

Do Carbon Permits Constitute a Respectable Asset Class?

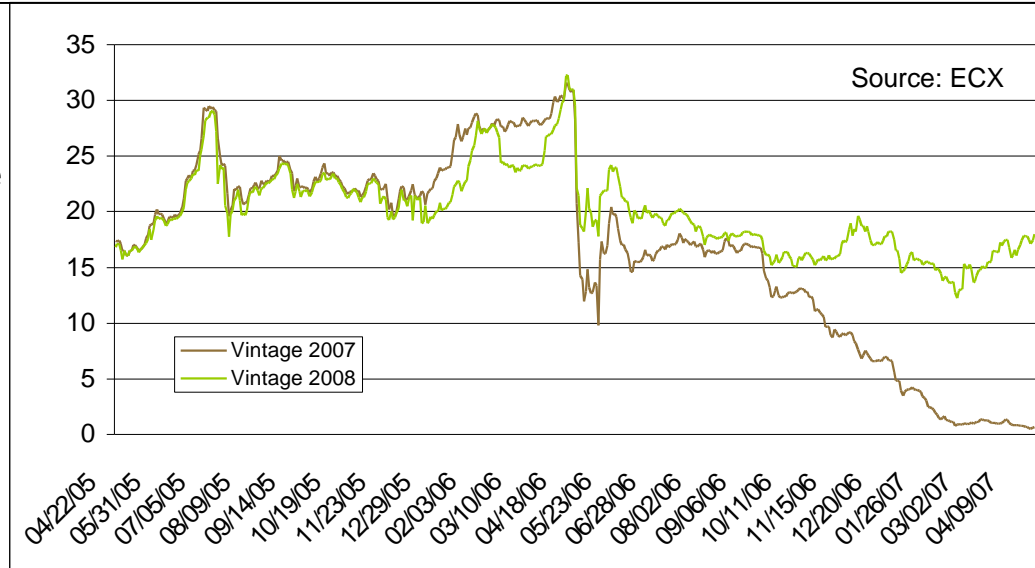
Efficiency, Liquidity and Volatility in comparison with Other Financial Markets

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Overview of emissions markets: CO₂

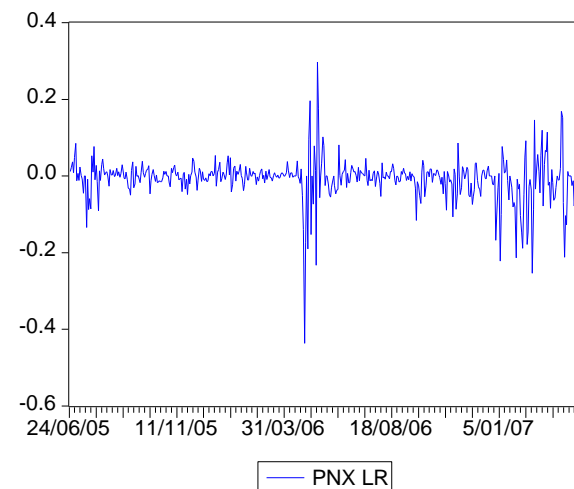
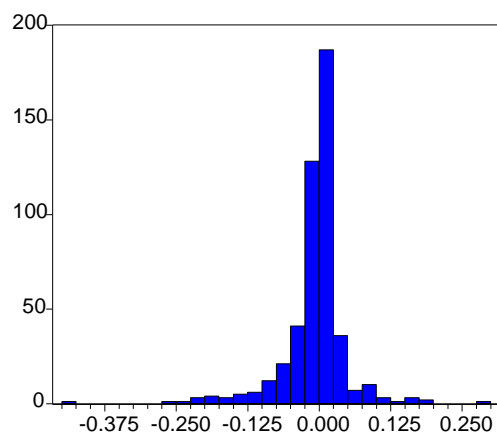
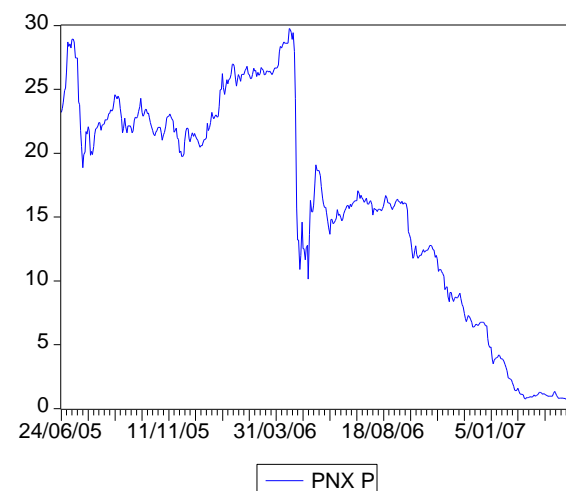
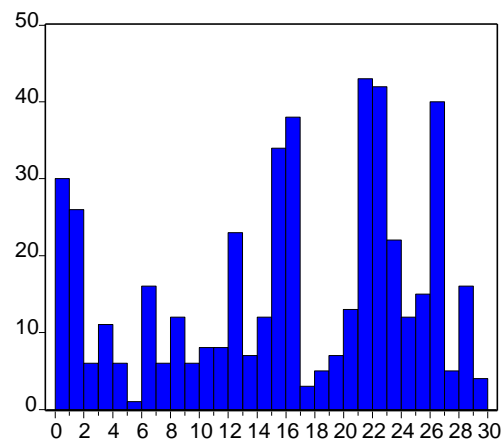
- **Aim:** help GHG-emitting installations curb their emissions in a cost-effective way through a cap-and-trade mechanism
- **Regulatory framework:** Kyoto Protocol and EU directive



- **Scope:** approx. 12,000 CO₂-emitting installations across the EU split among utilities and industrials
 - **Asset traded:** 1 EUA = the right to emit 1 ton of CO₂-equivalent
 - **Two trading phase:** 1st period (2005-2007) and 2nd period (2008-2012)
 - **Current price:** EUA 2007 = **EUR 0.29** and EUA 2008 = **EUR 24.00**.
- **Three characteristics of interest:** (1) **Market crash** in May 2006, (2) Phase I price convergence towards zero and (3) phase I and II **decoupling**.

