"Common Factors in Commodity Futures Curves" by Karstanje, van der Wel, and van Dijk (2015)

Molin Zhong

University of Pennsylvania

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Background

- This paper is about modeling **commodity futures curves**
- **Commodity:** A standardized good, which is traded in bulk and whose units are interchangeable
  - Natural gas, Coffee, Copper
- **Futures contract:** Commitment to a transaction on a future date at a prearranged price
  - Pay $80 for 1 barrel of oil 1 year in the future

Background: Why are commodity futures curves interesting?

- Futures important for commodities producers to hedge price risks
- Investors use commodities for diversification purposes

This paper

- Investigate **commonality** among factors driving many commodity futures curves
  - Comovement in price levels
  - Comovement in curve shapes

- **24 commodities** separated into **5 sectors**
  - Energy, Metals, Softs, Grains, and Meats

What the authors do

- **Dynamic Nelson Siegel** framework as in Diebold and Li (2006)
  - Decomposition into level, slope, curvature
- **Common (market and sector-specific) components** drive individual commodity factors as in Diebold, Li, and Yue (2008) and Kose, Otrok, and Whiteman (2003)

Preview of main results

- Important **common components** in level, slope, and curvature factors
  - On average $\approx$ **60%** of variation for level factor
  - On average $\approx$ **70%** of variation for slope and curvature factors
- Commonality mostly driven by **sector-specific components** as opposed to market components
  - On average $\approx$ **40%** of variation for level factor
  - On average $\approx$ **50%** of variation for slope and curvature factors
- Many other results that I will not go into today...
  - Economic interpretation of factors
  - Time-variation in importance of common components

Model

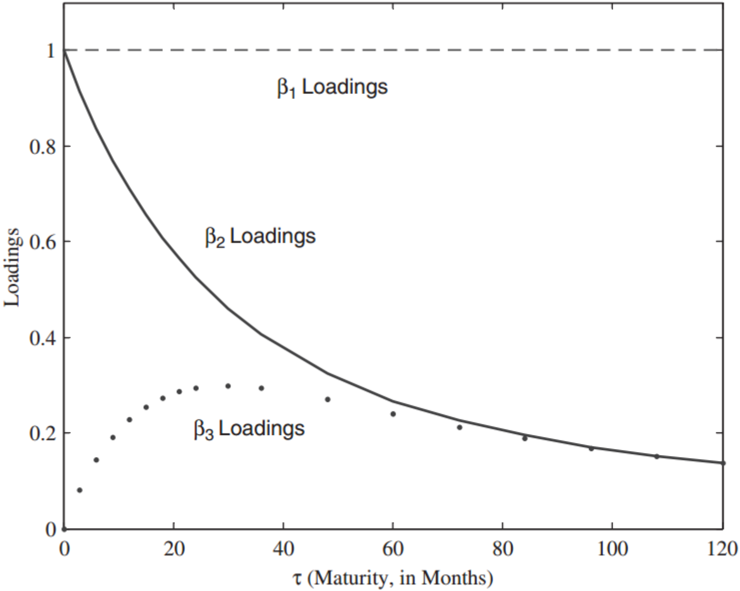
Model: Measurement equation

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

$$
\nu_{i,t}(\tau) \sim_{iid} N(0, \sigma^2_{\nu,i})
$$

- $f_{i,t}(\tau)$: Futures price for **commodity i** at **time t** with **maturity** τ
- $l_{i,t}, s_{i,t}, c_{i,t}$: level, slope, curvature
- λ_i : decay parameter
- $\kappa_i \cos\left(\omega\left(g_i(t,\tau) - \theta_i\right)\right)$: seasonal adjustment term

Factor loadings (from Diebold and Li, 2006)



Model: Common components

$$
\begin{aligned}
l_{i,t} &= \alpha_i^L + \beta_i^L L_{market,t} + \gamma_i^L L_{sector,t} + L_{i,t} \\
s_{i,t} &= \alpha_i^S + \beta_i^S S_{market,t} + \gamma_i^S S_{sector,t} + S_{i,t} \\
c_{i,t} &= \alpha_i^C + \beta_i^C C_{market,t} + \gamma_i^C S_{sector,t} + C_{i,t}
\end{aligned}
$$

- $X_{market,t}$: Market component
- $X_{sector,t}$: Sector-specific component
- $X_{i,t}$: Individual commodity component

