Volatility spillovers between agricultural commodity and financial asset markets

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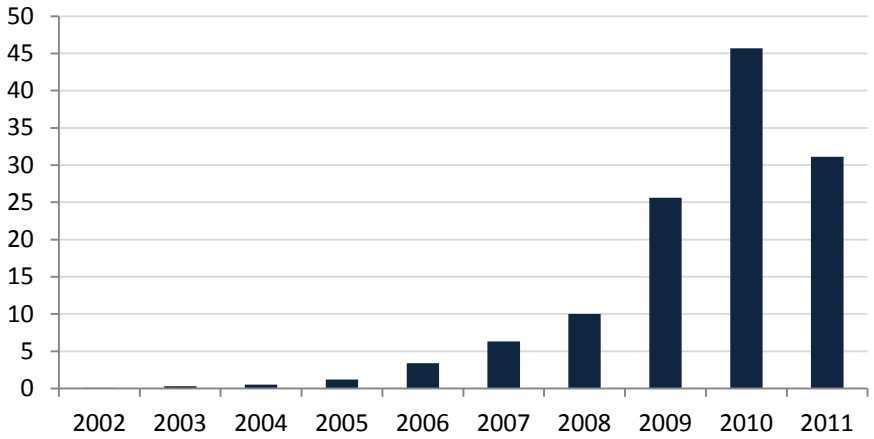
Growing importance of commodities as portfolio assets

More investment vehicles available

Growth in Commodity ETP assets
2002-11, bn USD



Use of agricultural commodities as portfolio diversifiers facilitated

Global financial crisis intensify

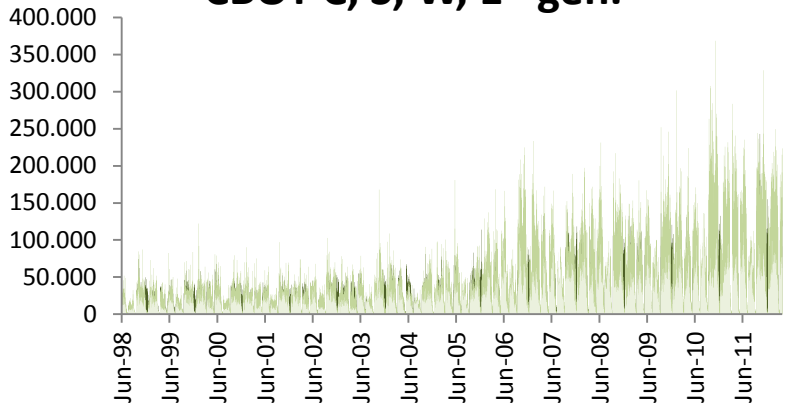
2007-2012 global financial crisis

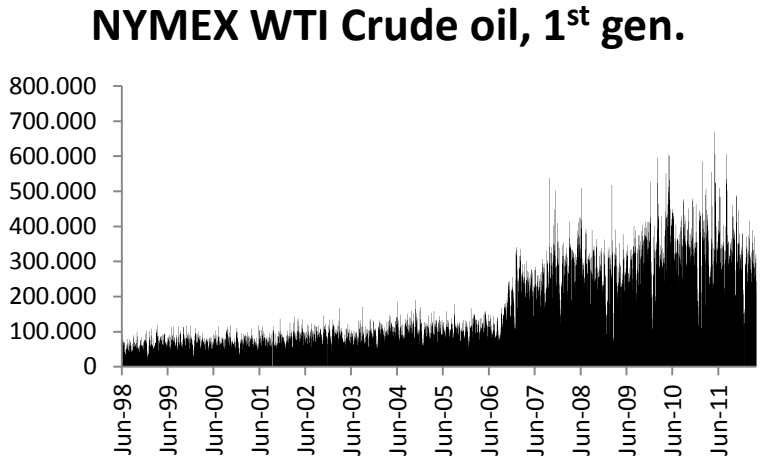
- Subprime mortgage crisis (2007/2008)
- Sovereign debt crisis (from ~2010)

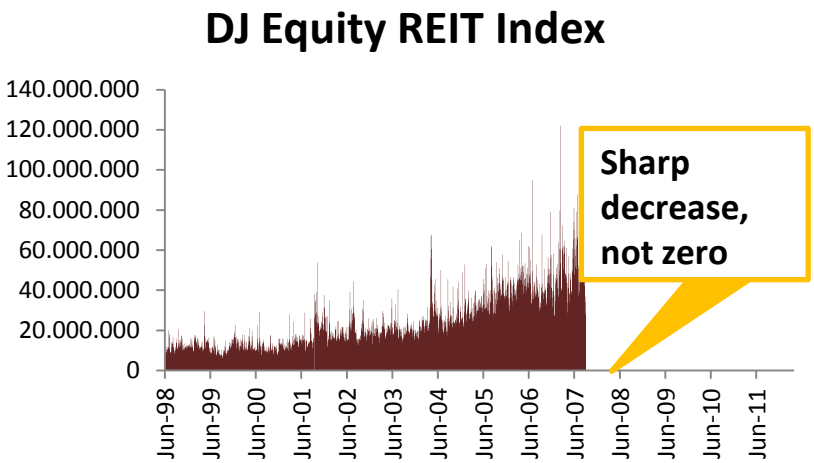
Higher importance of agricultural commodities refuge assets

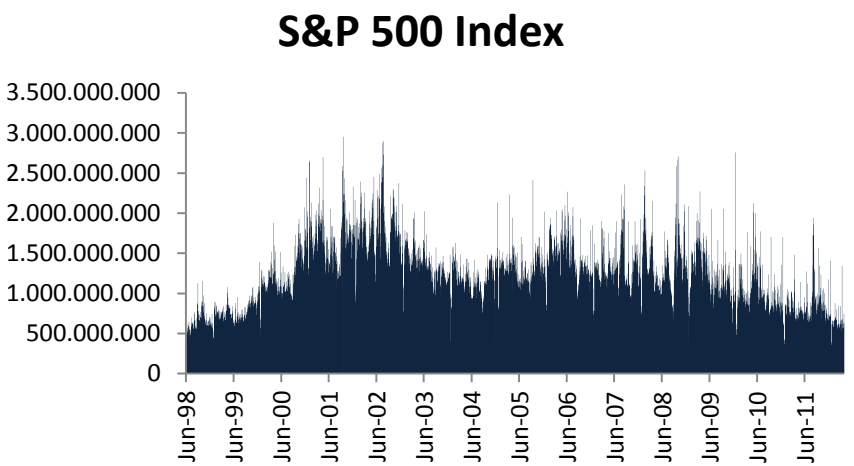
Source: BlackRock (2011); Conover et al. 2010, Chong and Miffre 2010, Gorton and Rouwenhorst 2006, Ankrim and Hensel 1993

Development of trading volume in asset markets









Significant increase in commodity trading volume after 2006

Source: Bloomberg

Research objective

Investigate whether market interdependence and volatility transmission between agricultural commodity markets and financial asset markets increases…

A **In normal markets:**

As a result of portfolio rebalancing and asset weight adjustments.

