Extracting Higher Option Value from Physical Assets

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Agenda

1. Commodity Trading Optionality
   - Time
   - Location
   - Quality
   - Lot Size

2. Power Plant as a Real Option
   - Motivating Example

3. Gas Storage Optimization
   - Optimal Control
   - Rolling Intrinsic
   - Basket of Spread Options
   - Comparison

4. Concluding Remarks
   - Towards a robust approach
   - Asset-backed trading in worldwide integrated business
Monetizing real optionality through interconnected set of logistical assets

**Location:** Procure Fuel oil from US refinery and sell forward three months on Asian benchmark

**Time:** Store Fuel oil for two months until price increases

**Quality:** Blend with cutter stock in tank to marine fuel specs

**Lot:** Take bunker fuel in smaller ship to Singapore

**Diversion option**
Power plant as a real option – motivating example

1 Plant’s P&L: \( \Pi_1 = X - HR \times P_G(\varepsilon/MWh) \)

2 Plant’s P&L: \( \Pi_2 = X - P_E(\varepsilon/MWh) \)

► The difference between the two strategies equals the spark spread:

\[ \Pi_1 - \Pi_2 = P_E - HR \times P_G(\varepsilon/MWh) \]

► If \( V \) is variable cost of running the plant, then

1. If \( P_E - HR \times P_G - V \geq 0 \), Run the plant.
2. If \( P_E - HR \times P_G - V \leq 0 \), Do NOT run

► The operational margins from running the plant following this strategy as

\[ \Pi = max \{ P_E - HR \times P_G - V, 0 \} \]

► This is payoff of the call option on the spread between power and fuel with the variable cost being the strike.

Electricity

Price (€/MWh): \( P_E \)

Tariff (€/MWh): \( X \)

Gas

Price (€/MWh): \( P_G \)
Gas storage – a profitable real option

- Storage facilities are time machines that let the operator move production capacity from one point in time to a later one.
- This mechanism enables smoothing of the supply response to demand fluctuations.

<table>
<thead>
<tr>
<th></th>
<th>Type</th>
<th>Working gas capacity</th>
<th>Cushion gas</th>
<th>Injection period</th>
<th>Withdr. period</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground</td>
<td>Depleted field</td>
<td>≈ 300 mcm</td>
<td>≈ 50% (already present)</td>
<td>150 - 250 days</td>
<td>50 - 150 days</td>
<td>Seasonal</td>
</tr>
<tr>
<td></td>
<td>Aquifer</td>
<td>≈ 300 mcm</td>
<td>Up to 80%</td>
<td>150 - 250 days</td>
<td>50 - 150 days</td>
<td>Seasonal</td>
</tr>
<tr>
<td></td>
<td>Salt cavern</td>
<td>≈ 150 mcm</td>
<td>≈ 25%</td>
<td>20 - 40 days</td>
<td>10 - 20 days</td>
<td>Peak shaving, balancing</td>
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<tr>
<td>Surface</td>
<td>LNG tank</td>
<td>≈ 500,000 m$^3$</td>
<td>none</td>
<td>1 - 2 days</td>
<td>1 - 10 days</td>
<td>Short term balancing</td>
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<tr>
<td></td>
<td>Compression</td>
<td>$\frac{1}{600}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gaso-meter</td>
<td>≈ 50,000 m$^3$</td>
<td>none</td>
<td>1 - 2 days</td>
<td>1 - 2 days</td>
<td>Daily / weekly balancing</td>
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<tr>
<td></td>
<td>Line pack</td>
<td>varying</td>
<td>none</td>
<td>≤ 1 day</td>
<td>≤ 1 day</td>
<td>Intraday balancing</td>
</tr>
</tbody>
</table>
### Three main approaches to gas storage valuation

<table>
<thead>
<tr>
<th>Approach</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>Optimal Control</td>
<td>- Rigourous mathematical formulation of the problem.</td>
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<tr>
<td></td>
<td>- Stochastic Dynamic Programming (SDP)</td>
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<td></td>
<td>- Least Squares Monte Carlo (LSMC)</td>
</tr>
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<td></td>
<td>- Solving Stochastic Differential Equations (SDE)</td>
</tr>
<tr>
<td>Rolling Intrinsic</td>
<td>- Most transparent and intuitive methodology</td>
</tr>
<tr>
<td></td>
<td>- Flexibility value is managed by locking-in observable forward curve spreads and then making (risk-free) adjustments to hedge positions as prices move, in order to monetise market volatility</td>
</tr>
<tr>
<td>Calendar Spread Options</td>
<td>- Considers a storage contract as a series of time spread options to swap gas from one period to another in the future</td>
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<td>- The volume of available spread options is constrained by the physical characteristics</td>
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</tbody>
</table>
Solving the optimal control

\[ V(t_0, S, I(t_0)) = \max_{c(S, I, t)} \mathbb{E}_{t_0}^* \left[ \int_{t_0}^{T} e^{-r(\tau-t_0)} (c - a(I, c)) S d\tau \right] \]

\[ c_{\text{min}}(I) \leq c \leq c_{\text{max}}(I) \]

\[ dl = -(c + a(I, c)) dt \]

\[ dS = \mu(S, t) dt + \sigma(S, t) dW + \sum_{k=1}^{N} \gamma_k(S, t, J_k) dq_k \]

\[ dq_k = \begin{cases} 1 \text{ with probability } \lambda_k(S, t) dt \\ 0 \text{ with probability } (1 - \lambda_k(S, t)) dt \end{cases} \]

\[ V(t, S, I) = \max_{c(S, I, t)} \mathbb{E}_{t}^* \left[ \int_{t}^{t+dt} e^{-r(\tau-t)} (c - a(I, c)) S d\tau + V(t + dt, S + dS, I + dl) \right] \]