Model: Transition equation

$$\begin{pmatrix} \Delta L_{y,t} \\ S_{y,t} \\ C_{y,t} \end{pmatrix} = \Phi \begin{pmatrix} \Delta L_{y,t-1} \\ S_{y,t-1} \\ C_{y,t-1} \end{pmatrix} + \begin{pmatrix} \eta^L_{y,t} \\ \eta^S_{y,t} \\ \eta^C_{y,t} \end{pmatrix}$$

$$\eta^X_{y,t} \sim_{iid} N(0, \sigma^2_{\eta,X,y})$$

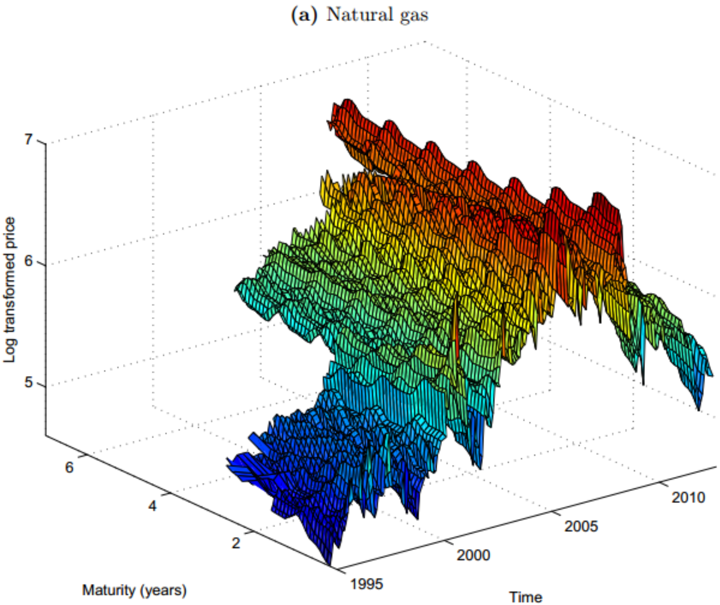
- $y = \{market, sector, idiosyncratic\}$
- Φ is diagonal
- **Note:** level factor modelled as nonstationary

Estimation

Data

- 24 commodities separated into 5 sectors: Energy, Metals, Softs, Grains, and Meats
- Choose commodities based off of inclusion in **S&P Goldman Sachs Commodity Index**
- Monthly data from **Jan 1995** to **Sept 2012**
- Heterogeneity in data availability **between commodities** and **across time**

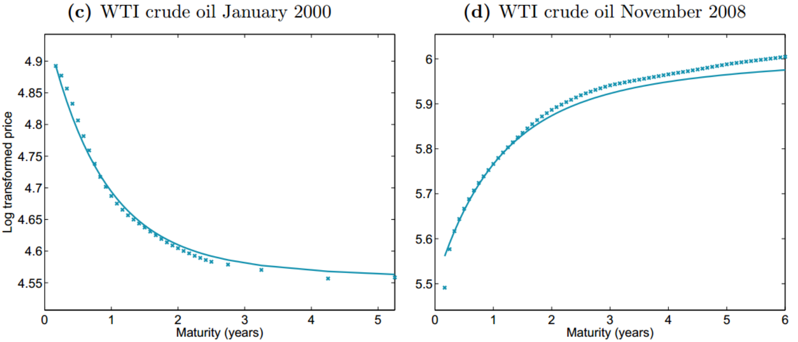
Data example: natural gas



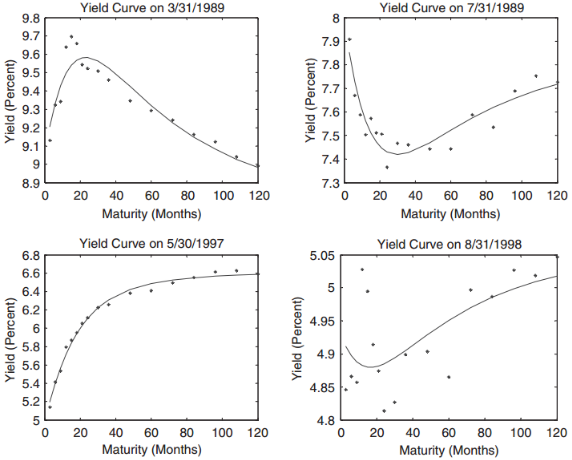
Is the Dynamic Nelson Siegel framework appropriate?

- Yield curve naturally decomposes into **level, slope, and curvature**
- Dynamic Nelson Siegel model has level, slope, and curvature factors
- **Question:** Does the same hold true for commodity futures curves?

Examples of futures price curve



Examples of yield curve (taken from Diebold and Li, 2006)



Answer: As a statistical approximation... YES!

