Common Factors in Commodity Futures Curves

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Main research question

Are there common factors in commodity futures curves?

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Main research question: Are there common factors in commodity futures curves?

Challenge: Large, highly unbalanced panel data set

Solution: Use Nelson-Siegel type model to specify futures curves in terms of level, slope and curvature factors, which are decomposed into market, sector, and individual components.

Finding: There is comovement in commodity futures curves’ factors:
  ▶ For level factors, more than 70% of the variation can be explained by a market-wide common component
  ▶ For slope and curvature factors, around 60% of the variation can be explained by (mostly sector) common components
Motivation

Why investigate comovement of commodity futures curves?

- Commodities are major input of industrial sector, comovement in prices affects economy as a whole
- Price comovement has effect on hedging decisions
- Comovement will affect risk management and dependencies should be accounted for
- Futures trading strategies and speculation
- Due to ‘financialization’ of commodity futures markets, prices may have become more closely linked
Contributions and Related Literature

First to include three dimensions: time series, cross-sectional, and term-structure.

- Model futures curve of single, individual commodity (time-series and term-structure)
  Gibson and Schwartz (1990); Schwartz (1997)

- Investigate differences and similarities across commodities (time-series and cross-section)
  Excess comovement hypothesis: Pindyck and Rotemberg (1990); Deb, Trivedi, and Varangis (1996)
  Common unobserved factors: Vansteenkiste (2009); Byrne, Fazio, and Fiess (2012)
Contributions and Related Literature

Methodological improvements to account for commodity specific features

- **Seasonality**
  Milonas (1991); Sorensen (2002); West (2012)

- **Global yield and business cycle models**
  Government bonds: Diebold, Li, and Yue (2008)
Our Approach

Nelson-Siegel type model for log futures price of commodity \( i \) with maturity \( \tau \) at time \( t \):

\[
f_{i,t}(\tau) = l_{i,t} + s_{i,t} \left( \frac{1 - \exp^{-\lambda_i \tau}}{\lambda_i \tau} \right) \\
+ c_{i,t} \left( \frac{1 - \exp^{-\lambda_i \tau}}{\lambda_i \tau} - \exp^{-\lambda_i \tau} \right) \\
+ \kappa_i \cos(\omega g_i(t, \tau) - \omega \theta_i) \\
+ \nu_{i,t}(\tau),
\]

typically combined with a VAR(1) for the level, slope and curvature factors \( l_{i,t}, s_{i,t}, \) and \( c_{i,t} \) (Nelson and Siegel (1987); Diebold and Li (2006))
Our Approach

We want to examine the comovement in $l_{i,t}$, $s_{i,t}$, and $c_{i,t}$ across commodities

$\Rightarrow$ Split each factor into market, sector, and idiosyncratic components:

$$l_{i,t} = \alpha^L_i + \beta^L_i L_{\text{market},t} + \gamma^L_i L_{\text{sector},t} + L_{\text{idio},t},$$

$$s_{i,t} = \alpha^S_i + \beta^S_i S_{\text{market},t} + \gamma^S_i S_{\text{sector},t} + S_{\text{idio},t},$$

$$c_{i,t} = \alpha^C_i + \beta^C_i C_{\text{market},t} + \gamma^C_i C_{\text{sector},t} + C_{\text{idio},t},$$

where these components are modeled by three separate VARs:

$$
\begin{pmatrix}
L_{x,t} \\
S_{x,t} \\
C_{x,t}
\end{pmatrix} =
\begin{pmatrix}
\phi^{x}_{11} & \phi^{x}_{12} & \phi^{x}_{13} \\
\phi^{x}_{21} & \phi^{x}_{22} & \phi^{x}_{23} \\
\phi^{x}_{31} & \phi^{x}_{32} & \phi^{x}_{33}
\end{pmatrix}
\begin{pmatrix}
L_{x,t-1} \\
S_{x,t-1} \\
C_{x,t-1}
\end{pmatrix} +
\begin{pmatrix}
\eta^L_{x,t} \\
\eta^S_{x,t} \\
\eta^C_{x,t}
\end{pmatrix}.
$$
Estimation

