Capturing Uncertainty in Prospect Economics*

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Abstract

This paper presents a procedure to describe prospects' uncertain outcomes in investment-decision-friendly terms. Oil and gas investment results are uncertain prior to drilling and producing. This uncertainty has been the focus of excellent papers over the years. However, published approaches usually stop before answers are translated into cash flow. The presented procedure forecasts prospect performance based on a probabilistic distribution of well performance rather than volumetric calculation. By estimating future well performance, cash flows can be forecast providing results in investment decision friendly terms. Using historic production data, examples are presented of data type to use, how to create a performance probability distribution, and how to understand the results. The presented procedure is not complicated, is intuitive to petroleum professionals, and should increase the quality of investment decisions. It can answer that questions like, “What is the likelihood of this investment having an IRR of greater than 15%” or “What is the likelihood of capital requirements of $10 million or more?” Any economic input can be described as a probability function and sampled during simulation making this approach very robust. Such a program can be built on a personal computer with commercially available software and can be very simple or very complex, depending on a user's needs. However, most commercially available economic programs do not provide for this functionality. A very important benefit of this procedure is that it expands the prospect conversation. Because inputs are related to well performance, reservoir, drilling, and completion engineers and geoscientists all have contributions to make. Such a discussion may identify new trends or best practices. While this procedure offers attractive benefits, it does present a number of challenges, notably, how a probabilistic distribution of results are to be used in making decisions. The discomfort, but not the inability, in dealing with this unfamiliar output may be a main reason management does not require this type of analyses! The presented procedure offers a means to improving the investment decision process and, consequently, the decisions made. This process drives technical investigation, encourages cooperative communication, and contributes to the success of exploration and production companies.

References Cited

Gomory, R.G., 1995, The Known, the Unknown and the Unknowable: Scientific American, v. 272/6, p. 120.


Capturing Uncertainty in Prospect Economics

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Outline

- Disclaimers
- Context
- The Problem(s)
- Introduction
- “Another Way”
- Simple Example
- The Tool
- More Realistic Examples
- Conclusions
Disclaimers & Challenges

- I am NOT AN EXPERT at
  - Decline Curve Analysis
  - Statistics
  - The software I was using (it became profoundly clear!)
- This presentation is an IDEA!
  - Not the final word
  - Intended to stimulate a discussion
- The Challenge
  - Offer a better solution
  - Fix this one
  - But do SOMETHING!
Job of a generating petroleum geologists consists of
1. Identifying attractive opportunities
2. Characterizing their risks and uncertainties so financial decision makers can make the best possible decisions

Geologists do not need to cede ownership of this most important function to others
The Problem(s)

- Tools commonly available for addressing uncertainty are
  - not able to be translated into cash flow
  - Are passive – they don’t lead to something you can work to improve

- Attempts to capture and manage uncertainty often met with
  - Resistance/Rejection
  - Disinterest
  - Laziness

“You can’t really know” is seen as acceptable treatment of uncertainty
Introduction

- Uncertainty – the lack of certainty; the unknown nature of future outcomes

- Uncertainty about what?
  - All “variables” - Porosity, Area, Recovery Factors, IP’s, Declines, Prices, Reserves, Revenues and Expenses, Schedules

- Will focus on the uncertainty of upstream capital investment

- Recommend: “The Known, the Unknown and the Unknowable” by Ralph Gomory, June 1995, Scientific American
**Figure 1:** Magnitude of uncertainty in reserves estimates

- UNCERTAINTY +

Figure 2-1: Sub-classes based on Project Maturity.
Use distributions of inputs to calculate volumetric distribution of reserves

\[ P(A) \times P(H) \times P(RF) = P(\text{Reserves}) \]

Quite simple and elegant

Adds value in learning

We stand on the shoulders of great educators/men
It’s Good but ....

