Co-movements between carbon, energy and financial markets

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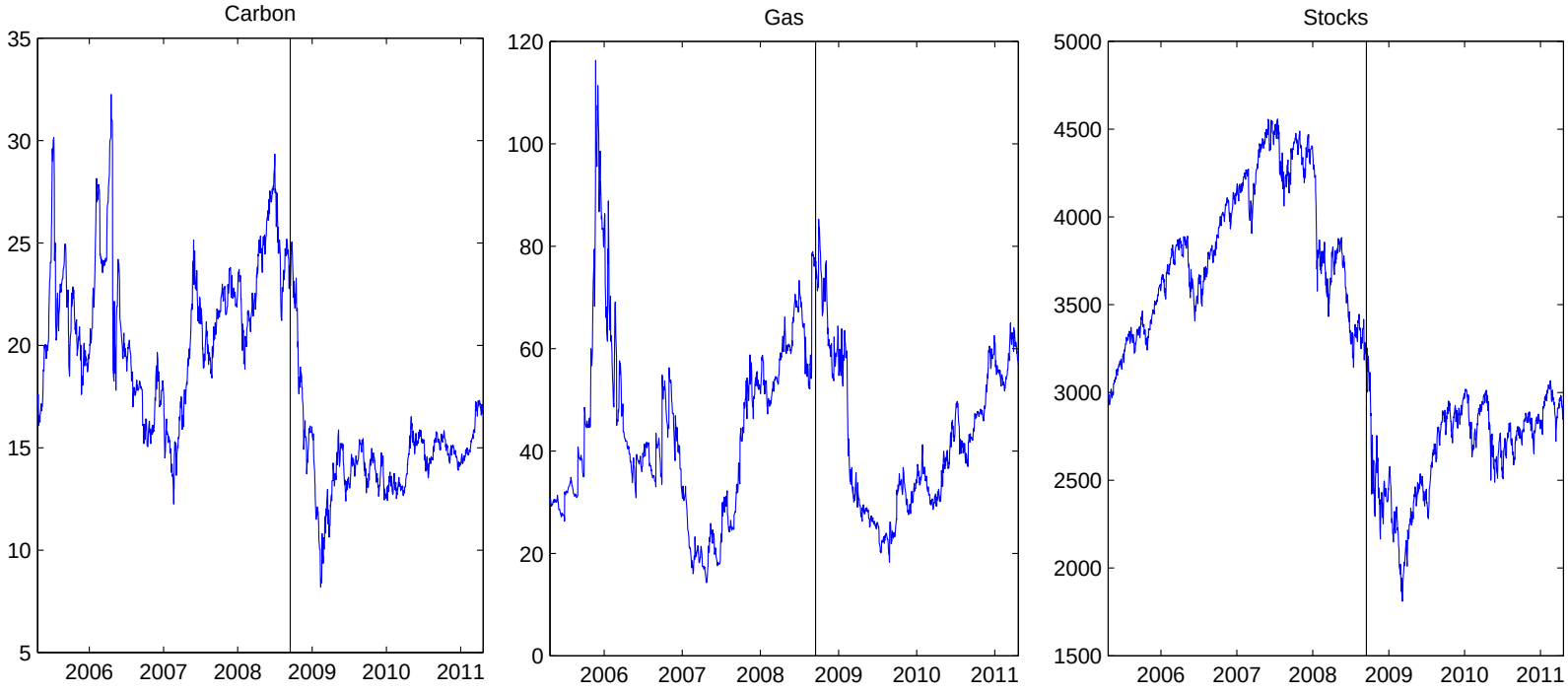
The Usual Suspects



- *Do price linkages between carbon and market fundamentals vary over time?*
- *What drives price dynamics? The financial crisis? Regulatory events?*

Outline

The EU Emissions Trading Scheme (EU ETS)

