Is the Theory of Storage valid for the European Gas Market?

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The Agenda

- The Issue
- Theory of Storage
  - General Propositions
  - Deduction of the Hypotheses
- Data
- Results
- Conclusions

The Issue

- Storage as an essential element to provide flexibility and promote competition in a liberalizing gas market
- The role of storage: intertemporal shifting of supply (high demand during winter)
- Markets across Europe show different maturities
- In a competitive environment the price developments should match the predictions of the Theory of Storage
- If not, arbitrage opportunities do exist
- Applications to
  - National Balancing Point (NBP), U.K.
  - Zeebrugge, Belgium
  - Title Transfer Facility hub (TTF), Netherlands

$$\underbrace{\frac{F(t,T)-S(t)}{S(t)}}_{\text{Basis or Spread}} = R(t,T) + \frac{W(t,T)-C(t,T)}{S(t)}$$

F(t,T): Futures price at t with maturity T

S(t): Spot price at t

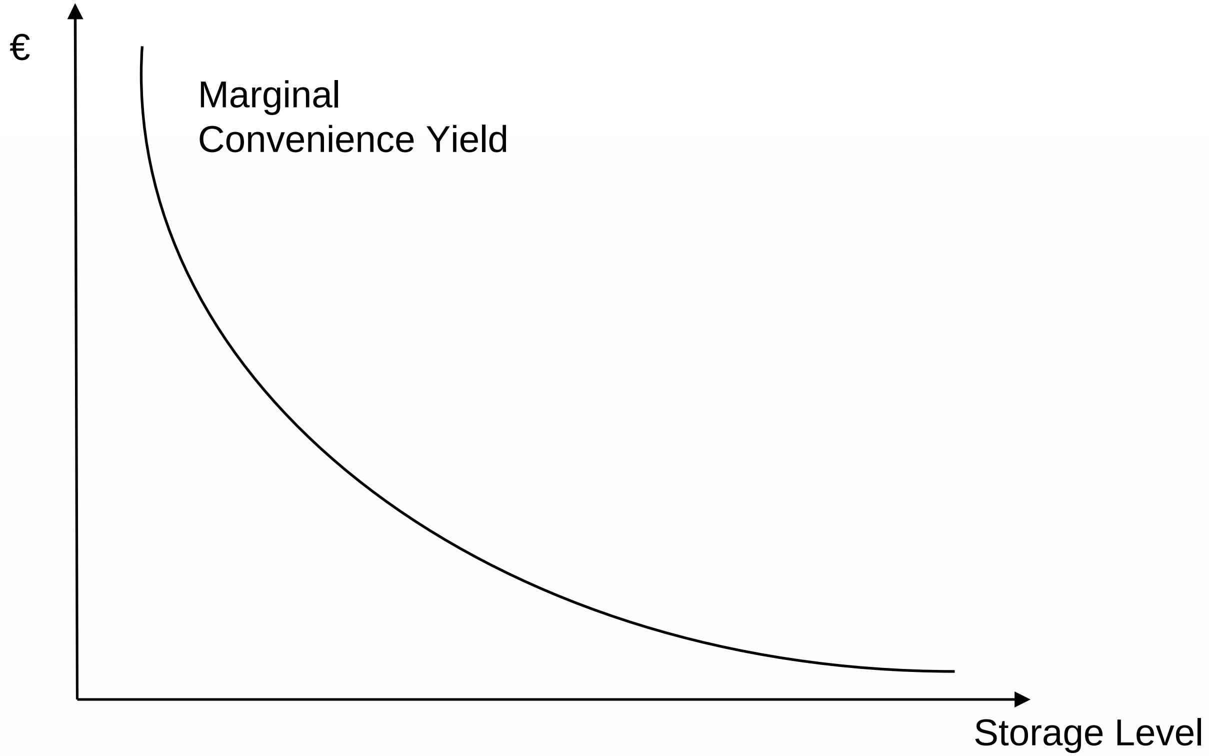
R(t,T): Interest rate at t with maturity T