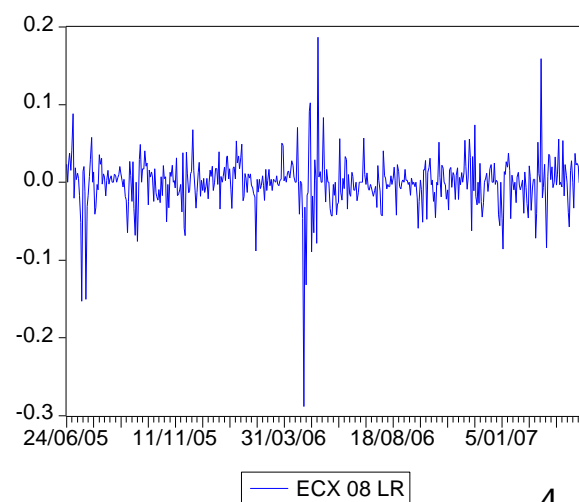
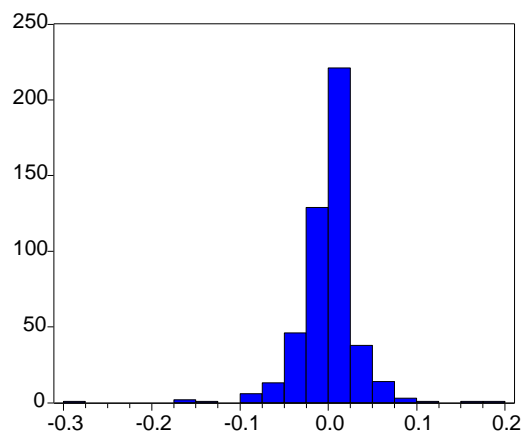
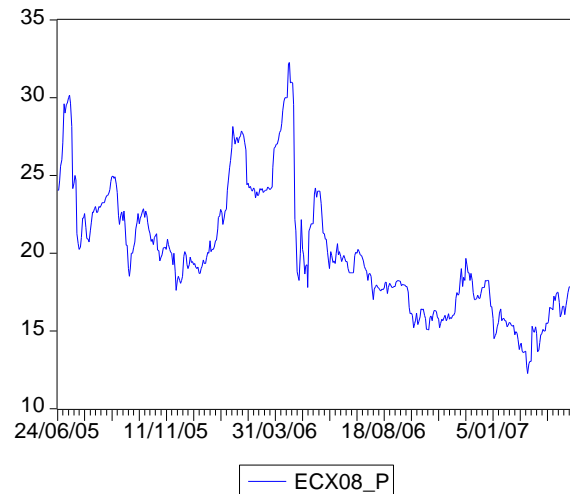
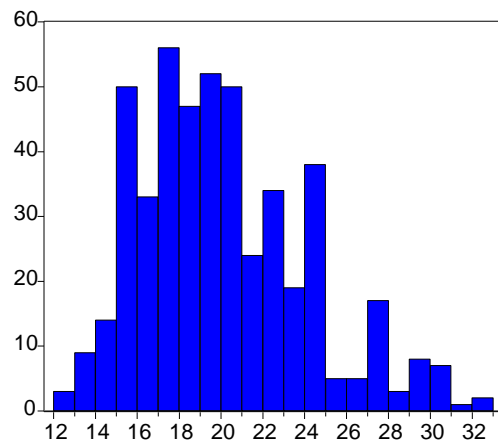
Series 1: CO₂ Allowance Spot - Powernext

| | PNX_P | PNX_LR |
|--------------|-----------|-----------|
| Mean | 16.16248 | -0.007543 |
| Median | 16.30000 | 0.000000 |
| Maximum | 29.75000 | 0.297252 |
| Minimum | 0.500000 | -0.436816 |
| Std. Dev. | 8.577132 | 0.056345 |
| Skewness | -0.449431 | -1.351661 |
| Kurtosis | 2.021691 | 14.86608 |
| Jarque-Bera | 35.00666 | 2937.549 |
| Probability | 0.000000 | 0.000000 |
| Observations | 476 | 476 |

