Storage Valuation

Gas Storage Valuation Methodologies, Quantitative Analysis & Trading Strategies

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Presentation Summary

- Key gas storage functions.
- Comparison of different valuation quantitative techniques.
- Quantitative analysis of the valuation steps.
- Measuring the extrinsic value risk.
- Storage trading strategies.

- **Key gas storage functions.**
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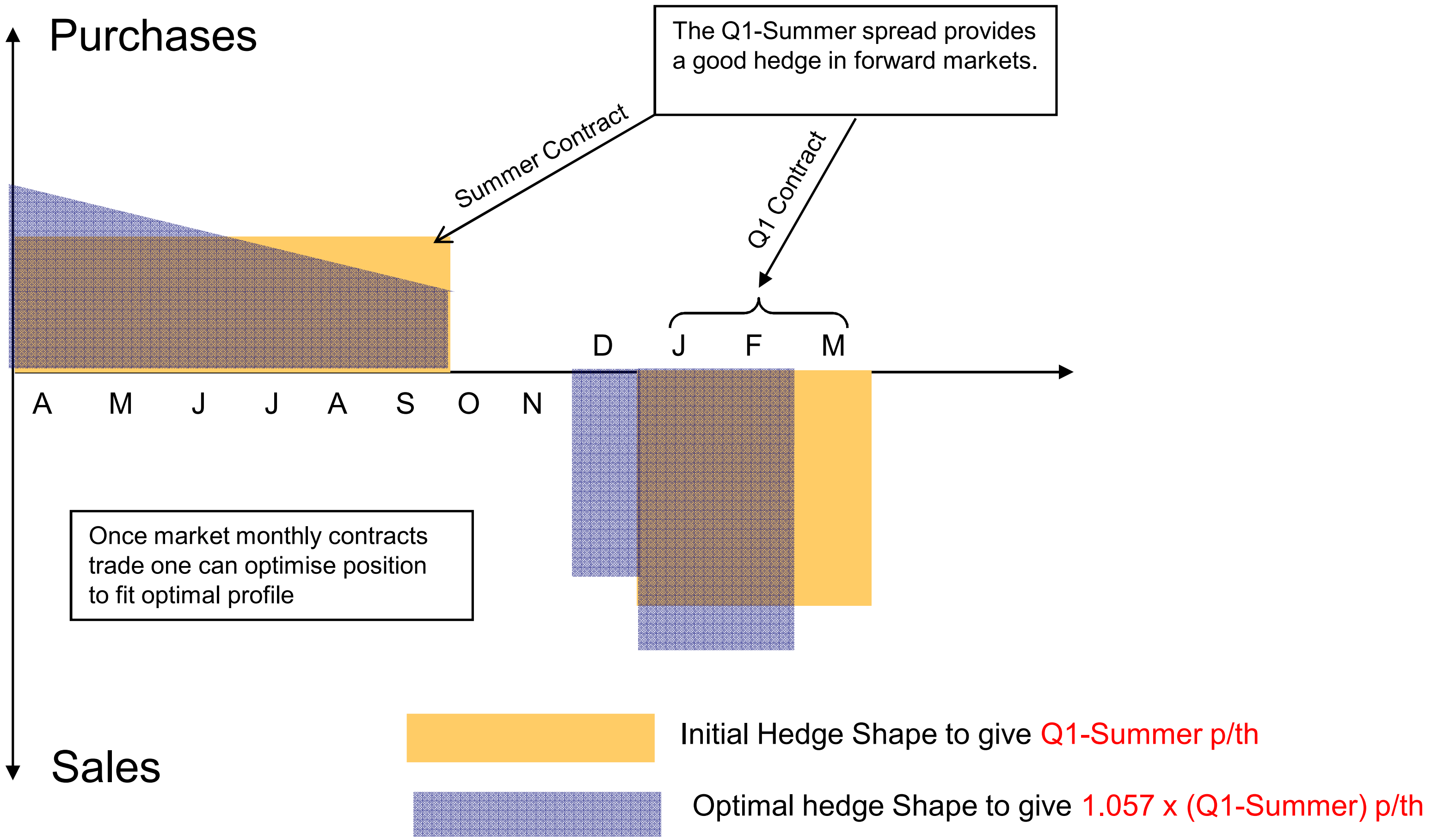
Key gas storage functions

Why storage facilities are developed?

- Three key functions behind the development of storage facilities:
  - Seasonal cycling – Shifting the summer gas production capacity into winter.
  - Peaking service/peaking deliverability – Responding fast to changing conditions and controlling the peak demand, i.e in cold days. (The advantage of a fast turning storage facility).
  - Balancing service – Balancing unpredicted small variations in demand/supply. Maintaining quick deliverability when pipeline system has been disrupted.

- Key gas storage functions.
- **Review of different valuation quantitative techniques.**
- Quantitative analysis of the valuation steps.
- Measuring the extrinsic value risk.
- Storage trading strategies.

Review of different valuation quantitative techniques
Hedging with storage using the forward curve



Review of different valuation quantitative techniques
How easy is it to get the storage value?

- Storage valuation function does not have a closed-form solution, therefore, alternative approaches are suggested.
- Storage is probably the most complicated option structure in energy markets. Its complexities exceed even those of power generation.
- Storage Value = Withdrawal Revenue – Injection Cost.
- However, given the option characteristics that storage gives and the forward curve variability, we need to estimate the solution using simulations for price paths and storage optimal volume spreads.

Review of different valuation quantitative techniques
Storage Valuation Approaches

- Three main valuation approaches:
  - Forward optimisation,
  - Forward dynamic optimisation,
  - Combinations.

Review of different valuation quantitative techniques
Forward Optimisation Approach

- Forward optimisation approach:

$$FV(F_t; S, I, W, t) = \sum_{i<j} \Delta F_t^{i,j} V_{i,j}(F_t; S, I, W, t)$$

$Where$:

FV = Forward Value

F_t = Forward Price

$V_{i,j}$ = Optimal Spread Volumes

S = Space

I = Injection

W = Withdrawal

- Value is s.t physical constraints (S, I, W).
- Storage value is the summation of all optimal spread volumes multiplied by the corresponding forward prices.
- Optimal spread volumes are the net volumes for a given period (i.e a month) spread. Negative spreads are not considered (=0).

Review of different valuation quantitative techniques
Forward Optimisation Approach continued

- Decision volume variable V is a function of the forward contracts prices at injection and it can be defined as:
  - The net volumes for a given period (i.e a month) and assuming as an optimal strategy to turn the storage facility's inventory only once or more,
  - The net volumes for a given spread period (i.e monthly).
- The advantages of using as a decision variable the volumes for a given spread is that this procedure suggests a hedging strategy, i.e long in summer and short in winter.
- This hedging strategy is static and is only revised to discount the cash flows. The cash flows will not change regardless of the future evolution of the forward curve.

Review of different valuation quantitative techniques
Forward Dynamic Optimisation Approach

- Forward Dynamic Optimisation Approach:
  - This approach takes into account that re-adjustment of the optimal hedges every time the forward curve moves to our favour this will result in a greater storage value without the downside risk.
  - This strategy is a spread option position.

$$\text{Spread Option Value} = FV(F_{t_0}; S, I, W, t_0) + E_{t_0}[\sum_{i=t_0+1}^{T} \max(FV_i - FV_{i-1}), 0]$$

- The storage value is a portfolio of complex spread options.
- The value of the spread option is a function of the value of the forward contracts plus the risk-neutral expectation of the future forward value spread.

Review of different valuation quantitative techniques
Forward Dynamic Optimisation Approach continued

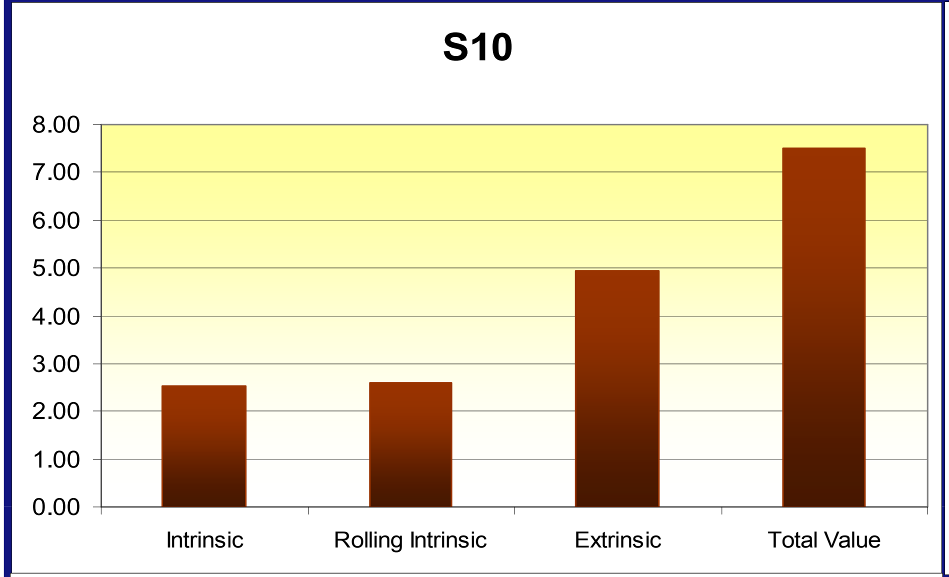
- The factor driving the spread option values (storage value) is the variability of the forward curve.
- The variability of the forward curve is a function of each single forward contract’s volatility and their correlation structure.
- The challenge is to hedge the time value (or else extrinsic value) of the option.

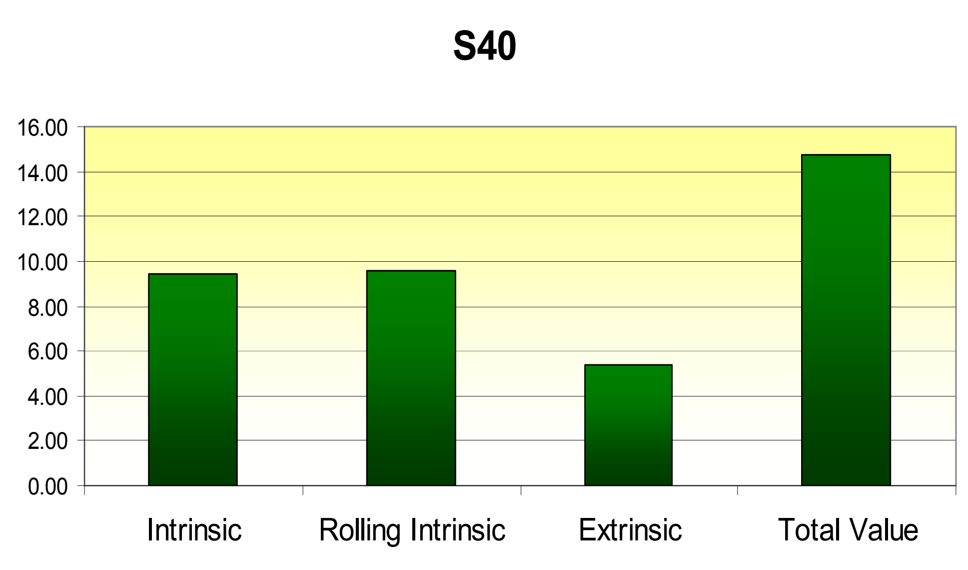
Review of different valuation quantitative techniques
Decomposing the storage value

