In this second article of the gas storage segment of the Masterclass series, *John Breslin, Les Clewlow, Tobias Elbert, Calvin Kwok, Chris Strickland* and *Daniel van der Zee* describe a simple to execute and risk-limiting trading strategy, the rolling intrinsic method

# Gas storage: rolling intrinsic valuation

★ In the previous article in this Masterclass series, we gave an overview of four common valuation methodologies for a gas storage facility. In particular, two of them, namely the intrinsic valuation and basket of spread methods, were discussed in detail. From a valuation perspective, these two methods are static strategies as the values are determined based solely on the market information that is available at the start of the valuation period. However, in reality, not only is the forward curve constantly evolving, but our views of the market volatility and correlations can also change. The static methods ignore the new information and so do not fully utilise the flexibility provided by the storage facility, which enables the owner to dynamically adjust their market positions in order to capture additional value.

In this article, we describe a storage valuation method known as the rolling intrinsic strategy, which extends the intrinsic strategy by allowing for regular reoptimisation and rebalancing of the portfolio. Similar to the intrinsic strategy, the rolling intrinsic strategy is relatively straightforward to evaluate, with the only additional complication arising from the need to compute the costs of readjusting the portfolio. As a trading strategy the rolling intrinsic method is simple to execute, as we will describe below. Finally, the rolling intrinsic method is a risk-limiting strategy; the strategy never gives a payoff that is lower than the original intrinsic value. These features make the rolling intrinsic methodology well suited for giving a realistic and prudent estimate of the value of a storage facility.

To remind readers of the definition of intrinsic valuation discussed in our previous article (Breslin, 2008a), it is a valuation method which assumes the value of the storage is given by a set of optimal long and short positions of monthly forward or futures contracts covering the period of the storage facility and observed on the valuation date. The optimal condition under this method is defined by the set of positions which maximises the total cash flows gained from settlements during the valuation period. In mathematical terms, this problem can be written as

$$\max_{v_{ij}} \sum_i \sum_j v_{ij} \Delta F_{ij}$$

subject to

$$v_{ij} \geq 0$$
$$W_j = \sum_i v_{ij} \leq W_{\max}$$
$$I_i = \sum_j v_{ij} \leq I_{\max}$$

where:
$\Delta F_{ij}$ is the discounted spreads for injection in month $i$ and withdrawal in month $j$; $v_{ij}$ is the position in spread $\Delta F_{ij}$; $I_i$ is the total injection at month $i$; $W_j$ is the total withdrawal at month $j$; $V_i$ is the storage level at month $i$; $V$ is the storage facility capacity; $I_{max}$ is the maximum daily injection the rate; $W_{max}$ is the maximum daily withdrawal rate; $c_I$ is the cost of injection; $c_w$ and is the cost of withdrawal.

A stylised storage facility is described in table 1. Using a hypothetical gas forward curve from March 31, 2007, with the discounted forward prices shown in the first row of table 2, we calculate the intrinsic value of the facility to

| **T1. Details of the example storage facility** |
|---|
| Total capacity 600,000 MMBtu (or 1 Bcf) |
| Maximum injection rate 20,000 MMBtu/day |
| Maximum withdrawal rate 20,000 MMBtu/day |
| No injection/withdrawal cost |
| The valuation period is from April 1, 2007 to March 31, 2008, with the valuation being performed as at March 31, 2007 |
| The original and terminal constraints are that the facility must be empty on the start and end dates |
| Assume a flat discount rate of 3.5% for the valuation period |

**T2. Discounted forward prices used in the example (pence/therm)**

| | Spot | Apr 07/ BOM | May 07 | Jun 07 | Jul 07 | Aug 07 | Sept 07 | Oct 07 | Nov 07 | Dec 08 | Jan 08 | Feb 08 | Mar 08 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar 31 | 20.50 | 20.50 | 20.00 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 23.00 |
| Apr 1 | 20.50 | 19.00 | 19.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 23.00 |
| Apr 16 | 22.50 | 21.00 | 20.40 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 23.00 |
| Apr 28 | 21.50 | 20.50 | 19.70 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 20.50 | 23.00 |