B **In crisis markets:**

As s a result of real asset substitution and use of agricultural commodities as refuge assets.

Methodology

Selection criteria

- Multivariate (~8 variables)
- Link to economic theory
- Account for potential regime-switches

Methodology

- Structural VAR (rolling estimation)
- *Generalized* Forecast Error Variance Decompositions (Pesaran and Shin, 1998)
- "Volatility spillover indices"

Application examples

- Diebold and Yilmaz (2009, 2012)
- Dimpfl and Jung (2012)

Modeling steps

I	▪ Selection of included financial and commodity assets ▪ Data gathering
II	▪ Computation of volatility proxies
III	▪ Estimation of rolling VAR models ▪ Generalized forecast error variance decompositions (FEVDs)
IV	▪ Calculation of volatility spillover indices

I Assets included in the analysis

Commodity

Agricultural

- Corn, CBOT (C1)*
- Wheat, CBOT (W1)*
- Soybeans, CBOT (S1)*

Energy

- WTI Crude oil , NYMEX (CL1)*

Financial

Equity

- S&P 500 Index (SPX)

Real estate

- DJ Equity All REIT Index (REIT)

Fixed income

- 10-y-U.S. Treasury, CBOT (TY1)*

Foreign exchange

- ICE Futures U.S. Dollar Index (DXY)

3 June 98 – 30 Mar 2012/ Daily data

* Future contracts, 1st generic (Bloomberg), rolling "relative to expiration", contracts rolled after last trading day of front month

II Volatility proxies used in the models

Focus

Range-based volatility*

$$\hat{\sigma}_{Range,it} = \sqrt{\frac{1}{4\ln 2}\left[\ln\left(\frac{P_{it}^{High}}{P_{it}^{Low}}\right)\right]^2}$$

Pro:

- Captures intraday movements

Con:

- May show high volatility in times of a persistent trend in returns
- May be inflated due to intraday periods of low trading volume

Return-based volatility

$$\hat{\sigma}_{Return,it}(m) = \sqrt{\frac{1}{m-1}\sum_{n=1}^{m}(R_{it-n} - \bar{R}_i(m))^2}$$

with $R_{it} = \ln\left(\frac{P^{Close}_{it}}{P^{Close}_{it-1}}\right)$

and $m = 5, 30, 90, 180$

Pro:

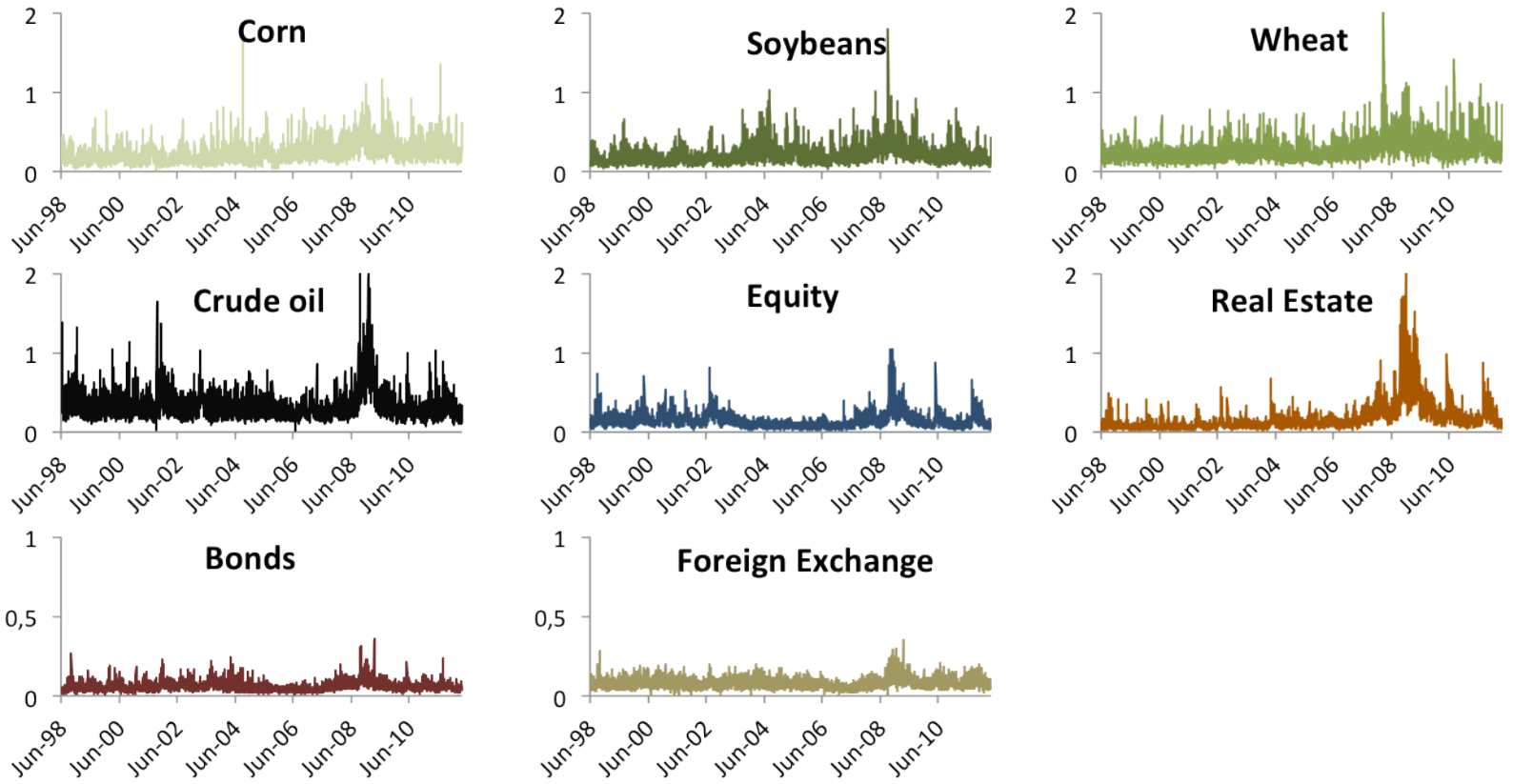
- Captures trends

Con:

- Neglects intraday movements
- Sensitive to included no. of observations/ time period of investigation

* based on Parkinson (1980)

II Asset volatility profiles(Range-based, Annualized*)