W(t,T): Marginal storage costs

C(t,T): Marginal convenience yield

$$\underbrace{F(t,T)-S(t)}_{\text{Return from buying at t and selling at T}}=\underbrace{S(t)R(t,T)}_{\text{Foregone interest}}+\underbrace{W(t,T)}_{\text{Marginal storage cost}}-\underbrace{C(t,T)}_{\text{Marginal convenience yield}}$$

Marginal Convenience Yield



- Benefit from holding inventory: meet unexpected demand
- Negative correlation between convenience yield and storage level

Theory of Storage

General Propositions

- “Store until the expected gain on the last unit put into store just matches the current loss from buying – or not selling it – now” (Williams/Wright (1991)
- Marginal convenience yield convex in inventory level -> implications for variance of spot and futures prices and their correlation
- High storage level, i.e. C is low (for low levels the opposite is true)
  - Change in storage level leads to only small changes in C
  - Similar variances of spot and futures price
  - High correlation between spot and futures prices
- Yield directly related to the variance of spot price and inversely related to the correlation between spot and futures prices

Theory of Storage

Deduction of Hypotheses

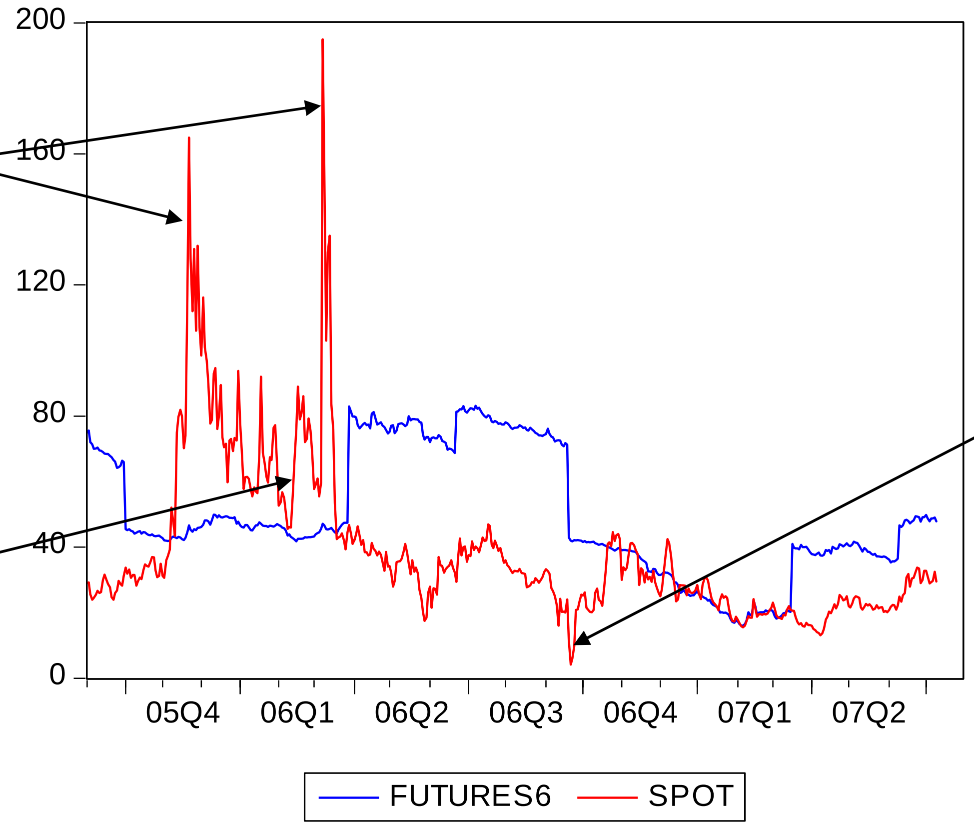
- Based on Fama/French (1987): no inventory data
- Seasonals in production or demand can generate seasonals in inventories which in turn generate seasonals in marginal convenience yield
  - seasonal dummies = significant
- (T-t) basis should vary one for one with (T-t) interest rate if for W and C is controlled
  - Interest rate = significant
  - coefficient = 1

