Volatility spillovers between agricultural commodity and financial asset markets

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Structure

- Background and research objective
- Methodology
- Results and conclusions
Growing importance of commodities as portfolio assets

More investment vehicles available

Growth in Commodity ETF assets
2002-11, bn USD


Global financial crisis

- 2007-2012 global financial crisis
  - Sovereign debt crisis (from ~2010)

Use of agricultural commodities as portfolio diversifiers facilitated

Higher importance of agricultural commodities as refuge assets or real asset substitutes

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

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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

1. Selection of included financial and commodity assets
   - Data gathering

2. Computation of volatility proxies

3. Estimation of rolling VAR models
   - Generalized variance decompositions

4. Calculation of volatility spillover indices
# Assets included in the analysis

<table>
<thead>
<tr>
<th>Assets</th>
<th>Commodity</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural commodities</td>
<td>- Corn, CBOT* (C1)</td>
<td>- Crude Oil, NYMEX* (CL1)</td>
</tr>
<tr>
<td></td>
<td>- Soybeans, CBOT* (S1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Wheat, CBOT* (W1)</td>
<td></td>
</tr>
<tr>
<td>Equity</td>
<td>- S&amp;P 500 Index (SPX)</td>
<td>- DJ Equity All REIT Index (REI)</td>
</tr>
<tr>
<td>Fixed income</td>
<td>- 10-y U.S. Treasury* (TY1)</td>
<td>- ICE Futures US Dollar Index (DXY)</td>
</tr>
<tr>
<td>Foreign exchange</td>
<td></td>
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</tr>
</tbody>
</table>

* Future contracts, 1st generic (Bloomberg), rolling “relative to expiration”, contracts rolled after last trading day of front month
2 Volatility proxies

Range-based volatility*

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

Return-based volatility

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

with \[ R_{it} = \ln \left( \frac{P_{it}^{\text{Close}}}{P_{it-1}^{\text{Close}}} \right) \]

and \[ m = 5, 30, 90, 180 \]

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

* based on Parkinson (1980)
2 Asset volatility profiles: Grains and oilseeds (Annualized*)

* Multiplied by \(252^{0.5}\)

Source: Own calculations
2 Asset volatility profiles: Other assets (1/2) (Annualized*)

* Multiplied by $252^{0.5}$

Source: Own calculations

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2 Asset volatility profiles: Other assets (2/2) (Annualized*)

* Multiplied by 252^{0.5}

Source: Own calculations
### Estimation of VARs – Rolling regression

<table>
<thead>
<tr>
<th>Model</th>
<th>Specification*</th>
<th>Included observations (No. per variable = T)</th>
<th>No. of windows</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \log \hat{\sigma}_{\text{Range}} )</td>
<td>VAR(4)</td>
<td>06/03/98 … 03/30/12 (3,488) 3,237</td>
<td></td>
</tr>
<tr>
<td>( \log \hat{\sigma}_{\text{Return (5)}} )</td>
<td>VAR(1)</td>
<td>06/10/98 … 03/30/12 (3,483) 3,232</td>
<td></td>
</tr>
<tr>
<td>( \log \hat{\sigma}_{\text{Return (90)}} )</td>
<td>VAR(1)</td>
<td>10/09/98 … 03/30/12 (3,398) 3,147</td>
<td></td>
</tr>
</tbody>
</table>

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

**Background**

Forecast error variance (FEV) decomposition:

- **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).

**Indices**

- **Total spillovers (H)**
  
  \[ \text{Total spillovers (H)} = \text{sum of spillovers across all asset classes in relation to the total forecast error variance.} \]

- **Directional spillovers FROM (H)**
  
  \[ \text{Directional spillovers FROM (H)} = \text{spillovers received by asset i from all other assets } j = 1, \ldots, N , j \neq i \text{ in relation to the total forecast error variance.} \]

- **Directional spillovers TO (H)**
  
  \[ \text{Directional spillovers TO (H)} = \text{spillovers transmitted by asset i to all other assets } j = 1, \ldots, N , j \neq i \text{ in relation to the total forecast error variance.} \]

- **Net (pair wise) spillovers (H)**
  
  \[ \text{Net (pair wise) spillovers (H)} = \text{spillovers transmitted by asset i to all other assets } j = 1, \ldots, N , j \neq i \text{ (one asset j)} - \text{spillovers received by asset i from all other assets } j = 1, \ldots, N , j \neq i \text{ (one asset j) in relation to the total forecast error variance.} \]

Source: Diebold and Yilmaz (2012, 2009)
### Index calculations based on FEVDs

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

**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

**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

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

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**Matrix with FEVDs for a given forecast horizon H**

Entries have been normalized with row sum

Source: Diebold and Yilmaz (2012, 2009)
Results – Total volatility spillover index, $H = 10$

Early 2000s recession

Late 2000s recession

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# Two periods of volatility spillover peaks

