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TopQuants Autumn Event

Asset-backed trading in energy markets

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Introduction KYOS

Background

- Activities started in 2002; KYOS founded in 2008
- Specialist in energy & commodity markets: trading, valuation, risk management
- Core competence: quantitative model and software development
- Experienced and dedicated expert team

Activities

- <u>Modelling</u>

  Apply quantitative financial techniques to energy markets

- <u>Consulting</u>

  Advise on energy trading, valuation and risk management

- <u>Training</u>

  Combine theory with real life examples

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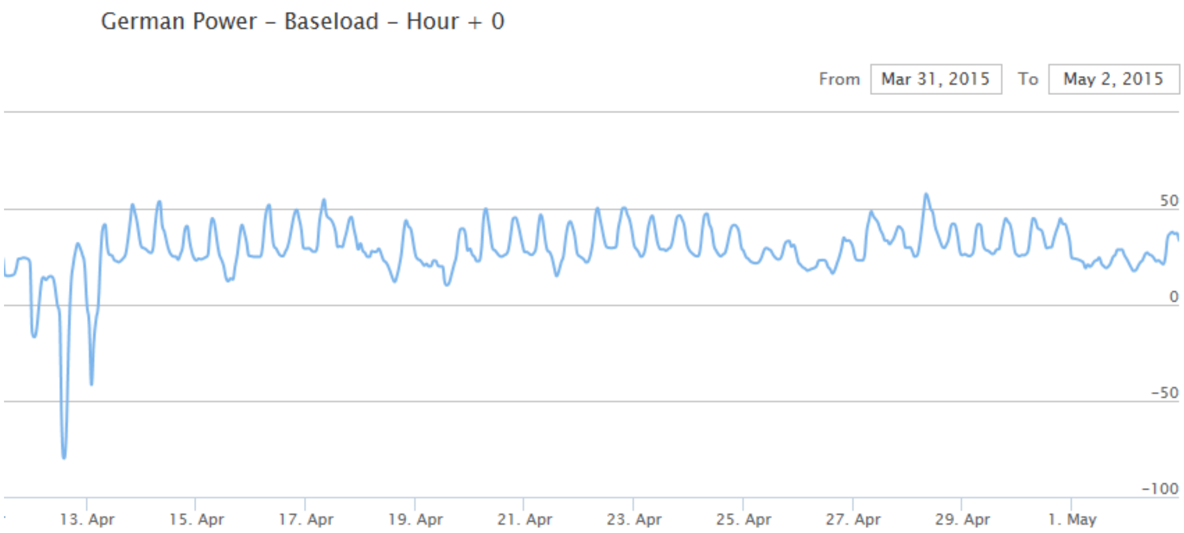
Companies with KYOS software

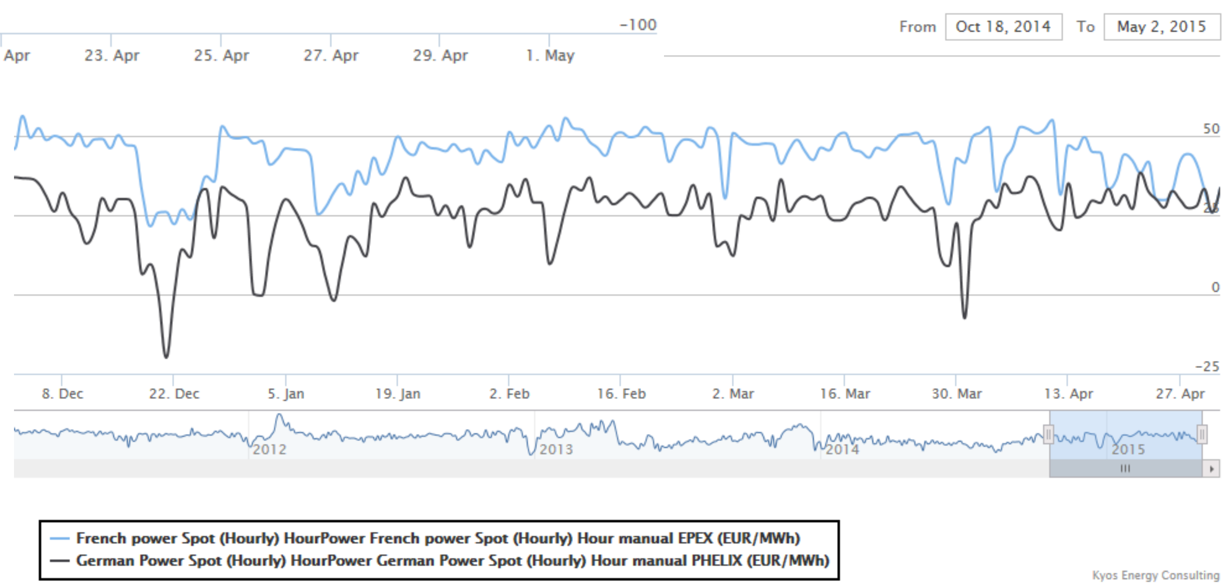
Introduction

Power as a tradable commodity

- Power:
  - Very uniform commodity
  - But: cannot easily be stored
  - And: transport is only possible via existing power cables
- Consequences:
  - Complex market mechanisms to balance demand and supply for every day, hour, minute
  - Quite distinct markets for different periods of delivery (forward, day-ahead, intra-day, imbalance)
  - Quite distinct prices per delivery area