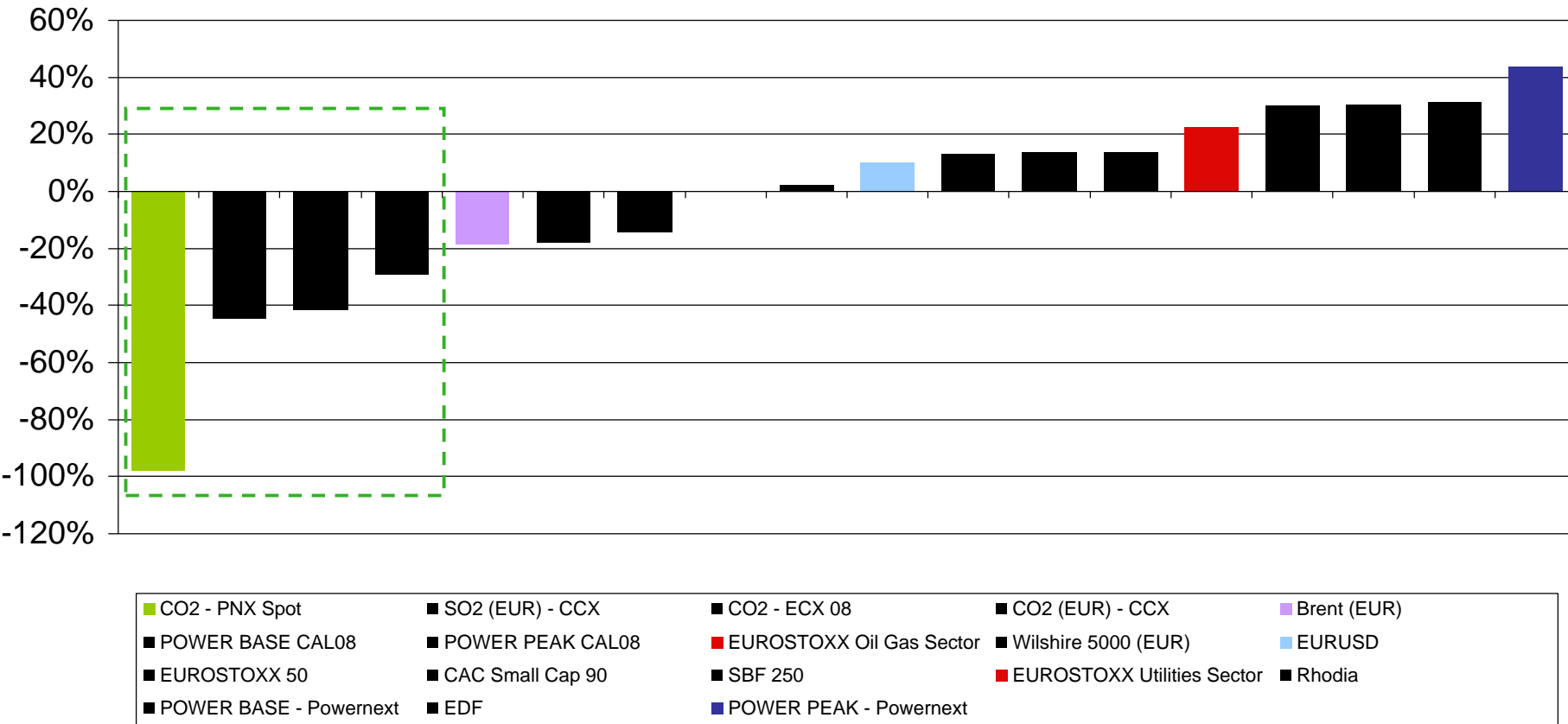


Series 2: CO₂ Allowance 2008 - ECX

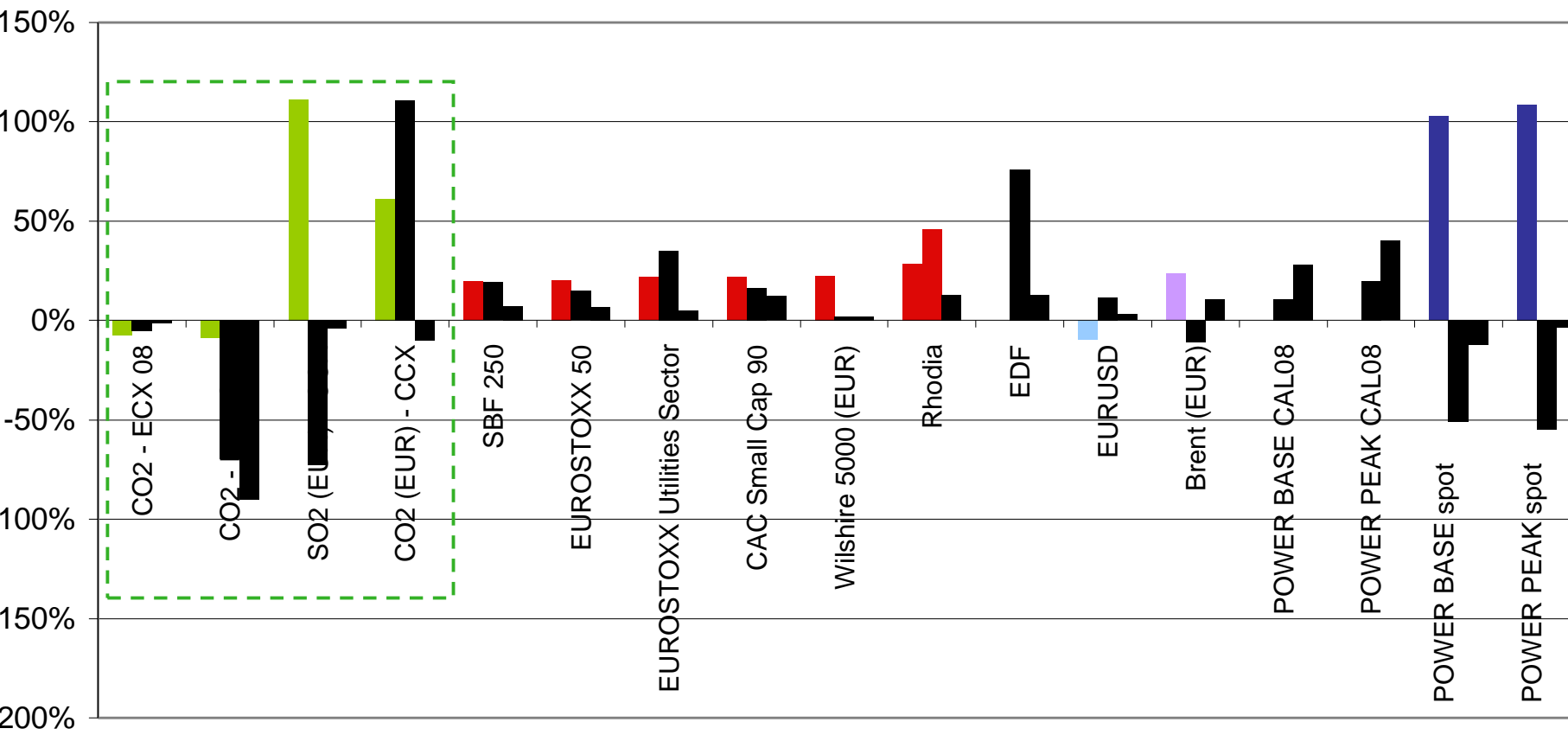
| | ECX08_P | ECX08_LR |
|--------------|----------|-----------|
| Mean | 20.05080 | -0.000559 |
| Median | 19.45000 | 0.000000 |
| Maximum | 32.25000 | 0.186526 |
| Minimum | 12.25000 | -0.288246 |
| Std. Dev. | 3.964770 | 0.033691 |
| Skewness | 0.697527 | -1.258423 |
| Kurtosis | 3.088401 | 18.29443 |
| Jarque-Bera | 38.83559 | 4775.053 |
| Probability | 0.000000 | 0.000000 |
| Observations | 477 | 477 |



Comparison of asset returns over 1 year



Comparison of asset returns from 2005 to 2007



Data sample: 22/04/2005 to 23/04/2007 - 2007 returns are calculated year-to-date - CO2 and EDF 2005 returns are calculated from inception - Dividends are excluded from asset return calculations for equity and equity indices - Sources: Powernext, ECX, CCX & Reuters.

Comparative study

- Sophistication degree of carbon exchanges
- Volatility
- Informational efficiency
- Liquidity
- Transaction costs
- Arbitrage opportunities
- Asset pricing

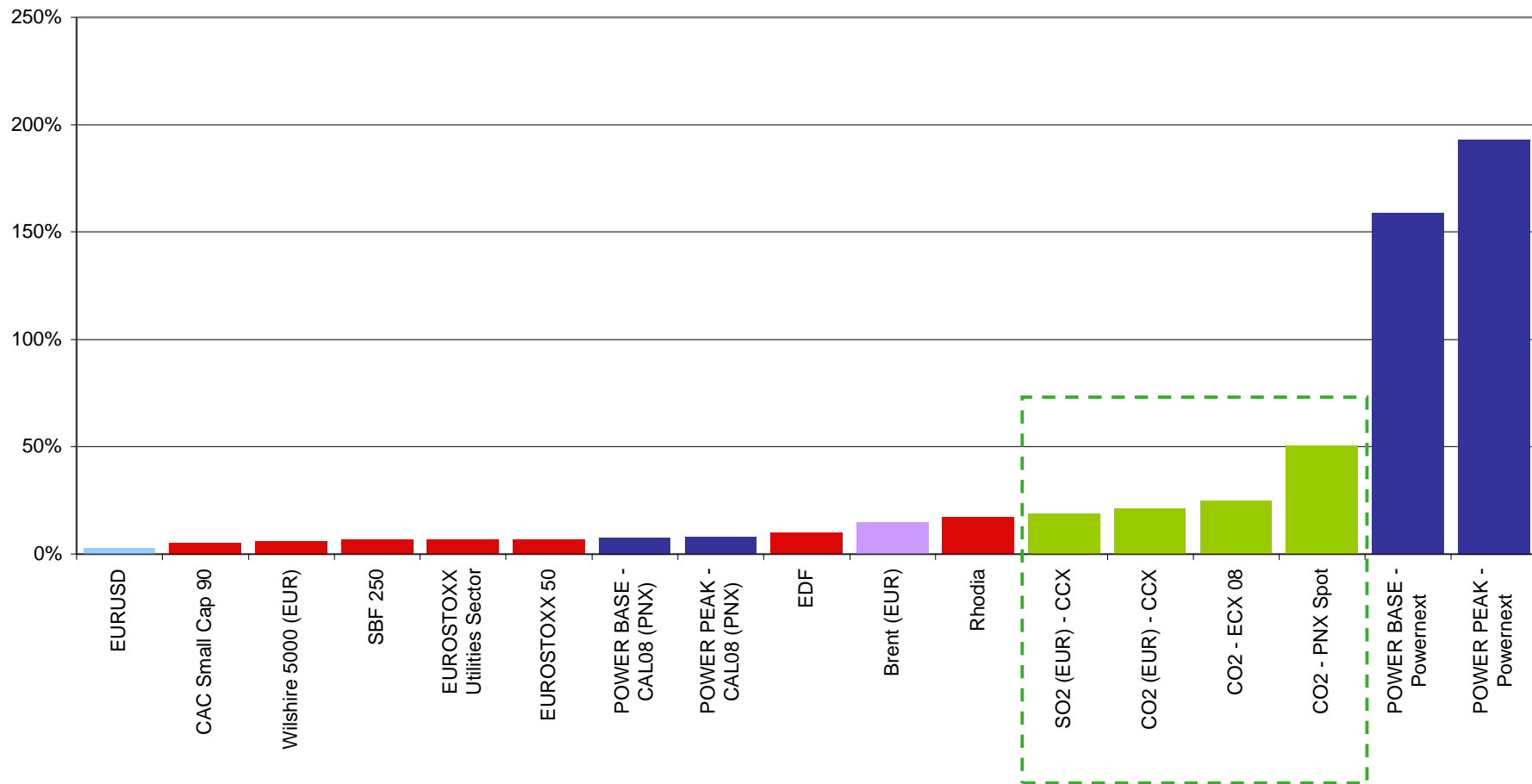
1. Sophistication degree of carbon exchanges