VERY simple case (nonstochastic)

$$f_t(\tau) = s_t + (r - c)\tau$$

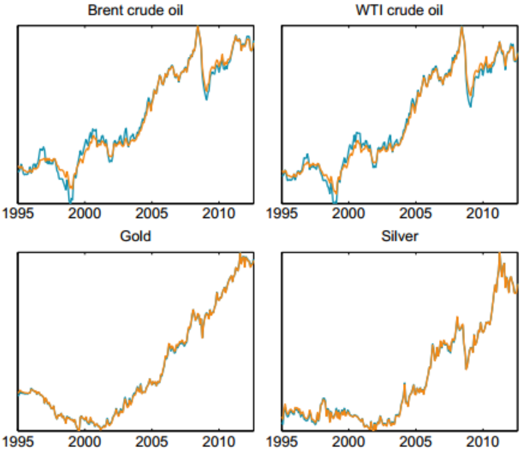
- $f_t(\tau)$: futures price with **maturity** τ
- s_t : spot price
- r : risk free rate
- c : convenience yield - the flow of services which accrues to the owner of a physical inventory but not to the owner of a contract for future delivery (Brennan, 1991)
- **Question:** Could there be a theoretical issue with DNS approximation as maturity goes to ∞?

Relationship with Schwartz (1997)

- Schwartz (1997) 3-factor model
  - **Arbitrage-free model** of commodities futures curve
  - Posits stochastic processes for **spot price, convenience yield, and risk free rate**
  - Uses no-arbitrage restrictions to compute commodities futures curve

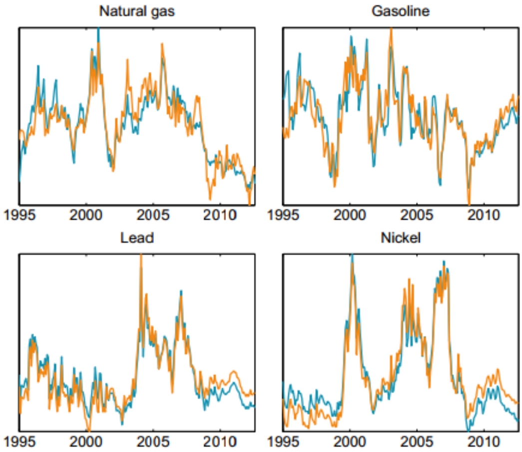
- **Commodity-by-commodity:** estimate individual factor DNS model and 3-factor arbitrage-free model

Comparison of DNS and Schwartz (1997) model estimates



- Orange: DNS level factor
- Blue: Spot price factor
- Average correlation across commodities: 0.67

Comparison of DNS and Schwartz (1997) model estimates



- Orange: DNS slope factor
- Blue: Convenience yield factor
- Average correlation across commodities: 0.76

Joint model factor estimates

Autoregressive parameters

	Δ Level	Slope	Curvature
Market	0.11	0.93	0.78
Energy	0.12	0.79	0.88
Metals	0.12	0.96	−−
Softs	0.45	0.93	0.87
Grains	−0.12	0.94	0.88
Meats	0.05	0.88	0.72

Red numbers are significant at 10% level

Factor estimates

Variance decompositions

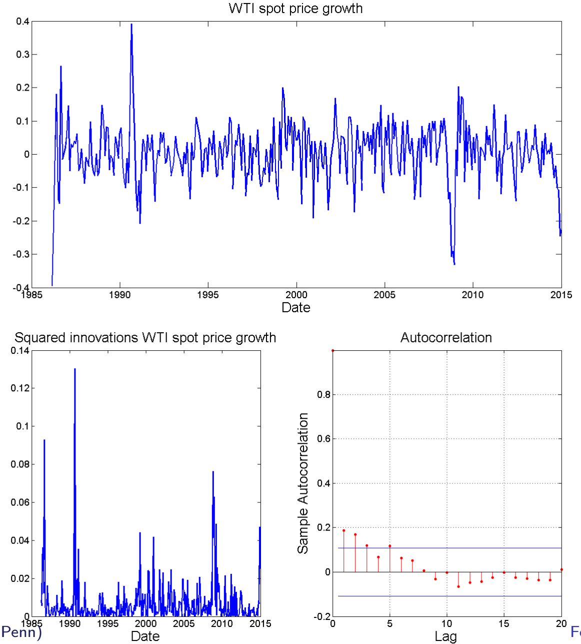
	Δ Level			Slope			Curvature		
	Market	Sector	Idio	Market	Sector	Idio	Market	Sector	Idio
Energy	12.4	61.3	26.3	74.6	12.3	13.1	28.3	44.0	27.7
Metals	16.1	49.1	34.7	17.5	75.6	6.9	——	——	——
Softs	34.1	12.8	53.2	1.7	26.6	71.7	22.7	34.0	43.3
Grains	53.5	21.6	25.0	0.1	74.1	25.9	25.4	66.8	7.9
Meats	7.3	25.2	67.4	7.2	53.3	39.5	15.4	61.8	22.7

Further comments/extensions

Extension 1: Forecasting exercise

- DNS model has been shown to forecast well (Diebold and Li, 2006), especially when compared to affine term structure models
- Forecast comparison:
  - Individual-commodity DNS model
  - Schwartz (1997) 3-factor model
  - Benchmark forecasting models (i.e. random walk)

Extension 2: Stochastic volatility



Extension 3: Going beyond the U.S. economy

- Economic interpretation of futures curves in terms of **U.S. macroeconomic variables** Economic interpretation

- What about other countries?