Hourly spot prices and regional differences





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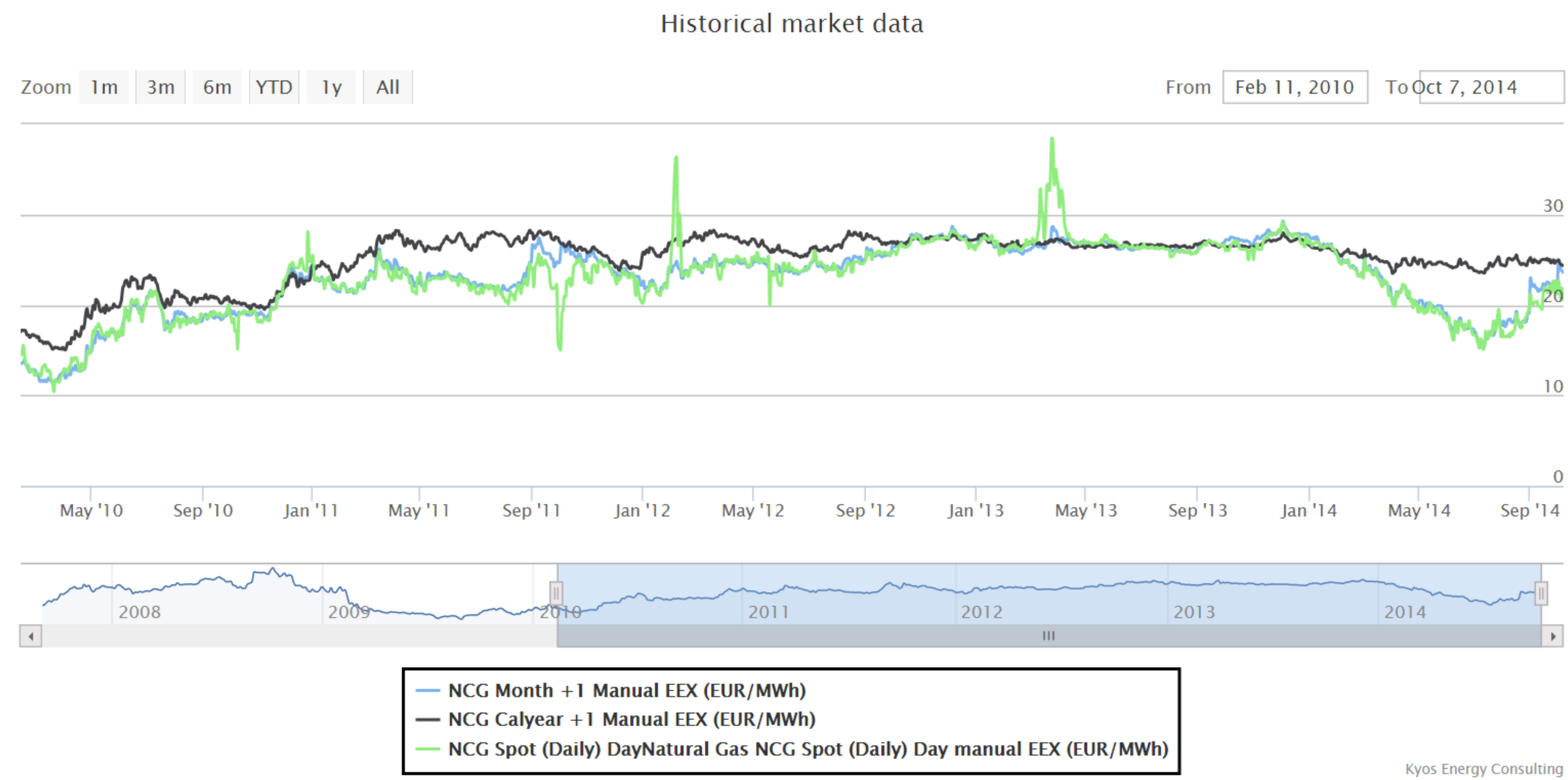
Gas comparison contracts

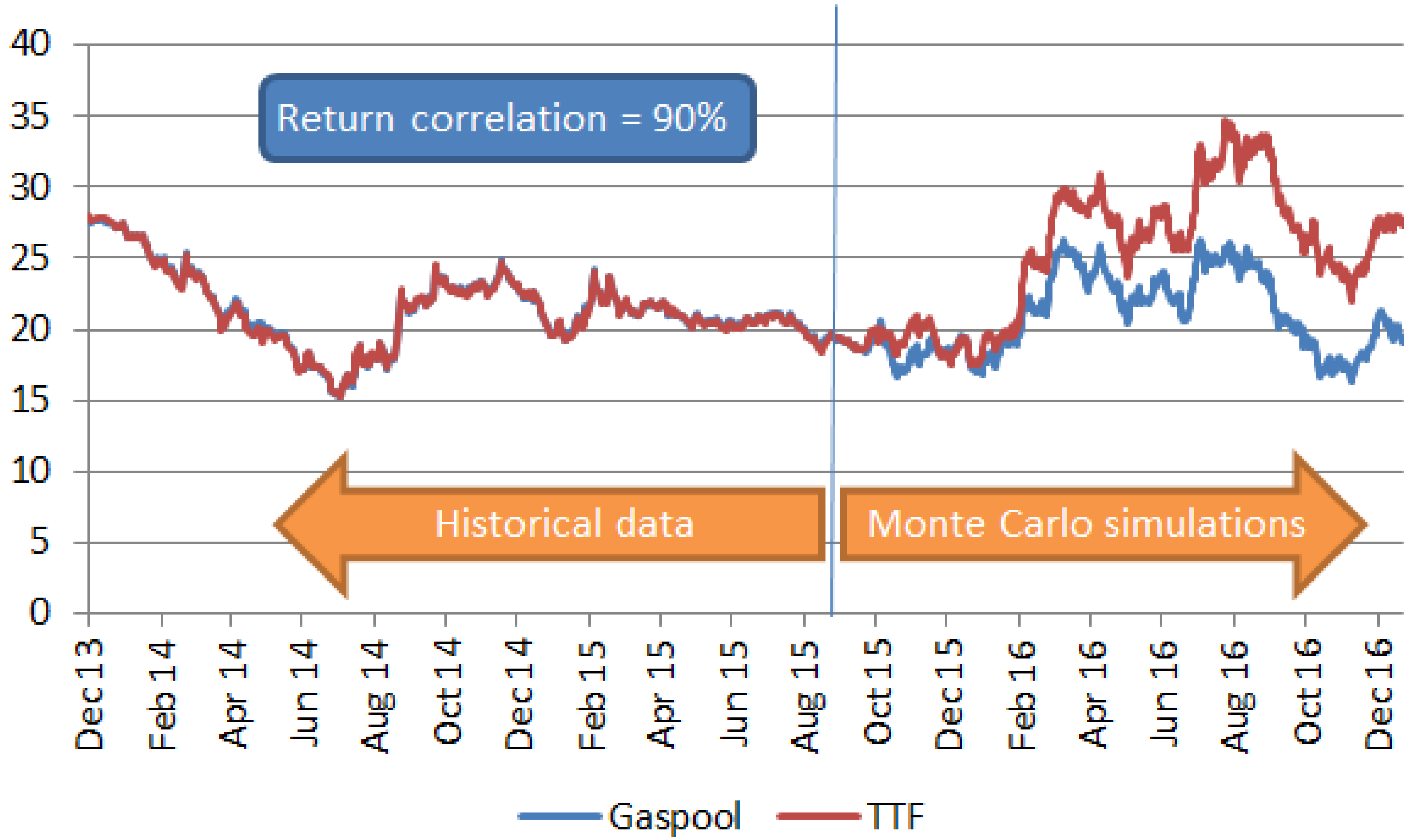
View uploaded price data

Export to Excel   Back to overview



Correlation: Effect on simulations…

- Graph shows historical development of Gaspool and TTF gas prices (front-month)
- Historical return correlation was 90%
- With ‘just’ return correlation, the Monte Carlo simulated prices may diverge and never get back. Daily changes look logical, but spread can get large