<table>
<thead>
<tr>
<th><strong>One-off events</strong></th>
<th><strong>Financial economy</strong></th>
<th><strong>Real economy</strong></th>
<th><strong>War/ conflict</strong></th>
<th><strong>Policy environment</strong></th>
<th><strong>Structural changes to commodity markets</strong></th>
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<tbody>
<tr>
<td>Late 2000 (from Jan 2007)</td>
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<td>Fed decreases interest rate 12 times b/w Aug 07 and Dec 08</td>
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<td>Stock market downturn of 2002</td>
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<td>Beginning of war in Afghanistan, Invasion in Iraq</td>
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- **One-off events**
  - Nasdaq crash, end of dot.com bubble (March 2003)
  - Stock market downturn of 2002

- **Financial economy**
  - Nasdaq crash, end of dot.com bubble (March 2003)
  - Stock market downturn of 2002

- **Real economy**

- **War/ conflict**
  - September 11
  - Beginning of war in Afghanistan, Invasion in Iraq

- **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**
  - Continued reduction of EU buffer stocks
  - Biofuel mandates in EU and US
  - Growth in imports from China (esp. Soybeans) and India
  - Further growth in imports from China and India
  - Low stock levels (see backup)
  - Commodity ETP, Trading volume growth

Source: Fed; EuroStat; Piesse and Thirtle (2009)
4 Net directional spillover indices: Commodities

\[
\log \hat{\sigma}_{\text{Range},it} \\
\log \hat{\sigma}_{\text{Return},it} (5) \\
\log \hat{\sigma}_{\text{Return},it} (90)
\]

Corn
Soybeans
Wheat
Crude oil

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Net directional spillover indices: Financial assets

\[ \log \hat{\sigma}_{\text{Range}, it} \]

\[ \log \hat{\sigma}_{\text{Return}, it} (5) \]

\[ \log \hat{\sigma}_{\text{Return}, it} (90) \]
Pairwise analysis (Range-based): Corn

- Corn, Soybeans
- Corn, Crude oil
- Corn, Real Estate
- Corn, Foreign Exchange
- Corn, Wheat
- Corn, Equity
- Corn, Bonds
- Corn, Foreign Exchange
4 Pairwise analysis (Range-based): Wheat

- Wheat, Corn
- Wheat, Crude Oil
- Wheat, Real Estate
- Wheat, Foreign Exchange
- Wheat, Soybeans
- Wheat, Equity
- Wheat, Bonds

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Pairwise analysis (Range-based): Soybeans

**Soybeans, Corn**

**Soybeans, Crude oil**

**Soybeans, Real Estate**

**Soybeans, Foreign Exchange**

**Soybeans, Wheat**

**Soybeans, Equity**

**Soybeans, Bonds**

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4 Pairwise analysis (Range-based): Crude oil

Crude oil, Corn

Crude oil, Wheat

Crude oil, Real Estate

Crude oil, Foreign Exchange

Crude oil, Soybeans

Crude oil, Equity

Crude oil, Bonds

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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 unprecedented levels during and after the subprime crisis
- Commodities (except soybeans) were mostly net receivers of volatility spillovers (from equity, real estate and bonds) 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

- Some evidence for closer integration of commodity and financial asset markets during times of crises (especially crude oil market as net volatility receiver)
- 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, different variable measurements (where possible))
- Check for whiteness of residuals for each window (Ljung Box Test, Breusch-Godfrey LM Test)
- Check for structural breaks within the windows

Possible extensions
- Check for structural breaks within volatility spillover indices
- Orthogonalized variance decompositions
- Complementary structural analysis (e.g. Impulse responses, Granger Causality Analysis)
- Inclusion of more details on “fundamental events” in the specific commodity markets
- Inclusion of more variables (e.g. Harvest dummies for C1, S1, W1; Metal markets)
- Linkage to IFPRI food price volatility early warning system: periods of excessive volatilities?
BACKUP
### Selection of econometric model

#### Candidate models

<table>
<thead>
<tr>
<th></th>
<th>Selection criteria</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Multivariate (~ 8 variables)</td>
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</tbody>
</table>

#### Granger causality in variance

- Two stage S-test, Cheung & Ng (1996)
- Two stage Q-test, Hong (2001)

- Theory link: ~
- Regime switches: ×

#### Multivariate GARCH

- a) without regime-switching
  - DCC, BEKK

- b) with regime-switching, e.g.
  - SWARCH model, Edwards and Susmel (2001)
  - Markov-switching, Chan et al. (2011)

- Theory link: ~
- Regime switches: ✓ (limited no. of regimes)

#### Structural VAR, variance decompositions

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

- Theory link: ~
- Regime switches: ✓ (but may have to be complemented with break tests)

#### Multiplicative Error Model (MEM)

- Engle et al. (2012)

- Theory link: ~
- Regime switches: ~

#### Copula approaches

- Rodriguez (2007)
- TVLCARR(X) model, Chiang and Wang (2011)

- Theory link: ×
- Regime switches: ✓

#### Stochastic volatility models

- with Merton Jump, Du et al. (2011)

- Theory link: ✓
- Regime switches: ~

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**Theory link**

**Regime switches**

**Focus**
5 Stock-to-use ratios

Source: USDA

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## Results from previous studies

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diebold and Yilmaz (2012)</td>
<td>Overall increase of volatility spillovers to the commodity market (DJ UBS Index) after the year 2006 (break in 2007)</td>
</tr>
</tbody>
</table>
| 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 |