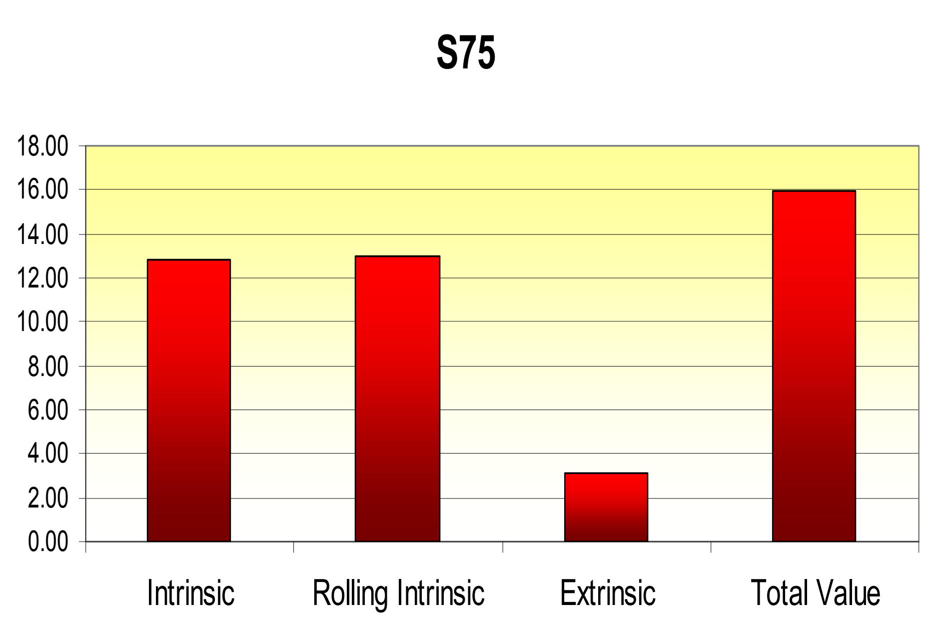
- Intrinsic Value = Valuation on the Forward Curve.
- Rolling Intrinsic = Re-adjusting the Intrinsic value evolution every time the FC moves to our favour.
- Extrinsic Value = Total Value – Intrinsic Value.
- The three key drivers of the additional value (or time value or extrinsic) are:
  - The shape of the forward curve. The wider and more variable the summer-winter gap , the greater the additional value.
  - Volatility, mean reversion, correlation (between forward contracts). Higher volatility, lower MR, lower correlation, higher option time value.
  - Storage facility's operational flexibility. Higher flexibility, higher both intrinsic and extrinsic values.

Review of different valuation quantitative techniques

Decomposing the storage value







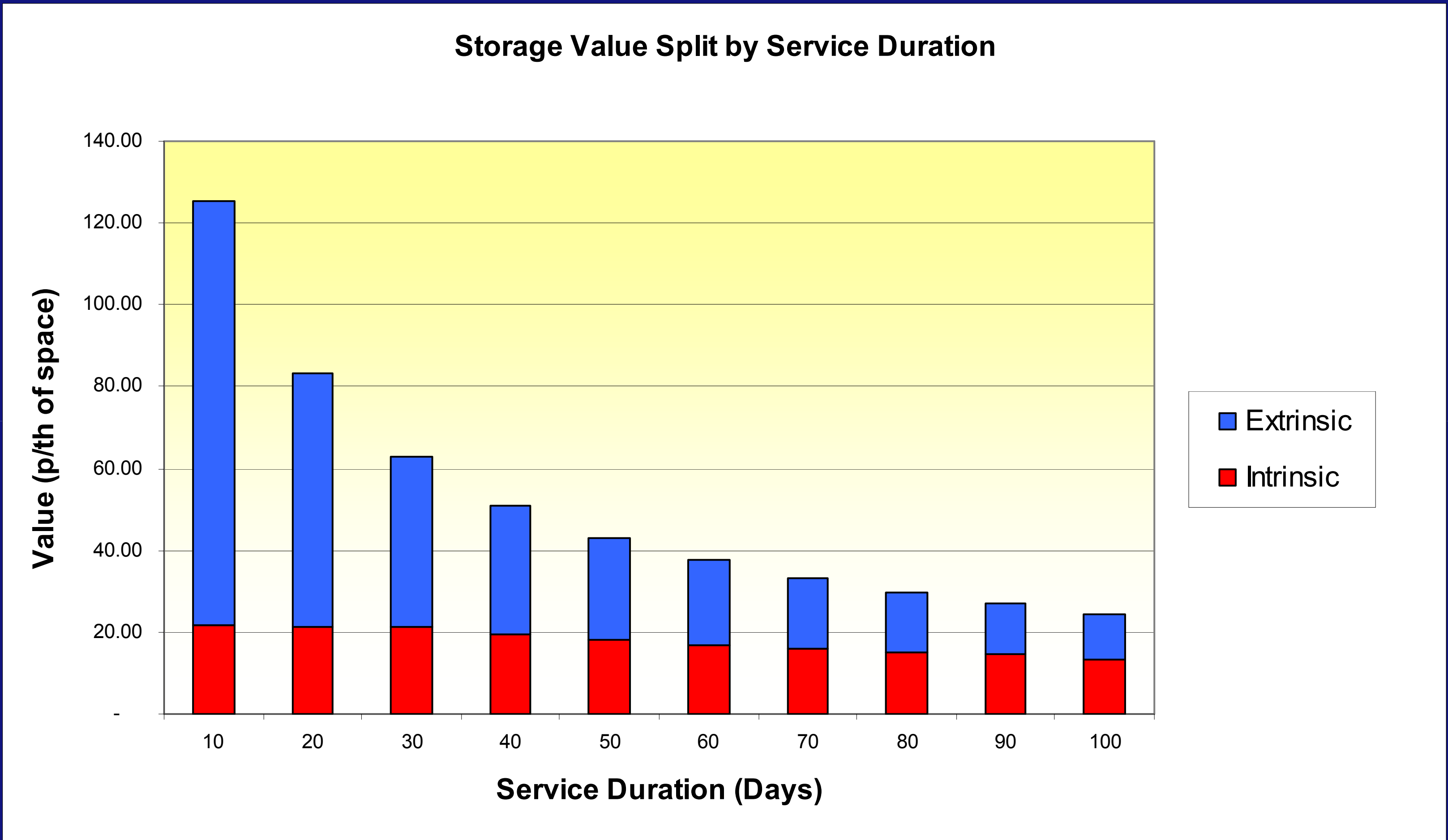
- Intrinsic/Total Value Ratio:

Seasonal > Medium > Short Duration

- Extrinsic/Total Value Ratio:

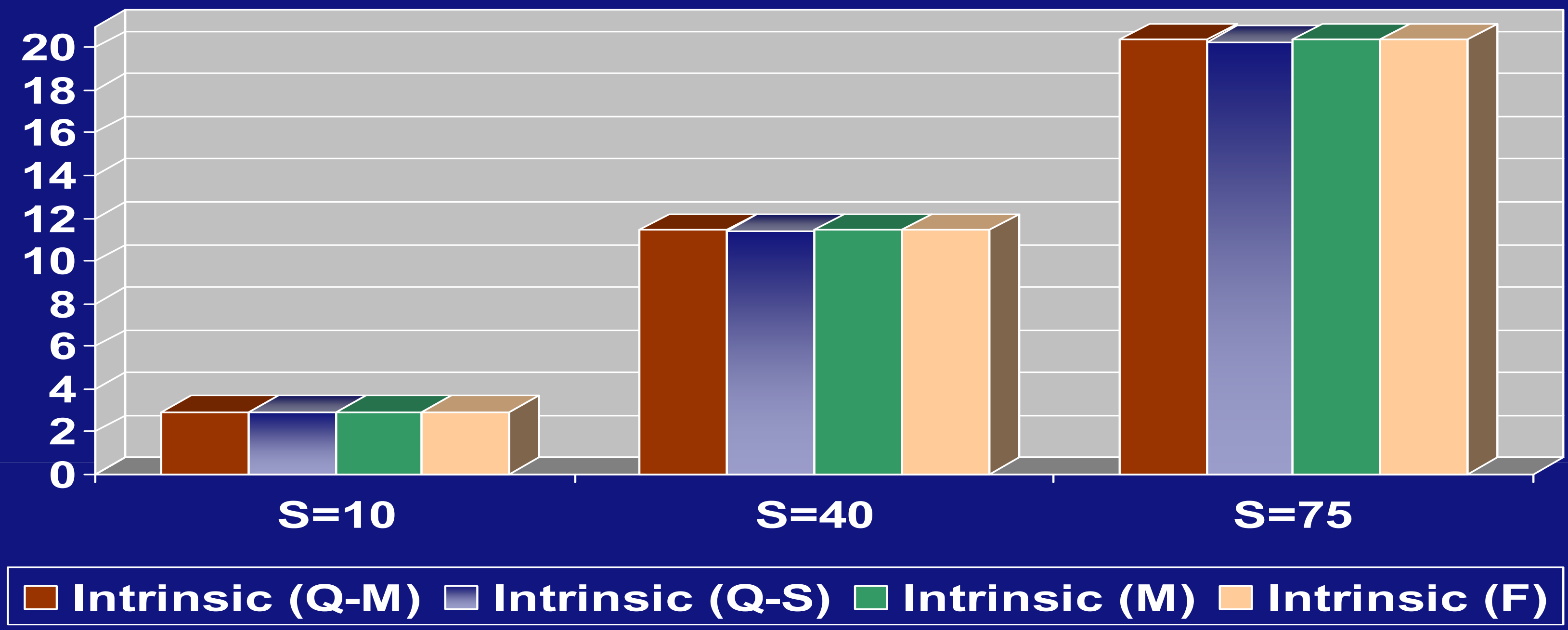
Short Duration > Medium > Seasonal

Review of different valuation quantitative techniques
Decomposing the storage value



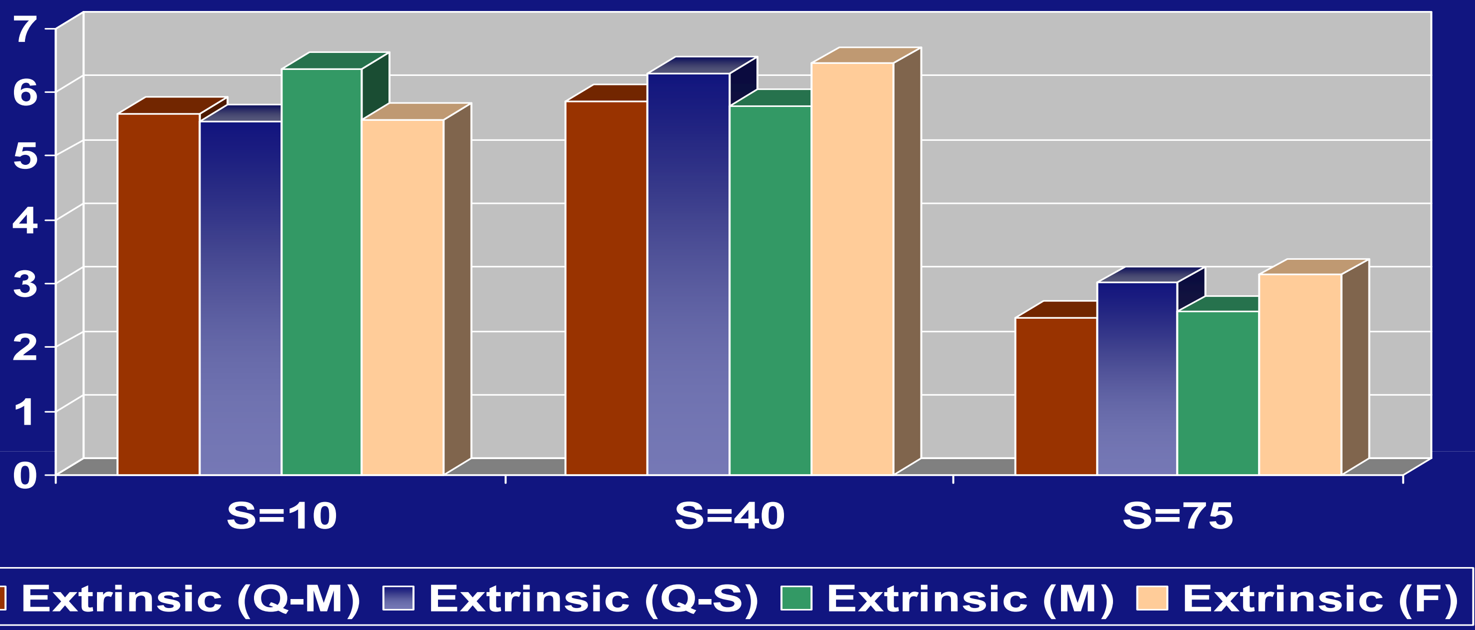
Review of different valuation quantitative techniques

Intrinsic Value Analysis



- All four models give roughly the same intrinsic values, therefore, trading on the forward curve without any price variability will generate the same amount of profit regardless of the models or methodology we are using.