.......... it stops at Reserves

Reserves provide no insight into

- Timing or Rate Uncertainty
- Likelihood of Production
Another Way

- Capture performance uncertainty from historic wells

Replace Volumetric Measures for Well Performance Measures

- Describe uncertain future by simulation
Historic Well Performance
Decline Curves

All of these require rate, decline, “b” and time. “b” reflects the degree of curvature which is a function of the rate and time.

| b=0  | Exponential          |
| 0<b<1 | Hyperbolic           |
| b=1  | Harmonic             |
| B=1+ | Resource plays       |

The Arps Equations

<table>
<thead>
<tr>
<th></th>
<th>b = 0</th>
<th>0 &lt; b &lt; 1</th>
<th>b = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>( \frac{\ln \left( \frac{q_1}{q_2} \right)}{t} )</td>
<td>( D_1 \left( \frac{q_2}{q_1} \right)^{\frac{1}{b}} )</td>
<td>( \frac{D_1 q_2}{q_1} )</td>
</tr>
<tr>
<td>q</td>
<td>( q_1 \exp(-D t) )</td>
<td>( \frac{q_1}{(1 + b t D_1)^\frac{1}{b}} )</td>
<td>( \frac{q_1}{(1 + b D_1)} )</td>
</tr>
<tr>
<td>Q_p</td>
<td>( \frac{q_1 - q_2}{D} )</td>
<td>( \frac{q_1}{D_1 (1 - b)} \left[ 1 - \frac{q_2}{q_1} \right]^{1-b} )</td>
<td>( \frac{q_1}{D_1} \ln(1 + D_1 t) )</td>
</tr>
<tr>
<td>t</td>
<td>( \frac{\ln \left( \frac{q_1}{q_2} \right)}{D} )</td>
<td>( \left( \frac{q_1}{q_2} \right)^{b} - 1 )</td>
<td>( \frac{q_1 - q_2}{D q_1} )</td>
</tr>
</tbody>
</table>

Arps Decline Curve Equation

General Case

\[ q_t = \frac{q_i}{(1+bD_i t)^{1/b}} \]

- \( D_i \) = the initial decline rate
- \( q_i \) = the initial flow rate
- \( b \) = the Arps decline curve constant or exponent
- \( t \) = time in question

Can calculate the rate at time “t” with \( \leq 3 \) unknowns

Use these inputs to calculate volumes
Example 1

\[
Q_i = 47,073 \\
D_i = 45.77 \\
b = 0.6
\]
Example 1 - Economics

- Production Profile:
  - Example 1
  - CAPEX: $400K
  - WI: 100%
  - NRI: 75%
  - Price: $2.50/mcfcg
  - STX + AdVal: 8% +1¢/mcfcg
  - OPEX: $1,500/mo

- Results
  - Gross Gas: 1,837 MMCFG
  - Net Cash Flow: $2,273 M
  - PV10: $1,425 M
  - IRR: 167%
Example 2

\[ Q_i = 6,624 \]
\[ D_i = 11.11 \]
\[ b = 0.6 \]
## Distribution of Values for Evans Sand

<table>
<thead>
<tr>
<th>Example</th>
<th>Qi</th>
<th>Di</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15,188</td>
<td>52.40</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>8,240</td>
<td>60.00</td>
<td>1.30</td>
</tr>
<tr>
<td>3</td>
<td>14,960</td>
<td>32.62</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>24,077</td>
<td>90.00</td>
<td>0.80</td>
</tr>
<tr>
<td>5</td>
<td>4,845</td>
<td>90.56</td>
<td>1.30</td>
</tr>
<tr>
<td>6</td>
<td>8,850</td>
<td>64.49</td>
<td>1.00</td>
</tr>
<tr>
<td>7</td>
<td>10,283</td>
<td>28.91</td>
<td>1.50</td>
</tr>
<tr>
<td>8</td>
<td>2,936</td>
<td>83.62</td>
<td>1.00</td>
</tr>
<tr>
<td>9</td>
<td>21,526</td>
<td>85.46</td>
<td>1.20</td>
</tr>
<tr>
<td>10</td>
<td>6,624</td>
<td>11.11</td>
<td>0.60</td>
</tr>
<tr>
<td>11</td>
<td>8,349</td>
<td>60.00</td>
<td>1.50</td>
</tr>
<tr>
<td>12</td>
<td>47,073</td>
<td>45.77</td>
<td>0.60</td>
</tr>
<tr>
<td>13</td>
<td>12,570</td>
<td>80.00</td>
<td>0.80</td>
</tr>
<tr>
<td>14</td>
<td>3,278</td>
<td>76.41</td>
<td>0.60</td>
</tr>
<tr>
<td>15</td>
<td>12,600</td>
<td>50.79</td>
<td>-</td>
</tr>
<tr>
<td>16</td>
<td>2,990</td>
<td>57.08</td>
<td>0.49</td>
</tr>
<tr>
<td>17</td>
<td>1,538</td>
<td>32.49</td>
<td>-</td>
</tr>
</tbody>
</table>
Another Way

**Replace static values with distributions of values**

\[ q_t = q_i / (1 + bD_i t)^{1/b} \rightarrow \]

\[ P(q_t) = P(q_i) / (1 + P(b)P(D_i t)^{1/P(b)} \rightarrow \]

Distribution of Time Series of Production → Volumes → CFs
Distribution of $Q$

Whatever type of distribution best fits the data!