| | 2005 | 2006 | 2007 YTD |
|---------|--|---|--|
| SPOT | <p>03/05 EEX creation</p> <p>06/05 Powernext creation</p> <p>10/05 Nord Pool creation</p> | <p>01/06 Nord Pool daily short trading allowed</p> <p>05/06 Powernext real-time trading</p> <p>10/06 Powernext launch payment- on-delivery for OTC contracts</p> | |
| FUTURES | <p>02/05 Nord Pool creation</p> <p>04/05 ECX creation</p> <p>10/05 EEX creation</p> | | <p>12/06 ECX min. tick size reduced</p> |
| OPTIONS | | | <p>10/06 ECX creation</p> |

Innovations to come:

- New products: CER (announced for this year), ERU and AAU.
- Standardized cross-asset products: clean spark and dark spreads.

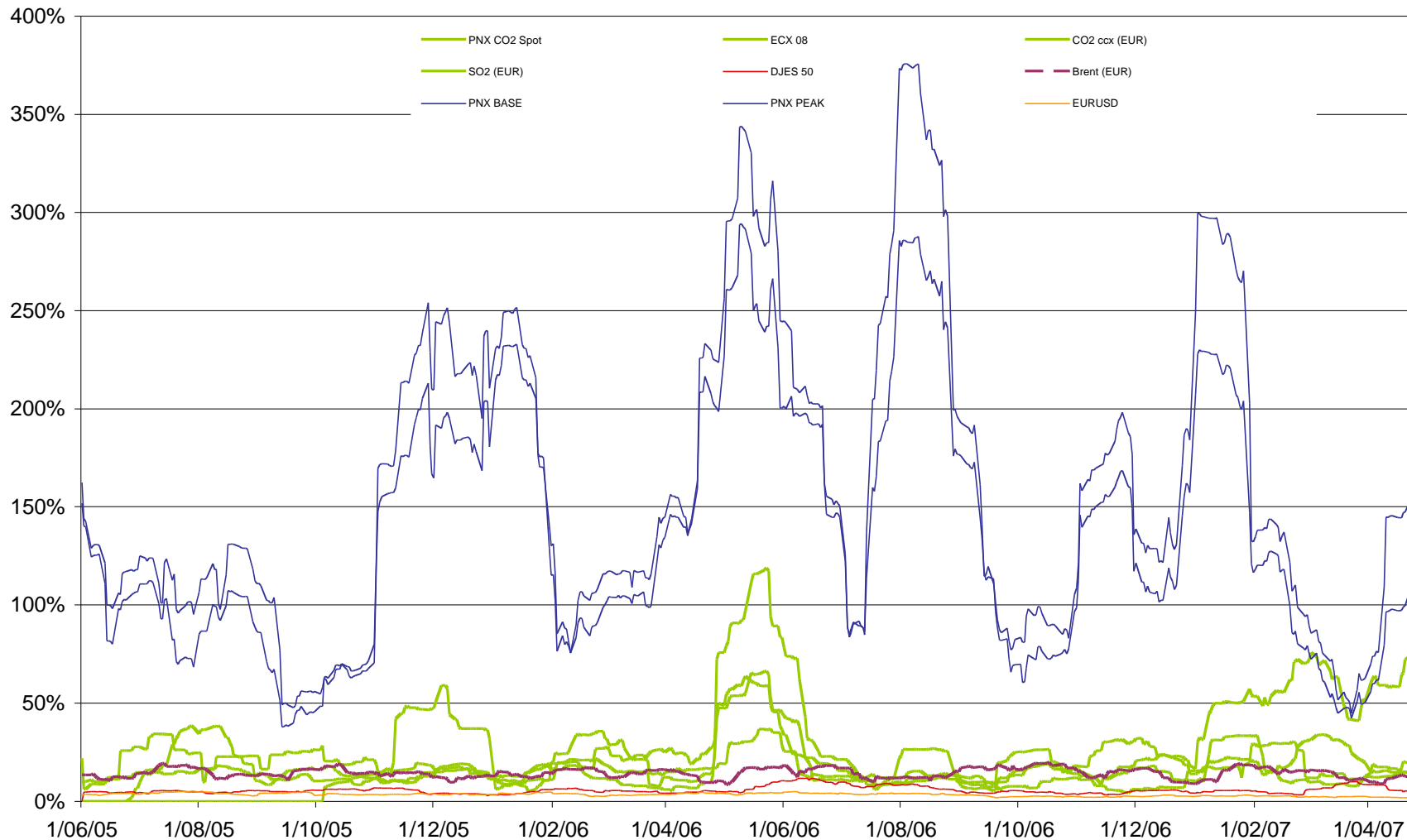
2. Annualized volatility over 1 year



Data sample: 21/04/2006 to 23/04/2007 - common annualizing factor chosen = 260

Sources: Powernext, ECX, CCX & Reuters

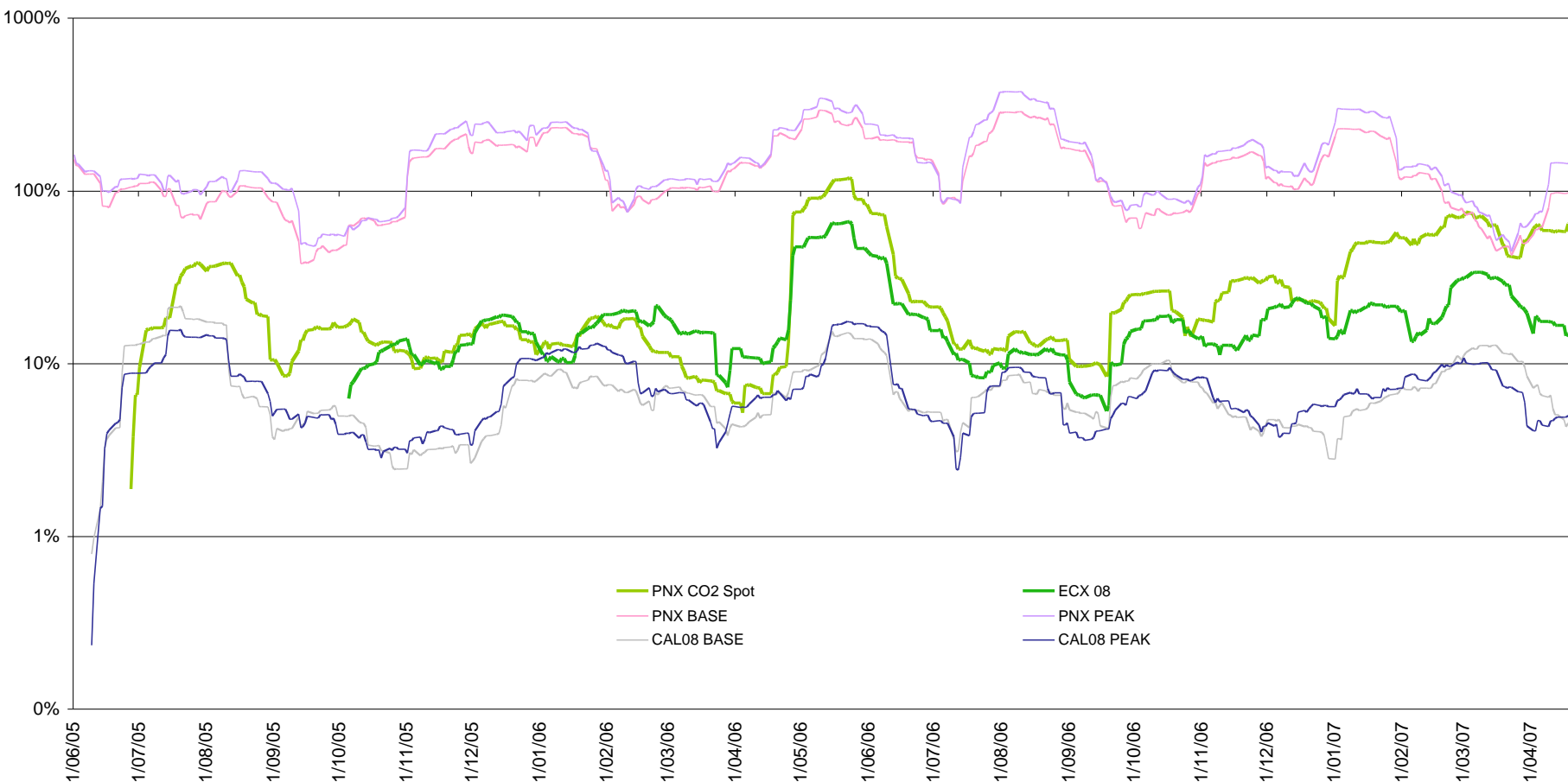
2. Annualized volatility over 20 observations



Data sample: 24/04/2005 to 23/04/2007 - common annualizing factor chosen = 260

Sources: Powernext, ECX, CCX & Reuters

2. Annualized volatility over 20 observations



Data sample: 24/04/2005 to 23/04/2007 - logarithmic scale - common annualizing factor chosen = 260

Sources: Powernext, ECX, CCX & Reuters

3. Informational efficiency: unit root tests

Unit root tests for prices

| | AIC | ADF - Exogenous factors | | | PP - Exogenous factors | | |
|------------------------|-----|-------------------------|----------------------------|-------------|------------------------|---------------------------|------------|
| | | ADF w/ intercept | ADF w/ intercept and trend | ADF w/ none | PP w/ intercept | PP w/ intercept and trend | PP w/ none |
| CO2 Spot (Powernext) | 2 | -0,715 | -2,653 | -1,334 | -0,653 | -2,681 | -1,275 |
| CO2 2005 (ECX - EUR) | 2 | -2,386 | -2,912 | -0,414 | -2,376 | -2,870 | -0,412 |
| CO2 2006 (ECX - EUR) | 2 | -1,022 | -2,424 | -1,091 | -1,094 | -2,504 | -1,086 |
| CO2 2007 (ECX - EUR) | 2 | -0,592 | -2,467 | -1,240 | -0,635 | -2,525 | -1,235 |
| CO2 2008 (ECX - EUR) | 2 | -2,572 | -3,465 | -0,756 | -2,478 | -3,347 | -0,758 |
| CO2 2009 (ECX - EUR) | 2 | -2,629 | -3,405 | -0,729 | -2,517 | -3,270 | -0,729 |
| CO2 2010 (ECX - EUR) | 2 | -1,240 | -2,250 | 0,183 | -1,732 | -2,650 | -0,040 |
| CO2 (CCX - USD) | 0 | -1,516 | -1,520 | 0,404 | -1,528 | -1,576 | 0,387 |
| SO2 2007 (CCX - USD) | 9 | -1,108 | -2,130 | -0,733 | -0,672 | -1,866 | -0,682 |
| EDF (EUR) | 2 | -0,579 | -2,154 | 1,934 | -0,483 | -2,093 | 2,035 |
| DJ Eurostoxx 50 (EUR) | 10 | -0,544 | -2,355 | 1,984 | -0,720 | -2,743 | 1,766 |
| Wilshire 5000 (USD) | 12 | -0,087 | -1,909 | 1,986 | -0,407 | -2,412 | 1,707 |