* Multiplied by $252^{0.5}$

Source: Own calculations

III Estimation of VARs – Rolling regression

Model	Specification*	Included observations (No. per variable = T)				No. of windows
		w = 252 →				(T-w + 1)
$\log \hat{\sigma}_{Range}$	VAR(4)	06/03/98	…	03/30/12	(3,488)	3,237
$\log \hat{\sigma}_{Return}(5)$	VAR(1)	06/10/98	…	03/30/12	(3,483)	3,232
$\log \hat{\sigma}_{Return}(90)$	VAR(1)	10/09/98	…	03/30/12	(3,398)	3,147

* Lag length selected with SBC, VAR models for 30 and 180 day return-based volatilities estimated, results not reported

IV Generalized vs. Orthogonalized impulse responses

MA representation: $y_t = \mu + \sum_{h=0}^{\infty} \Phi_h u_{t-h}$

IR function: $\Phi_j(h)$ — *Restriction* required

Focus

Orthogonalized

- Response to *specific shock* in one variable (equation j, c.p.)
- Via Cholesky decomposition of covariance matrix $\Sigma = PP'$:

$$\Phi_j^o(h) = \Phi_h P e_j$$

- Sensitive to ordering
- Theory required

Generalized (Pesaran and Shin 1998)

- Response to *typical composite shock* (equation j and others)
- Via information on history contained in estimated Σ:

$$\Phi_j^g(h) = \sigma_{jj}^{-\frac{1}{2}} \Phi_h \Sigma e_j$$

- Not sensitive to ordering
- Sensitive to past behavior

σ_{jj} = variance of errror term for j^{th} equation
e_j = selection vector (1 as jth element, 0 otherwise)

h = time period for forecast

IV Variance decompositions and volatility spillovers

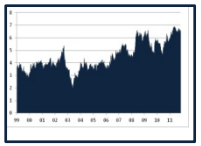
Generalized FEVDs

- **Own variance shares:** fraction of H-step ahead FEVs for one asset class (i) that are due to shocks to this asset class (i).
- **Spillovers (cross variance shares):** fraction of H-step ahead FEVs for one asset class (i) that are due to shocks to another asset class (j).

Spillover indices (Diebold and Yilmaz 2009, 2012)

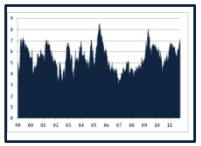
- **Total spillovers (H)**

= sum of spillovers across all asset classes in relation to the total forecast error variance.



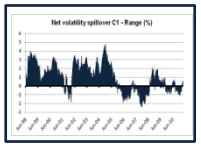
- **Directional spillovers FROM (H)**

= spillovers received by asset i from all other assets j = 1,…,N , j≠i in relation to the total forecast error variance.



- **Directional spillovers TO (H)**

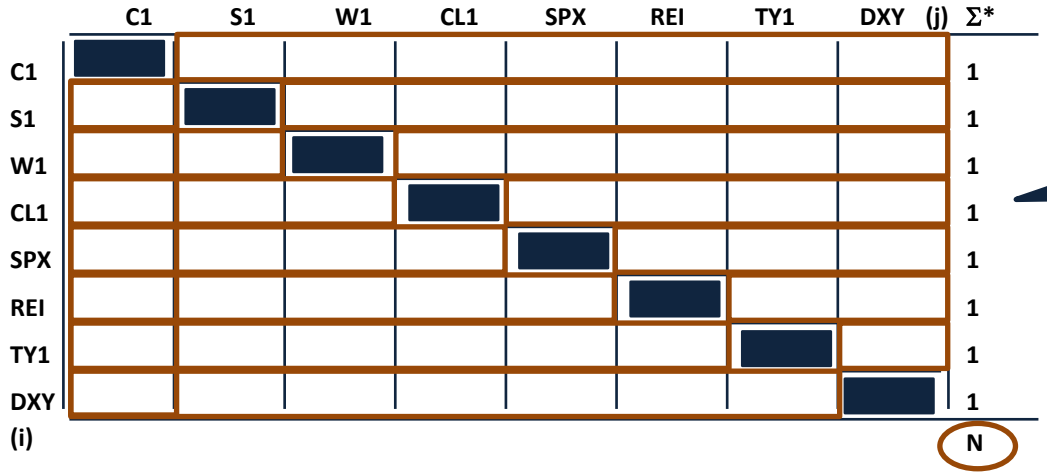
= spillovers transmitted by asset i to all other assets j = 1,…,N , j≠i in relation to the total forecast error variance.



- **Net (pair wise) spillovers (H)**

= spillovers transmitted by asset i to all other assets j = 1,…,N , j≠i (one asset j) – spillovers received by asset i from all other assets j = 1,…,N , j≠i (one asset j) in relation to the total forecast error variance.

IV Index calculations based on FEVDs



Own variance share

Cross variance shares (spillovers)

Matrix with FEVDs for a given forecast horizon H

* Entries have been normalized with row sum

A **Total spillover index =**
Sum of cross-variance shares rows 1:N / Sum of all variance shares rows 1:N (=N) * 100

B **Spillover index FROM all j to i =**
Sum of cross variance shares in row (i)/ sum of all variance shares in rows 1:N (= N) *100

