EVALUATING THE IMPACT OF OIL PRICE VOLATILITY ON INVESTOR AND FISCAL REVENUES
Real Options in a real world

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Plan

• Development decisions in the upstream industry
• Building a development decision model
• Case study: Uganda fields
• Conclusion and further developments
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IOC Field development decisions in the upstream industry

Decisions are mainly based on Net Present Value (NPV) of Cash Flows (CF) metrics

\[ NPV = \sum_{t=1}^{N} \frac{CF_t}{(1+i)^{t-1}}, \text{ i discount rate, t year} \]

Simple smooth oil price scenarios

\[ CF_t = P_t \times Q_t - Cost_t - Tax_t \]

Tax for the host country
- Tax rate * Tax Base:
  - NOC participation
  - Royalty
  - Profit Oil tax
  - Taxes on profit

Fixed taxes:
- Bonus
- Fees

Fiscal models

From continuous to discrete

Reservoir models

Subjective oil in place distributions

Cost = Capex + Opex + Decommissioning

Cost estimating models

IOC: International Oil Company
NOC: National Oil Company
Scenarios : An explorer’s guide, Shell

Relatively wide spread of long term oil price assumptions amongst respondents

Most companies have reduced their long term oil price assumptions significantly in light of the recent fall in oil prices

WoodMac: Growing list of deferred upstream projects reaches 68

Comments by analysts: deferrals due to lower oil prices and relatively high costs they seldom mention fiscal terms
Dealing with uncertainty through Breakeven prices

10% discount rate Breakeven price metric
Minimum oil price for after-tax NPV = 0 @ generally 10% discount rate
Upstream taxes

\[ \text{IOC NPV} = \text{PV Sales} - \text{PV Costs} - \text{PV Tax} , \]
\[ \text{as PV Tax} = t \ast (\text{PV Sales-PV Deductions}) , \text{with PV Deductions} \leq \text{PV Costs} \]

Taxes can be seen as a partner receiving \((t \ast \text{PV Sales})\) and paying \((t \ast \text{PV Deductions})\)

Undiscounted

10% discount rate

**NOC participation**: full deduction delayed if NOC carried or not (depending on countries)

**Royalty**: no deduction

**Profit oil tax**: Deductions up to a % of production value (cost oil cap) and delayed

**Tax on profit**: Deductions up to 100% of production value (if ring fenced) and delayed

At lower oil prices or when profitability is negative, only NOC participation can have a positive impact on IOC NPV as if it was a negative Tax (Brown Tax)
Upstream taxes

IOC NPV non-linear profile under a:
15% NOC 10% royalty, 40% Profit oil tax, 30% tax on profit fiscal regime

Deviation from linear trend when profitability decreases
Higher weight of costs for the IOC
Higher exposure to unfavorable situations
• Development decisions in the upstream industry

• **Building a development decision model**

• Simulations on a case study: Uganda fields

• Conclusion and further developments
Taking into account exposure to stochastic prices

Stochastic prices are of course used in derivatives and in many real options papers (Dixit, Pindyck, J. Smith...) but not much by the industry.

Field development decisions still based on NPV metrics using internal smooth price scenarios Exposure to “tortuous” price paths once the field is in production

We model this situation with a statistical approach looking at expected NPV of distributions of NPVs as a function of simulated “tortuous” price paths inputs. Price paths inputs are generated by a stochastic model which parameters are based on historical price data.

One of the few companies Illustrating non regular oil price trend

ConocoPhilips

Goldman Sachs Energy conference, January 2017
Stochastic price model

Historical data: EIA Brent yearly average 1987-2016 => Statistical software
=> Output: two-regime Markov switching => yearly oil price simulations from 2017

\[ \Delta \ln P_t = \begin{cases} \alpha_0 + \beta_0 \Delta \ln P_{t-1} + \varepsilon_t & \text{with } \varepsilon_t \sim N(0, \sigma_0) \text{ if } s_t = 0 \\ \alpha_1 + \beta_1 \Delta \ln P_{t-1} + \varepsilon_t & \text{with } \varepsilon_t \sim N(0, \sigma_1) \text{ if } s_t = 1 \end{cases} \]

<table>
<thead>
<tr>
<th>Regime</th>
<th>( \hat{\alpha} )</th>
<th>( \hat{\beta} )</th>
<th>( \hat{\sigma} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-0.049 (-0.669)</td>
<td>-0.125 (-0.513)</td>
<td>0.250</td>
</tr>
<tr>
<td>1</td>
<td>0.134 (8.204)</td>
<td>0.877 (11.191)</td>
<td>0.030</td>
</tr>
</tbody>
</table>