- \( S \) = current price per unit of natural gas.
- \( I \) = current amount of working gas inventory.
- \( c \) = amount of gas currently being released from \((c > 0)\) or injected into \((c < 0)\) storage.
- \( I_{\text{max}} \) = maximum storage capacity.
- \( c_{\text{max}}(I) \) = maximum deliverability rate
- \( c_{\text{min}}(I) \) = maximum injection rate
- \( a(I, C) \) = amount of gas lost given \( c \) units of gas being released or injected into storage.
1. Simulate N independent price paths $S^n_1, S^n_2, \ldots, S^n_T, n = 1, \ldots, N$

2. Carry out backward induction:
   For $t = T, \ldots, 1$
   For each simulation $n = 1, \ldots, N$
      For each storage level $I^n_t (m = 1, \ldots, M)$
      Solve the one stage problem and find a decision rule,
      $$V^n_t = \max_c \left\{ (c - a(c))S^n_t + e^{-rt}E[V^n_{t+1} | \mathcal{F}_t] \right\}$$
      subject to: storage physical constraints
   Next
   Next
   Next

3. For $n=1, \ldots, N$
   Compute the present value of the storage by summing the discounted future cash flows following the decision rule
   Next

4. Storage value is the average of the present values under $n$ paths

► Longstaff and Schwartz (2001)
$$V_{t+1} = \gamma_0 + \gamma_1 S_t + \gamma_2 S^2_t + \epsilon_t$$
Rolling Intrinsic

April 1<sup>st</sup>

€ / MWh

Net Position | P&L | Market Value
--- | --- | ---
+ long Jul at 15 | 0 | = short highest spread € 15 / MWh
- short Dec at 30 | | € 15 / MWh

locked spread
**Rolling Intrinsic**

**April 2nd**

Net Position

- + long Jul at 15
- - short Jul at 12.5
- + long Aug at 10
- - short Dec at 30

= short highest calendar spread € 20 / MWh

P&L

- loss of € 2.5 / MWh

Market Value

- - €2.5/MWh
- €20/MWh
Rolling Intrinsic

April 8th

Net Position

€ / MWh

+ long₅₀% Jun at 10
- short₅₀% Feb at 35
+ long₅₀% Aug at 10
- short₂ Aug at 12.5
- short₅₀% Dec at 30
+ long₅₀% Dec at 27

P&L

= short highest spread (at 25) for 50% of capacity
+ short highest spread (at 14.5) for 50% of capacity

= profit of € 2.5 / MWh
- € 0.5 / MWh

Market Value

€ 19.75 / MWh

loss

locked spread₁

locked spread₂
Valuation using the rolling intrinsic approach

► This is the most transparent and intuitive methodology and thus is often favoured by asset managers and traders.

1. We enter into the forward positions suggested by the optimal injection/withdrawal schedule for this forward curve.
2. If the forward changes favourably, we readjust our positions to capture the positive difference. If the curve moves in an unfavourable way, we do nothing.

► A simulation based methodology can be implemented based on the following logic:
   ➤ t = 0: Optimise the storage facility against the currently observed forward curve and execute hedges to lock in intrinsic value.
   ➤ t = 1 to T: Simulate the movement in the forward curve and re-optimise storage contract.
   ➤ Calculate the value of unwinding existing hedges and placing on new hedges against re-optimised profile and execute profitable hedge adjustments.

► At any point in time the hedge position matches the planned injection and withdrawal profile and the outturn margin will always be higher than the initial intrinsic hedge as adjustments are only made if it is profitable to do so
Valuation of Gas Storage using basket of Calendar Spread Options

Sell Calendar Spread option:

- **Payoff**: \( \max(F_{Feb} - F_{Nov}, 0) \)
- **Expiry**: October 31\(^{st}\)
- **Intrinsic Value**: 10 pc/th
- **Time Value**: 7 pc/th

**Total Value** = 17 pc/th
Valuation of Gas Storage using basket of Calendar Spread Options

Oct. 31st

Trader

Spread decreasing

The option is worthless
Trader keeps the premium.

Spread increasing

Option exercised
Spread option loss = 25p/th

However, the availability of storage allows him to buy October gas at 25p/th and short forward the Feb. at 50p/th.

He stores the Oct. gas, keep it until 1st Feb, and sells it using Feb. contract at 50p/th.

From this position Trader's profit = 25p/th.

Trader's net position is: -25p/th (CS option loss) + 25p/th (storage and futures spread) + 17p/th (CS option premium) = 17p/th (the premium).
Concluding Remarks

- The example of storage shows the complexity of optimizing a physical asset.
- Taking a macro view, can we optimize the portfolio of power plants, gas storage, pipeline capacity, shipping .. for a large scale commodity trading?
Thank You!