- Time (availability and reliability of data)
  - Zeebrugge: 01/03/2003 till 08/08/2007
  - NBP and TTF: 09/01/2005 till 08/08/2007
- Prices (daily)
  - Spot: day ahead
  - Futures with maturities of 1 month, 6, 12, 18, and 24 months
- Risk-free interest rates: Euribor and Libor with the corresponding maturities
- Seasonal dummies
  - Monthly, quarterly, winter/summer
  - Indicates when the futures contract matures

Data

Spot and Futures Prices for 6 Months Delivery at NBP

Shortages in Norwegian gas fields and low temperatures

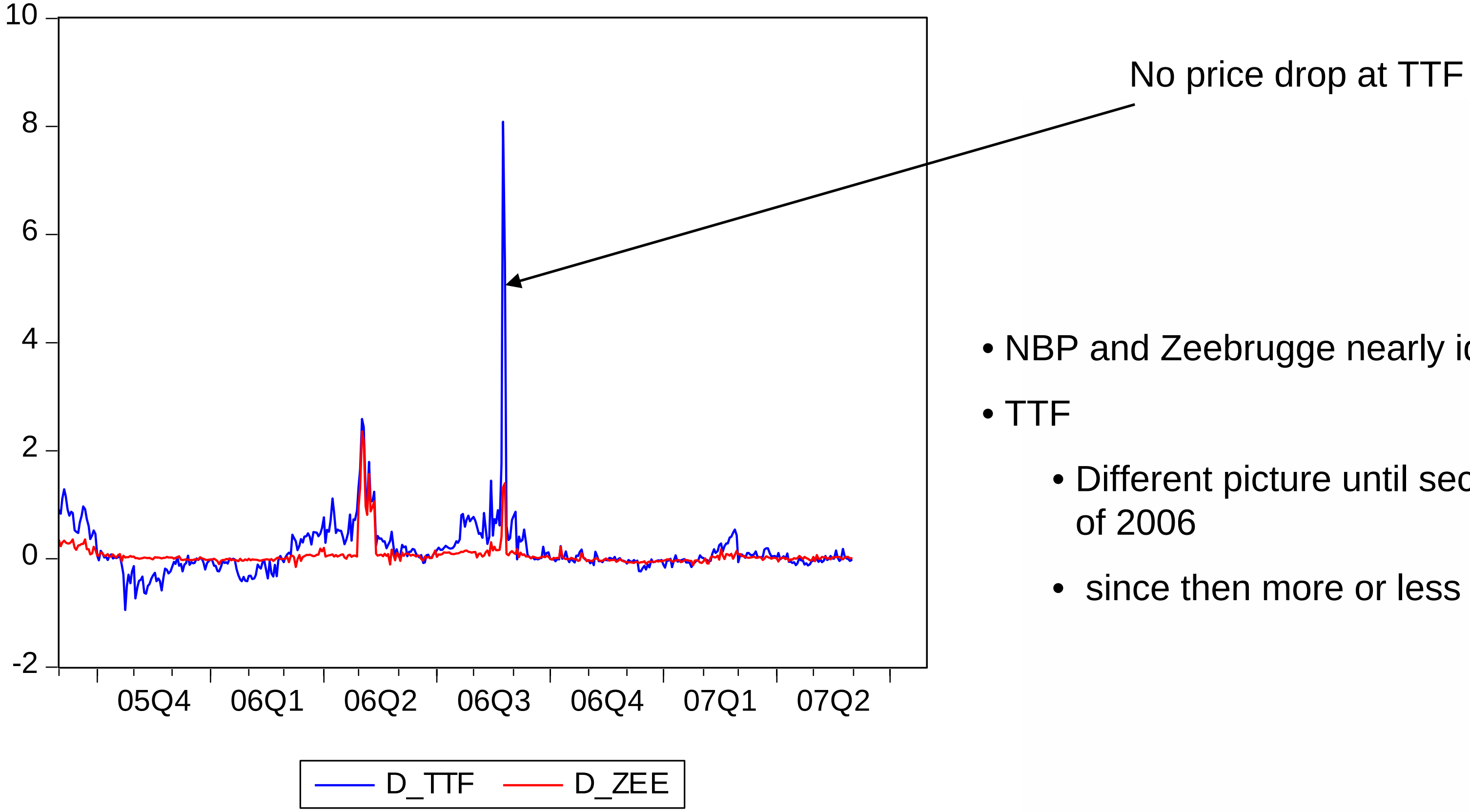


Shut down of Rough (fire)