Review of different valuation quantitative techniques
Extrinsic Value Analysis



- The greater the model flexibility, the more flexible the extrinsic value.
- Extrinsic value differs across models due to the different pricing algorithms for gas prices and the numerical methodology in order to solve the storage function optimisation problem.

Review of different valuation quantitative techniques

How important is extrinsic value?

- According to industry experts, the time value (extrinsic) of storage can be from a fraction of the intrinsic (like ¼) up to seven or even eight times the intrinsic value.
- The intrinsic and extrinsic values of storage are defined exactly as the intrinsic and extrinsic values of options, since storage is an option. Therefore, extrinsic value has the same properties as in finance:
- It increases along with volatility and it declines as we approach maturity (T). The further out we stand, the greater the time-value of storage.
- Being able to estimate this time value is to be able to figure out how to unlock extra value, beyond the intrinsic.
- The most flexible pricing model is employed by model “M” (stochastic winter-summer spread), therefore, exhibits the most flexible extrinsic value.
- Furthermore, some trading strategies are shown at the end on how to generate greater than intrinsic cash flows by using calendar spread options.

Review of different valuation quantitative techniques

Storage value sensitivity analysis

- Storage value is sensitive to both market parameters and physical constraints.

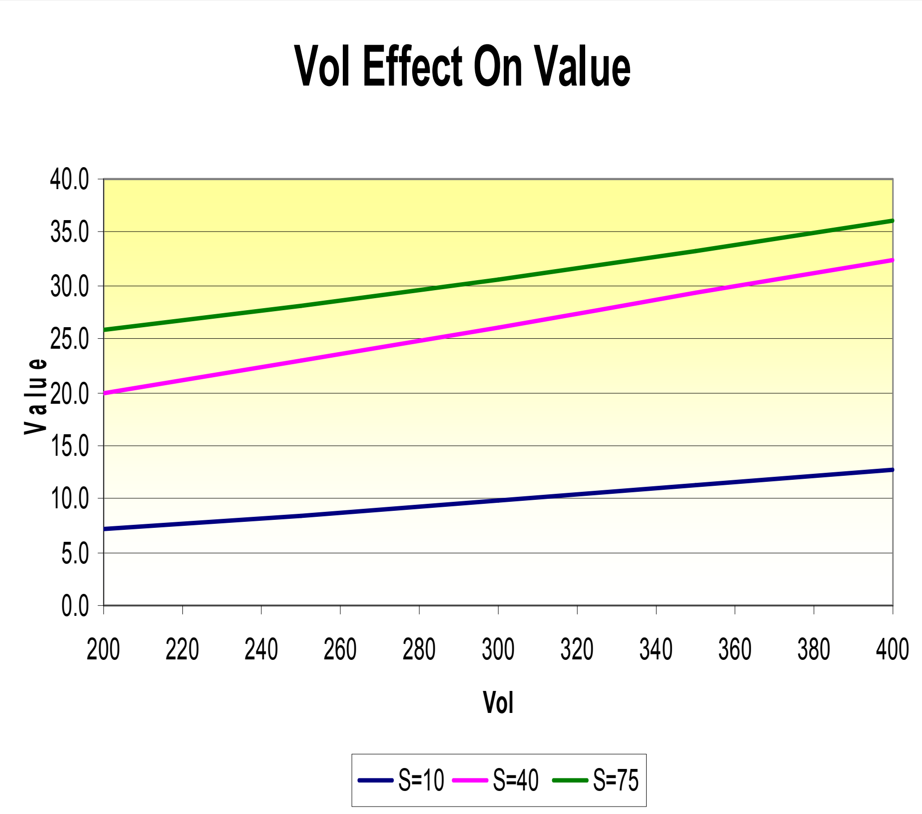
- Market parameters:
  - Volatility
  - Correlation
  - Mean reversion

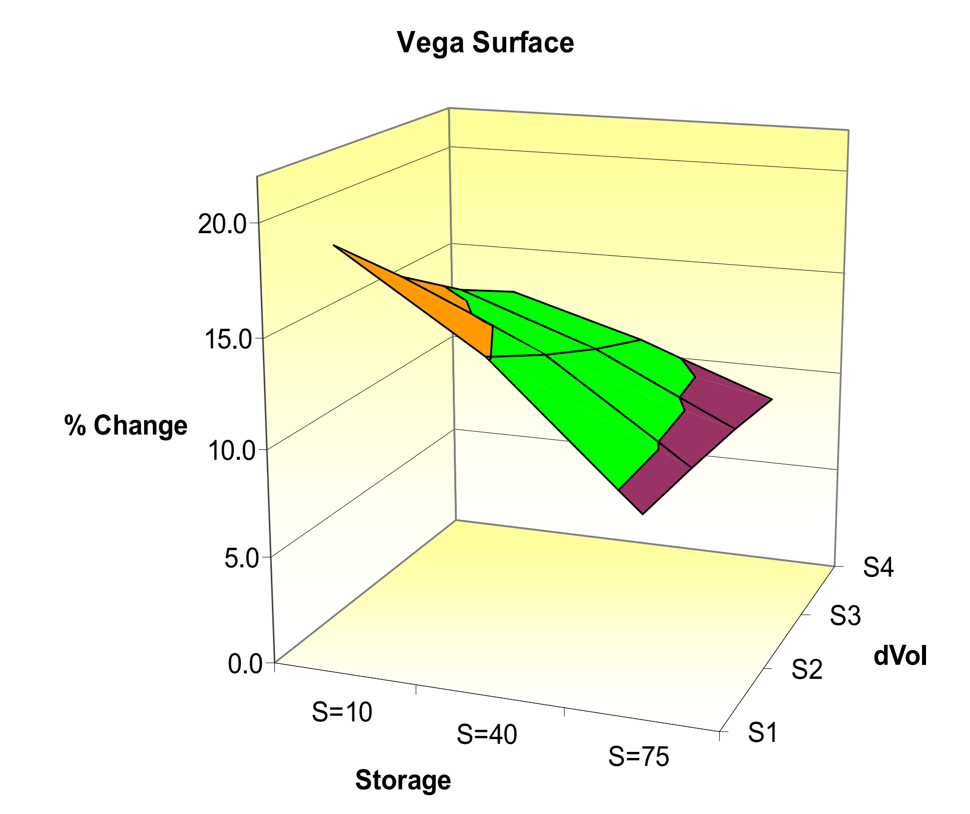
- Physical constraints:
  - Injection
  - Withdrawal
  - Total space

Review of different valuation quantitative techniques

Storage value sensitivity to volatility

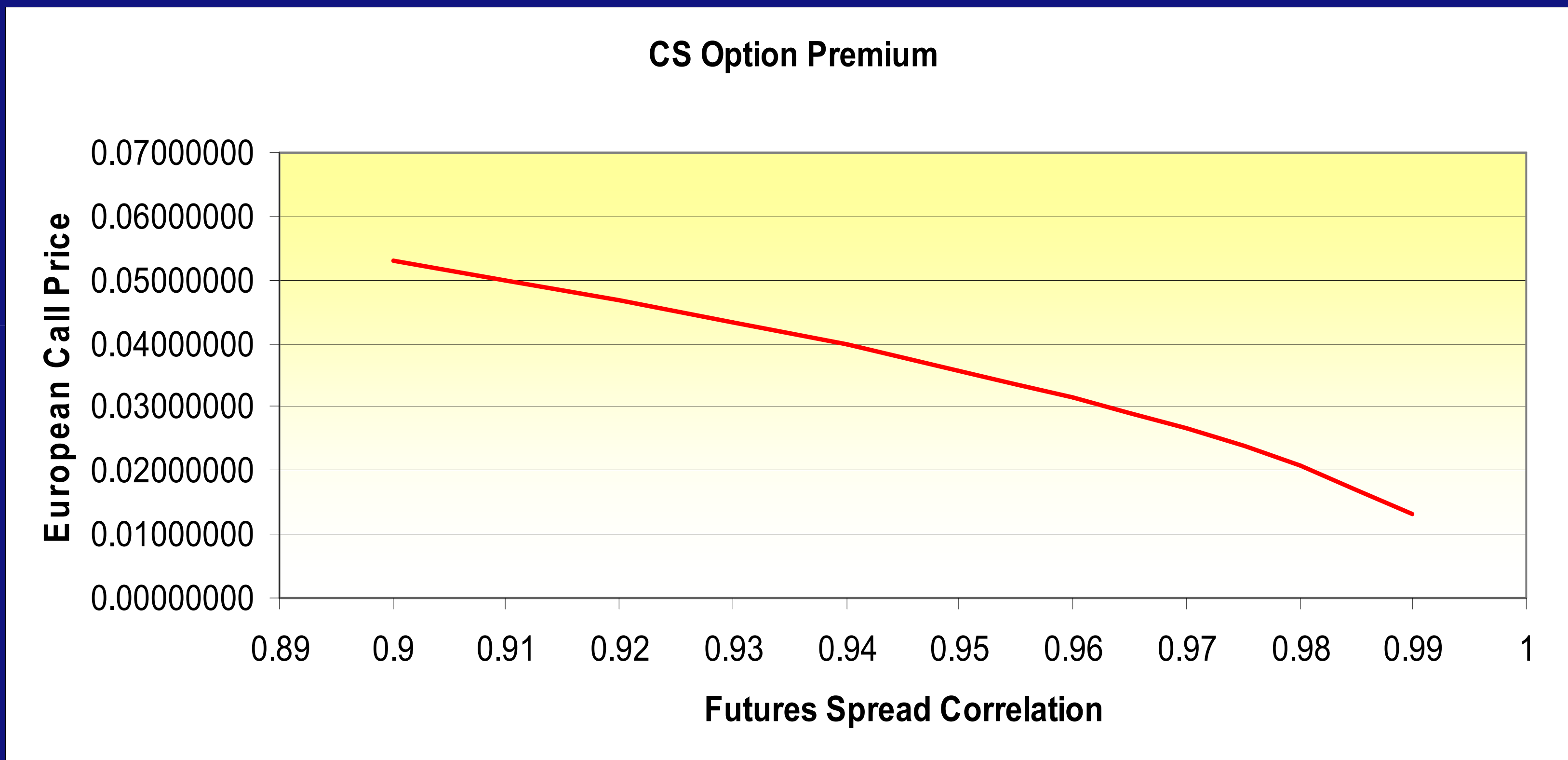
- Volatility has a positive impact on value.
- Vega is one of the Greeks in financial mathematics, it shows the sensitivity of the storage option value to volatility: $\partial V/\partial \sigma$
- Value Sensitivity to Vol: Short duration > Medium duration > Seasonal Storage