- **Two-step approach**
  1. Extract unobserved factors from all curves
  2. Investigate comovement in these factors
     - Estimation is easier since it is done in parts
     - Estimation error first step is not taken into account in second step

- **One-step approach**
  Alternatively, we could cast the model in state space form and estimate everything at once
  - Can use both time series and term-structure info to estimate parameters
  - The model contains a large number of parameters

Highly nonbalanced panel dataset > multivariate to univariate approach

LISA server of SURFsara
State Space Representation - Measurement Eq.

\[
\begin{pmatrix}
  f_1, t(\tau_1) \\
  f_1, t(\tau_2) \\
  \vdots \\
  f_1, t(\tau_{J_1}) \\
  \vdots \\
  f_N, t(\tau_{J_N})
\end{pmatrix}
= \begin{pmatrix}
  \alpha_1^L \\
  \alpha_1^S \\
  \alpha_1^C \\
  \vdots \\
  \alpha_N^C
\end{pmatrix}
+ \begin{pmatrix}
  L_{\text{market}, t} \\
  S_{\text{market}, t} \\
  C_{\text{market}, t}
\end{pmatrix}
+ \begin{pmatrix}
  L_{\text{Energy}, t} \\
  S_{\text{Energy}, t} \\
  C_{\text{Energy}, t} \\
  \vdots \\
  L_{\text{Meats}, t} \\
  S_{\text{Meats}, t} \\
  C_{\text{Meats}, t}
\end{pmatrix}
+ \begin{pmatrix}
  L_{1, t} \\
  S_{1, t} \\
  C_{1, t} \\
  \vdots \\
  C_{N, t}
\end{pmatrix}
+ \begin{pmatrix}
  \nu_1, t(\tau_1) \\
  \nu_1, t(\tau_2) \\
  \vdots \\
  \nu_1, t(\tau_{J_1}) \\
  \vdots \\
  \nu_N, t(\tau_{J_N})
\end{pmatrix}
+ \begin{pmatrix}
  \kappa_1 \\
  \kappa_2 \\
  \vdots \\
  \kappa_N
\end{pmatrix}
\]
Alternative Approaches

- Non-stationary level factors

\[ \Delta L_{x,t} = \delta \Delta L_{x,t-1} + \eta_{x,t} \]

\( x = [\text{market-wide, sector}] \)

- Adjustment of Nelson-Siegel loadings

\[ s_{i,t}^* \left[ \left( \frac{1 - \exp^{-\lambda_i \tau}}{\lambda_i \tau} \right) - \left( \frac{1 - \exp^{-\lambda_i}}{\lambda_i} \right) \right] \]

\[ c_{i,t}^* \left[ \left( \frac{1 - \exp^{-\lambda_i \tau}}{\lambda_i \tau} - \exp^{-\lambda_i \tau} \right) - \left( \frac{1 - \exp^{-\lambda_i}}{\lambda_i} - \exp^{-\lambda_i} \right) \right] \]
Alternative Approaches

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\[ c_{i,t}^* \left[ \left( \frac{1 - \exp^{-\lambda_i \tau}}{\lambda_i \tau} - \exp^{-\lambda_i \tau} \right) - \left( \frac{1 - \exp^{-\lambda_i}}{\lambda_i} - \exp^{-\lambda_i} \right) \right] \]
Data

- 24 commodities (all constituents of the S&P GSCI)
- Monthly futures prices; Jan 1995 - Sept 2012

<table>
<thead>
<tr>
<th>Energy</th>
<th>Metals</th>
<th>Softs</th>
<th>Grains</th>
<th>Meats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brent crude oil</td>
<td>Gold</td>
<td>Cocoa</td>
<td>Corn</td>
<td>Feeder cattle</td>
</tr>
<tr>
<td>WTI crude oil</td>
<td>Silver</td>
<td>Coffee</td>
<td>Soybeans</td>
<td>Lean hogs</td>
</tr>
<tr>
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<td>Aluminum</td>
<td>Cotton</td>
<td>C. wheat</td>
<td>Live cattle</td>
</tr>
<tr>
<td>Heating oil</td>
<td>Copper</td>
<td>Sugar</td>
<td>K. wheat</td>
<td></td>
</tr>
<tr>
<td>Natural gas</td>
<td>Lead</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td>Nickel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zinc</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Coffee