- Scope: Almost 50% of EU's CO2 emissions from power sector and most energy-intensive industries is capped
- Unit: EUA grants right to emit one metric tonne of CO2-e
- Three regulatory periods: Phase I (2005-2007), Phase II (2008-2012); Phase III (2013-2020)
- Structural change with respect to market regulation, expertise and liquidity:
  - institutional rules which proved inefficient considerably changed, e.g. ban on inter-phase banking
  - EU ETS has become a highly liquid market with the common trading patterns of mature commodity markets

Theoretical Literature

Solution of firm's pollution cost minimization problem:
allowance price = marginal abatement costs

1. Fuel-switching in power sector is abatement method of choice (Fehr and Hinz, 2006; Delarue et al., 2008)
   $\rightarrow$ energy and carbon prices are expected to be correlated
2. Economic activity determines need for abatement (Christiansen et al., 2005; Ellerman and Buchner, 2008)
   $\rightarrow$ stock prices are indicator of economic conditions should determine carbon prices

Empirical Literature

- Energy prices are important carbon price drivers (Mansanet-Bataller et al., 2007; Alberola et al., 2008; Hintermann, 2010)
- But, institutional determinants show equal importance
- Carbon market only remotely connected to variations of stock and bond markets (Chevallier, 2009; Daskalakis et al., 2009)
- Correlations between carbon, gas and electricity are not constant over time (Koenig, 2011)

Financial economics (e.g. Capiello et al., 2006): price formation across markets evolves over time and is materially influenced by

- institutional change
- time-varying market uncertainty
  $\rightarrow$ dynamics widely unexplored

Research questions

1. Structural breaks: Has a new correlation regime between EUAs and fundamentals emerged over time?

   Has carbon-energy correlation increased in Phase I-to-Phase II period?

2. Asymmetries under different market uncertainty conditions: Are correlations exacerbated during episodes of financial turmoil or do we observe a decoupling of the markets?

   Is the carbon market interconnected to the broader financial system?

Data

- Sample period: April 22, 2005 until April 21, 2011, a total of 1,537 observations.
- Carbon
  - ICE/ECX EUA December futures for Phase II
- Energy
  - Fuel: 1-month ahead futures for Natural Gas, Hard Coal, Brent Oil.
  - Electricity: 1-month futures contract for baseload power in UK.
- Financials
  - EURO STOXX 50 index
  - 10-year benchmark government bond index for the EMU

Smooth transition conditional correlation (STCC) model

Silvennoinen and Teräsvirta (2005)

- Correlations vary smoothly between two extreme states and the dynamics are driven by logistic function G_t of an observable transition variable $s_t \in \Omega_{t-1}$

$$P_t = (1 - G_t)\, P_{(1)} + G_t P_{(2)}$$

$$G_t = \left(1 + e^{-\gamma(s_t - c)}\right)^{-1}, \ \gamma > 0$$

- When s_t has values less than c, the correlations are closer to state $P_{(1)}$. For $s_t > c$, the situation is the opposite
  - Calender time: t/T (Berben/Jansen, 2005)
  - Implied volatility: EURO STOXX 50 Volatility ($VSTOXX_{t-1}$)
- Parameter γ determines the speed of transition.

Double Smooth transition conditional correlation (DSTCC)

Silvennoinen and Teräsvirta (2009)

- Conditional correlations moves smoothly between four extreme states of constant correlation driven by two transition variables (i.e. $s_{2t} = t/T$ and $s_{1t} = VSTOXX_{t-1}$)

$$P_t = (1 - G_{2t})\left((1 - G_{1t})P_{(11)} + G_{1t}P_{(21)}\right) + G_{2t}\left((1 - G_{1t})P_{(12)} + G_{1t}P_{(22)}\right)$$

$$G_{it} = \left(1 + e^{-\gamma_i(s_{it} - c_i)}\right)^{-1},\ \gamma_i > 0,\ i = 1, 2$$

- Bivariate estimation by quasi maximum likelihood (QML)
- LM-type test procedure to verify constancy of correlations and existence of links to economic variables or proxies for latent factors