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Cointegration implementation (general)

'Engle Granger 2 step procedure'

- Step 1: Regress the price levels of commodity Y on those of commodity X (or more than 1 commodity X)
  - We find e.g. GO(t) = 9 * Brent(t) + e(t)
  - We call GOest(t) = 9 * Brent(t) = "expected gasoil price"

- Step 2: Regress the Gasoil return on the difference between the actual and estimated Gasoil price (in logs):
  - rGO(t) = -0.18 * (lnGO(t-1) – ln(9*B(t-1))) + u(t)
  - The parameter 0.18 is like a mean-reversion rate of the spread

- This cointegration has to be embedded in a multi-commodity multi-factor model, including time-varying volatility and spot spikes / regime-switches

Part of the spot price specification

Mean-reverting regime M: $dx_t^M = \alpha(\mu_t - x_{t-1}^M) + \sigma \cdot \varepsilon_t$

Spike regimes: $x_t^S = \mu_t + \sum_{i=1}^{n_t+1} Z_{t,i}$

High spike regime H: $Z_{t,i} \sim N(\mu^H, \sigma^H), \quad n_t \sim POI(\lambda^H), \quad \mu^H > 0$

Low spike regime L: $Z_{t,i} \sim N(\mu^L, \sigma^L), \quad n_t \sim POI(\lambda^L), \quad \mu^L < 0$

Markov transition matrix: $\Pi = \begin{bmatrix} 1-\pi^{MH}-\pi^{ML} & \pi^{MH} & \pi^{ML} \\ \pi^{HM} & 1-\pi^{HM} & 0 \\ \pi^{LM} & 0 & 1-\pi^{LM} \end{bmatrix}$

Power plant hedging

What is intrinsic value?

Intrinsic value =

Expected value of the asset based on the current forward curves, so ignoring any price volatility

Different versions of intrinsic value:

1. Value which can be locked in on the market (certain value)
2. Expected value if the asset is optimized against the current (hourly) forward prices

Tradable intrinsic value of a power plant (1)

Tradable intrinsic value = value which I can lock in today

Example, for 2016 (assume 3000 peak hours):

- 500 MW power station with 50% HHV efficiency,
- Plant has variable costs of 2 EUR/MWh (ignore CO2 costs)
- Baseload forward price = 40 EUR/MWh, peakload 50 EUR/MWh
- Gas forward price = 22 EUR/MWh

Tradable intrinsic value of a power plant (2)

Spread calculation:

- Baseload spark spread = -6 EUR/MWh
- Peakload spark spread = 4 EUR/MWh
  - Tradable intrinsic value = 3000 x 4 x 500 = 6 mln EUR

But:

- Plant needs to start 52 times a year. Costs e.g. 1 mln EUR
- Plant has to undergo maintenance, may trip
- When monthly products or quarterly products are tradable, it may be optimal to produce not at all, or produce baseload.
- Is it really optimal to lock in the full positive margin when it is only marginally positive?

Hourly intrinsic value

Approach:

- Take an hourly price forward curve, together with forward curves for all relevant commodities
- Find the optimal dispatch per hour, e.g. using dynamic programming.
- Take into account all asset details and costs
- Calculate the cash-flows

Value will be higher than tradable intrinsic value

However: you are not 100% sure this amount of money will be realized.

Real options modeling in the energy practice

Financial option theory assumes risk-neutral pricing, meaning that risk is not relevant, because it can fully be hedged.

This is NOT realistic in energy markets.

We combine NPV valuation and Option approach as follows:

1. Generate price simulations
2. Per simulation find optimal strategy (without perfect foresight): use flexibility = option   Least-squares Monte Carlo
3. Calculate discounted cash-flows per simulation (NPV)
4. Average NPV's = real option value

This can be combined with dynamic hedging strategies

Intrinsic hedge <-> Delta hedge

- Intrinsic hedge = maximum margin is locked in
- Delta hedge:

  = make the value of your total portfolio (quite) insensitive to changes in forward market prices

  ≈ trade your expected value

In both cases, hedges should be asset-backed = without any further hedges, you can (almost) fulfill your trades with the asset

In both cases, you keep flexibility to adjust positions (forward and spot) and production.

Gas storage hedging

Intrinsic hedging of gas storage

Static strategy

Entered into at the start of storage contract:

- Inject in cheapest periods (Buy)
- Withdraw in most expensive periods (Sell)
- Take into account technical constraints and fuel costs, transaction costs
- Use forward curve to lock in intrinsic value, by capturing time spreads

Rolling/dynamic intrinsic hedging

Dynamic strategy: adjust intrinsic strategy over time when relevant time spreads change value

Advantage:

- No down-side risk
- Forward trading could be more liquid than spot trading

Result in practice:

- Adjust primarily short-end of curve
- Limited extra value: time spreads less variable than spot

(Full) option / spot approach

Dynamic strategy: trading decisions on day-to-day basis

Advantage:

- Forward strategy ignores daily asset flexibility and daily market volatility
- Exploit unexpectedly low prices to inject and unexpectedly high prices to withdraw

Result in practice:

- Typically combined with rolling intrinsic strategy or with delta hedging (explained later)
- Spot liquidity can be practical limitation
- Will generally result in more value than ‘just’ forward trading. Extra value can be approximated by option valuation methods (including least-squares Monte Carlo)

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Backtesting trading and hedging strategies
Gas storage

What is backtesting?

- In general, we are interested in the future:
  - Future price levels
  - Future market price volatility
  - Future expected value of assets and positions
  - Potential future losses (risk)
- We need methodologies to assess the future
- Backtesting:
  - How well did a methodology in the past predict the future?
  - How well did trading strategies work out in the past?