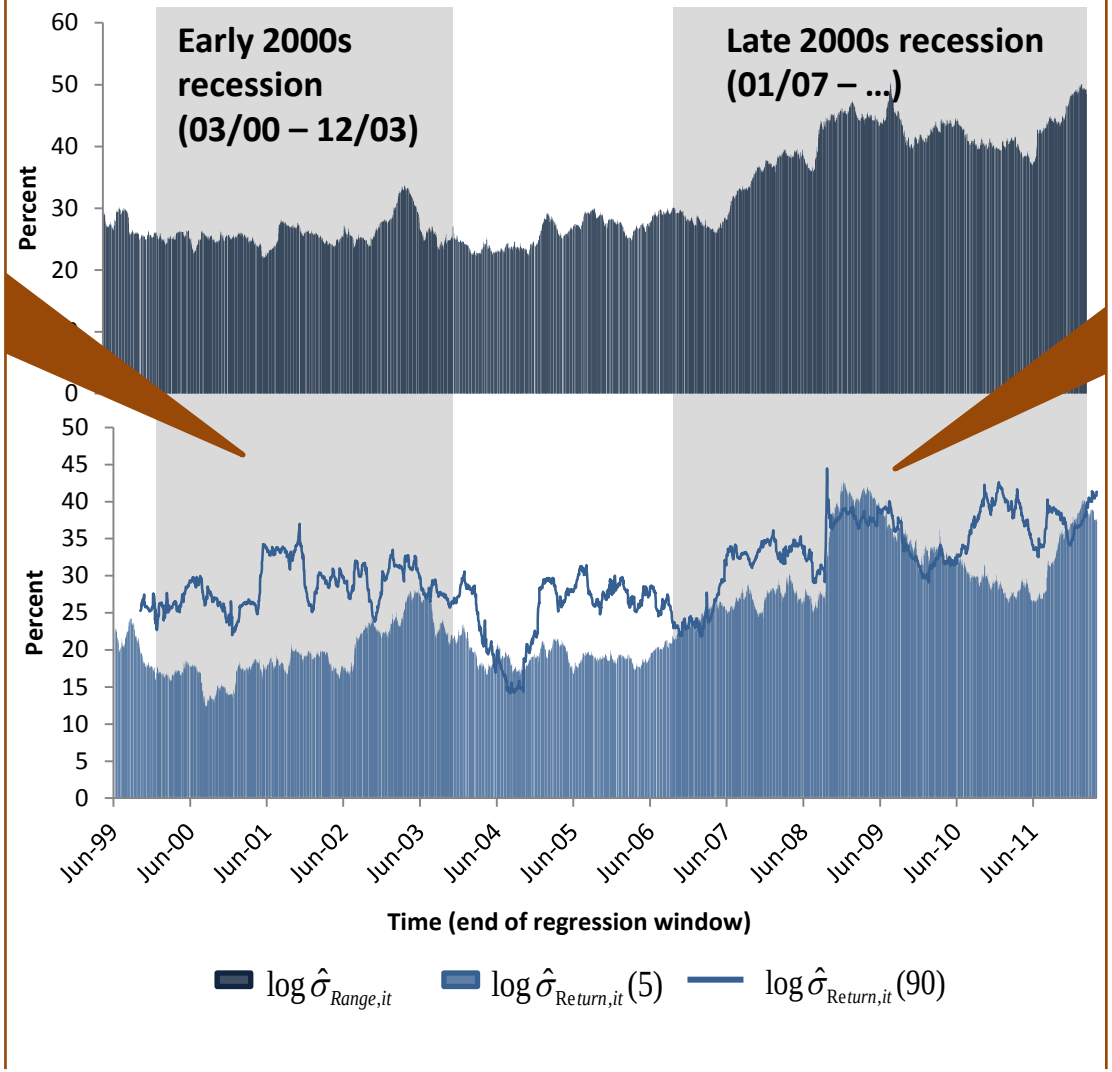
C **Spillover index from i TO all j =**
Sum of cross variance shares in column (i)/ sum of all variance shares in columns 1:N (= N) * 100

D **Net (pairwise) spillover index i=**
Spillover index from i TO all j (one j) – spillover index FROM all j (one j) to i

Source: Diebold and Yilmaz (2012, 2009)

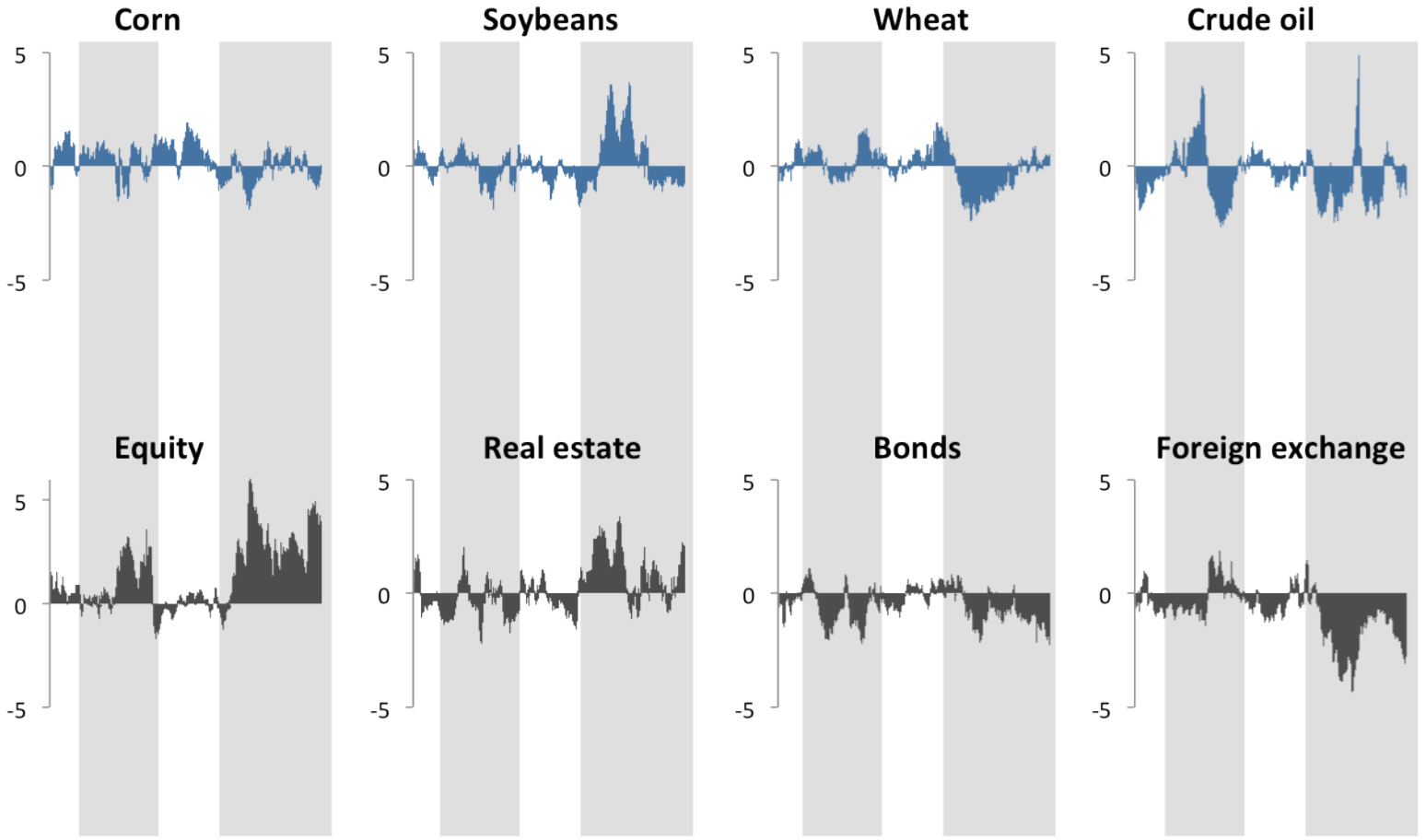
IV Results – Total volatility spillover index, H = 10

- Nasdaq crash, end of dot.com bubble (03/03)
- Stock market downturn of 2002
- Low real GDP growth in EU 27 and US
- September 11
- Beginning of war in Afghanistan, Invasion in Iraq
- Continued reduction of EU buffer stocks
- Growth in imports from China (soybeans) and India