**T3. Injection and withdrawal decisions (MMBtu)**
(positive values = injection; values in parenthesis = withdrawal)

| | Spot | Apr 07/ BOM | May 07 | Jun 07 | Jul 07 | Aug 07 | Sept 07 | Oct 07 | Nov 07 | Dec 08 | Jan 08 | Feb 08 | Mar 08 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar 31 | 0 | 0 | 600,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (600,000) |
| Apr 1 | 0 | 600,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (600,000) |
| Apr 16 | (20,000) | (280,000) | 600,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (600,000) |
| Apr 28 | (20,000) | (40,000) | 600,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (600,000) |

**T4. Storage levels at the end of each month (MMBtu)**

| | Spot | Apr 07/ BOM | May 07 | Jun 07 | Jul 07 | Aug 07 | Sept 07 | Oct 07 | Nov 07 | Dec 08 | Jan 08 | Feb 08 | Mar 08 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar 31 | 0 | 0 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 0 |
| Apr 1 | 0 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 0 |
| Apr 16 | 280,000 | 0 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 0 |
| Apr 28 | 40,000 | 0 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 0 |

be £180,000. The value is obtained as the discounted total revenue the facility will generate if the positions shown in the corresponding row of table 3 are entered into on March 31, 2007. (The corresponding storage levels are displayed in detail in table 4).

Assuming we lock in the interest rates and the counterparty of the trade does not default on the settlements, the above amount is guaranteed to be received regardless of any changes in the gas forward curve. However, one natural question that arises is whether this would be the maximum amount that could be extracted from the storage facility over its life. Depending on the evolution of the forward curve, the answer is probably not.

In the above example, the largest discounted spread of the forward prices on March 31 is represented by the May 07-Mar 08 spread, which is equal to 3 pence/therm, so the owner of the storage could enter this position and lock in the 3p profit. Let us assume that the next day, April 1, the forward curve moves such that the Apr 07-Mar 08 spread is 4 pence/therm. This makes the Apr 07-Mar 08 spread more appealing than the existing May 07-Mar 08 position, even though the May 07-Mar 08 spread has also increased to 3.5 pence/therm.

In such a scenario, it would be sensible to unwind some or all of the long position for May 07 and simultaneously enter into a long position for the Apr 07 contract. Assuming the amounts to be closed out and entered are the same, this would yield a negative cash flow, since the May 07 price has decreased from 20.00 to 19.50 between March 31 and April 1, so a loss would be incurred in unwinding the May 07 position. However, this decline is offset by the positive cash flow generated by the new position and the overall result is a net positive profit. This procedure, of changing positions in the replicating forward portfolio to capture extra profit, is the essence of the rolling intrinsic strategy.

To make this example clearer, we consider the detailed calculations involved. The second row in table 2 shows the discounted forward curve on April 1, 2007 – that is, the day following the initial valuation date. Based on this new information, an intrinsic optimisation is performed, with the resulting intrinsic value on April 1 being £240,000 (compared with £180,000 on March 31). However, we need to take into account the existing positions, so the net profit of the total position after rebalancing is given by

$$\text{new intrinsic value} - \text{old intrinsic value} - \text{loss on closing out existing positions} \quad (1)$$

where the last term represents the loss for closing out the April 07 positions and is calculated to be £30,000, ie,

(new May price – May price that has been locked in) × unwinding volume
= (19.5 pence/therm – 20.0 pence/therm) × 600,000MMBtu
= –£30,000

By substituting this amount to equation (1), it is clear that the rolling intrinsic strategy has brought an additional value of £30,000 from this rebalancing. Of course, no rebalancing should be performed if it would result in a reduction in the overall profit.

## Practical considerations

While the above has illustrated the main concept of the rolling intrinsic strategy, it is a simple case in which we assume no injection or withdrawal has yet been made to the facility before the rebalancing date. As we move further into the valuation period, the level of the storage in the facility may be different from the initial volume as physical settlements of the forward contracts may have already taken place.

Such a change in the level of storage must be taken into account in our calculations. For example, extra value could be extracted from injections already made if the front end of the forward curve has been rising since the valuation date. Suppose now that on April 16, 2007 there is a short-term supply shock causing the spot price to jump to 22.5 pence/therm and the balance-of-month price to 21 pence/therm. By this date, the owner would have taken 15 days of injection with a total amount of 300,000MMBtu. Given this level of storage and the discounted forward curve shown in the third row of table 2, the optimal strategy on this date is to close out some of the long positions in April, sell all the storage in the spot market and balance-of-month, then lock in 600,000MMBtu of long positions in May. The corresponding injection and withdrawal decisions are shown in table 3 and the storage profile is shown in table 4. This rebalancing adds an additional £36,000 of revenue to the storage portfolio.