| Base spot (Powernext) | 8 | -3,543 | -3,915 | -1,425 | -5,763 | -6,276 | -2,028 |
| Peak spot (Powernext) | 9 | -3,956 | -4,281 | -1,723 | -6,515 | -6,917 | -2,682 |
| Base CAL08 (Powernext) | 2 | -1,540 | -1,027 | 0,462 | -1,570 | -1,140 | 0,396 |
| Peak CAL08 (Powernext) | 3 | -1,659 | -0,696 | 0,753 | -1,642 | -0,704 | 0,749 |
| Brent Spot (IPE - EUR) | 3 | -2,210 | -2,211 | 0,163 | -2,329 | -2,332 | 0,141 |
| EURUSD | 0 | -0,669 | -2,730 | 1,101 | -0,530 | -2,628 | 1,198 |

Signif. @ 90, 95 and 99%
 Signif. @ 90% and 95%
 Signif. @ 90%
 Not significant @ least @ 90%



Hypothesis tested: "Ho : Series has a unit root"

- Emissions prices follow a non-stationary process

3. Informational efficiency: unit root tests

Unit root tests for 1st difference

| | AIC | ADF - Exogenous factors | | | PP - Exogenous factors | | |
|------------------------|-----|-------------------------|----------------------------|-------------|------------------------|---------------------------|------------|
| | | ADF w/ intercept | ADF w/ intercept and trend | ADF w/ none | PP w/ intercept | PP w/ intercept and trend | PP w/ none |
| CO2 Spot (Powernext) | 2 | -10,010 | -10,010 | -9,954 | -16,415 | -16,418 | -16,391 |
| CO2 2005 (ECX - EUR) | 2 | -6,000 | -5,978 | -6,021 | -8,230 | -8,200 | -8,262 |
| CO2 2006 (ECX - EUR) | 2 | -9,367 | -9,388 | -9,343 | -14,787 | -14,794 | -14,782 |
| CO2 2007 (ECX - EUR) | 2 | -10,424 | -10,442 | -10,379 | -16,627 | -16,632 | -16,605 |
| CO2 2008 (ECX - EUR) | 2 | -11,081 | -11,070 | -11,089 | -18,635 | -18,617 | -18,651 |
| CO2 2009 (ECX - EUR) | 2 | -11,018 | -11,007 | -11,027 | -19,068 | -19,049 | -19,084 |
| CO2 2010 (ECX - EUR) | 2 | -4,675 | -4,768 | -4,691 | -8,281 | -8,412 | -8,336 |
| CO2 (CCX - USD) | 0 | -23,519 | -23,524 | -23,497 | -23,454 | -23,459 | -23,452 |
| SO2 2007 (CCX - USD) | 9 | -6,150 | -6,199 | -6,144 | -19,143 | -19,171 | -19,151 |
| EDF (EUR) | 2 | -10,722 | -10,711 | -10,423 | -17,697 | -17,675 | -17,506 |
| DJ Eurostoxx 50 (EUR) | 10 | -6,752 | -6,750 | -6,450 | -22,571 | -22,552 | -22,433 |
| Wilshire 5000 (USD) | 12 | -6,796 | -6,833 | -6,460 | -21,490 | -21,482 | -21,375 |
| Base spot (Powernext) | 8 | -9,239 | -9,228 | -9,247 | -28,138 | -28,103 | -28,170 |
| Peak spot (Powernext) | 9 | -8,990 | -8,978 | -8,998 | -27,462 | -27,428 | -27,495 |
| Base CAL08 (Powernext) | 2 | -12,743 | -12,810 | -12,739 | -23,638 | -23,695 | -23,644 |
| Peak CAL08 (Powernext) | 3 | -12,180 | -12,378 | -12,128 | -25,630 | -25,830 | -25,590 |
| Brent Spot (IPE - EUR) | 3 | -10,918 | -10,907 | -10,921 | -23,042 | -23,019 | -23,060 |
| EURUSD | 0 | -22,150 | -22,155 | -22,113 | -22,216 | -22,226 | -22,167 |