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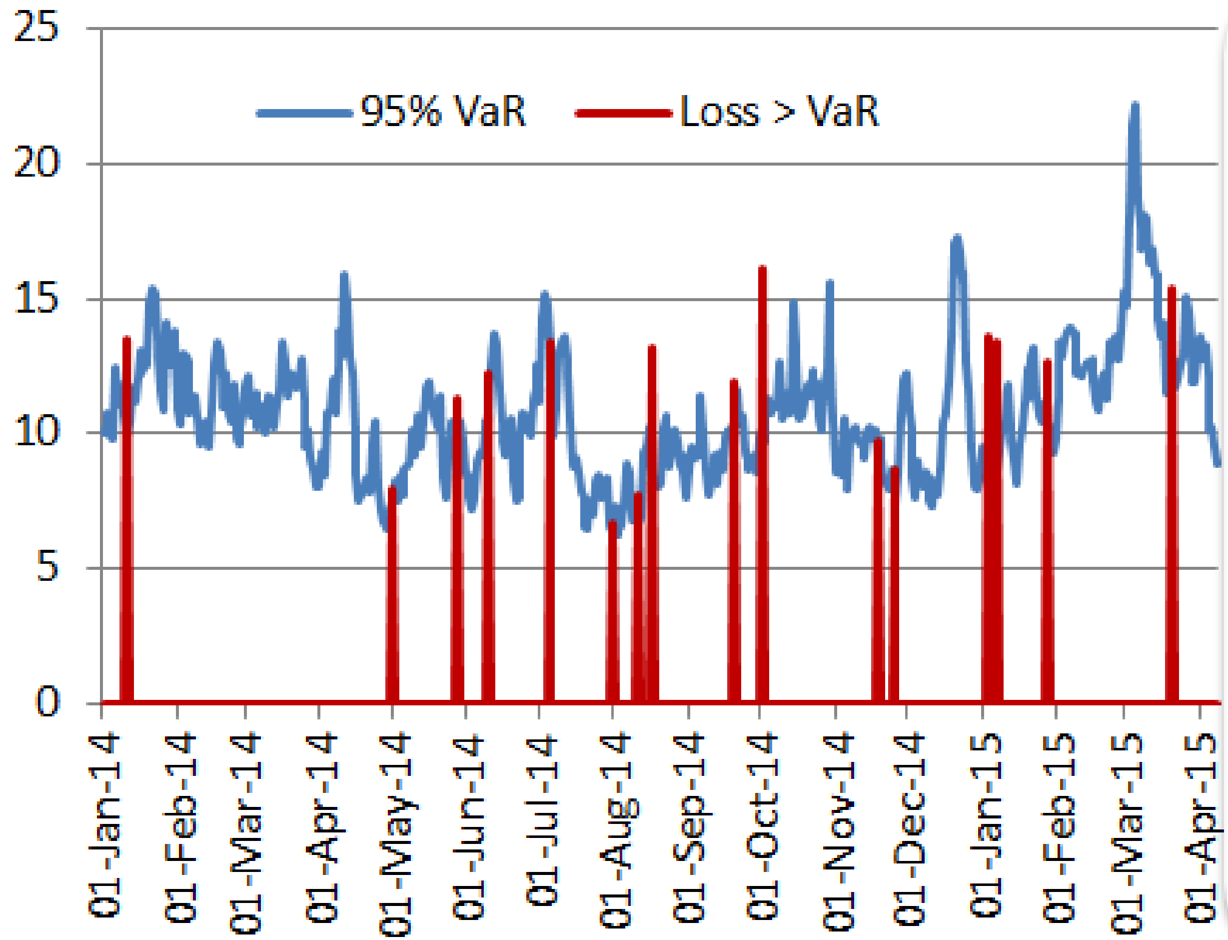
Most common application: Value-at-Risk



95% VaR recalculated daily.

Backtest: Trading loss exceeds VaR in 3.5% of the time.

Good or bad?

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Set-up KYOS gas storage back-test

Purpose:

- Analyse what you could have earned with a storage in the past
- Validate gas storage valuation software (compare expected value with realized value)

Data:

- 17 years of forward data available from NBP
- Period: 1 April 1997 - 1 April 2014
- For every working-day: quotes DA, 5 MA / 5 QA / 1 YA

3 storage facilities, all with a working volume of 100 therms:

- Slow – 150 days cycle: injection = 1, withdrawal = 2 therm / day
- Fast – 75 days cycle: injection = 2, withdrawal = 4 therm / day
- Very fast – 40 days cycle: injection = 5, withdrawal = 5 therm / day

Allow monthly forward trading, no transaction costs, no injection/withdrawal costs, no discounting

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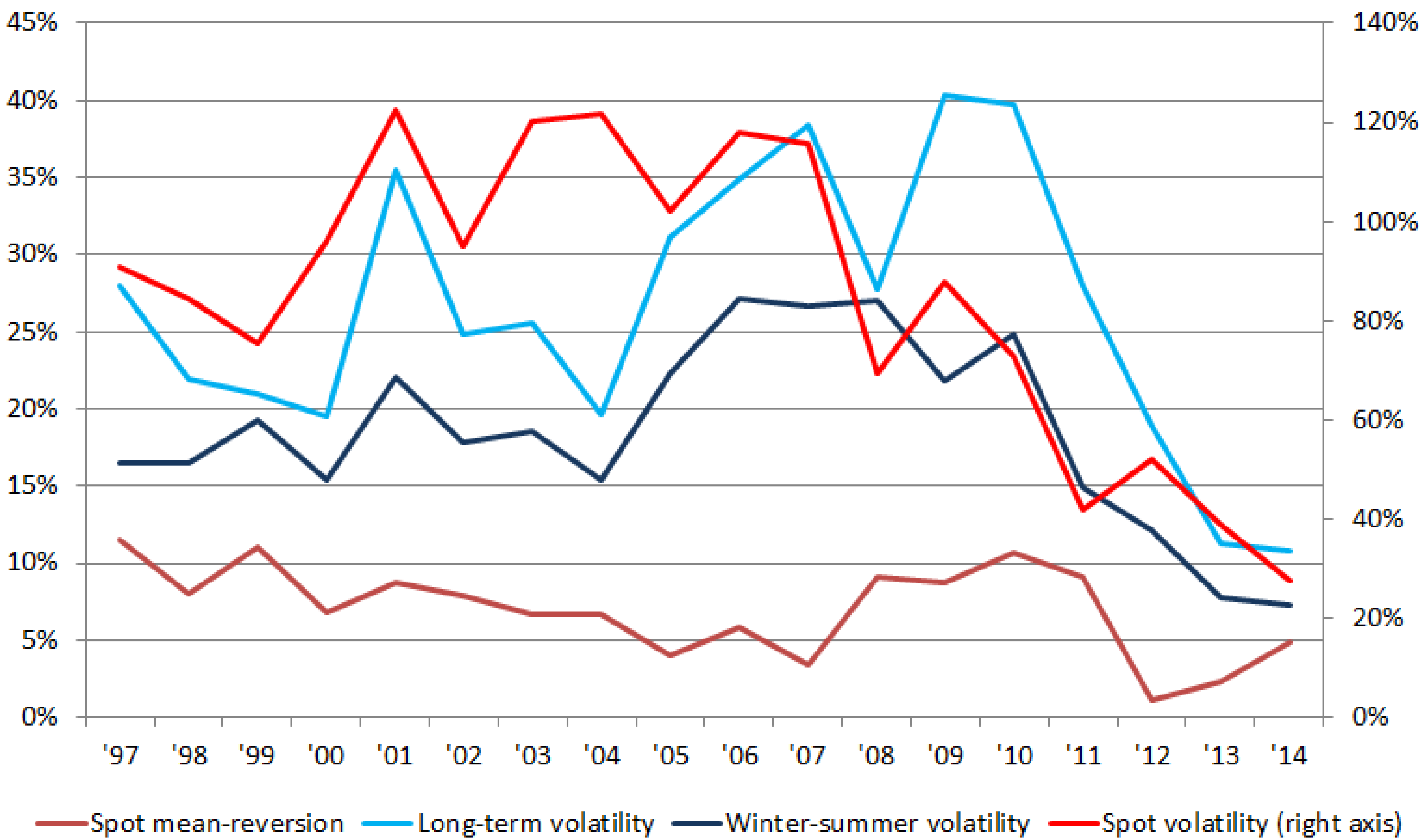
Development volatility during backtest