Best Fit for this Distribution is an Exponential Distribution
Distribution of $D$

Whatever type of distribution best fits the data!

Best Fit for this Distribution is a Triangular Distribution
Best Fit for this Distribution is a Uniform Distribution

Whatever type of distribution best fits the data!
A Word about the Tool

- Excel Spreadsheet
  - Simple algorithms – complex relationships
  - Lots of logical and other functions
  - Complexity from built in flexibility
  - Complexity from pushing Excel functions to their limits
- Build the spreadsheet with static inputs in mind
- Use an Excel Add-In to substitute distributions for static values
  - @RISK add-in (by Palisade Corp.)
- Probably better software for this than Excel but that’s what I had and know how to use
Results from Distributions

Lognormal distribution

Gross Gas (mcf)

- P10, 1,303,840
- P50, 181,981
- P90, 21,797
- Static, 1,837,773

Log scale
Results from Distributions

Lognormal distribution

Net WI CF

Static, 2,272,978

BE, 32%

P10, 1,122,419

P50, (207,209)

P90, (389,544)
Results from Distributions

Lognormal distribution

PV10 (\$)

P10, 481,090
Static, 1,425,048
P50, -241,898
P90, -391,435

(1,000,000) - 1,000,000 2,000,000 3,000,000 4,000,000 5,000,000 6,000,000

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Results from Distributions

![Graph showing IRR with key data points: P10, 39%; Static, 167%; P50, -100%; P90, -100%.]
## Summary of Results

<table>
<thead>
<tr>
<th></th>
<th>P(90)</th>
<th>P(50)</th>
<th>P(10)</th>
<th>Static</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gross Gas (MMCFCF)</strong></td>
<td>22</td>
<td>182</td>
<td>1,304</td>
<td>1,837,773</td>
</tr>
<tr>
<td><strong>Net WI CF</strong></td>
<td>-389,544</td>
<td>-207,209</td>
<td>1,122,419</td>
<td>2,272,978</td>
</tr>
<tr>
<td><strong>PV10</strong></td>
<td>-391</td>
<td>-207</td>
<td>1,122</td>
<td>1,425,048</td>
</tr>
<tr>
<td><strong>IRR</strong></td>
<td>-100%</td>
<td>-100%</td>
<td>39%</td>
<td>167%</td>
</tr>
<tr>
<td><strong>Payout (mos)</strong></td>
<td>1,398</td>
<td>1,398</td>
<td>21</td>
<td>11</td>
</tr>
</tbody>
</table>
A Significant Challenge

- More information does not simplify things
- Traditional static decision processes don’t work
- There is no “right” answer to handling
- Figure out what you are comfortable with and use that
- There are portfolio tools that can help decision making
More Realistic

- Initial Example was simple – to communicate the process
  - No dependencies
  - Only one decline period
  - Only one well (& 1 CAPEX)
  - Did not consider Ps
  - Only one Prospect

- All of the above simplifications can be addressed using the same tools!

Example 3

Example 4
Example 3 – Murphy Lake Field

Production Profiles

SU

SUB

SUC

SUD

Copy of MARG V RA SUC;DOW-NORMAN 001
Field: MURPHY LAKE
Oper: LLOG EXPL. CO.
St. Martin, LA
Major Phase: Oil
0.00 M$
Oil EUR: 1,050.20 Mbbl
Gas EUR: 466.76 MMcf
Oil Rem: 0.00 Mbbl
Gas Rem: 0.00 MMcf
Proj Oil Cum: 1,050.20 Mbbl
Proj Gas Cum: 466.76 MMcf
Oil (bbl/day)

Copy of MARG V RA SUA;DOW-NORMAN 002
Field: MURPHY LAKE
Oper: WHITE OAK OPERATING CO, LLC
St. Martin, LA
Major Phase: Oil
0.00 M$
Oil EUR: 2,556.31 Mbbl
Gas EUR: 1,481.51 MMcf
Oil Rem: 0.00 Mbbl
Gas Rem: 0.00 MMcf
Proj Oil Cum: 2,556.31 Mbbl
Proj Gas Cum: 1,481.51 MMcf
Oil (bbl/day)