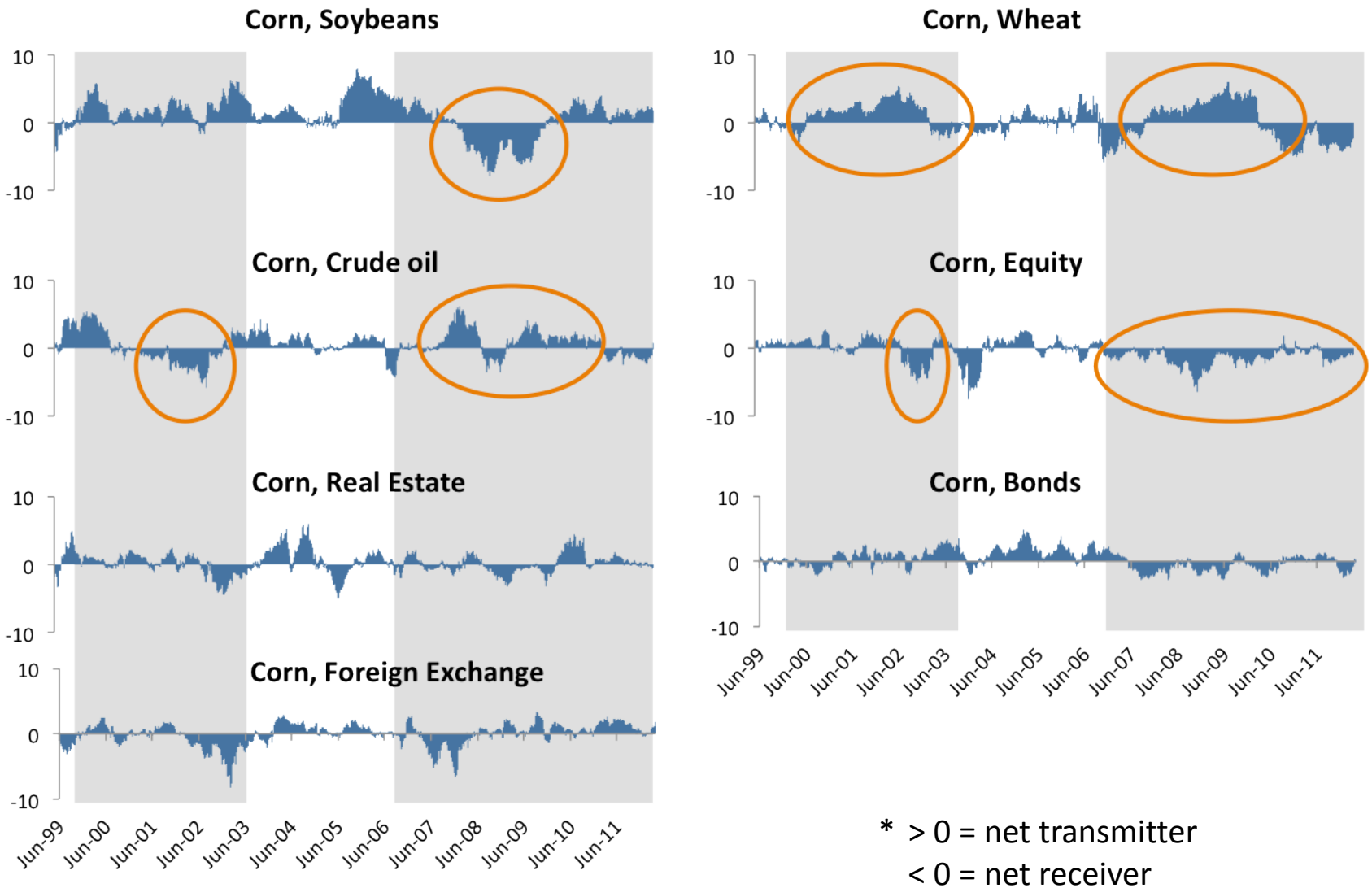
- Subprime crisis/ Sovereign Bond Crisis
- Low /negative real GDP growth in in EU27 and US
- Aftermath of Afghanistan/ Iraq wars
- 12 successive decreases of interest rates by Fed b/w Aug 07 and Dec 08
- Biofuel mandates in EU and US
- Further growth in imports from China and India
- Low stock levels
- Commodity index fund trading volume growth

IV Net directional spillovers* (Range-based)



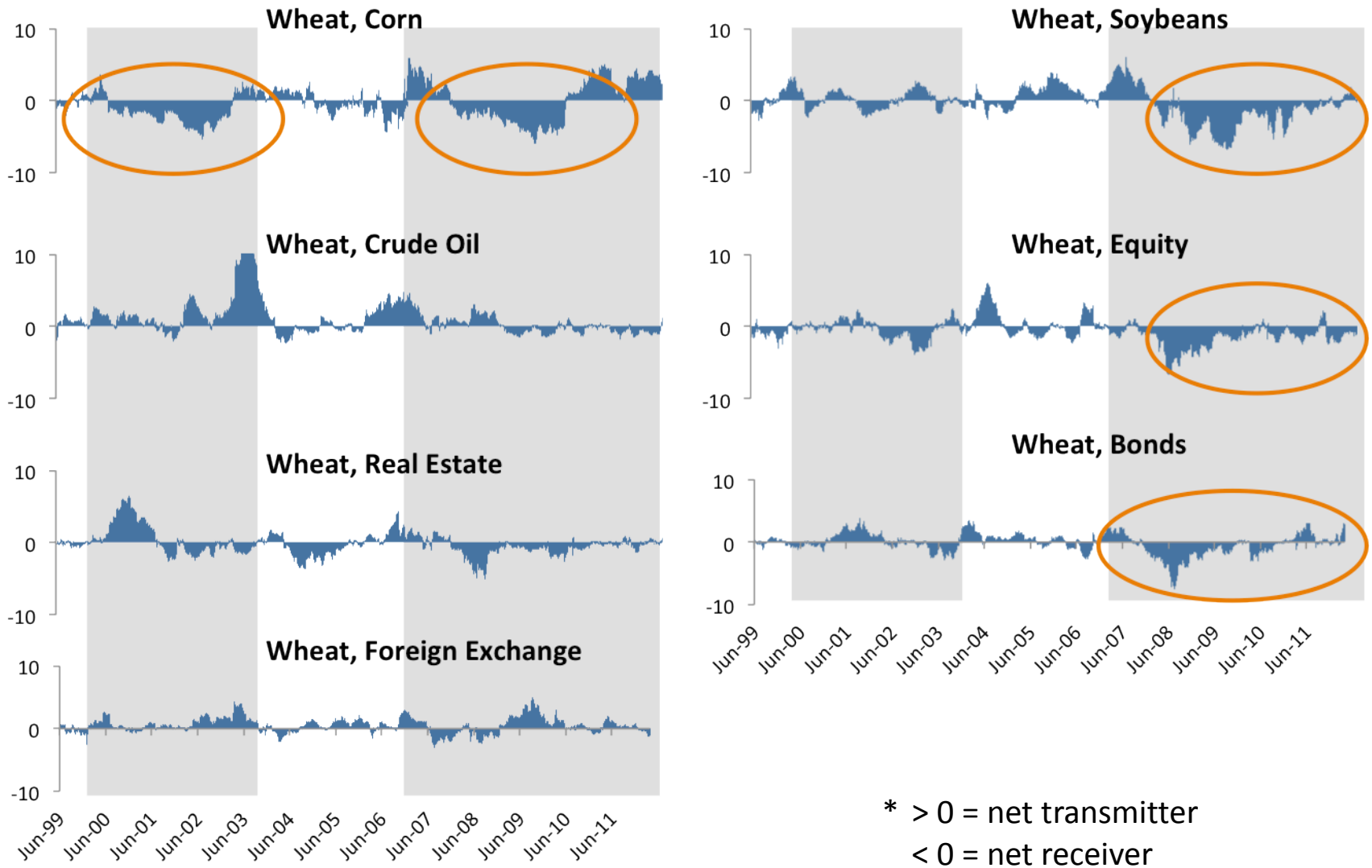
* > 0 = net transmitter
< 0 = net receiver