Backtest possibilities

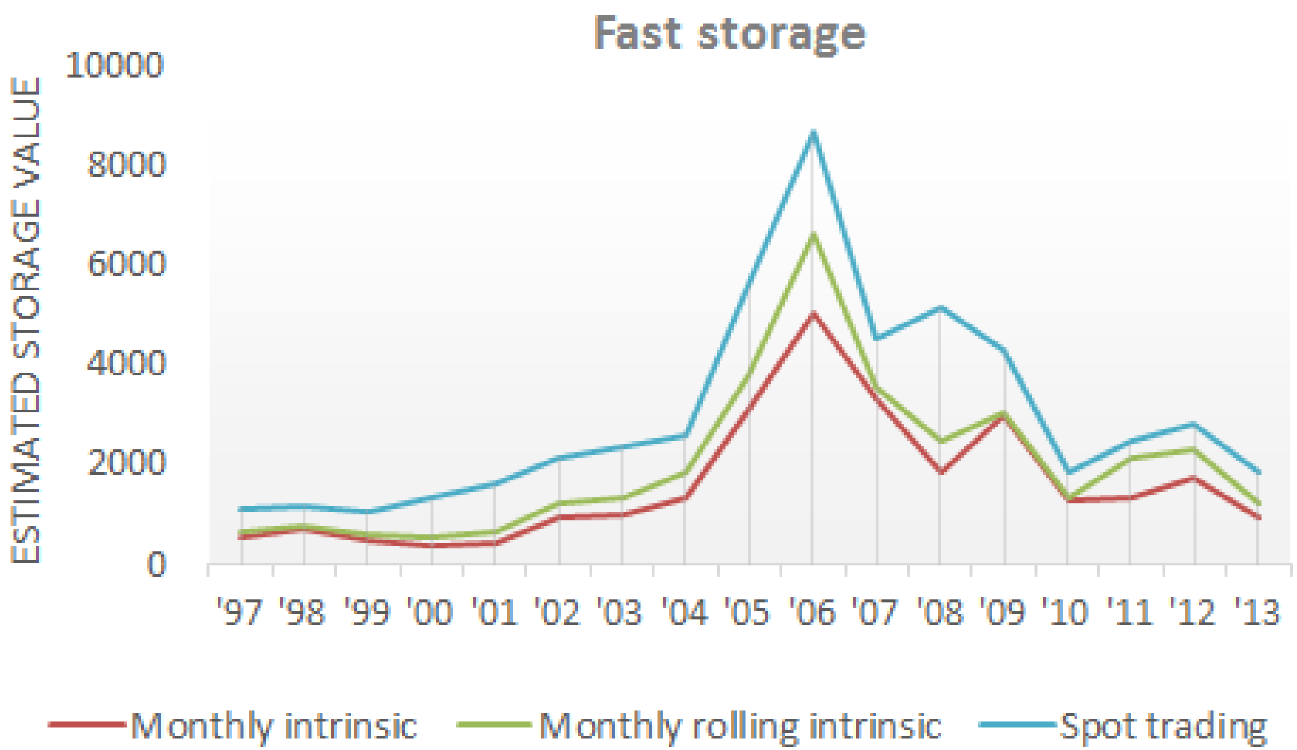
❶ **Out-of-sample:**

The sampling period precedes the storage year. This would be the set of information that you have at the date of valuation.

❷ **In-sample:**

The sampling period equals the storage year. At the date of valuation this can be considered perfect foresight regarding the future price dynamics. However, comparing the out-of-sample estimated storage values with the in-sample based estimated allows us to evaluate the impact of parameter uncertainty on storage value.

Results – in sample valuation



- Intrinsic value = Winter-Summer spread
- UK gas market extreme situation 2005-2007
- Storage long-term investment: benefit once in a while from extreme situation