Copy of MARG V RA SUB 001
Field: MURPHY LAKE
Oper: WHITE OAK OPERATING CO, LLC
St. Martin, LA
Major Phase: Oil
0.00 M$
Oil EUR: 4,869.48 Mbbl
Gas EUR: 2,260.34 MMcf
Oil Rem: 0.00 Mbbl
Gas Rem: 0.00 MMcf
Proj Oil Cum: 4,869.48 Mbbl
Proj Gas Cum: 2,260.34 MMcf
Oil (bbl/day)

Copy of MARG V RA SUD;DOW-NORMAN 002
Field: MURPHY LAKE
Oper: LAMSON PETROLEUM CORPORATION
St. Martin, LA
Major Phase: Oil
0.00 M$
Oil EUR: 110.44 Mbbl
Gas EUR: 41.47 MMcf
Oil Rem: 0.00 Mbbl
Gas Rem: 0.00 MMcf
Proj Oil Cum: 110.44 Mbbl
Proj Gas Cum: 41.47 MMcf
Oil (bbl/day)
Gas (Mcf/day)
Production Profile

**Type 1** well no correlation between Q & De,

- **Q**: 575 – 800; *uniform distribution*
- **De**: 0.10 - 0.35; *uniform distribution*

Duration of “flat” production from 1 month to 10 years.

<table>
<thead>
<tr>
<th>Well</th>
<th>Type 1</th>
<th>Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90%</td>
<td>10%</td>
</tr>
<tr>
<td>2</td>
<td>25%</td>
<td>75%</td>
</tr>
</tbody>
</table>

**Type 2** well have correlation between Q & De

- Excellent correlation coefficient (0.9999)
- **Q**: 100 – 800; *triangular distribution*
- **De** = -0.0242(Q) + 54.359; *calculated from Q*

Performance of Analogous Wells
Example 3 Results

2 Possible Wells

Pse = 65%
Psd = 100%
Example 4 - Portfolio - Results

Net WI CAPEX

<table>
<thead>
<tr>
<th>Prospect</th>
<th>P50</th>
<th>P90</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6,234,354</td>
<td>4,045,514</td>
</tr>
<tr>
<td>2</td>
<td>2,658,729</td>
<td>9908,729</td>
</tr>
</tbody>
</table>

IRR

<table>
<thead>
<tr>
<th>Prospect</th>
<th>P50</th>
<th>P90</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32%</td>
<td>7%</td>
</tr>
<tr>
<td>2</td>
<td>54%</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>93.9%</td>
<td>-</td>
</tr>
</tbody>
</table>

# Successful 1st Wells

<table>
<thead>
<tr>
<th>Successful Wells</th>
<th>P10</th>
<th>P50</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>10</td>
</tr>
</tbody>
</table>

# Wells Drilled

<table>
<thead>
<tr>
<th>Wells Drilled</th>
<th>P10</th>
<th>P50</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

5 Prospects

# wells Pse/Psd

<table>
<thead>
<tr>
<th>Number</th>
<th>Pse/Psd</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>65%/95%</td>
</tr>
<tr>
<td>2</td>
<td>65%/100%</td>
</tr>
<tr>
<td>10</td>
<td>40%/80%</td>
</tr>
<tr>
<td>9</td>
<td>45%/90%</td>
</tr>
<tr>
<td>4</td>
<td>80%/85%</td>
</tr>
</tbody>
</table>
Conclusions

- Uncertainty – it’s everywhere and it’s important – ignoring it does not help!
- This process is simple and intuitive
- It will complicate SIMPLE decision making
- The data is already widely available
Conclusions (cont)

- This **process is an exploration tool** – it helps understand the reservoir
  - *Production performance is the reservoir talking to you through a translator (wellbore, completions, etc.)*
  - Interpret what it’s saying
  - Identify new trends or sub-trends, whether geological or operational

- **Communications tool** – expert input from other disciplines
Conclusions (cont)

- Source of experts’ accountability – including its uncertainties and risks

- Future well performance is informed by historic performance not prisoner to it – consider resource plays

- The tools are here – will they be used? Will they be demanded?