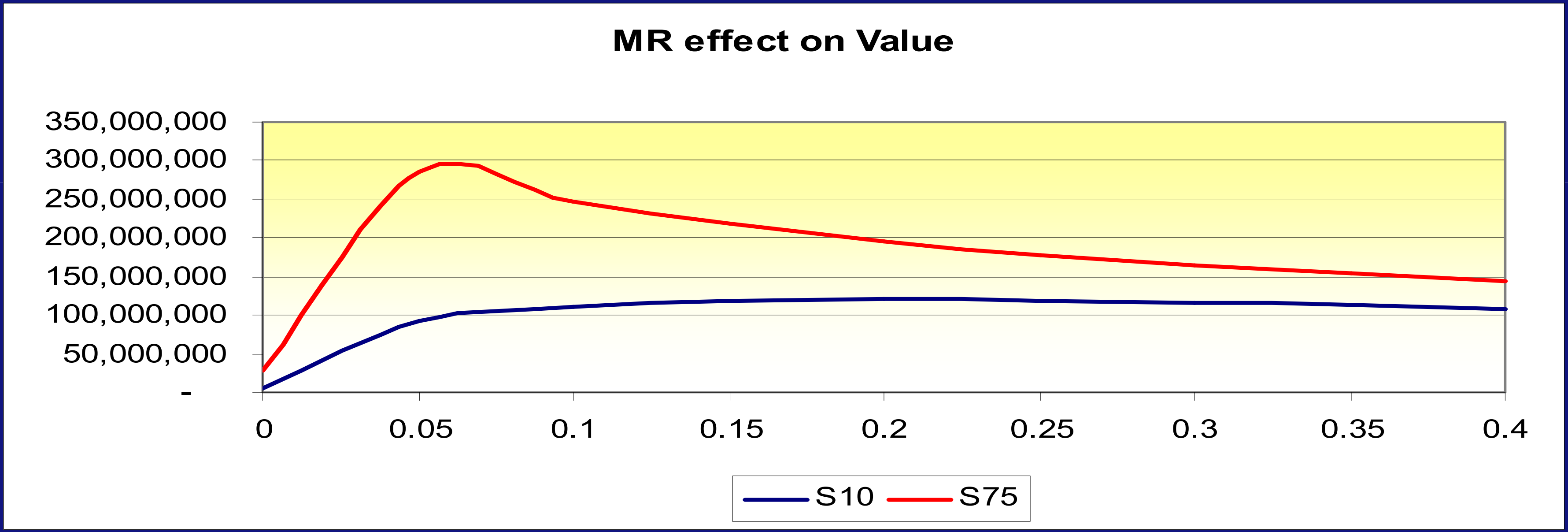
Review of different valuation quantitative techniques

Calendar Spread Option Value Sensitivity to Correlation



Review of different valuation quantitative techniques
Storage value sensitivity to MR

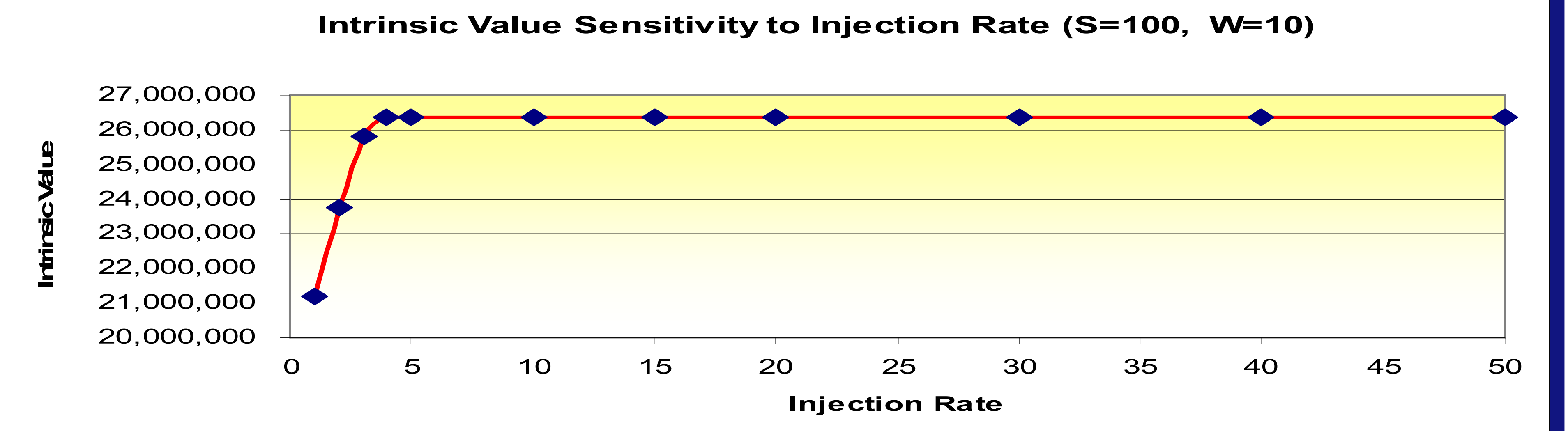
- Energy prices have shown to revert to a long-run level (marginal cost level).
- Mean reversion is needed for profitable storage facility in order to be able to cycle gas, however, after a certain point mean-reversion acts as a detrimental factor to storage value.
- Mean Reversion has a different kind of impact to seasonal than to short duration storage.

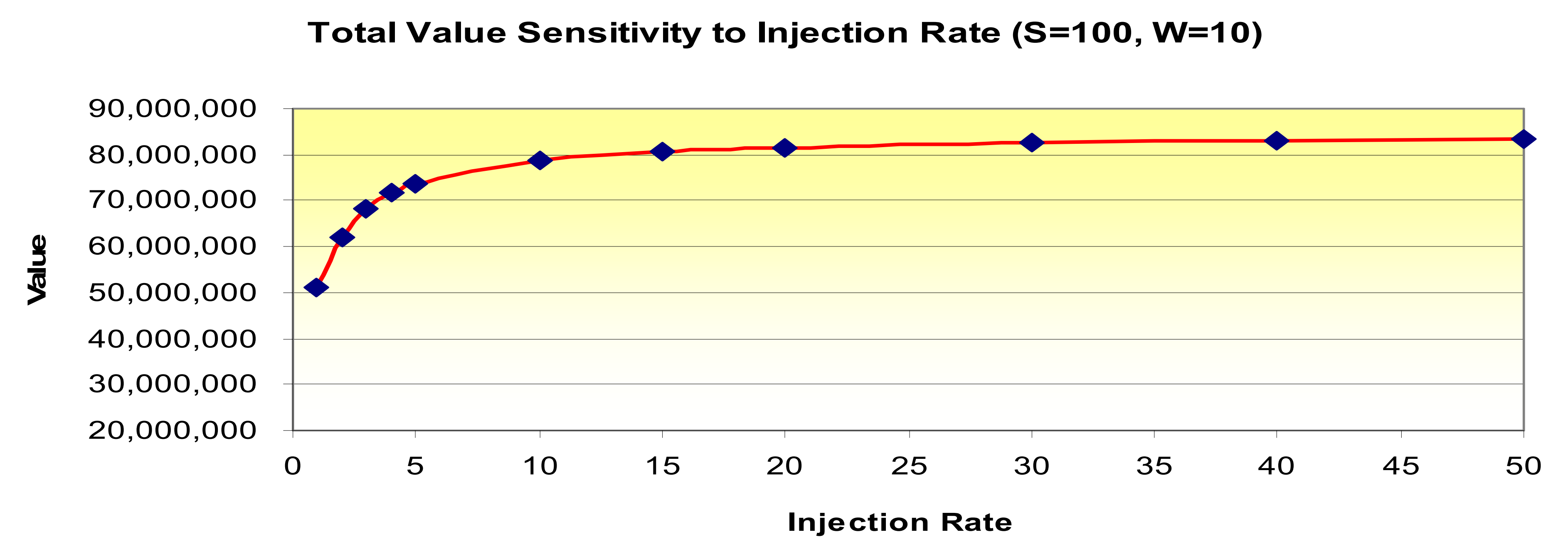


- Seasonal storage should give higher value since it can take greater advantage of expected price swings in a low MR environment. As MR increases, it acts as a detrimental factor especially to the value of the seasonal storage as there are no great price swings expected causing the facility not often filled so much, hence not getting fully exploited.

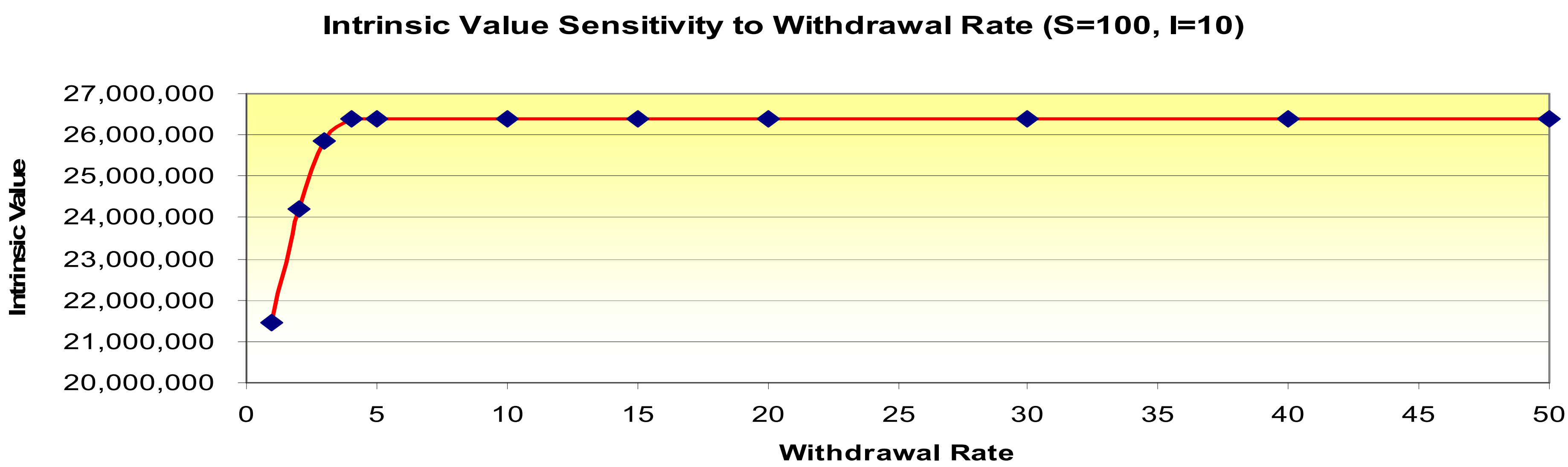
Review of different valuation quantitative techniques