(\( t \) statistics)

Transition probabilities from regime 0 or 1 in \( s_{t-1} \) to regime 0 or 1 in \( s_t \)

\[ \begin{align*} \Pr[s_t = 0 | s_{t-1} = 0] &= 0.667 \\ \Pr[s_t = 1 | s_{t-1} = 0] &= 0.333 \\ \Pr[s_t = 1 | s_{t-1} = 1] &= 0.303 \\ \Pr[s_t = 0 | s_{t-1} = 1] &= 0.697 \end{align*} \]
Oil prices simulations 2017 to 2072

Constraints: $20/bbl < P_t < $300 /bbl, volatility < 3 \times \text{historical volatility}

6000 Simulations

It is a simulation, not a forecast

Historical prices

Simulation 810 - 2023
Reproduces 1987-2016 oil prices sequence

growth rate of average 2040/2017: 3.4%

P10, P90 and mean and not individual price paths
Oil prices simulations 2017 to 2072

Constraints: $20/bbl < P_t < $300/bbl, volatility < 3 x historical volatility

6000 Simulations

Distribution of prices by year 6 first years

Distribution of prices by year 2043 to 2045

P10 and P90 are independent points representing envelopes of the distributions and not price paths.
Impact of initial conditions

Lower initial price => associated with lower subsequent prices and NPVs

Higher initial price => associated with higher subsequent prices and NPVs
Example Decision process 1 year allowed for development decision delay

### Simulation 1

<table>
<thead>
<tr>
<th>Year</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>...</th>
<th>2072</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil price $/bbl</td>
<td>34.85</td>
<td>44.05</td>
<td>66.78</td>
<td>65.60</td>
<td>48.76</td>
<td>42.09</td>
<td>...</td>
<td>33.95</td>
</tr>
</tbody>
</table>

NPV(S*34.85 +1%/y) >= 0

**2017 Decision price**

NPV(S*34.85 +1%/y) < 0

**2018 Decision price**

NPV(S*44.05 +1%/y) >= 0

**2018 Decision price**

NPV(S*44.05 +1%/y) < 0

**2018 Decision price**

\[ P_{2017} = 34.85 \]

Sim1

Sim2

Sim6000

\[ S: \text{Stress factor}, S>1: \text{risk tolerant}, S<1: \text{risk averse} \]

**2019...**

Allowed delay to postpone development depends on contracts, around 3 years

Loss of production license if field not developed during allowed period
## Simulation 1 with Stress = 1

<table>
<thead>
<tr>
<th>Oil price sequence of Simulation 1</th>
<th>year</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>...</th>
<th>2072</th>
</tr>
</thead>
<tbody>
<tr>
<td>oil price $/bbl</td>
<td></td>
<td>34.85</td>
<td>44.05</td>
<td>66.78</td>
<td>65.60</td>
<td>48.76</td>
<td>42.09</td>
<td>...</td>
<td>33.95</td>
</tr>
</tbody>
</table>

### 2017 Decision price

<table>
<thead>
<tr>
<th>Decision NPV (</th>
<th>34.85</th>
<th>35.20</th>
<th>35.55</th>
<th>35.91</th>
<th>36.27</th>
<th>...</th>
</tr>
</thead>
</table>

Decision NPV ( < 0 => no development in 2017, wait for 2018

### 2018 Decision price

<table>
<thead>
<tr>
<th>Decision NPV (</th>
<th>44.35</th>
<th>44.79</th>
<th>45.24</th>
<th>45.69</th>
<th>46.15</th>
<th>...</th>
</tr>
</thead>
</table>

Decision NPV ( < 0 => no development in 2018, wait for 2019

### 2019 Decision price

<table>
<thead>
<tr>
<th>Decision NPV (</th>
<th>66.78</th>
<th>67.45</th>
<th>67.78</th>
<th>68.46</th>
<th>68.78</th>
<th>...</th>
</tr>
</thead>
</table>

Decision NPV ( > 0 => development in 2019

**Compute NPV of simulation1:**

\[
\text{Simulation1 NPV} = \text{NPV} (66.78, 65.60, 48.76, 42.09, 67.46, 112.84, ...) \times \frac{1}{1.1^2}
\]

**Go to Simulation 2 and so on until Simulation 6000**
Development decision and Break Even price (BE)

Develop when
\[ S \times \text{market price} \geq \text{BE} \]
is equivalent to
\[ \text{market price} \geq \frac{\text{BE}}{S} \]