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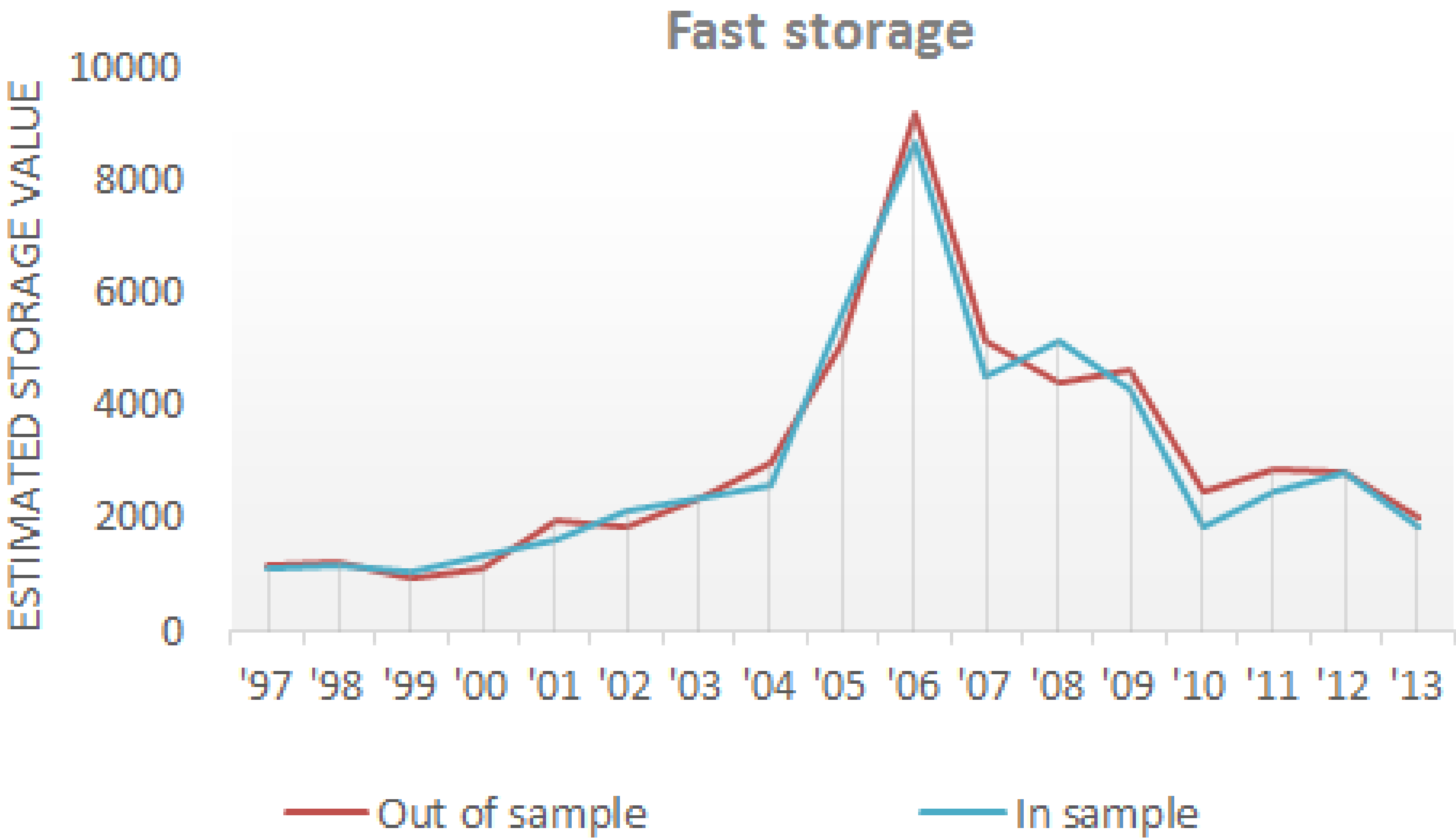
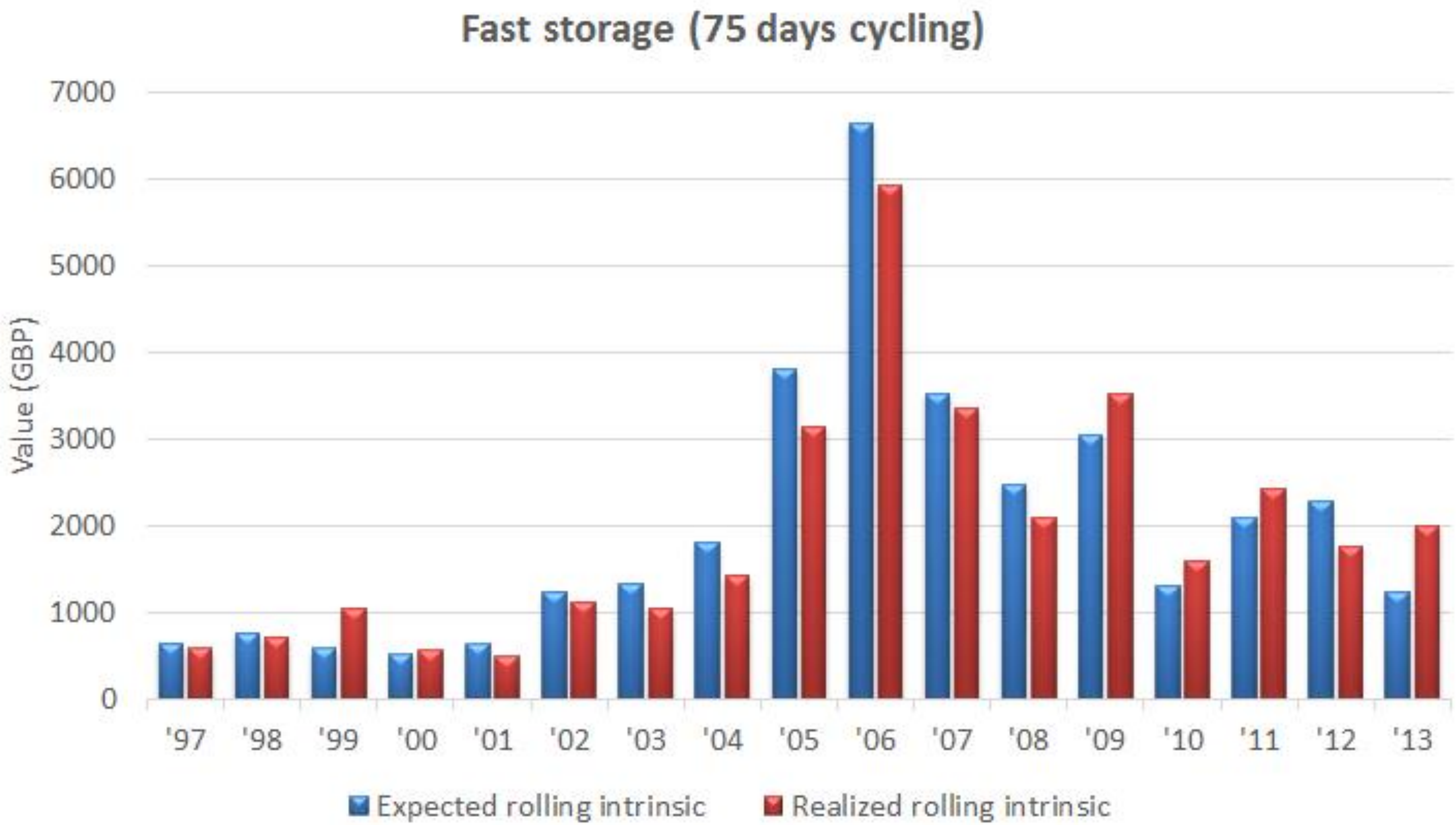
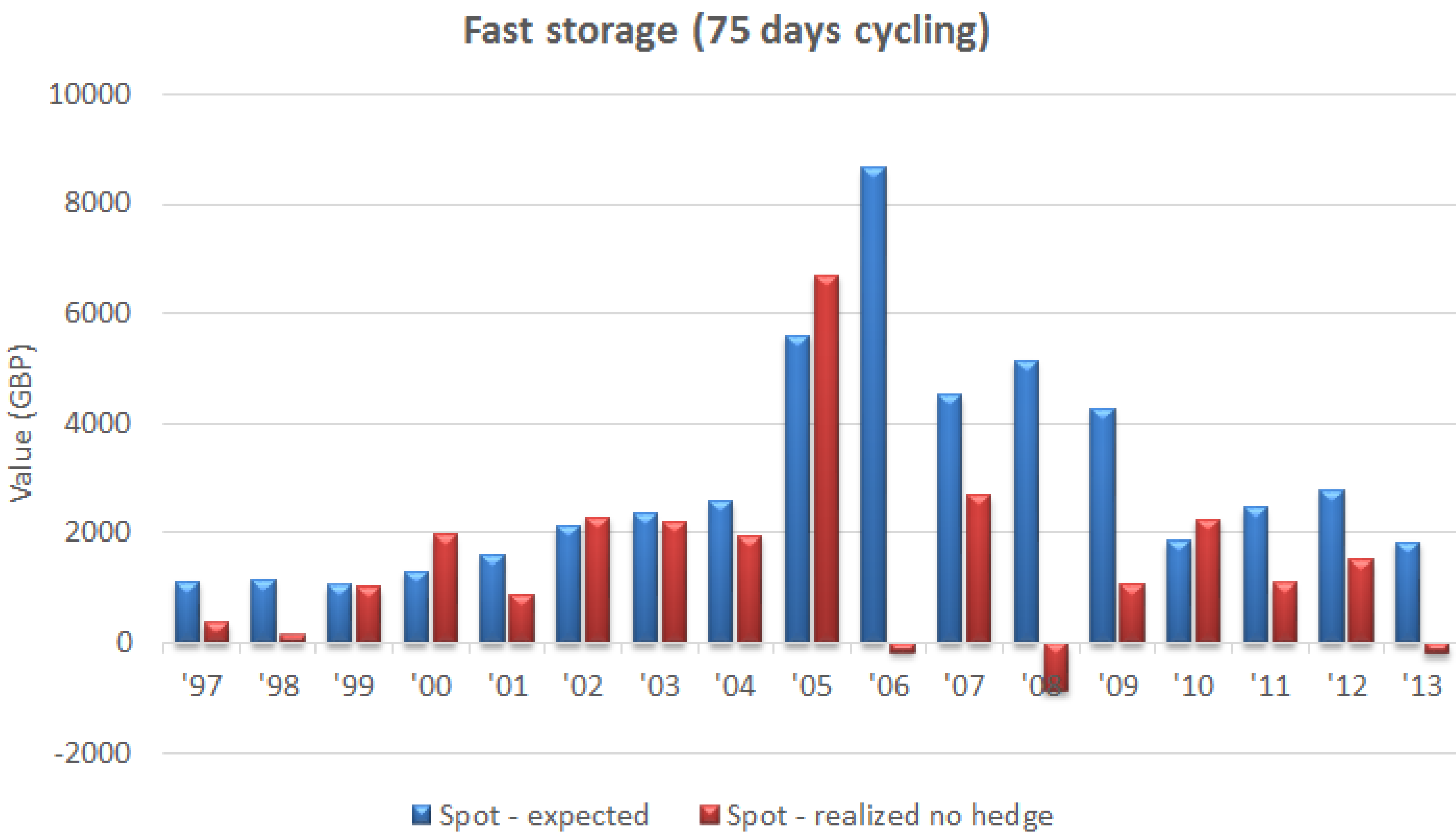
Spot value: in sample versus out of sample