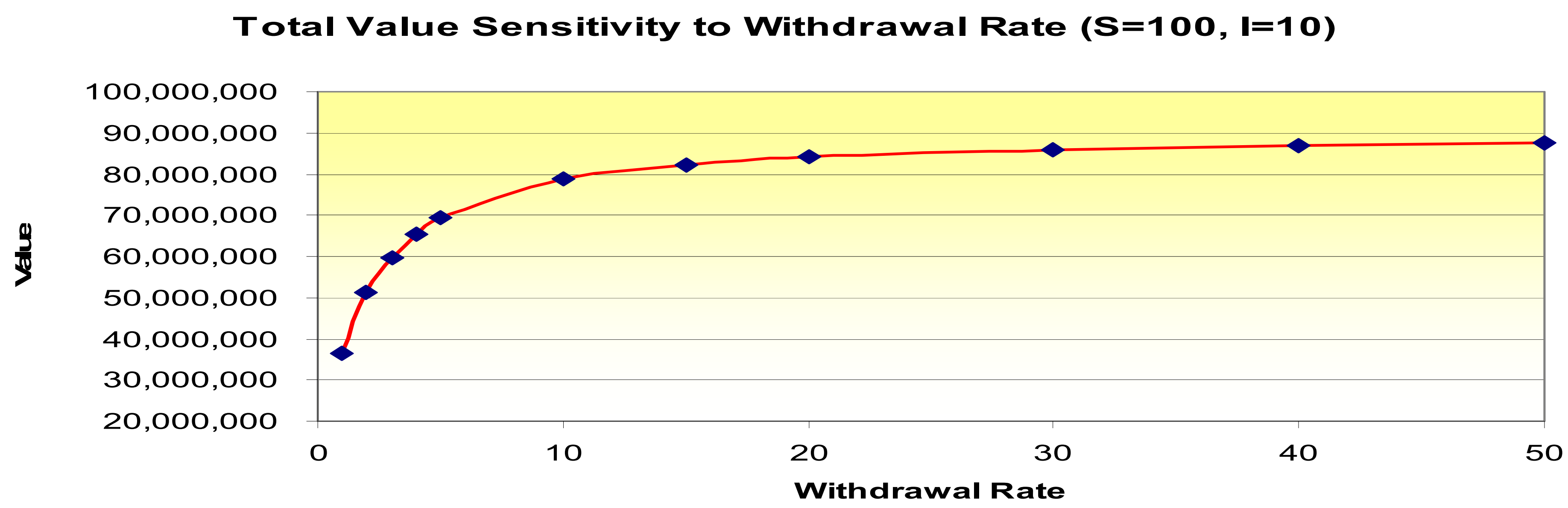
Injection Rate Value sensitivity



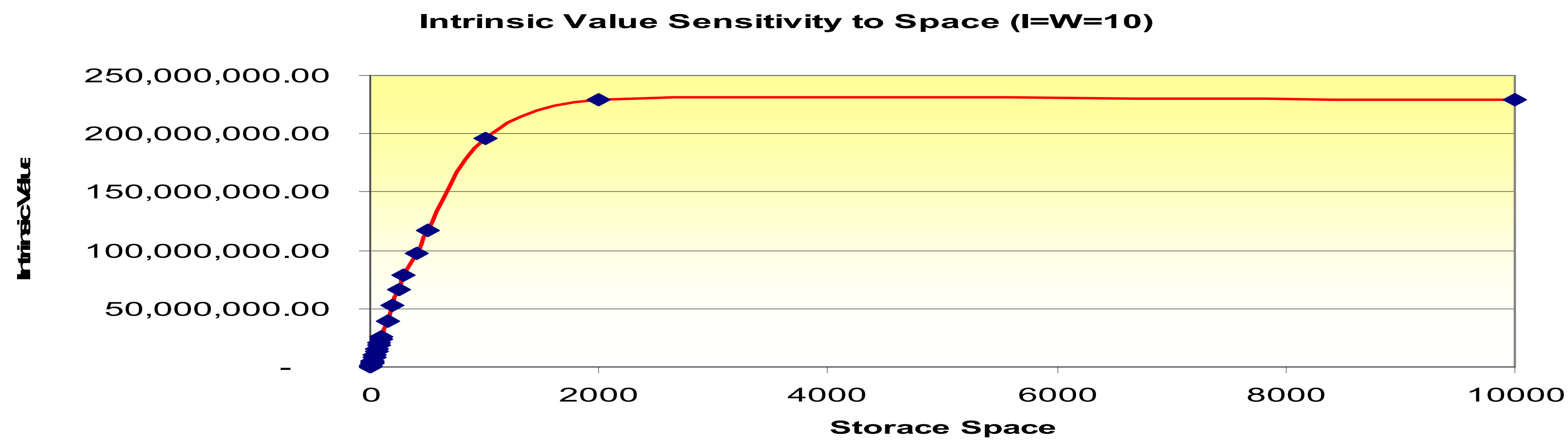


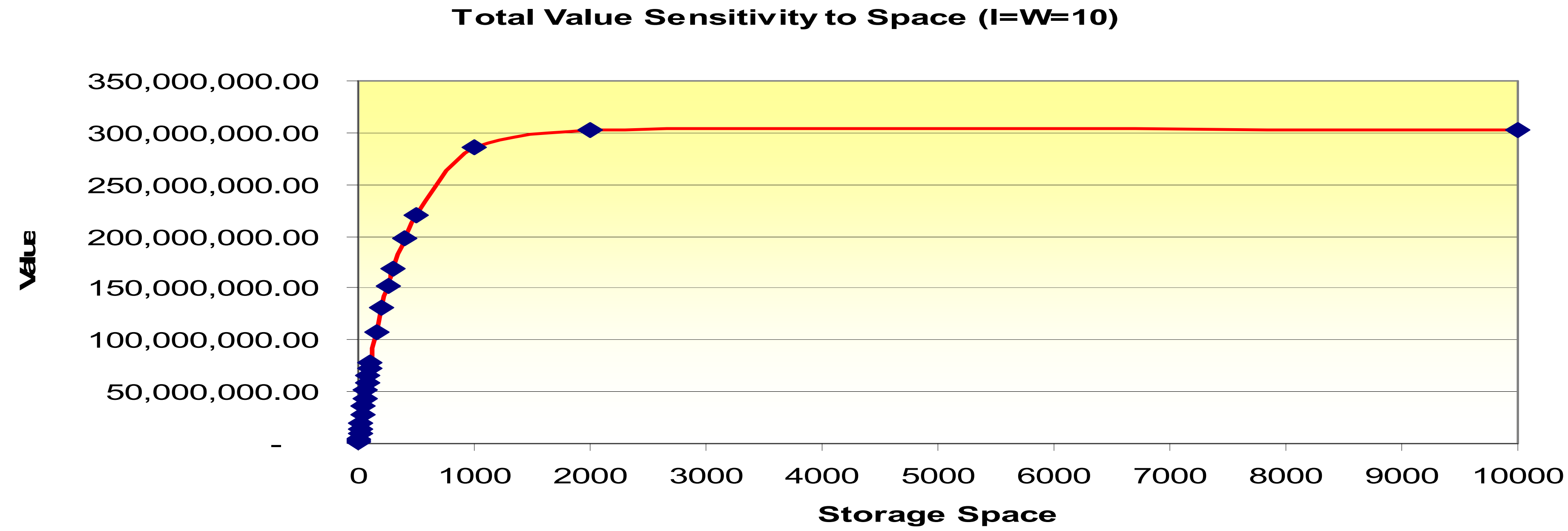
Review of different valuation quantitative techniques
Withdrawal Rate Value sensitivity





Review of different valuation quantitative techniques
Total Space Value sensitivity





- Key gas storage functions.
- Comparison of different valuation quantitative techniques.
- **Quantitative analysis of the valuation steps.**
- Measuring the extrinsic value risk.
- Storage trading strategies.

Quantitative analysis of the valuation steps

The key tasks in order to value storage

- The storage valuation involves the following stages:
  - Modelling the gas price evolution process.
  - Obtain the probability distribution function from thousands of simulated price paths following the pre-specified process.
  - Determine the optimal gas volume flows according to the observed price spreads given the physical constraints of the storage facility.
  - Simulate a distribution of the discounted cash flows values by combining the critical probability surface with the optimal volume flows and obtain the average traded profit = withdrawal revenue – injection cost.

Quantitative analysis of the valuation steps

By modelling the gas prices, can we really guess the future price?

- The reason for modelling the gas spot dynamics is in order to obtain a price distribution that approximates the real distribution.
- In financial derivatives valuation (storage valuation) we never try to predict the exact future spot prices but we rather try to get the future price distributional properties right.
- Only in that case will our pricing and our hedges be efficient overall.
- Price distribution can only be obtained from a simulated price process.

Quantitative analysis of the valuation steps
Modelling the gas price evolution process

- One-factor models capture the random-walk property of prices using a Brownian Motion term.
- Two-factor models consider a Brownian Motion process that gravitates around a pre-determined level (long-run marginal cost) using a mean-reverting drift term.
- Three-factor models may consider:
  - Two stochastic mean reverting processes in the drift term of the spot price plus a Brownian Motion, or
  - A Brownian Motion that mean-reverts plus a Jump process (the Jump size and frequency are calibrated from data), etc.

Quantitative analysis of the valuation steps

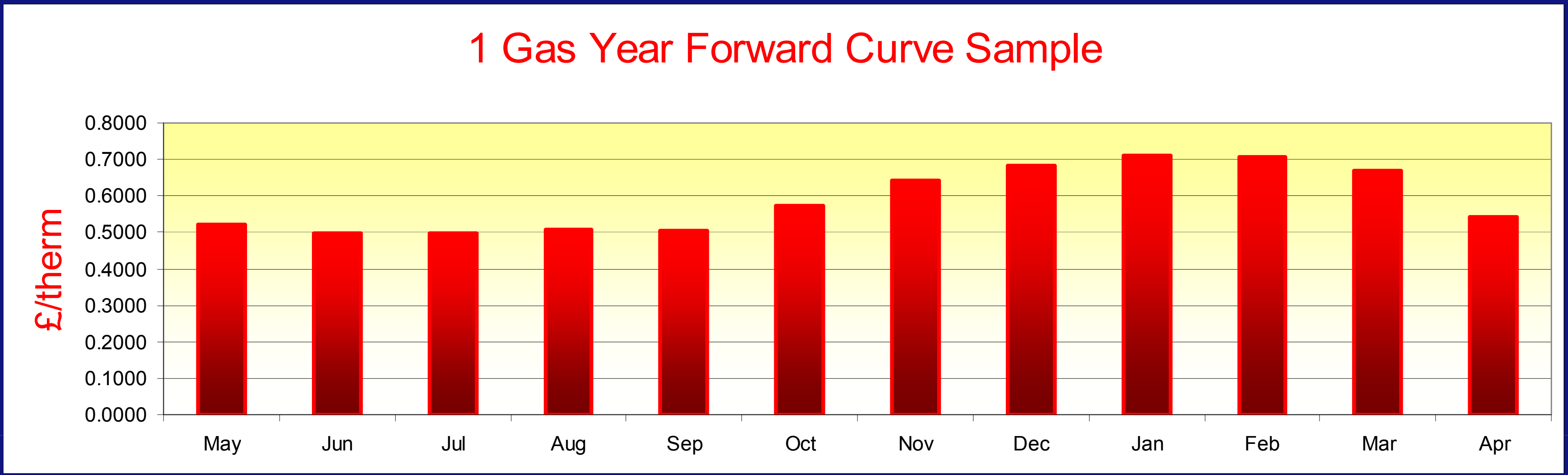
Modelling the gas price evolution process

- The pricing algorithm is applied on the given forward curve.
- MR Model = Mean-Reverting Model
- MRJD = Mean-Reverting Jump Diffusion Model

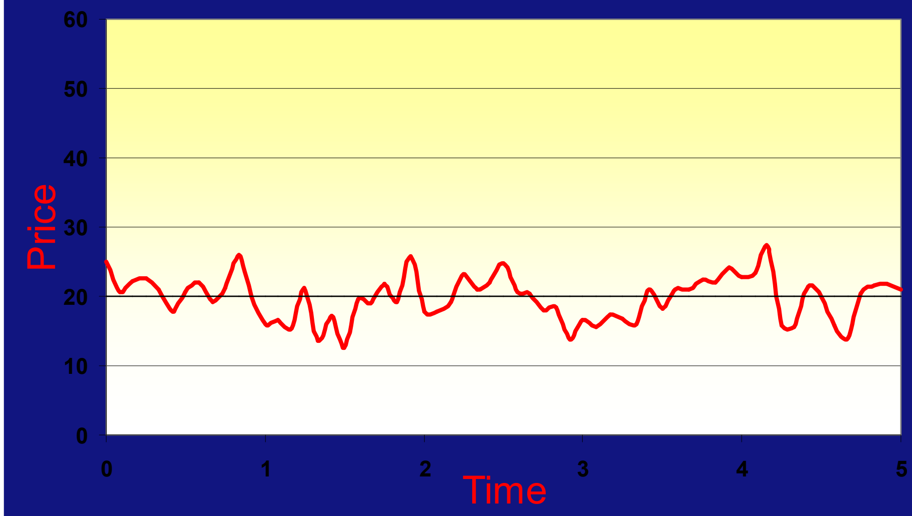
- Forward Curve for 1 Gas Year (May – April)
- Sample price path of a MR (mean-reverting) model
- Sample price path of a MRJD (mean-reverting jump diffusion) model