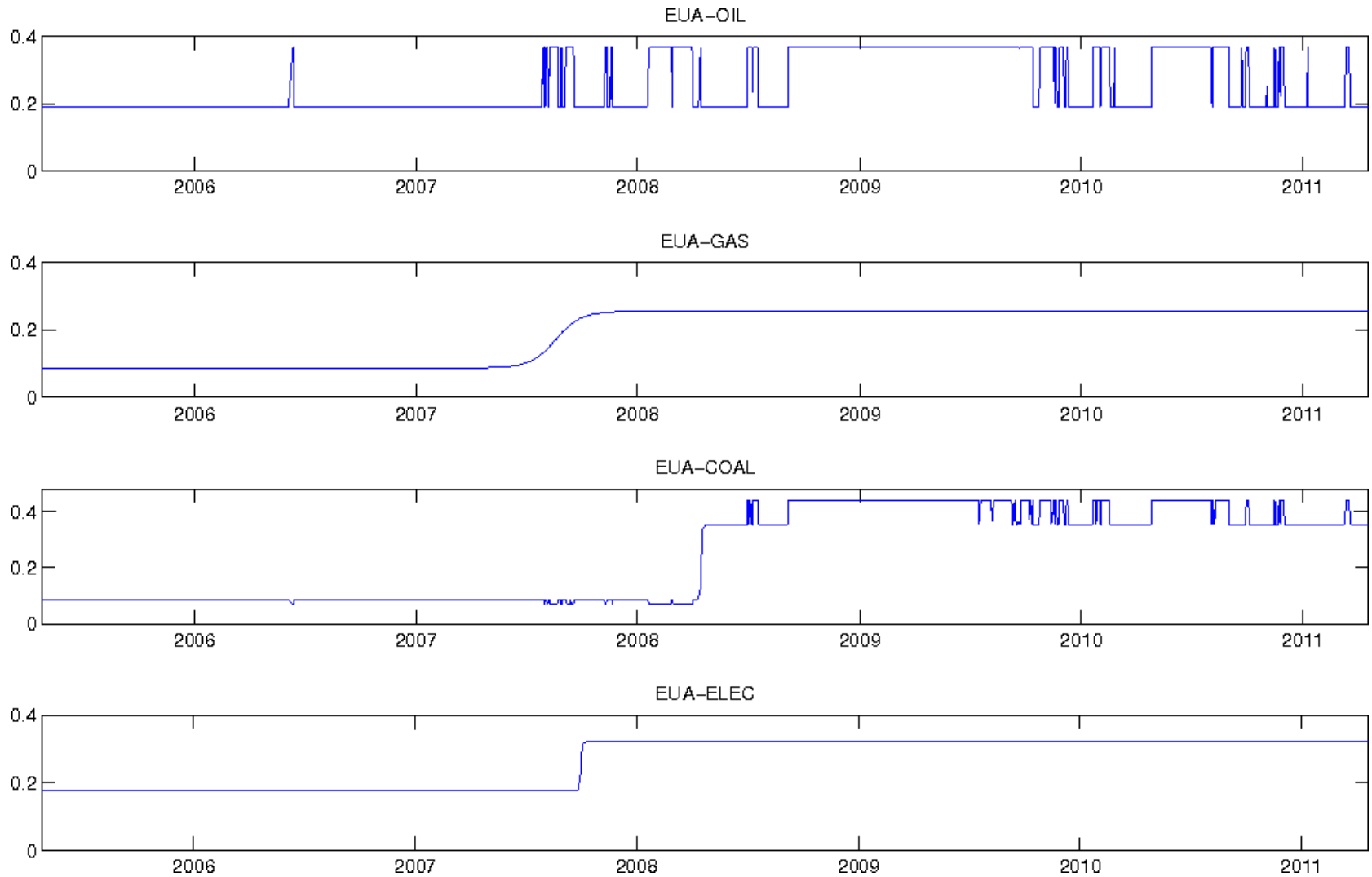
Choosing the transition variable

LM test results

This table reports the results from bivariate tests of constant correlations against a STCC GARCH model (LM_{CCC}) and from bivariate tests of a STCC against a DSTCC GARCH model (LM_{STCC}). The transition variables in the tests are calendar time (t/T) and the one-day lag of the VSTOXX index ($VSTOXX_{t-1}$). The p-values listed in bold type indicate the selected most relevant transition variable(s) for each bivariate asset combination.