In the presence of injection or withdrawal cost, the rebalancing of positions may no longer be profitable. For instance, suppose injecting and withdrawing from the storage facility attracts a cost of 5 pence/therm and 3 pence/therm, respectively. For the forward curve movement from March 31 to April 1, it would still be profitable to readjust the positions but the rebalancing profit would reduce from £30,000 to £29,000. However, the decision of rebalancing on April 16 is no longer profitable as doing so would result in a loss, and so we would leave the position unchanged in the presence of injection and withdrawal costs.

## Pros and cons

Although the rolling intrinsic strategy is relatively easy to implement, it has some drawbacks. Firstly, the rolling intrinsic method yields the highest value when different calendar months move in opposite directions. However, as months tend to be strongly positively correlated, the extra value captured by the rolling intrinsic strategy may not be large. Secondly, the major drawback of the strategy is that it can sometimes lead to suboptimal decisions being made. Let us once again consider in our example the May 07 contract and assume that the price declines further to be 19.70 pence/therm on April 28, 2007 (shown in row 4 of table 2). As we have already committed our full capacity on the May 07 contracts, there is no remaining capacity to take advantage of the widening spread. Furthermore, the loss incurred from closing out existing positions might be so great that it stops us from unwinding the May 07 position in order to capture the upside movement of different pairs of spreads. In other words, the rolling intrinsic strategy is not efficient if the best calendar spreads shift to different maturities, which is actually a key aspect of the dynamics of gas forward curves. So while the rolling intrinsic is a low risk trading strategy guaranteeing a non-negative value, the opportunity cost associated with it has potential to outweigh its simplicity of implementation.

## Valuation using rolling intrinsic

Despite its limitations, the rolling intrinsic method is still one of the most popular approaches for valuing a storage facility, due to its simplicity. There are two popular methods of apply the rolling intrinsic strategy for estimating the value of a facility. The first is to run the rolling intrinsic valuation over some historical period. For instance, the intrinsic value of the example facility discussed in the previous article of our Masterclass series (Breslin, 2008a) is £3,190,696 over a 12-month period. Running a rolling intrinsic valuation using the forward curves observed over the period of the contract and with daily rebalancing yields a value of £4,041,183, that is an additional £850,487 to the intrinsic value. However, this historical simulation approach only produces one instance of the storage value based on the specific evolution of the historical forward curve over the historical period chosen. This is unlikely to be representative of the future evolution of the forward curve and does not give any information for risk management purposes.

Another way of applying the rolling intrinsic strategy is by performing Monte Carlo simulation. In this case, a model is used for simulating the evolution of forward curves over the valuation period and the rolling intrinsic strategy is applied on the simulated forward curves in order to compute the distribution of the cash flows associated with the storage facility. One such model for producing these forward quote simulations is the multi-factor, multi-commodity (MFMC), discussed in April 2008 issue of this Masterclass series.

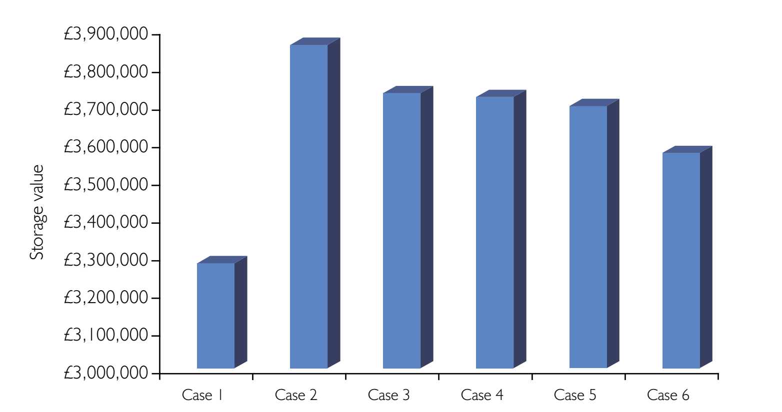
To remind readers of the MFMC model (Breslin, 2008b), it assumes forward prices follow a geometric Brownian process where the diffusion volatility, a function of time and maturity, governs the magnitude and direction of the random movement of each point on the forward curve. This can be expressed in the general form