Quantitative analysis of the valuation steps

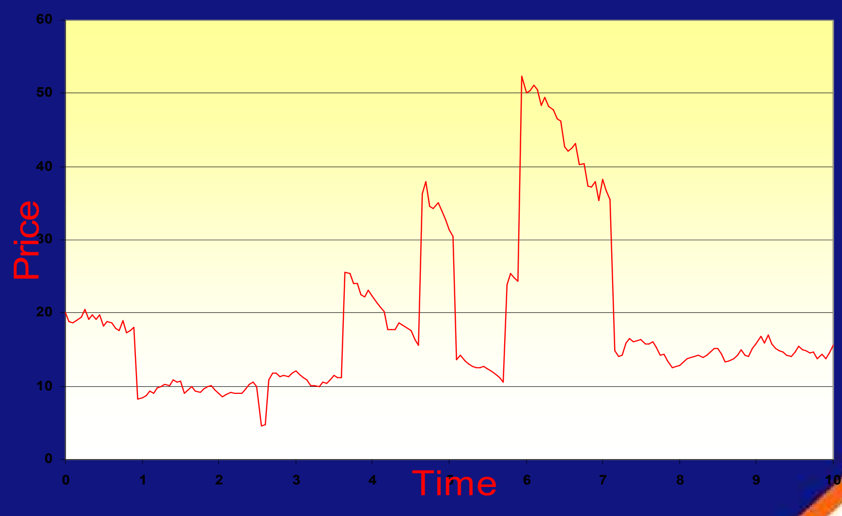
Modelling the gas price evolution process