IV Pairwise analysis* (Range-based): Corn



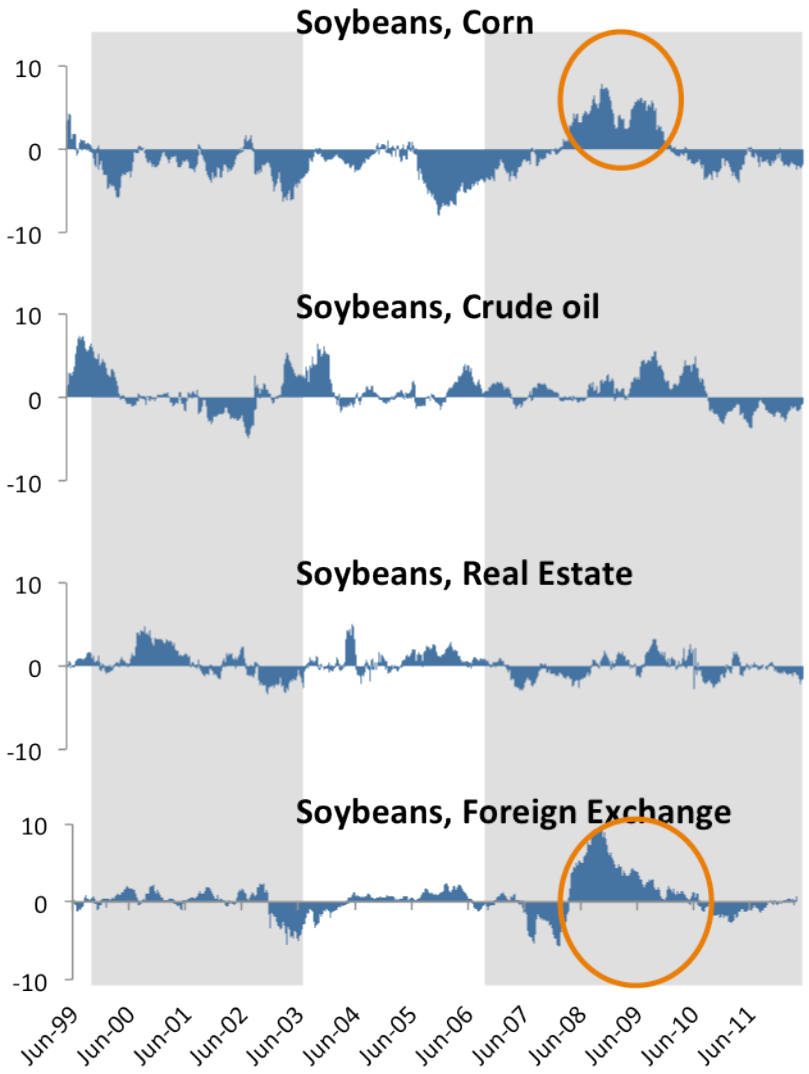
* > 0 = net transmitter
< 0 = net receiver

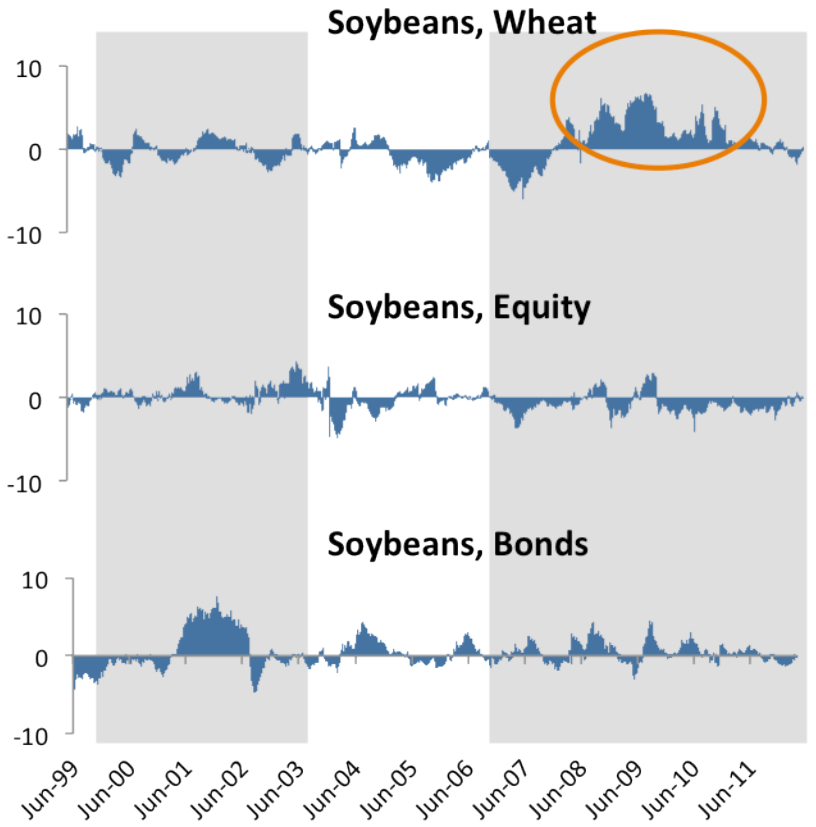
IV Pairwise analysis* (Range-based): Wheat



