RISKY BUSINESS: MANAGING UNCERTAINTY IN UPSTREAM DECISION-MAKING

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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?”

February 1, 2016

“Will we survive?”
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\textsubscript{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\textsubscript{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 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

100,000 iterations
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

<table>
<thead>
<tr>
<th>Spearman's Correlation Coefficients</th>
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<tr>
<td>qi</td>
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<td>q1 (adj)</td>
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<td>t1</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

Rate of shock dissipation: 5 years (based on historical data, detailed in SPE-162629)

Equilibrium Price: 60 USD/bbl
WTI EXPECTED TO BE BETWEEN $18/BBL AND $108/BBL THROUGH 2017

Implied volatility can be calculated from options prices

Initial price: $31

95% confidence

June 2014
95% confidence interval for December 2015 WTI price: $65/bbl to $130/bbl
HENRY HUB EXPECTED TO BE BETWEEN $1.30/MMBTU AND $5.60/MMBTU THROUGH 2017

95% confidence
UNCERTAINTY = REALITY

Source: Carl Richards, New York Times
POSSIBLE FUTURE WTI PRICE REALIZATIONS

WTI Historical and Futures Prices

Date

USD/bbl

Possible future price realizations
GENERATING FINAL CASH FLOWS

Capital Costs $600k-$850k per well Operating Costs

GLJ Database + Probabilistic Sampling

Price Adjustments Byproduct Yields Surface Loss
SINGLE WELL NET PRESENT VALUE, 10% DISCOUNTING

Mean: $135k
P90: -$584k
P50: -$159k
P10: $1245k
SINGLE WELL TIME TO PAYOUT

- **P90**: DNPO
- **P50**: DNPO
- **P10**: 9 mo

53% never pay out
SINGLE WELL PROFITABILITY INDEX, 10% DISCOUNTING

- Mean: 1.19
- P90: 0.20
- P50: 0.78
- P10: 2.73
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.
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

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

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? 19%
2. What average 2017 WTI price are we 90% confident will be exceeded? 25 USD/bbl
3. How likely is it that a single horizontal Kerrobert Viking well will pay out? 47%
4. What is the chance of realizing a NPV<sub>10</sub> greater than zero for a 10-well drilling program spread across the Kerrobert field? 65%
   – What if all 10 wells are drilled in the same section? 59%
5. How many wells would need to be drilled to be 50% confident of a PI<sub>10</sub> greater than 1.2? 20
   – What if all wells are drilled within two miles of each other? 23

Based on February 1, 2016 market data
APPLICATIONS

Probabilistic Analysis

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

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