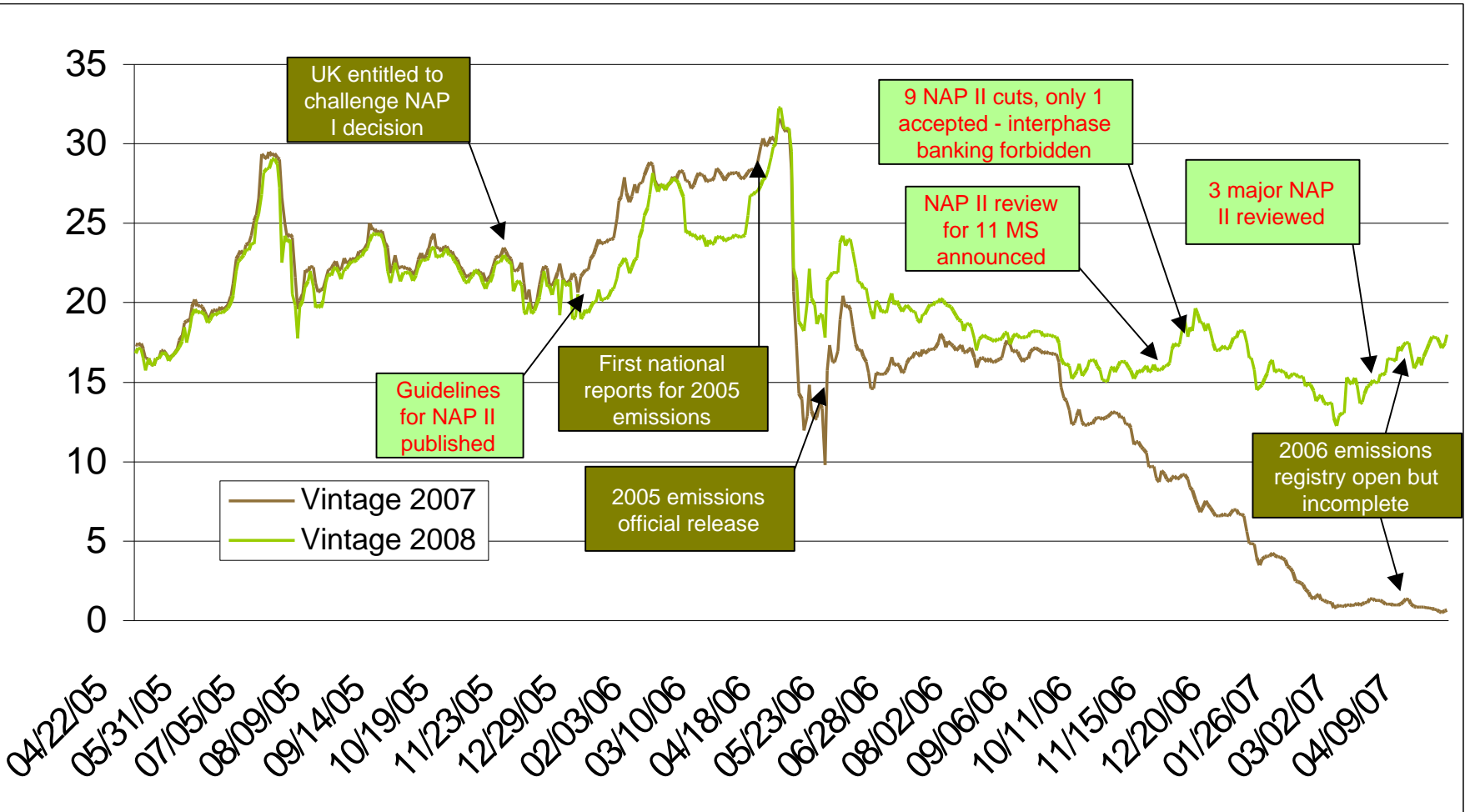
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 Not significant @ least @ 90%



Hypothesis tested: "Ho : Series has a unit root"

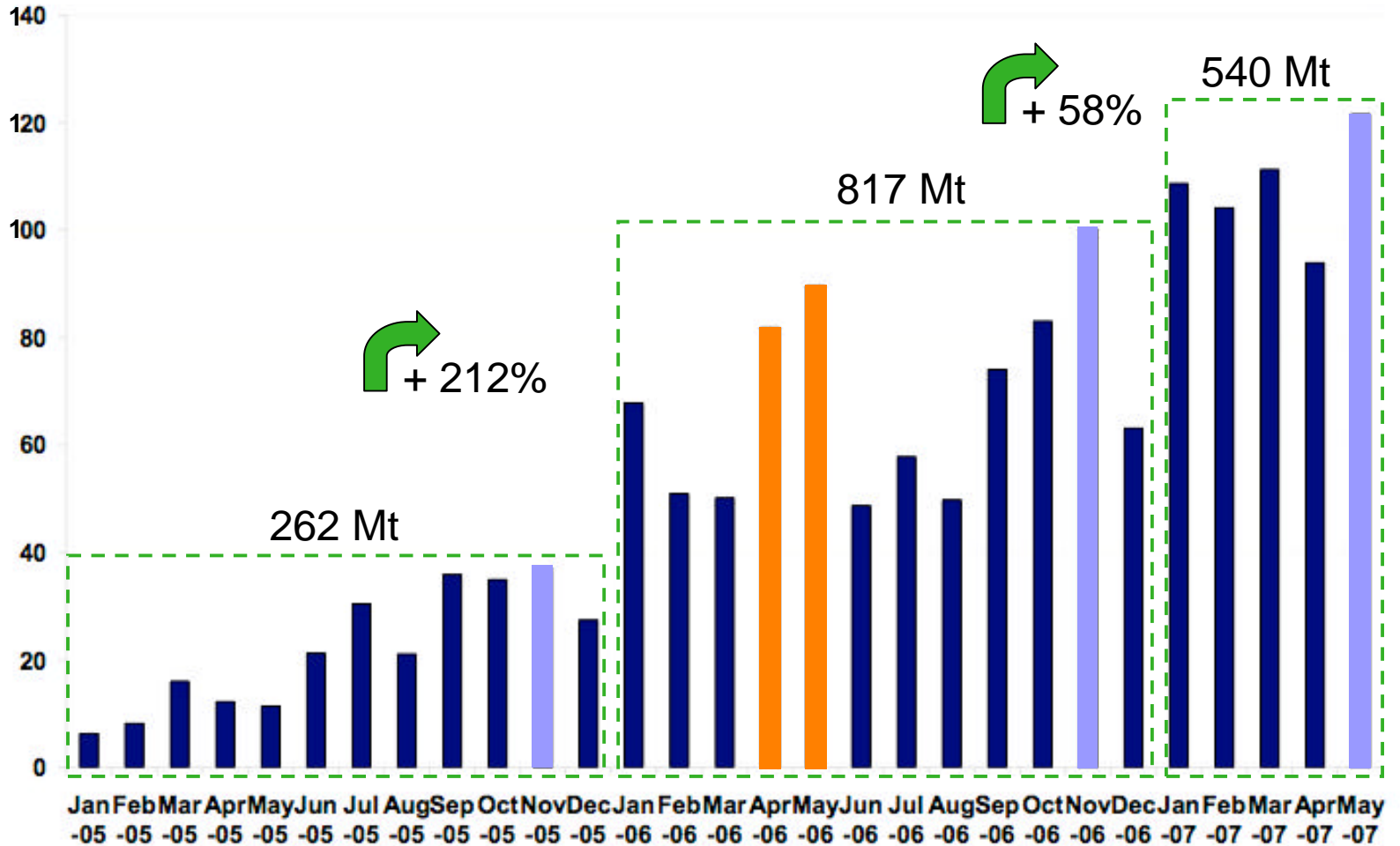
- Emissions prices 1st differences follow a stationary process: spot and Vintage CO₂ prices are first-order integrated, I(1).
- These results for EUA prices are as expected consistent with Albrecht, Verbeke and De Clerq (2005) efficiency analysis for the US SO₂ market: "The SO₂ permit market is basically as efficient as financial markets".