- Importers versus exporters of commodities (Peersman and van Robays, 2012)

Extension 4: Real effects of commodities futures curve uncertainty shocks

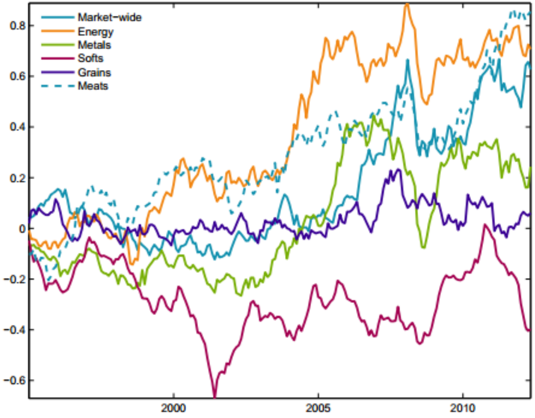
- How does uncertainty about the shape of commodity futures curves impact the real economy?
  - Overall economy versus commodity sectors
  - Commodity importers versus exporters
  - Monetary policy implications?

- Creal and Wu (2014): Effects of short and long-term interest rate uncertainty on the macroeconomy

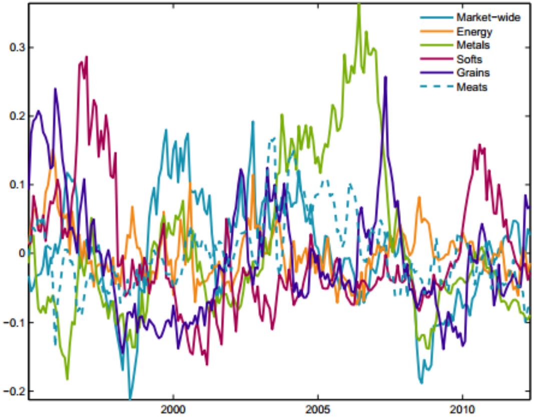
Conclusion

- I really like this paper
  - Novel application of DNS methodology
  - **Lots** of clean empirical results
- Opens up a lot of interesting empirical questions (of which I have only listed 4)

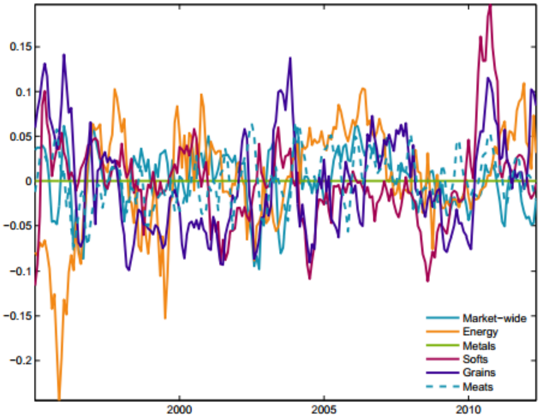
(a) Level - market-wide



(a) Slope - market-wide



(a) Curvature - market-wide



Return

Economic interpretation of factors

- Theory of normal backwardation (Keynes, 1930)
  - Commodity producers and inventory holders hedge risk by selling commodity futures
  - Requires setting futures prices at discount to encourage speculators to take opposite long position
  - **Empirical implication:** relationship between **hedging pressure** and commodity futures curve
- Theory of storage (Kaldor, 1939, Working, 1949)
  - Relationship between futures price, spot price, inventory storage benefits, and inventory storage costs
  - **Empirical implication:** relationship between **inventory levels** and commodity futures curve

Return

Economic interpretation of factors

Market-wide components:

- Δ Level
  - Hedging pressure (+), Equity returns (+), USD exchange rate returns (−)
- Slope
  - Business inventories (+), Hedging pressure (+), Leading economic indicators (+), Current economic indicators (−)
- Curvature
  - Business inventories (+), Hedging pressure (−), Interest rates (+)

Time-variation in importance of factors

Investigate time-variation in importance of common components

- Weights $\delta^{|k|}$ to each observation
- $\delta = 0.99$
- $k = ..., -2, -1, 0, 1, 2, ...$
- Centered at $\Theta = 1, 2, ..., T$

(a) ΔLevel