MR Model

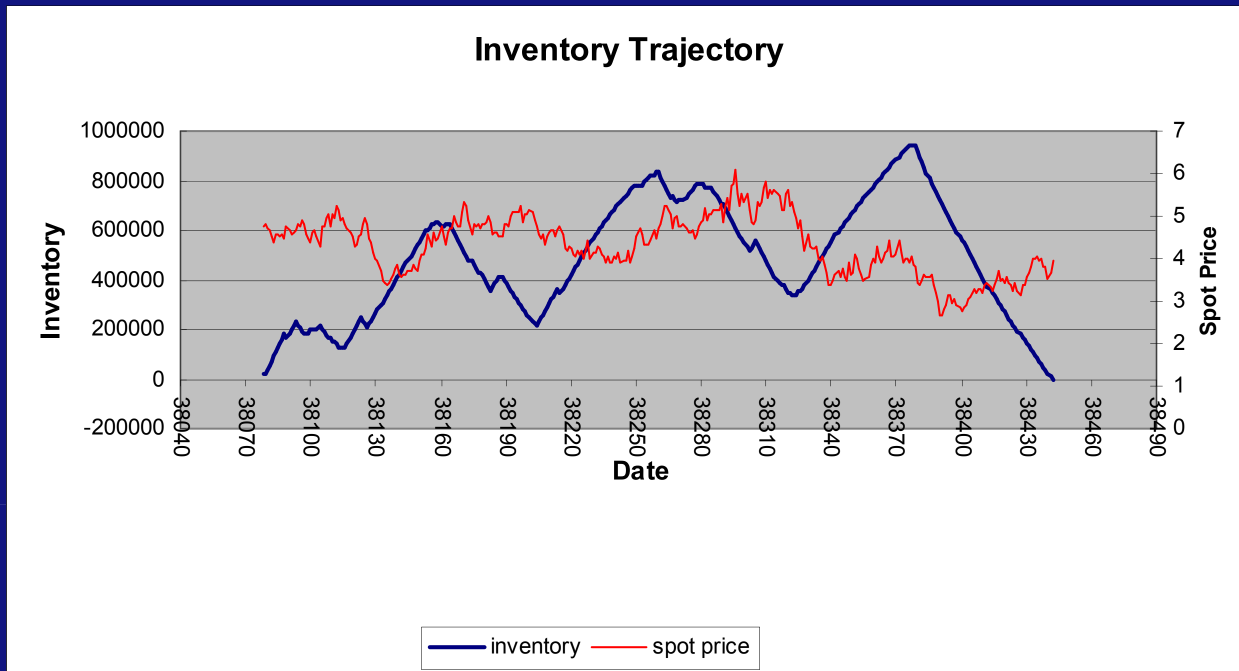


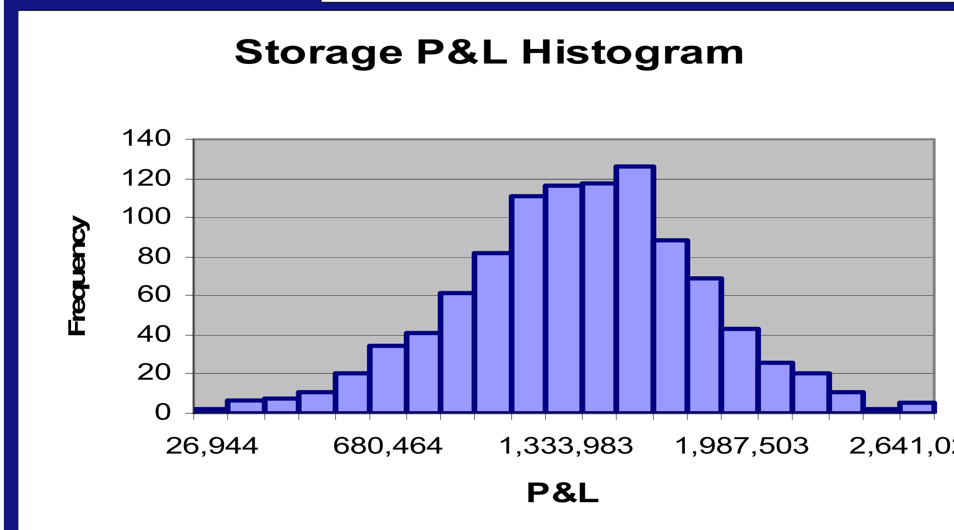
MRJD Model

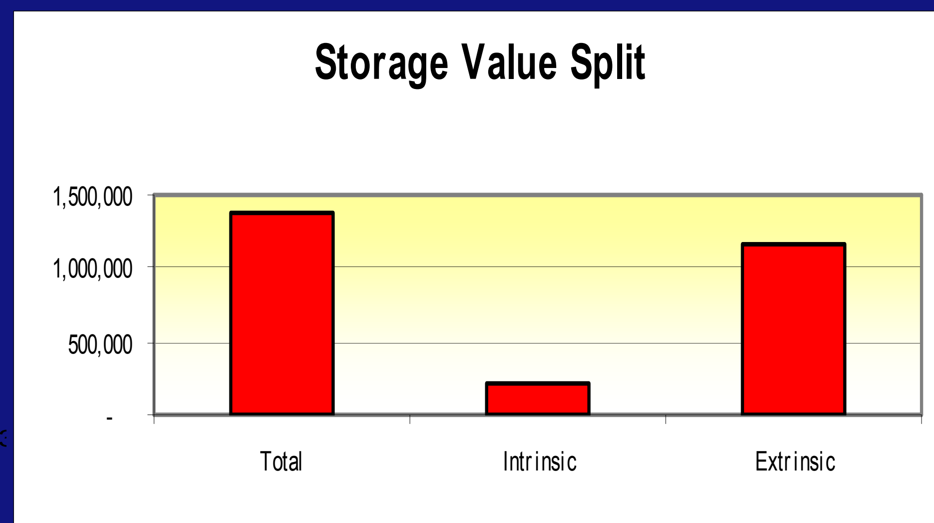


Storage trading strategies

1 – Factor MR Pricing model, Spot & Forwards trading strategy

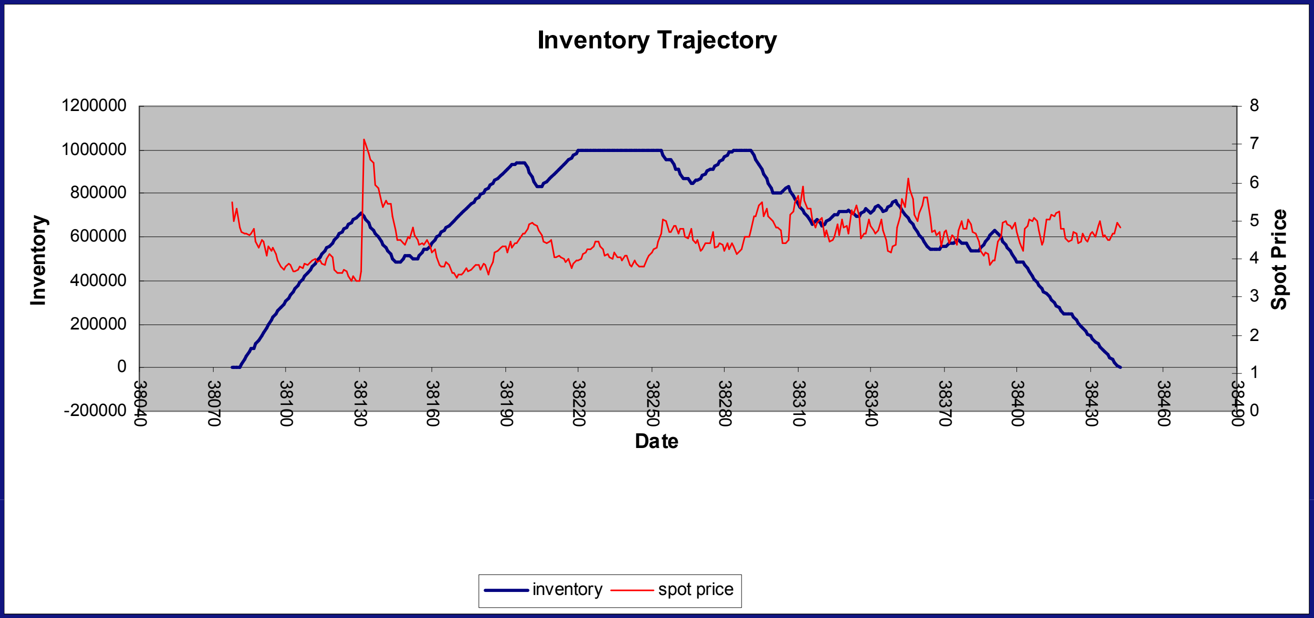


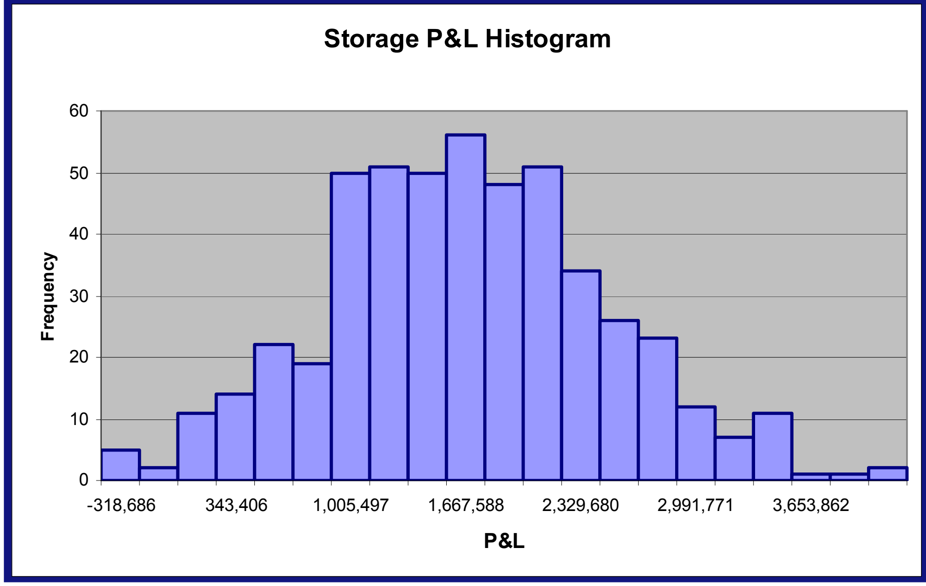


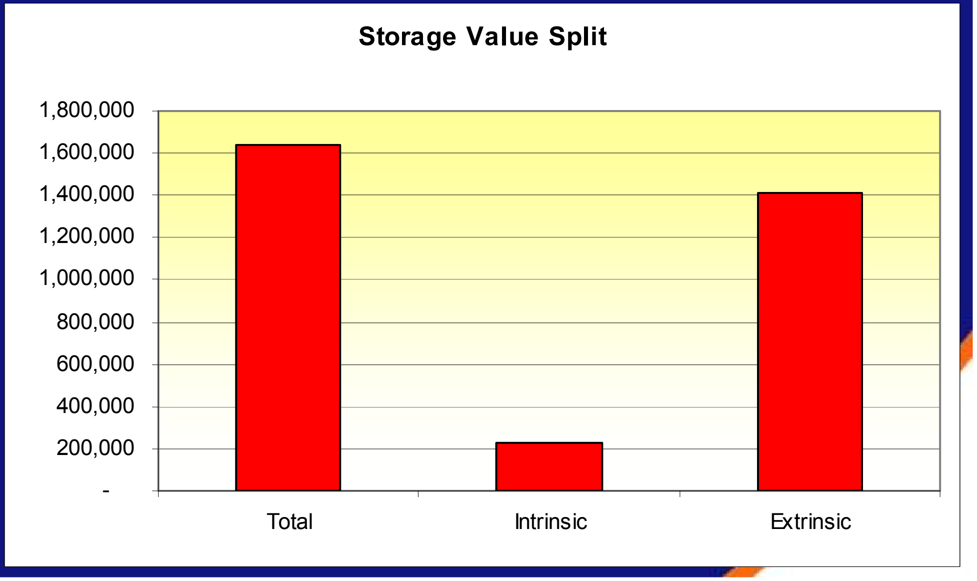


Storage trading strategies

1 – Factor MRJD Pricing model, Spot & Forwards trading strategy

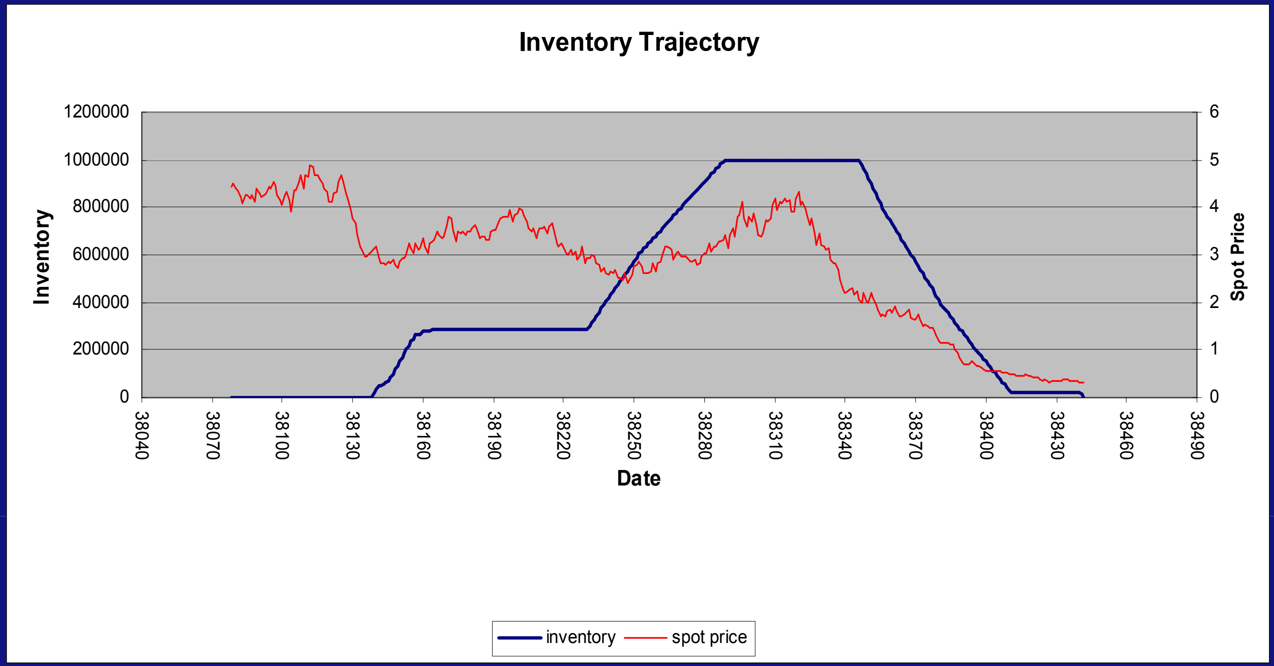


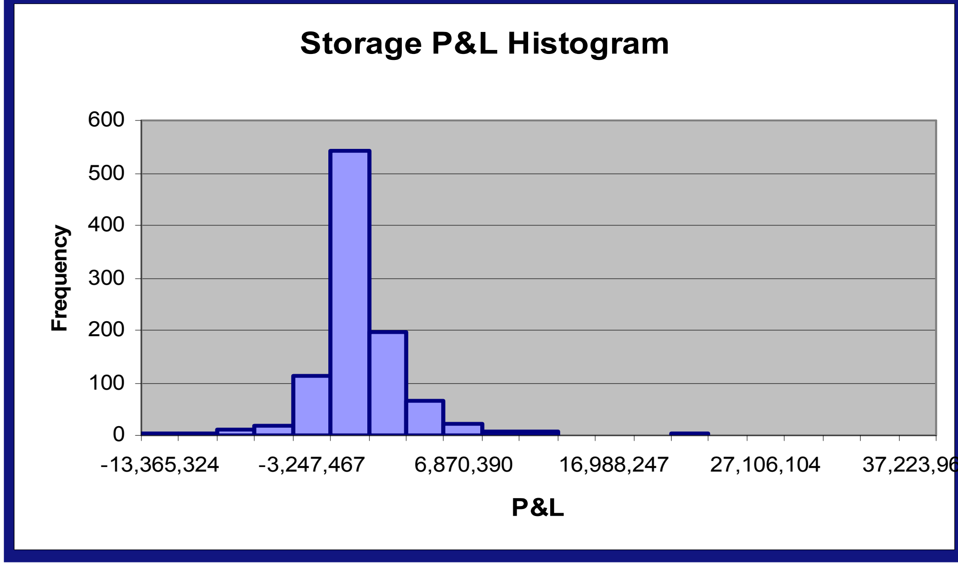


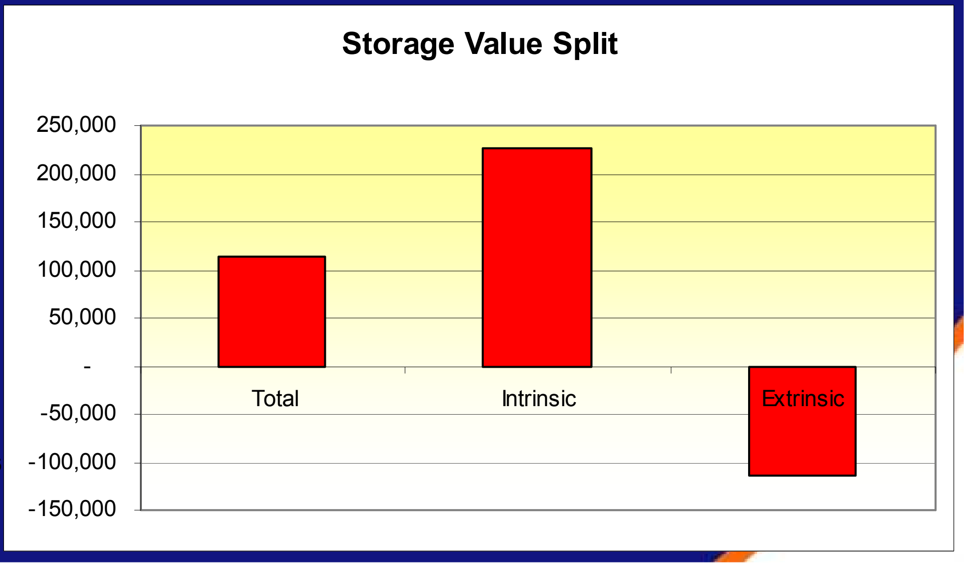


Storage trading strategies

1 – Factor B&S Pricing model, Spot & Forwards trading strategy

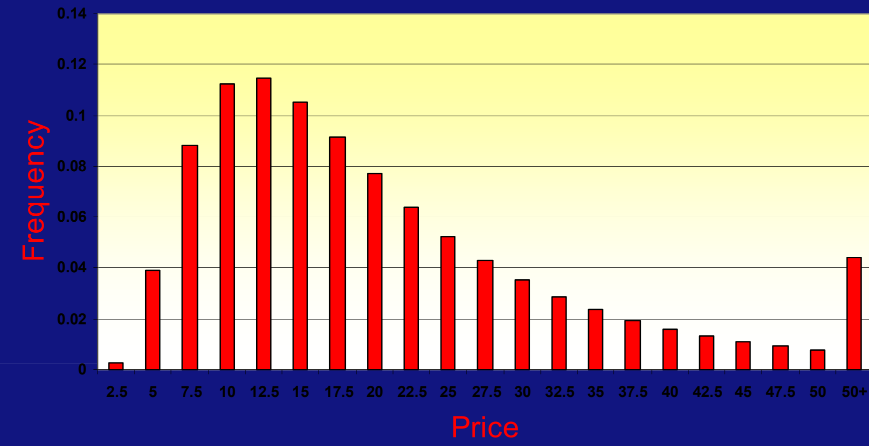




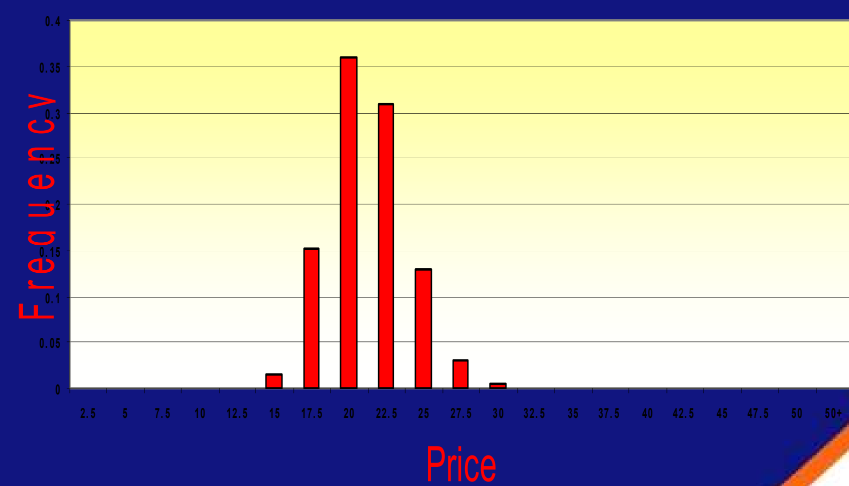


Quantitative analysis of the valuation steps
Price distribution simulation examples

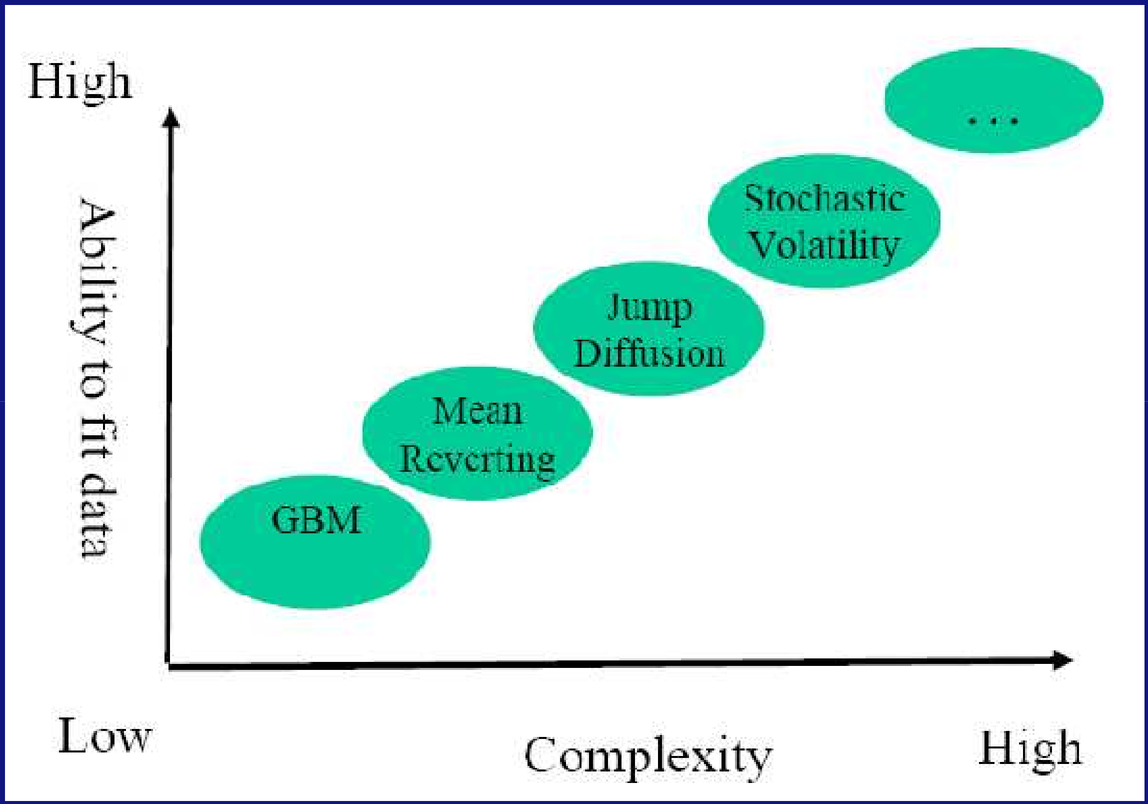
- Simulation example of a mean reverting model:
  - CASE A: Vol = 300, MR = 10



  - CASE B: Vol = 100, MR = 30



Quantitative analysis of the valuation steps
How appropriate are our modelling techniques?