3. Informational efficiency: phase I and II prices



Source: ECX

4. Liquidity: monthly historical volumes



In Mt - Data from ECX, Powernext, Nord Pool, EEX, EXAA and Point Carbon OTC deals estimation - year-to-date data for 2007
 Source: Point Carbon

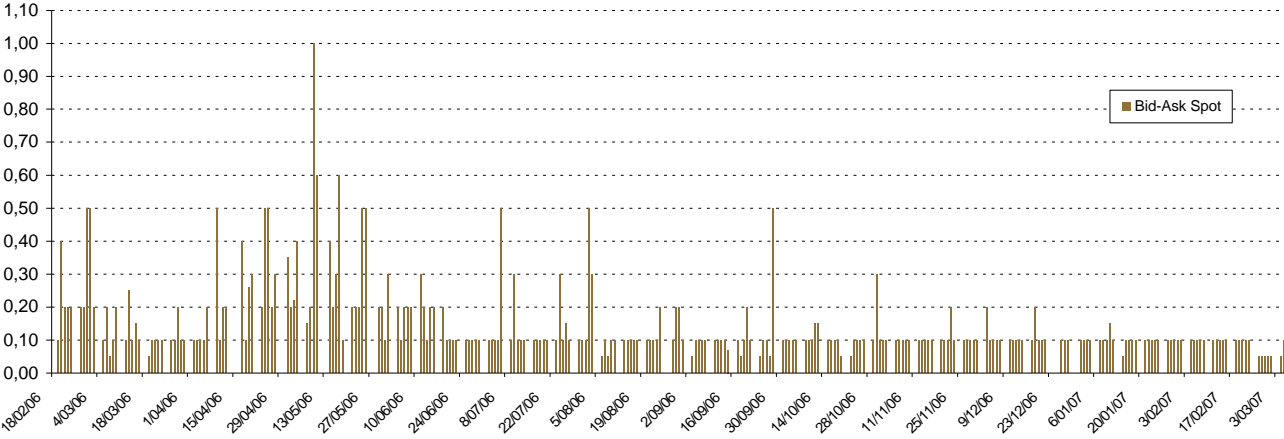
4. Liquidity: volumes and turnover

| | CO ₂ (Mt) | EDF (nb shares) |
|-------------------------------|----------------------|-----------------|
| Volume 2005 since inception | 262 | 133 134 345 |
| Volume 2006 FY | 817 | 399 508 226 |
| Volume 2007 YTD | 540 | 122 470 390 |
| Turnover 2005 since inception | 0.12x | 1.03x |
| Turnover 2006 FY | 0.38x | 2.89x |
| Turnover 2007 YTD | 0.25x | 0.94x |

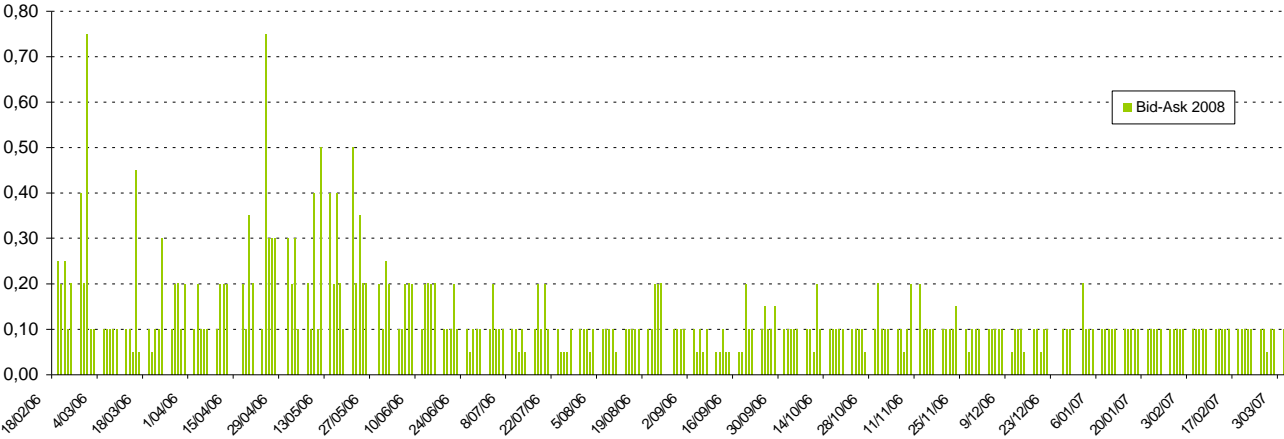
Data source: Point Carbon and Euronext

- EUA total volume estimate for 2007 is 1,550 Mt (Point Carbon). **Forecasted turnover for 2007 is 0.72x.**
- For comparison purpose, turnover for oil is approximately 4.00x in 2004.