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Model fit

- Fitted values versus observed prices:
  - All average percentage pricing errors are below 0.25%
  - The largest percentage pricing error is less than 5%

- Unobserved factors versus Schwartz (1997) factors

- Unobserved factors versus Principal Component Analysis
Extracted level factors - Energy

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Extracted level factors - Softs

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Extracted slope factors - Energy

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## Variance decompositions

<table>
<thead>
<tr>
<th>Commodity</th>
<th>slope</th>
<th>idio</th>
<th>curvature</th>
<th>idio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>13%</td>
<td>61%</td>
<td>26%</td>
<td>25%</td>
</tr>
<tr>
<td>Brent crude oil</td>
<td>0%</td>
<td>90%</td>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>WTI crude oil</td>
<td>0%</td>
<td>90%</td>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>Gasoil</td>
<td>0%</td>
<td>88%</td>
<td>11%</td>
<td>46%</td>
</tr>
<tr>
<td>Heating oil</td>
<td>1%</td>
<td>82%</td>
<td>17%</td>
<td>81%</td>
</tr>
<tr>
<td>Natural gas</td>
<td>0%</td>
<td>30%</td>
<td>70%</td>
<td>52%</td>
</tr>
<tr>
<td>Gasoline (RBOB)</td>
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<td>79%</td>
<td>19%</td>
<td>52%</td>
</tr>
<tr>
<td>Gold</td>
<td>8%</td>
<td>67%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Silver</td>
<td>5%</td>
<td>62%</td>
<td>34%</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
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<td>92%</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>0%</td>
<td>96%</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>3%</td>
<td>83%</td>
<td>14%</td>
<td></td>
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<tr>
<td>Nickel</td>
<td>1%</td>
<td>97%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>0%</td>
<td>97%</td>
<td>3%</td>
<td></td>
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<tr>
<td>Cocoa</td>
<td>1%</td>
<td>73%</td>
<td>26%</td>
<td>4%</td>
</tr>
<tr>
<td>Coffee</td>
<td>13%</td>
<td>67%</td>
<td>20%</td>
<td>1%</td>
</tr>
<tr>
<td>Cotton</td>
<td>7%</td>
<td>20%</td>
<td>73%</td>
<td>8%</td>
</tr>
<tr>
<td>Sugar</td>
<td>11%</td>
<td>2%</td>
<td>87%</td>
<td>73%</td>
</tr>
<tr>
<td>Corn</td>
<td>67%</td>
<td>5%</td>
<td>28%</td>
<td>3%</td>
</tr>
<tr>
<td>Soybeans</td>
<td>62%</td>
<td>0%</td>
<td>38%</td>
<td>28%</td>
</tr>
<tr>
<td>Chicago wheat</td>
<td>33%</td>
<td>60%</td>
<td>7%</td>
<td>29%</td>
</tr>
<tr>
<td>Kansas wheat</td>
<td>19%</td>
<td>69%</td>
<td>12%</td>
<td>35%</td>
</tr>
<tr>
<td>Feeder cattle</td>
<td>5%</td>
<td>48%</td>
<td>47%</td>
<td>5%</td>
</tr>
<tr>
<td>Lean hogs</td>
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<td>4%</td>
<td>39%</td>
<td>1%</td>
</tr>
<tr>
<td>Live cattle</td>
<td>2%</td>
<td>68%</td>
<td>30%</td>
<td>13%</td>
</tr>
</tbody>
</table>

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One-step model - Market-wide components

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Market-wide Level and Macroeconomic Variables

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Summary

Do commodity futures curves comove?

- We add a third dimension to incorporate term-structure information.
- We reduce the dimension using an enhanced version of the Nelson-Siegel model.
- We investigate if the extracted level, slope, and curvature factors are mostly driven by market, sector specific, or idiosyncratic components.
- Our results indicate that there is comovement in common factors of commodity futures curves, mostly due to sector components.
Possible extension - Rolling PCA level