Rolling intrinsic: expected versus realized values



Spot trading: expected versus realized values



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Spot combined with hedging

We tested 4 hedging strategies:

A 'static' intrinsic hedge and a 'static' delta hedge

- Both are implemented on the first day of the storage period. The pay-off of the hedges is evaluated separately from the spot trading performance and are deemed pure financial hedges.

A 'dynamic' intrinsic hedge and a 'dynamic' delta hedge

- Both are implemented on the first day of the storage period for all months, except nearby month. One month later, the optimal hedge is calculated anew and implemented for each month, except (again) the nearby month. No overlap forward-spot.

Are projected values realized?

Fast storage		Intrinsic	Rolling - expected	Rolling - realized	Spot - expected	Spot - realized			
Begin	End	monthly	monthly	monthly	no hedge	no hedge	dynamic delta	dynamic intrinsic	static intrinsic
Apr-97	Mar-98	544	646	587	1107	373	1280	795	521
Apr-98	Mar-99	694	759	713	1159	146	1363	1109	1054
Apr-99	Mar-00	450	590	1044	1062	1029	1428	1233	1051
Apr-00	Mar-01	377	522	562	1312	1968	1292	1673	969
Apr-01	Mar-02	422	636	488	1599	879	1491	1042	409
Apr-02	Mar-03	926	1224	1117	2125	2287	3003	2392	2188
Apr-03	Mar-04	1004	1324	1041	2356	2202	2334	1336	1869
Apr-04	Mar-05	1330	1815	1416	2584	1960	2363	1945	2528
Apr-05	Mar-06	3076	3803	3140	5599	6711	6166	4868	5858
Apr-06	Mar-07	5051	6653	5919	8659	-185	9964	5794	5327
Apr-07	Mar-08	3315	3531	3349	4511	2692	5273	4674	3627
Apr-08	Mar-09	1844	2479	2091	5152	-878	3628	2767	1996
Apr-09	Mar-10	2958	3046	3520	4276	1085	3561	3475	2645
Apr-10	Mar-11	1266	1303	1596	1861	2257	1878	2045	2248
Apr-11	Mar-12	1320	2102	2414	2458	1088	3028	2596	2271
Apr-12	Mar-13	1709	2281	1759	2783	1512	2169	1424	2300
Apr-13	Mar-14	932	1232	2006	1842	-201	1348	1077	474
Average result		1601	1997	1927	2967	1466	3033	2367	2196