Opening of a new pipeline connecting UK with NOR

Data

TTF and Zeebrugge compared to NBP (Basis6)



- NBP and Zeebrugge nearly identical
- TTF
  - Different picture until second half of 2006
  - since then more or less identical

- Equation

$$basis_{T,t} = \beta_1 \log(r_{T,t}) + \beta_2 Q_{2,t} + \beta_3 Q_{3,t} + u_t$$

  - Quarterly dummies (summer season)
  - Log Interest rates
  - AR(1) process

Results

OLS regression for Basis6 at NBP

	Coefficient	Std. Error	t-Statistic	Prob.
Libor	0.601	0.079	7.660	0.000
F6Q2	-0.584	0.175	-3.338	0.001
F6Q3	-0.980	0.176	-5.552	0.000
AR(1)	0.827	0.026	31.826	0.000

Observations	484	Mean dependent var	0.584
R-squared	0.810	S.D. dependent var	0.893

- All variables significant at 1% level
- Interest rate: coefficient < 1 – arbitrage opportunities or bad approach?
- Capturing of seasonalities: inventory data over a longer period

Results

OLS regression for Basis6 at TTF

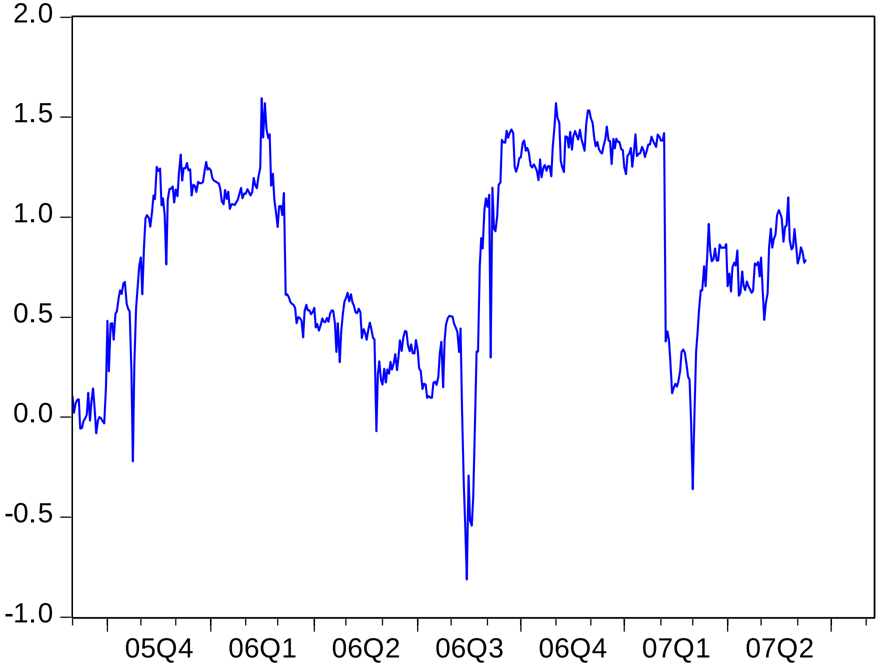
	Coefficient	Std. Error	t-Statistic	Prob.
Euribor	0.587	0.047	12.389	0.000
F6Q2	-0.493	0.063	-7.860	0.000
F6Q3	-0.716	0.062	-11.525	0.000
AR(1)	0.897	0.021	43.103	0.000

Observations	462	Mean dependent var	0.421
R-squared	0.939	S.D. dependent var	0.478