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- Storage trading strategies.

Measuring the extrinsic value risk
Is storage value normal?

- The final figure at each valuation is the average full storage value from 1000 or more simulations.
- Thus, we can calculate the sample sigma (Standard Deviation) from the simulated final storage values.
- However, storage values are non-normally distributed.
- Therefore, we cannot apply the symmetric mean-sigma rule to get a 95% value range.

Measuring the extrinsic value risk

Searching for a risk figure

- One possible solution is to:
  - Directly calculate the 5th and 95th percentile (P5 & P95s) of the value from the simulated total values,
  - Calculate the 95% VaR,
  - And obtain the minimum extrinsic with a 95% confidence interval.
- The same method can be applied for calculating a 99% CI.

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Storage trading strategies I

Lets trade in the futures spreads, storage will cover us…!

- Trading as a simple gas futures spread (intrinsic strategy):
  - On 1st Jan, Trader XYZ values a storage lease for seven months: June – December.
  - 1st Jan, the F_{JUN} = 25p/th and F_{DEC} = 50p/th. Thus, on Jan 1st the gas futures spread = 25p/th (intrinsic value of storage).
  - On 1st Jan, Trader XYZ sells the Jun-Dec spread (long Jun, short Dec). Meaning he can buy June gas at 25p/th and sell December gas at 50p/th.
  - On 1st June, he uses June contract to buy gas@25p/th and puts in storage.
  - Keeps gas in storage until December and on the1st of Dec uses Dec contract (F_{DEC}) to sell gas from storage and lock profit = 25p/th.
  - For simplicity all costs have been ignored (injection, withdrawal, capacity, financing).

Storage trading strategies II

Want to make more money? Again storage will cover us…!

- We proved that a storage value is at least equal to the futures spread, however, in reality storage is worth more, and in order to extract this additional value we need to adapt a different strategy.
- Trader XYZ sells a Calendar June – December Futures Spread Option on Jan 1st with expiry on the 1st of June.
- This means that he sells to the option owner the RTB gas from Trader XYZ using the F_{JUN} contract and the RTS gas to Trader XYZ using the F_{DEC} contract.
- Thus, the CS option has a payoff on the 1st of June: max [$F_{DEC} - F_{JUN}$, 0]
- Suppose that on Jan 1st: F_{JUN} = 25p/th, F_{DEC} = 50p/th. This means that the intrinsic value of the CS option is 25p/th on Jan 1st.
- However, on Jan 1st the CS option has non-zero time value = 10p/th.
- Therefore, on Jan 1st Trader XYZ sells CS option for 35p/th.
- The CS option value is given by: $V_{CS} = (F_{DEC} - F_{JUN}, 0)_+$ @ T = 1st June. Therefore, the option owner will exercise the option if the Jun – December spread widens.
- On 1st Jan, option has non-zero time value (extrinsic).

Storage trading strategies II

Using storage to back up the Calendar Spread Option trading

- CASE A: On 1st June, the spread widened: F_{JUN} = 20p/th, F_{DEC} = 60p/th. The option gets exercised from the option's owner on Trader XYZ.
- In order to meet his obligations to the CS option's owner he has to buy December gas at 60p/th and sell June gas at 20p/th. He has a loss from the option of: -40p/th.
- However, the availability of storage allows him to buy June gas at 20p/th and short the F_{DEC} contract (to sell in December at 60p/th).
- He stores the June gas, keep it until 1st December, and sells it using F_{DEC} contract at 60p/th.
- From this position Trader XYZ won now 40p/th.
- Trader XYZ net position is: -40p/th (CS option loss) + 40p/th (storage and futures spread) + 35p/th (CS option premium) = 35p/th (the premium).

- CASE B: Spread narrowed: F_{JUN} = 30p/th, F_{DEC} = 50p/th. The option is worthless, Trader XYZ keeps the premium.
- Again for simplicity all costs have been ignored (injection, withdrawal, capacity, financing).

Storage trading strategies II

Want to make more money? Again storage will cover us…!

- This strategy simply takes advantage of the fact that having storage we can always capture the gas futures spread value (intrinsic strategy) at any point of time that the CS option's owner decides to exercise and benefit from the current gas future's spread.
- If futures spread moves favourably for the option's owner then he exercises to get the futures spread benefit and at the same time Trader XYZ can take a position on the same futures spread and using storage he can extract exactly the same value the CS option's owner got from him.
- Therefore, using a storage futures spread position someone can always offset the CS option loss (futures spread).
- The CS time value needs to be sufficiently large to cover all costs incurred.
- The wider the time gap between the date of selling the CS option (valuation date) and the maturity date (1st day of the 1st month on the CS months spread), the greater the time value of the CS option.
- This time value can vary from fractions of the futures spread (intrinsic value) to multiples (x8) of the futures spread.
- Therefore, the potential option premium, the amount we always end up with when using the CS Option – Storage strategy, can be very significant.
- We would expect option premiums to be very big as vol and MR rise to high levels and as correlations breaks down in the future markets and the more time we allow to maturity.

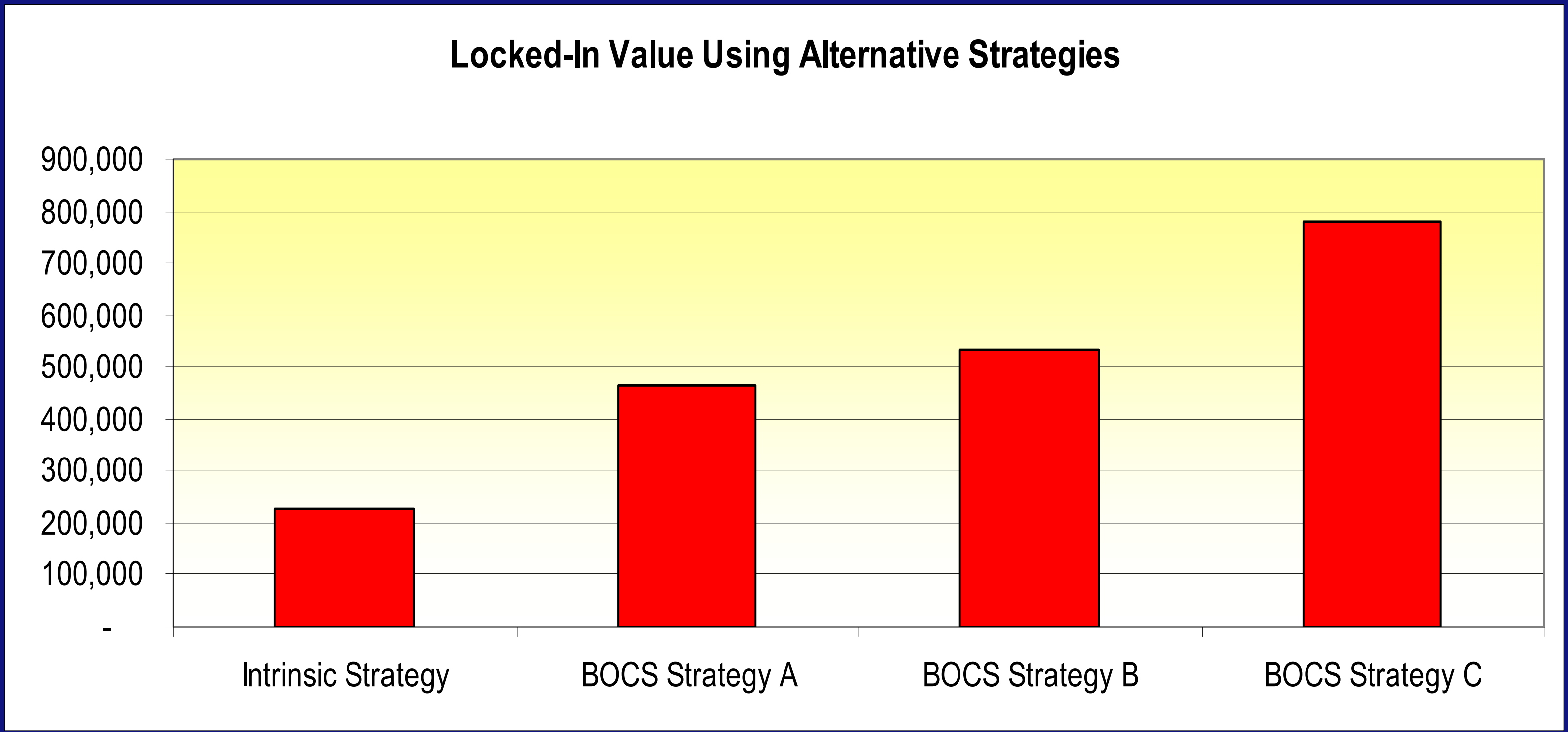
Storage trading strategies III

Some natural extensions…

- Instead of structuring a single CS option, we can design a Basket of CS and get a higher value for it.
- In addition to the Basket of CS, we can use straddle strategies for the highly volatile CS and get an ever greater value.
- A straddle strategy would be adopted for a highly volatile CS or a Forward contract (F) by going long (buying) simultaneously a Call (RTB) and a Put (RTS) on the CS / F, with the same strike price (K) and maturity (T).
- For example, we buy a 1.5p Call and a 1.5p Put on a Dec – Nov CS, 1.5p being the closest K to the current CS price of 1.3p.
- The Call premium (0.2p OTM) = 0.075p, and the Put premium (0.2p ITM) = 0.3p.
- Our total initial cost for the straddle = 0.375p.
- After a few days, the Dec – Nov CS price jumps to 2.2p.
- The 1.5p Call is now 0.7p ITM and its premium is now 0.8p.
- The 1.5p Put is now 0.7p OTM and its premium is now 0.025p.
- If we close the straddle position now we earn 0.825p.
- Profit from straddle strategy = 0.825 – 0.375 = 0.50p.

Storage trading strategies

Locking – in value with alternative strategies



- Intrinsic Strategy = Static forward optimisation on current FC
- BOCS A = Trading Forwards, Rolling Basket of CS
- BOCS B = Trading Forwards, Rolling Basket of American Style CS
- BOCS C = Trading Forwards, Rolling Basket of CS & Straddles
- Delta, Gamma & Vega Hedging volumes for BOCS Strategies: C > B > A

Questions?