $NPV_{10}$ Per Well Probability Density Distributions

$NPV_{10}$ per well (CAD, thousands)
WHAT IF SEVERAL WELLS ARE DRILLED IN ONE PARTICULAR AREA?

Medicine Hat/Milk River Shallow Gas Example

Wells drilled near each other are likely to perform more similarly than wells drilled farther apart from each other.
EXPECTATIONS DON’T TIGHTEN AS MUCH IF AREA OF DEVELOPMENT IS CONCENTRATED

Kerrobert Area Viking NPV_{10} Per Well, 10 Wells, Geocorrelation Sensitivities

If 10 wells are all drilled in the same section, then some of the “law of large numbers” effect is lost.

- R=0.0 P50: $461k
- R=0.1 P50: $457k
- R=0.3 P50: $441k
- R=0.5 P50: $402k
- R=0.7 P50: $347k

Acknowledging that some uncertainties are correlated results in a more realistic aggregation.
1. What is the chance that WTI will average at least 60 USD/bbl in 2017? **27%**

2. What average 2017 WTI price are we 90% confident will be exceeded? **29 USD/bbl**

3. How likely is it that a single horizontal Kerrobert Viking well will pay out? **64%**

4. What is the chance of realizing a NPV_{10} greater than zero for a 10-well drilling program spread across the Kerrobert field? **94%**
   - What if all 10 wells are drilled in the same section? **89%**

5. How many wells would need to be drilled to be 90% confident of a PI_{10} greater than 1.2? **15**
   - What if all wells are drilled within two miles of each other? **17**

Based on May 3, 2016 market data
APPLICATIONS

Probabilistic Analysis

- Hedge evaluation
- Backstopping reserves work on major fields
- Acquisition prospect targeting
- Asset valuation with intelligent price sensitivities
- Comparing drilling programs by risk/reward
- Generating informed distributions to apply to emerging plays
- Portfolio and efficient frontier analysis
- Full impact regulatory regime sensitivities
THANK YOU

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