4. Liquidity: bid-ask spread for spot and 2008 contracts



Source: Argus



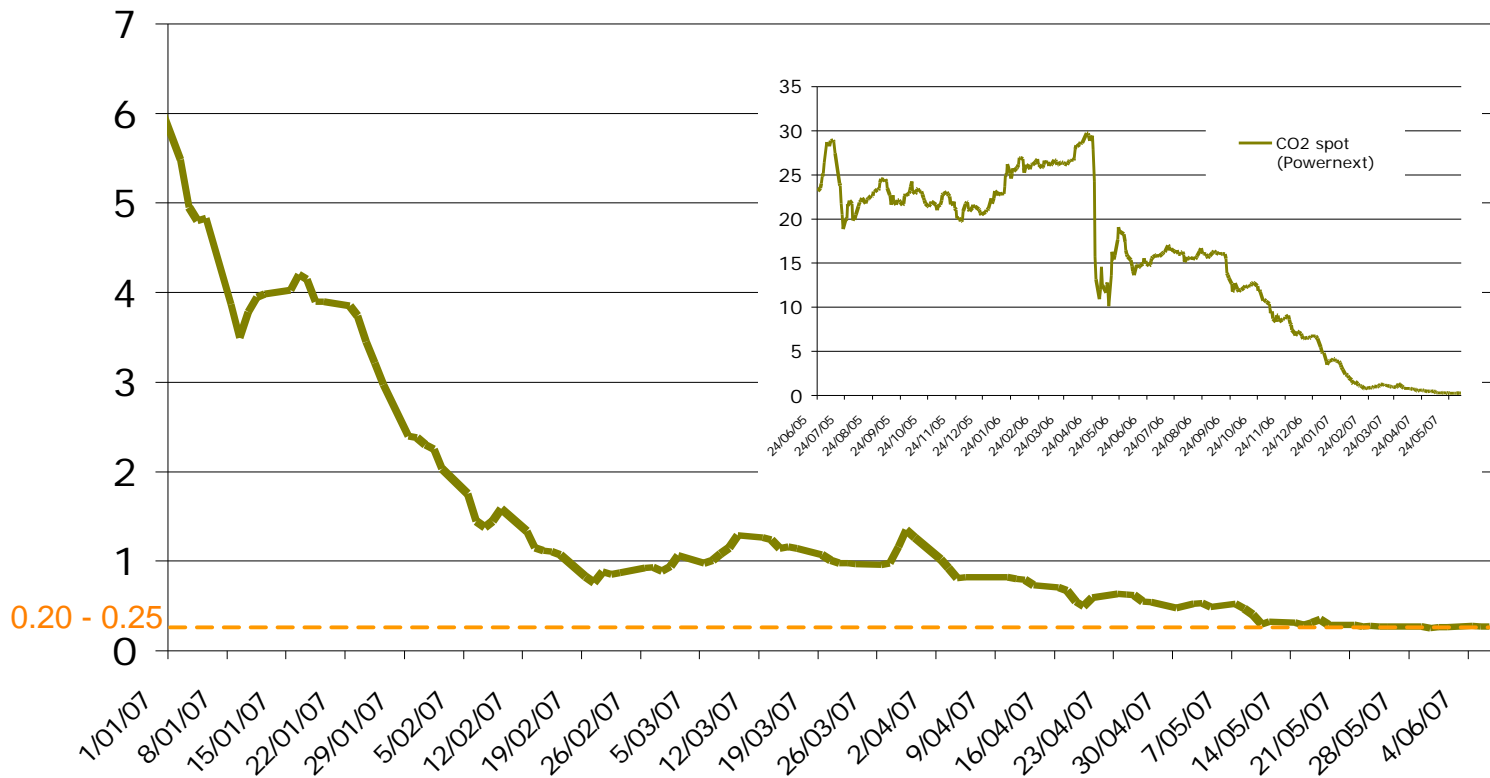
Source: Argus

5. Transaction costs

- Country-level:
 - transaction costs varies upon Member State application of the Directive and organization (EEA report, 2007).
- Carbon exchange-level:
 - various fees reduced over time.

5. Transaction costs

- Insight from current spot and vintage 2007 prices
 - As a result of a long market, spot and current vintage price converge toward zero.



6. Arbitrage opportunities

Intra-market arbitrages over time

- Spot prices exhibited **basis convergence** for Vintage 05 and 06.
- **High correlation** between spot and phase I vintages (2005-2007).
- Futures prices analysis implies **standard no-arbitrage pricing** (Daskalakis, Psychoyios & Markellos, 2006).

Cross-market arbitrages

- Correlation between phase 2 EUA contracts (2008-2012) and **Calendar power contract for 2008**.
- Arbitrages between CO₂ prices and **theoretical CO₂ switch price**.

7. Carbon assets pricing: a pre-crash survey

- Benz and Trück (2006) review the stylized facts of emission allowances and proposes modeling spot prices behaviour with **regime-switching models** that enable to capture the characteristics of CO2 allowances.
- Daskalakis, Psychoyios and Markellos (2006) propose an empirical study of CO2 prices using spot and future prices from the EEX. They found that spot prices can be well approximated by a **jump-diffusion model** and that futures prices implies that the market participants adopt **standard no-arbitrage pricing**.
- Seifert, Uhrig-Homburg and Wagner (2006) propose a “**tractable stochastic equilibrium model** reflecting stylized features of the EU ETS and analyze the resulting CO2 spot price dynamic”. They found that an adequate CO2 process “does not necessarily have to follow any seasonal pattern”, “should possess the martingale property” and “exhibit a time- and price-dependent volatility structure”.
- Uhrig-Homburg and Wagner (2006) prepared a survey on CO2 price drivers and CO2 derivatives expectations. They also present an expert survey on CO2 prices risk management, CO2 derivatives availability and design properties. Uhrig-Homburg and Wagner find there are chances of success for futures and forward on CO2 and for options as well. They **propose a European-style standardized CO2 option with a cap set at EUR 40**.

Summary table

| | CO2 Spot | CO2 2008 | SO2 2007 | CO2 (CCX) 2007 | Wilshire 5000 | Eurostoxx 50 | EDF | Power spot - base | Power spot - peak | Power fut - base | Power fut - peak | Brent | EURUSD |
|---|---|-------------|---------------------|----------------|------------------------------|------------------------------|-----------|---|-------------------|------------------|------------------|---------------------------------|---------------------------|
| Sophistication degree | Spot, futures and options | | Futures and options | Futures | Tracker, futures and options | Tracker, futures and options | Spot | Spot and futures | | | | Spot, futures and options | Spot, futures and options |
| Volatility (average over sample period) | High* (29%) | High* (16%) | High (16%) | High* (21%) | Low (6%) | Low (6%) | Low* (8%) | Very high (138%) | Very high (162%) | Low (7%) | Low (7%) | Average (14%) | Very low (3%) |
| Informational efficiency | I(1) | I(1) | I(1) | I(1) | I(1) | I(1) | I(1) | I(1) | I(1) | I(1) | I(1) | I(1) | I(1) |
| Liquidity | Carbon markets volume grow to more mature level already achieved among financial and commodity markets | | | | High except for some ETFs | | | High | | | | High | High |
| Transaction costs | As markets develop, transaction costs are being reduced : estimate for CO ₂ circa EUR 0.25 | | | | Low except for some ETFs | | | Low | | | | Low | Low |
| Arbitrage opportunities | Cross-market arbitrage opportunities might exist | | | | In case of mispricing | | | Arbitrages depends on interconnection capacity and production ability of the arbitrageur. | | | | Physical arbitrages might exist | Cross-rate |
| Asset pricing | Regime-switching and jump-diffusion models | | | | Various models tested | | | Various stochastic processes tested | | | | Various models tested | Various models tested |

* indicates a highly changing volatility

Concluding remarks

- Carbon permits constitute a proper asset class.
- Quantitative models alone are not sufficient to explain carbon prices movements because:
 - The main drivers are often changing when trying to explain historical price evolution and
 - Highest price movements are led by regulatory announcements.
- Stabilization of the institutional framework is key to carbon market future success.