$$\frac{dF(t,T)}{F(t,T)} = \sum_{i=1}^{n} \sigma_i(t,T)dz_i(t)$$

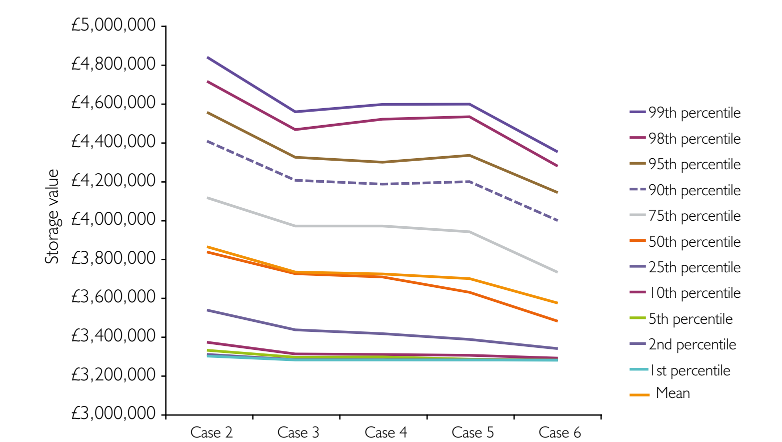
where $F(t,T)$ denotes a forward price for delivery at time $T$ (the maturity date) recorded on date $t$ and $\sigma_i(t,T)$ is the volatility function associated with the source of uncertainty $dz_i(t)$. We refer to this as an $n$ factor model. Using this model, we have performed a 5000 sample path simulation of the rolling intrinsic strategy for the facility described in table 1 over the period April 1, 2007 to March 31, 2008. The parameters of the models were estimated from the four years of data preceding the valuation date.

**T5. Expected values for the storage facility for each test case**

| |
|---|
| Case 1: Daily Hedge Intrinsic £3,279,155 |
| Case 2: Daily Hedge – Daily Rebalance £3,858,870 |
| Case 3: Monthly Hedge – Daily Rebalance £3,730,774 |
| Case 4: Monthly Hedge – 2-Day Rebalance £3,720,926 |
| Case 5: Monthly Hedge – 7-Day Rebalance £3,696,389 |
| Case 6: Single Volatility Function – Monthly Hedge – 7 Day Rebalance £3,571,861 |




**F1. Chart illustrating the expected values of the storage facility for each test case** *Source: Lacima Group*




**F2. Distribution of values of the storage facility for each test case**
*Source: Lacima Group*

## Performance of rolling intrinsic

There are several key aspects of the rolling intrinsic strategy that affect its performance and the value that can be extracted. The first is the type of the forward contracts which are available to trade (eg, daily, monthly or seasonal), the second is the rebalancing frequency (eg, daily, weekly, etc) and the third is the nature of the covariance between the different forward contracts. For modelling purposes, the number of factors used in the MFMC model determines how well the covariance between forward contracts is captured. In order to illustrate the effect of these inputs we have run the following examples:

1. Daily forward contracts with an intrinsic hedge;
2. Daily forward contracts and a daily rebalancing period under a 3-factor forward curve model;
3. Monthly forward contracts and a daily rebalancing period under a 3-factor forward curve model;
4. Monthly forward contracts and a 2-day rebalancing period under a 3-factor forward curve model;
5. Monthly forward contracts and a 7-day rebalancing period under a 3-factor forward curve model;
6. Monthly forward contracts and a 7-day rebalancing period under a 1-factor forward curve model.

Table 5 and figure 1 show the expected values for these six cases.

With daily rebalancing of the daily hedge rolling intrinsic strategy we obtain the highest value relative to the base case 1 daily intrinsic strategy, with an additional 20% of value realised. However, daily rebalancing of a daily hedge is not realistic. When we switch to daily rebalancing of a monthly hedge (case 3) we have a value of 115% of the base case 1. Reducing the rebalancing frequency from daily to 2 days and 7 days results in very little loss of value. This is good news for traders as a 7-day rebalancing period is far more practical than daily or 2-day rebalancing.