- Similar results
- Better fit: lower spot price volatility due to higher storage capacity ?
- Negative sign of dummy coefficients: expected for basis6, but not for basis12

Results

Convenience Yield (TTF, Basis6)



- Interest rate minus basis
- Clear seasonal pattern: dummies significant at 1% level

Conclusions

- Zeebrugge and NBP belong more or less to the same market
  - Interconnector
- Theory of storage partly confirmed
  - Interest rate and seasonal dummies have a significant influence
  - But: Coefficient of interest rate < 1
- TTF slightly different with a tendency to converge towards NBP prices
  - co-integration tests and extension to GARCH: NBP volatility to explain TTF price developments
- Higher spot price volatility at NBP
  - matter of efficiency or of available storage capacity?
- Inventory data: Extension to convenience yield and risk premium analyses

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Descriptive Statistics

NBP (basis6)

	BASIS6	FUTURES6	SPOT	INTEREST6
Mean	0.59	49.63	38.48	5.14
Median	0.57	44.95	31.66	5.07
Maximum	9.05	83.15	194.98	6.19
Minimum	-0.76	16.03	4.18	4.51
Std. Dev.	0.89	19.00	24.19	0.52
Skewness	2.54	0.30	2.40	0.48
Kurtosis	21.21	2.00	10.72	1.82
Jarque-Bera	7,210.73	27.73	1,669.34	46.60
Probability	0.00	0.00	0.00	0.00
Sum	283.50	24,022.73	18,622.78	2,488.03
Sum Sq. Dev.	385.11	174,348.24	282,662.51	132.10
Observations	484	484	484	484

Descriptive Statistics

Zeebrugge (basis6)

	BASIS6	FUTURES6	SPOT	EURIBOR6
Mean	0.33	18.86	15.52	2.74
Median	0.20	16.61	13.56	2.27
Maximum	7.73	40.47	93.83	4.51
Minimum	-0.75	0.86	0.91	1.95
Std. Dev.	0.59	8.70	8.87	0.74
Skewness	2.63	1.03	3.46	1.02
Kurtosis	26.05	3.11	19.67	2.57
Jarque-Bera	26,567.91	200.56	15,485.58	207.04
Probability	0.00	0.00	0.00	0.00
Sum	376.56	21,516.36	17,710.05	3,127.14
Sum Sq. Dev.	403.41	86,245.57	89,618.04	619.73
Observations	1141	1141	1141	1141

Descriptive Statistics
TTF (basis6)

	BASIS6	FUTURES6	SPOT	EURIBOR6
Mean	0.42	22.98	17.00	3.44
Median	0.50	20.38	16.88	3.49
Maximum	2.09	38.90	50.00	4.51
Minimum	-0.54	8.30	6.75	2.17
Std. Dev.	0.48	7.83	5.64	0.67
Skewness	0.38	0.37	1.03	-0.22
Kurtosis	2.54	2.32	6.58	1.85
Jarque-Bera	15.10	19.60	327.98	29.15
Probability	0.00	0.00	0.00	0.00
Sum	194.96	10,617.70	7,855.53	1,588.13
Sum Sq. Dev.	104.97	28,274.43	14,681.17	207.08
Observations	462	462	462	462

Results

OLS regression for Basis12 at NBP

	Coefficient	Std. Error	t-Statistic	Prob.
Libor	0.574	0.089	6.478	0.000
F12Q2	-0.606	0.212	-2.856	0.005
F12Q3	-0.912	0.216	-4.216	0.000
AR(1)	0.818	0.027	30.472	0.000

Observations	484	Mean dependent var	0.5895
R-squared	0.6530	S.D. dependent var	0.8020

Results

OLS regression for Basis12 at TTF

	Coefficient	Std. Error	t-Statistic	Prob.
Euribor	0.621	0.064	9.748	0.000
F12Q2	-0.597	0.077	-7.745	0.000
F12Q3	-0.592	0.077	-7.722	0.000
AR(1)	0.916	0.019	49.299	0.000

Observations	462	Mean dependent var	0.511
R-squared	0.856	S.D. dependent var	0.362