Spot only performed well in combination with forward hedging

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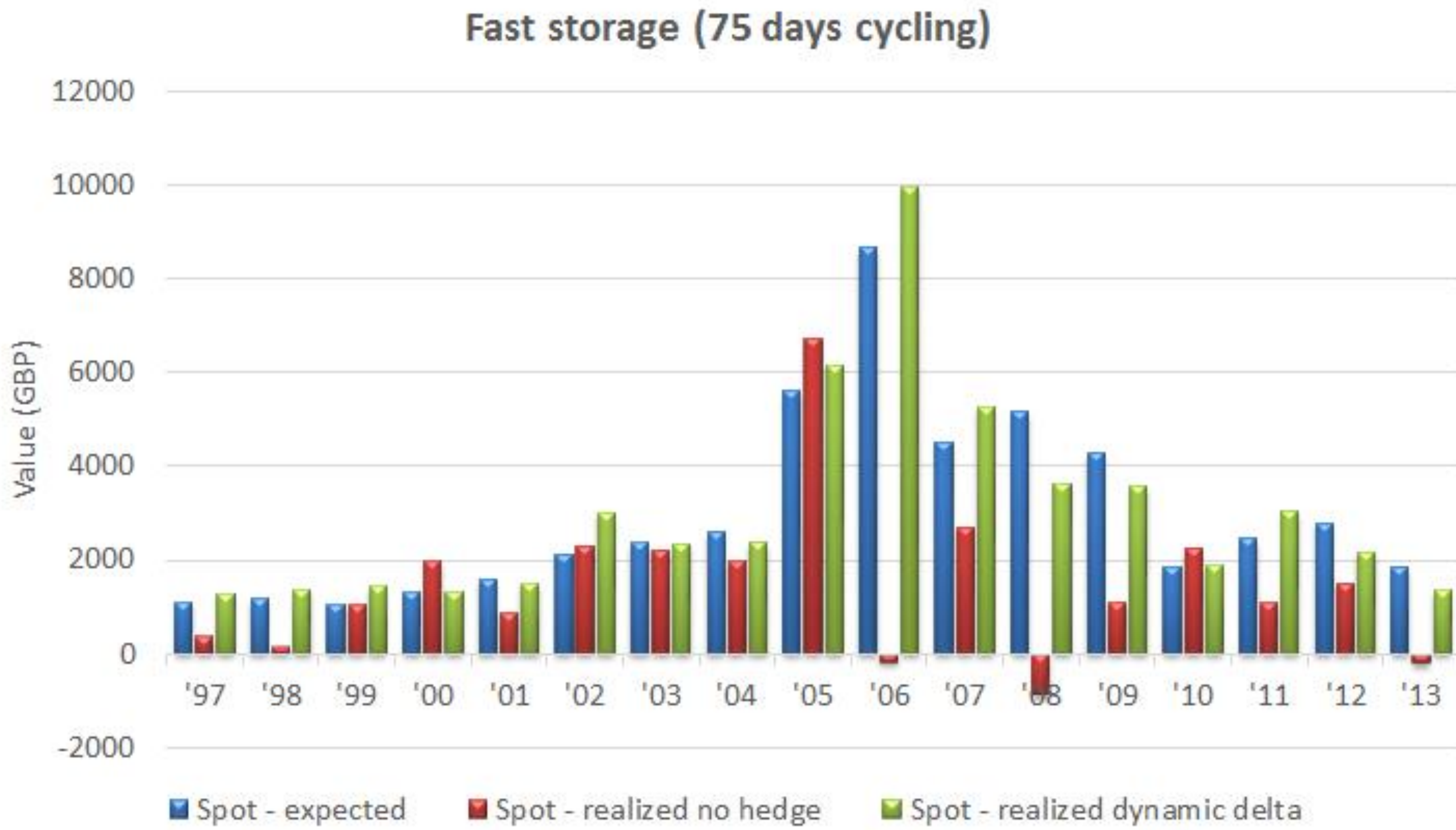
Overall results including hedging



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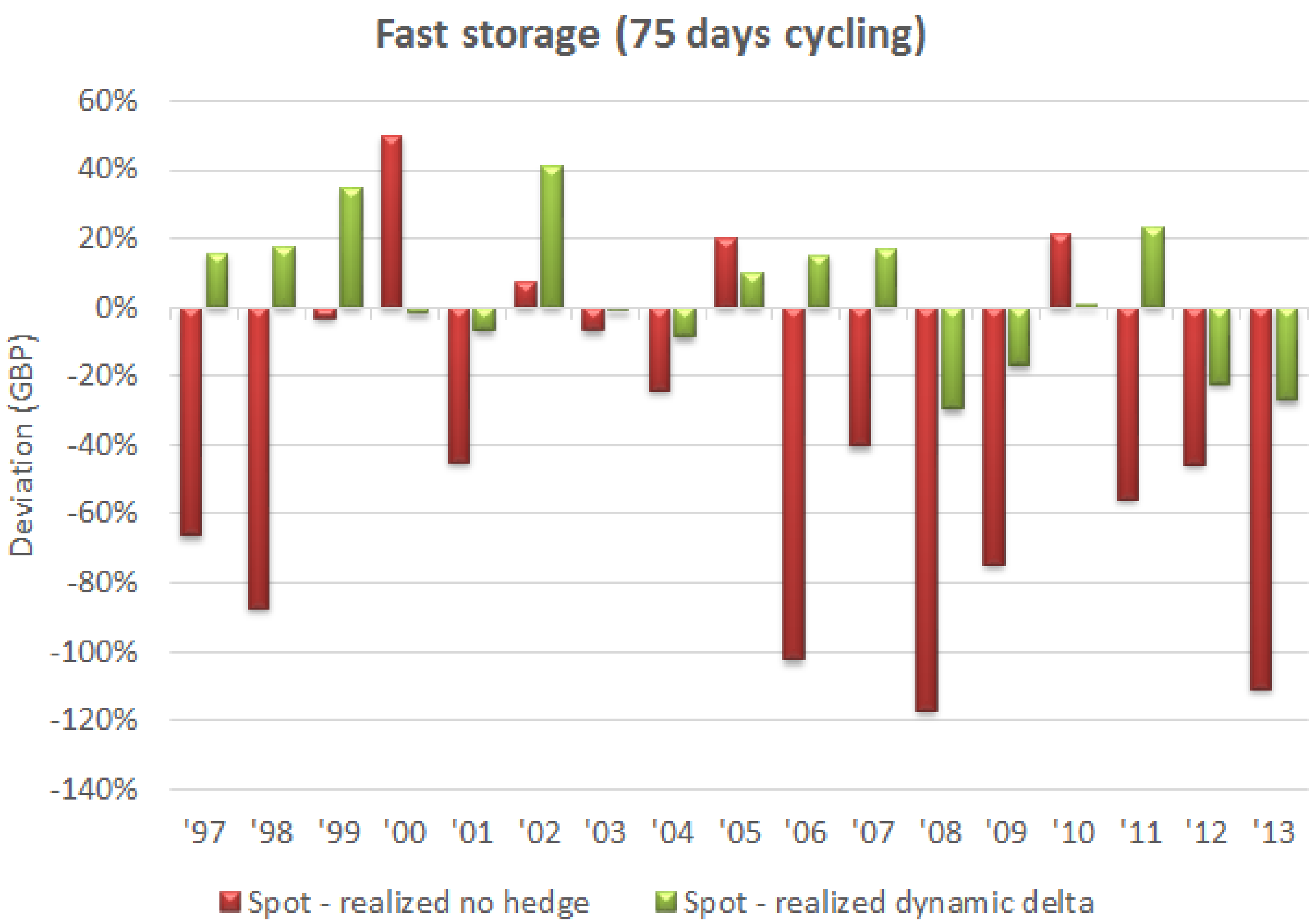
Influence hedge on result



The spot results are compared with the expected values

The red bar indicates that the actual P&L excluding hedging can deviate largely from the expected value

The green bar demonstrates the effectiveness of hedging

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