There is a significant reduction in value of approximately 5% in the case of the single volatility function (case 6), which has the same overall forward curve volatility as the 3-factor model, but has the forward contracts instantaneously perfectly correlated. This shows that it is important to have a realistic multi-factor forward curve model in order to realistically model the rolling intrinsic strategy.

Figure 2 shows the distributions of values (in terms of percentiles) for cases 2 to 6. Note that the lower bound for all the cases is the base intrinsic value of £3,279,155.

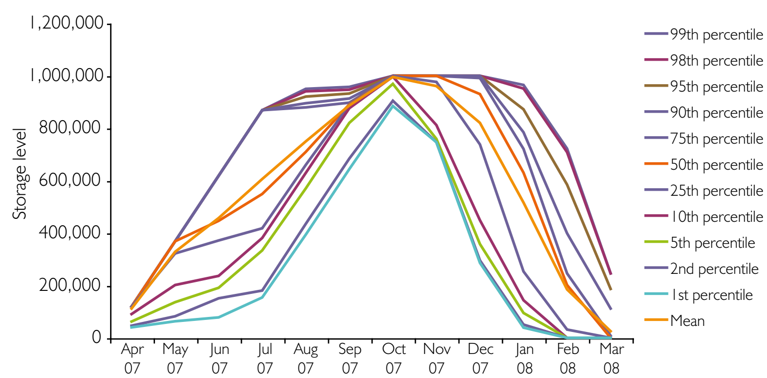
Figure 3 shows the distribution of storage levels by month for case 5, and figure 4 shows the distributions of injection and withdrawals by month for the same case.

It can be seen from figure 3 and figure 4 that the expected operation of the facility under the rolling intrinsic strategy is broadly similar to the intrinsic strategy, ie, inject during the relatively low priced summer months and withdraw during the relatively high priced winter months. However the distribution of storage levels and injection/withdrawal decisions clearly illustrate the benefit of a dynamic strategy compared to the static intrinsic strategy.

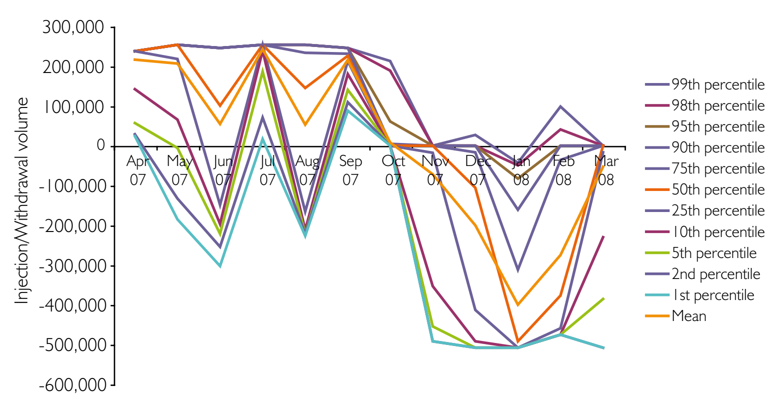
Although it is sub-optimal, as discussed above, the rolling intrinsic strategy allows the owner of the storage facility to adjust their position in order to capture additional value as the market evolves through time. This is highlighted in figure 4, which shows a small number of paths for which withdrawal has occurred during summer and injection has occurred during winter. Although unlikely, the model has produced relatively higher prices in summer in a small number of simulations, and the rolling intrinsic strategy has been able to capture a small amount of value from these events.

In this and our previous article on storage valuation, we have described several methods to value a storage facility, based on static and dynamic forward or option trading strategies. An alternative approach is to use a spot optimisation model, which can be used to calculate the storage value based on making daily decisions for the injection or withdrawal of gas from the facility.

In our next Masterclass on storage valuation, we will discuss the spot optimisation model and how the value obtained can be captured. ER




**F3. Distribution of storage levels in each month** *Source: Lacima Group*




**F4. Distribution of injections/withdrawals in each month** *Source: Lacima Group*

Les Clewlow and Chris Strickland are the founders and directors of Lacima Group, where John Breslin and Daniel van der Zee are principals, and Tobias Elbert and Calvin Kwok quantitative analysts

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