* > 0 = net transmitter
< 0 = net receiver

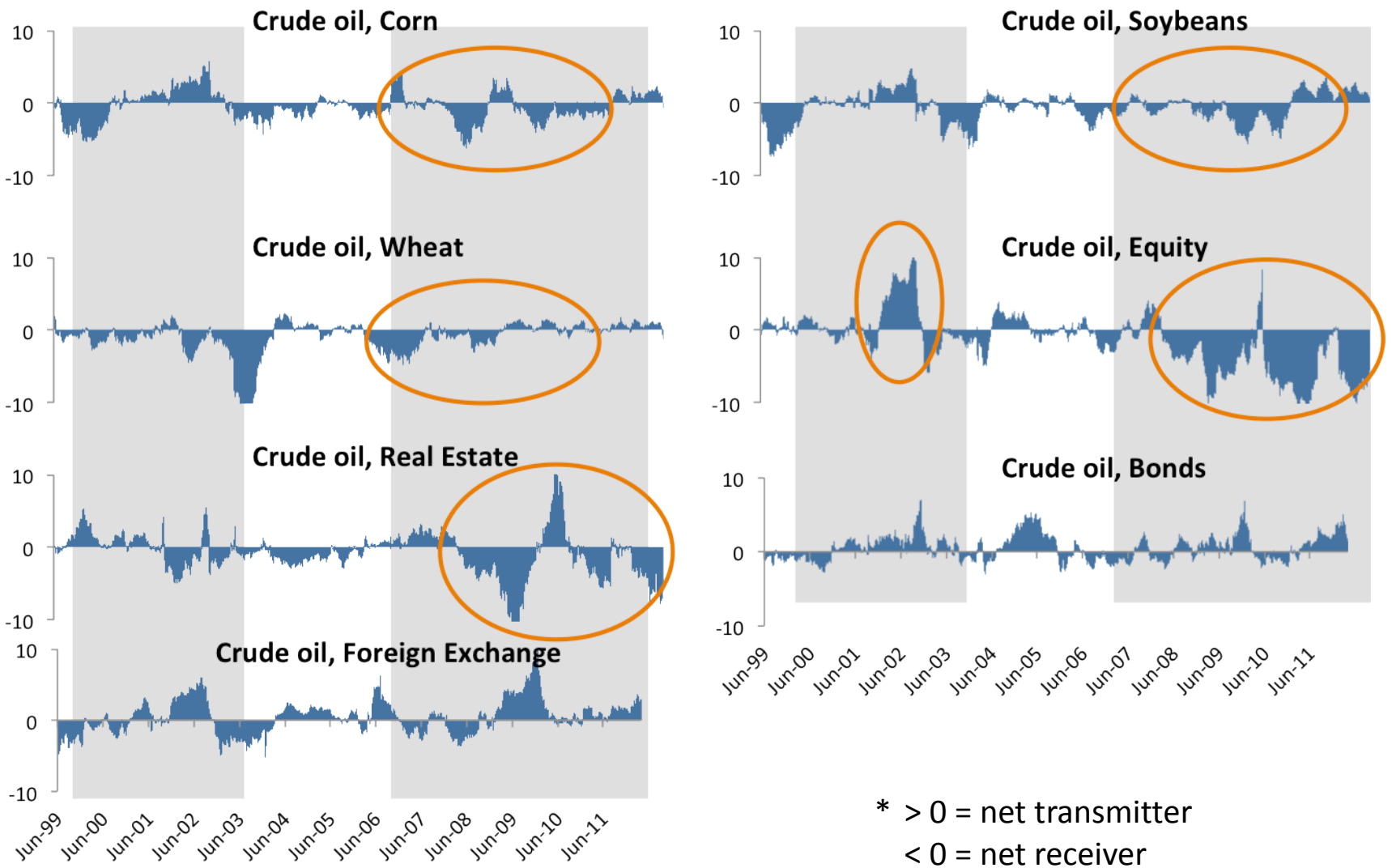
IV Pairwise analysis* (Range-based): Soybeans





* > 0 = net transmitter
< 0 = net receiver

IV Pairwise analysis* (Range-based): Crude oil



* > 0 = net transmitter
< 0 = net receiver

First insights and preliminary conclusions

- Total volatility spillovers generally increase during times of financial crises
- Net volatility spillovers from equity and real estate markets reached high levels during and after subprime crisis
- Commodities (except soybeans) mostly net receivers of volatility spillovers during and after subprime crisis ⇔ crude oil net transmitter of volatility during early 2000 crisis
- Most effects more pronounced in the short-term (range-based / 5D return-based)
- No general evidence on effects of financial crises on *intra-commodity* market spillovers

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- Some evidence for closer integration of commodity and financial asset markets during times of crises
- Some evidence for a structural change in volatility spillovers in *soybean-corn* and *soybean-wheat* market pairs, soybean market net volatility transmitter

Robustness checks and possible extensions

Robustness checks

- Sensitivity analysis (e.g. different lag lengths (HQ, AIC criteria), different forecast horizons, different window size)
- Check for whiteness of residuals for each window (Ljung Box Test, Breusch-Godfrey LM Test)
- Check for structural breaks within the *windows*

Planned extensions

- Use of index composed of wheat, corn, soybeans (weight e.g. trading volume?)
- Check for structural breaks within *volatility spillover indices*
- Complementary structural analysis (e.g. Impulse responses, Granger Causality Analysis)
- Inclusion of metal markets
- Introduction of seasonality (e.g. harvest dummies)

- Comparison with conditional volatility model (M-GARCH)
- Use of implied volatility

BACKUP

IV Generalized vs. Orthogonalized FEVDs

Orthogonalized

$$\theta_{ij}^{o}(h) = \frac{\sum_{l=0}^{h-1} (e_i' \Phi_l P e_j)^2}{\sum_{l=0}^{h-1} (e_i' \Phi_l \sum \Phi_l' e_i)}, \quad i, j = 1, 2, \ldots, N$$

Generalized

$$\theta_{ij}^{g}(h) = \frac{\sigma_{jj}^{-1} \sum_{l=0}^{h-1} (e_i' \Phi_l \sum e_j)^2}{\sum_{l=0}^{h-1} (e_i' \Phi_l \sum \Phi_l' e_i)}, \quad i, j = 1, 2, \ldots, N$$

Selection of econometric model

Candidate models	Selection criteria: Multivariate (~ 8 variables)	Theory link	Regime switches	…
Granger causality in variance - Two stage S-test, Cheung & Ng (1996) - Two stage Q-test, Hong (2001)	~	✓	✗	
Multivariate GARCH **a) w/o regime-switching** -DCC , BEKK	✗	✓	✗	
b) with regime-switching, e.g. -SWARCH model, Edwards and Susmel (2001) -Markov-switching, Chan et al. (2011)	~	✓	✓	(limited no. of regimes)
Structural VAR, variance decompositions - Diebold and Yilmaz (2009, 2012) - Dimpfl and Jung (2012)	~	✓	✓	(but may have to be complemented with break tests)
Multiplicative Error Model (MEM) - Engle et al. (2012)	~	✓	~	
Copula approaches -Rodriguez (2007) -TVLCARR(X) model, Chiang and Wang (2011)	✗	~	✓	
Stochastic volatility models - with Merton Jump, Du et al. (2011)	✗	✓	~	