\( S \) : Stress factor

Example asset with BE = $40/bbl
Risk tolerant \( S > 1 \), here 1.2
Develop when market price \( \geq $33/bbl \)

Risk neutral \( S=1 \)
Develop when market price \( \geq $40/bbl \)

Risk averse \( S < 1 \), here 0.75
Develop when market price \( \geq $53/bbl \)

Risk tolerant IOC will develop earlier and more often for the same BE

Here \( S \) constant, but other rules could be explored : \( S = f(\, \text{Pt} \, ; \, \text{Pt/Pt-1}) \) ...
Analysis of outcomes

Outcome: distribution of 6000 IOC and State NPVs generated by 6000 simulations
NPV of each simulation: NPV=0 if no development
NPV <0 or NPV >0 in case of development

Mean, standard-deviation of the NPV distribution,
Best for investor: higher NPV with the lowest standard deviation ("efficient frontier")

Sensitivity analysis: Impact of Stress factor on IOC and State

Example IOC NPV with 4 years allowed development delay
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Ugandan three onshore oil blocks due to be developed

Why Uganda?
High BE

Complete contract: NOC, royalty, PSA, tax

Total country oil revenues from these fields => DSGE model with stochastic fiscal revenues

<table>
<thead>
<tr>
<th>Waxy crude quality discount</th>
<th>TOTAL</th>
<th>Unit cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MM$</td>
<td>$/bbl</td>
</tr>
<tr>
<td>CAPEX</td>
<td>8,236</td>
<td>7.8</td>
</tr>
<tr>
<td>FIELD OPEX</td>
<td>9,088</td>
<td>8.6</td>
</tr>
<tr>
<td>Decommissioning</td>
<td>732</td>
<td>0.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>18,056</td>
<td>17.1</td>
</tr>
</tbody>
</table>

**Breakeven price**
before tax: $37.6 / bbl
after tax: circa $57 /bbl
3 illustrative simulations: immediate, delayed and no development

Stress factor = 1

Breakeven price curve
The block is developed in the first year when the breakeven price and simulated price curves intersect.
6000 simulations: Development delays

Maximum allowed delay in our model: 25 years
6000 simulations: Yearly cash flows

P10, P90 and mean and not individual cash flow paths
6000 simulations: IOC and State NPVs

IOC more exposed to negative outcomes (dissymmetry of taxes)
Sensitivity to Stress factor and “efficient frontier”

Points with same mean
Stress 1 Stress 0.5
Their distributions are compared below

State mean NPV increases with S but so does std as State gets more often exposed to negative outcomes through the NOC participation

Earlier developments at lower prices, higher exposure to negative outcomes
IOC and State mean and std NPVs under various cases

Base case: two-regime Markov
Random walk stochastic process
Cost elasticity to oil prices
Brown (proportional) tax

IOC NPV under Brown tax: lower std for the same mean due to less exposure to negative outcomes as losses are equally shared (in proportion) with the State
Comparison with Brown tax

Illustration of earlier development under the same price sequence

*Brown tax unique rate fitted for same mean NPV than reference regime*

In this case earlier development under the Brown tax and negative NPV
Later development under reference regime but better price development segment and positive NPV

Mean NPV = Mean NPV but different distributions

Much higher probability of development (98% against 80%) over 25 years earlier developments as well negative outcomes (36% against 29%) with less exposure to negative outcomes
Impact of shorter delays

25 years

Worth waiting when more time to delay is allowed opportunity to encounter higher oil prices
Impact of lower costs

Lower costs

More development cases
Stress factor less critical
due to lower impact of negative outcomes

Similar to Brown Tax profile (slide 25)
because costs are relatively low in comparison to revenues
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Developments - Conclusion

Potential Use:
A complementary tool to the NPV analysis that could be useful for risk management.

There are different best Stress factors strategies for every asset. Choose individual Stress factors rather than a global corporate factor, portfolios effects?

Fiscal regimes comparison and design

Converging interest for IOC and State: accelerate development. Not a zero sum game.

Abandonment decisions, sales and purchase agreements...

Use stochastic distribution of State revenues in DSGE country model.

Other sectors than upstream

Methodology developments:
Other parameter than standard deviation for unwanted outcome, negative NPVs...

Test stochastic process other than with increasing prices in time (mean-reverting for example)

Using smooth price of the year is an imperfect decision rule compared to actual real option framework: evaluate the gap.

Changing in time stress factors