	t/T		$VSTOXX_{t-1}$		$VSTOXX_{t-1}$ and t/T	
	LM_{CCC}	p-value	LM_{CCC}	p-value	LM_{STCC}	p-value
EUA-OIL	13.6318	0.0035	19.8526	$\mathbf{8x10^{-6}}$	0.2163	0.6419
EUA-COAL	30.1360	$4x10^{-8}$	32.4736	$1x10^{-8}$	10.9943	**0.0009**
EUA-GAS	10.5969	**0.0011**	2.1383	0.1437	-	-
EUA-ELEC	8.8783	**0.0029**	0.1925	0.6608	-	-
EUA-STOCK	11.9488	0.0005	41.2401	$\mathbf{1x10^{-10}}$	2.5282	0.1118
EUA-BOND	5.8607	0.0155	25.8439	$\mathbf{4x10^{-7}}$	0.0490	0.8248

Carbon-energy market correlation



Carbon-energy market correlation

	s_1	s_2	$P_{(11)}$	$P_{(21)}$	$P_{(12)}$	$P_{(22)}$	c_1	c_2	γ_1	γ_2	*Date*
EUA-OIL	*VSTOXX*		0.19	0.37			25.45		500		
			(0.031)	(0.035)			(0.819)		(.)		
EUA-COAL	*VSTOXX*	t/T	0.09	0.07	0.35	0.44	26.08	0.49	500	500	17-Apr-2008
			(0.037)	(0.129)	(0.050)	(0.036)	(0.177)	(0.003)	(.)	(.)	
EUA-GAS	t/T		0.09	0.26			0.39		29.80		22-Aug-2007
			(0.033)	(0.040)			(0.046)		(42.595)		
EUA-ELEC	t/T		0.18	0.32			0.40		500		02-Oct-2007
			(0.034)	(0.033)			(0.026)		(.)		

Notes: Values in parentheses are Bollerslev-Wooldridge QML standard errors.

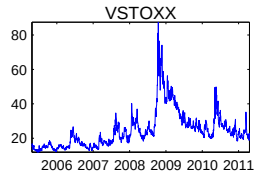
Date is the day that corresponds to c_i when $s_i = t/T$.