Focus

5 Results from previous studies

Diebold and Yilmaz (2012)	▪ Overall increase of volatility spillovers to the commodity market (DJ UBS Index) after the year 2006 (break in 2007)
Du et al. (2011)	▪ Volatility spillovers between crude oil and agricultural commodities increased after 2006 ▪ Volatility in the wheat market significantly affects volatility in the corn market before 2006 and vice versa after 2006
Trujillo-Barrera et al. (2011)	▪ Strong volatility spillovers from U.S. crude oil to corn markets
Chan et al. (2011)	▪ Flight from quality during „tranquil“ market regimes ▪ Evidence of contagion between stocks, bonds and real estate during „crisis“ market regime

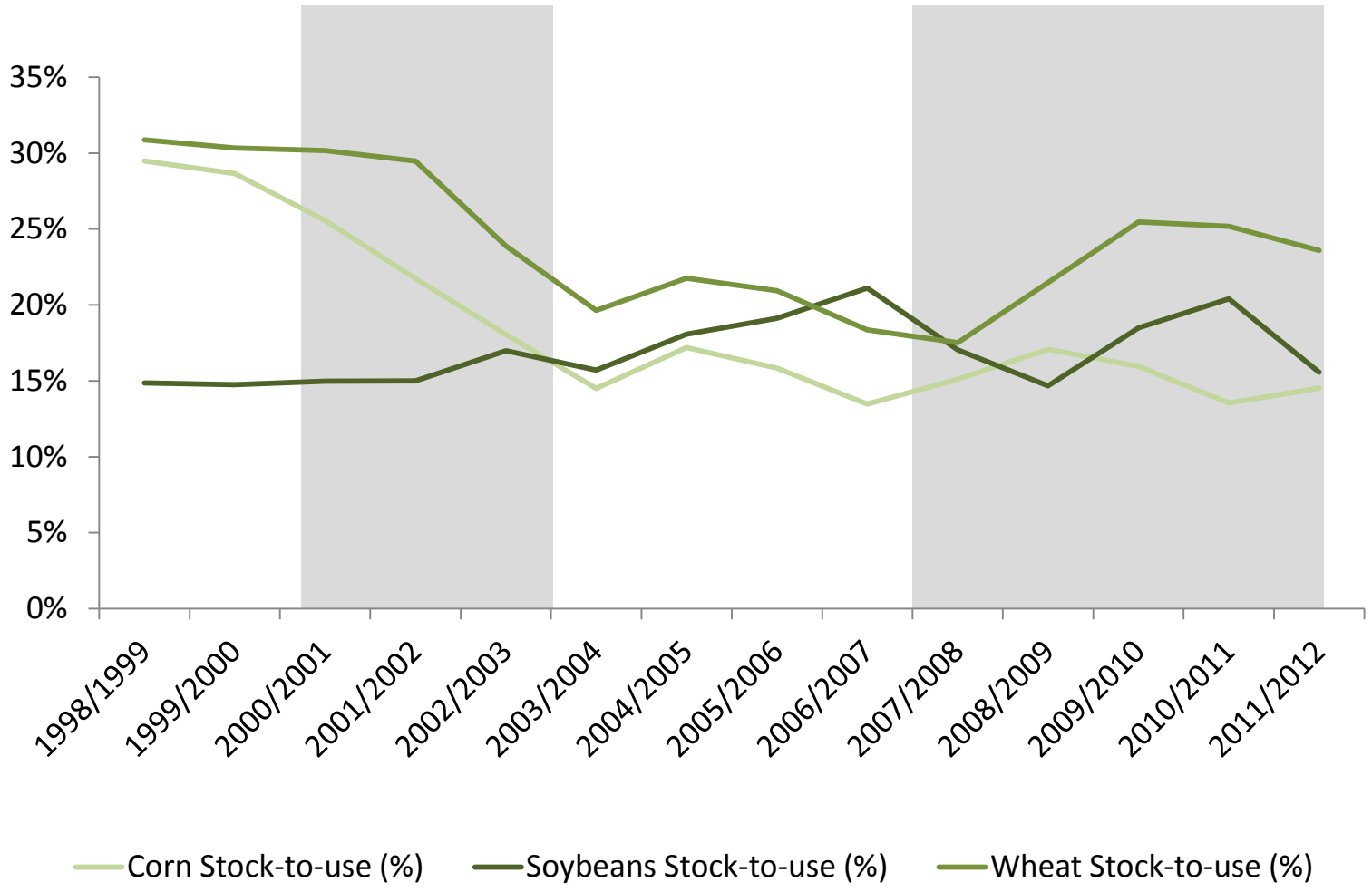
Idea for paper

a) Real option strategy as a way to simulate trading behavior of producers and processors and other traditional market participants who hold inventory

a) For second paper: The price for a commodity and its volatility are positively correlated, both are dependent on global stock levels. If stocks are low, volatility is high and prices will be high (Geman 2005, p 28). This is in difference to stock markets where volatility is high if prices are low (inverse relation). For the volatility spillover indices that means that the Forecast Errors for Stock markets are high in low market price environments and for Commodities high in high price market environments. This could have an impact on the calculated volatility spillover indices as the proportions of Forecast error Variances attributed to e.g. the equity market may be different depending on whether there is a high or low price market environment

b) -→ compare with following slide (that doesn't really fit)

5 Stock-to-use ratios



Source: USDA

To do

a) Return-based vola caluclation based on squared returns

→ recalculation of index

a) Whiteness of residuals

4 Two periods of volatility spillover peaks

New design

	Early 2000 (Mar 2000 – Dec 2003)	Late 2000 (from Jan 2007)
One-off events		
Financial economy	▪ Nasdaq crash, end of dot.com bubble (March 2003) ▪ Stock market downturn of 2002	▪ Subprime crisis (2007/08) ▪ Sovereign bond crisis (from 2009)
Real economy	▪ Relatively low real GDP growth in EU 27 in 2002/2003 and in US in 2001/2002	▪ Low /negative real GDP growth in 2008/2009 in EU27 and US
War/ conflict	▪ September 11 ▪ Beginning of war in Afghanistan, Invasion in Iraq	▪ Aftermath of Afghanistan/ Iraq wars
Policy environment	▪ Fed decreases interest rate 15 times b/w Jan 01 and Jun 03	▪ Fed decreases interest rate 12 times b/w Aug 07 and Dec 08
Structural changes to commodity markets		
Policy	▪ Continued reduction of EU buffer stocks	▪ Biofuel mandates in EU and US
Fundamental environment	▪ Growth in imports from China (esp. Soybeans) and India	▪ Further growth in imports from China and India ▪ Low stock levels (see backup)
Financial environment		▪ Commodity ETP, Trading volume growth

Source: Fed; EuroStat ; Piesse and Thirtle (2009)