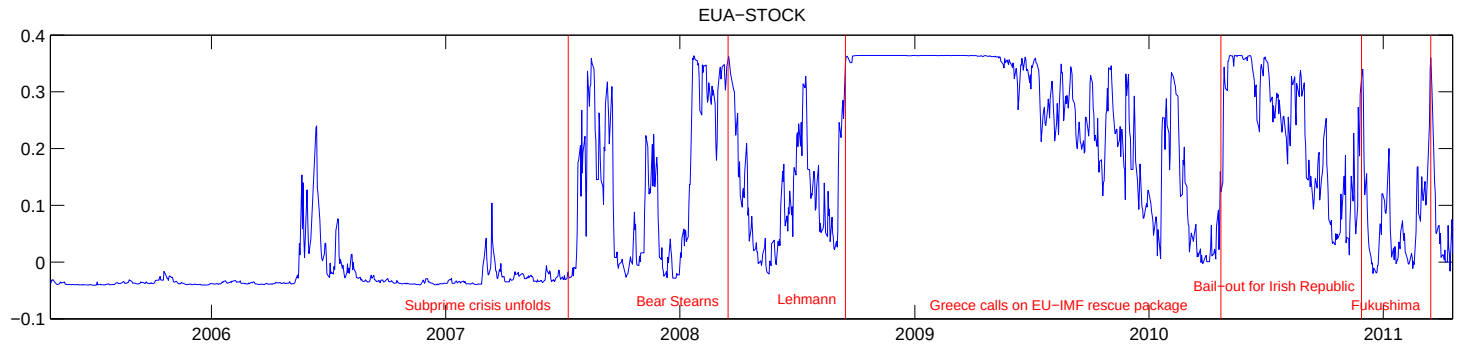
Key messages

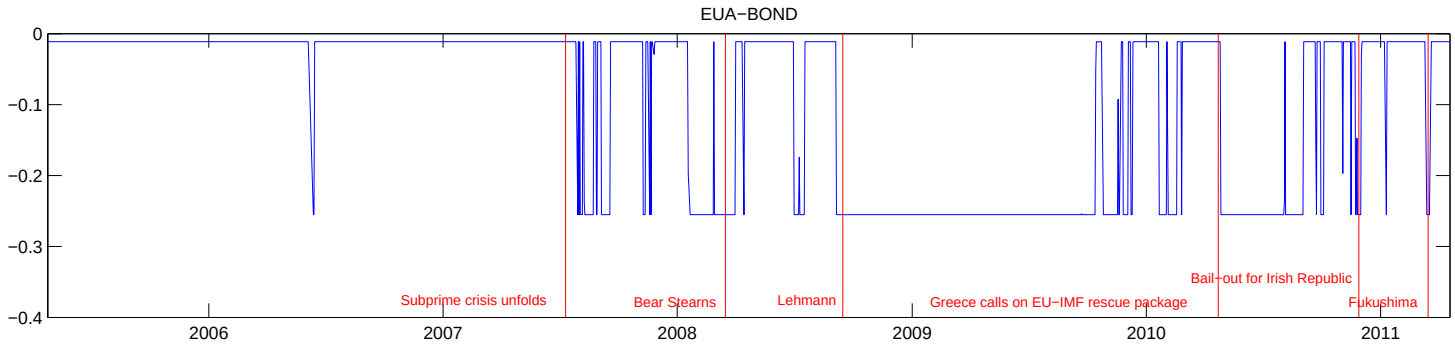
Carbon-energy market co-movements

- Evidence for a stronger integration between carbon and energy markets in the aftermath of the EU ETS trial phase.
- Correlations between carbon and gas, coal and electricity are four, three and two times as high in Phase II as in Phase I, respectively.
- Structural breaks fall into the period January 2007 - April 2008 $\rightarrow$ finding of different break dates and adjustment speeds illustrates model advantages
- Economic rationale: improved institutional framework and information processing of the now mature carbon market

Carbon-financial market correlation







Carbon-financial market correlation

	s_1	s_2	$P_{(11)}$	$P_{(21)}$	$P_{(12)}$	$P_{(22)}$	c_1	c_2	γ_1	γ_2
EUA-STOCK	*VSTOXX*		-0.04	0.36			24.84		4.77	
			(0.051)	(0.046)			(1.601)		(2.438)	
EUA-BOND	*VSTOXX*		-0.01	-0.26			25.42		500	
			(0.033)	(0.038)			(0.657)		(.)	

Notes: Values in parentheses are Bollerslev-Wooldridge QML standard errors.

Key messages

Carbon-financial market co-movements

- Carbon and financial markets are not segmented $\rightarrow$ correlations heavily depend on market conditions
- VSTOXX index is a useful state variable
- Economic rationale:
  - Decline in carbon-bond correlations: "flight-to-quality" phenomenon
  - Hike in carbon-stock correlations: (i) decrease in industrial production and energy demand and (ii) increase in funding needs of companies
- Overall, the results suggest that benefits of carbon-stock diversification seem to be weak for the sample at hand.

Policy Implications

- New pricing regime with an increased dependency between EUA prices and energy prices emerges in Phase II
  - indicates that energy market fundamentals become more important in the EUA price formation
  - should have a positive effect on the cost-efficiency of the EU ETS
- Practical implications for risk management of companies and specialized traders
  - optimal hedging strategies have changed
  - efficient hedging positions should be based on time-varying correlation estimates
  - Implied volatility index may partly help on hedging the risk of adverse price movements

Thank you!