Section 11: Commodities

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1. Basic structure of the notes

- High-level summary of theoretical frameworks to interpret empirical facts.
- Per asset class, we will discuss:
  1. Key empirical facts in terms of prices (unconditional and conditional risk premia) and asset ownership.
  2. Interpret the facts using the theoretical frameworks.
  3. Facts and theories linking financial markets and the real economy.
  4. Active areas of research and some potentially interesting directions for future research.
- The notes cover the following asset classes:
  1. Equities (weeks 1-5).
     - Predictability and the term structure of risk (week 1)
     - The Cross-section and the Factor Zoo (week 2)
     - Intermediary-based Asset Pricing (week 3)
     - Production-based asset pricing (week 4)
     - Demand-based asset pricing (week 5)
  2. Mutual Funds and Hedge Funds
  3. Options and volatility (week 7).
  4. Government bonds (week 8).
  5. Corporate bonds (week 9).
  6. Currencies (week 10).
  7. Commodities (week 11).
  8. Real estate (week 12).

2. Commodities

2.1. Introduction

- Commodities are typically classified into three groups
  - Energy: Oil, gasoline, . . .
  - Metals (precious and industrial): Gold, copper, . . .
  - Agricultural and livestock: Corn, wheat, lean hogs, . . .
- The cross-section is fairly small, in particular when compared to equities, corporate bonds, options, . . .
- Despite the importance of understanding prices and quantities in commodity markets, the literature in finance is limited. There are few models to explain the cross-section of commodities returns.
- Commodities have become more important in recent years as an asset class, leading to the discussion on "financialization" of commodities (more on this later).
- In economics, there is a literature on specific commodities like oil (more on this later).

- Data sources:
  - Prices: Bloomberg or the Commodities Research Bureau.
  - Fundamentals (inventory, production, ...): Commodities Research Bureau or the sources in Gorton, Hayashi, and Rouwenhorst (2012).
  - Basic data on holdings: The CFTC has data on holdings by hedgers, speculators, ...
- Broad commodity index: S&P Goldman Sachs Commodity Index (GSCI).
  - There are sub-indices for energy, non-energy, industrial metals, precious metals, agriculture, livestock, agriculture & livestock.
- Similarly: Bloomberg Commodity Index (BCOM), Thomson Reuters Core Commodity Index (CRB), Deutsche Bank Liquid Commodity Index (DBLCI), UBS Bloomberg Constant Maturity Commodity Index (CMCI), Rogers International Commodity Index (RICI)

- For certain commodities, there are extremely detailed data. For instance, for agricultural commodities, there are WASDE data.

April 2018

WASDE - 576 - 19

World Wheat Supply and Use 1/ (Cont'd.)
(Million Metric Tons)

2017/18 Proj.		Beginning Stocks	Production	Imports	Domestic Feed	Domestic Total 2/	Exports	Ending Stocks
World 3/	Mar	252.60	758.79	181.75	144.57	742.50	182.03	268.89
	Apr	254.60	759.75	181.81	145.71	743.13	182.01	271.22
United States	Mar	32.13	47.37	4.22	2.72	30.40	25.17	28.15
	Apr	32.13	47.37	4.22	1.91	29.58	25.17	28.96
Total Foreign	Mar	220.47	711.42	177.53	141.85	712.10	156.86	240.74
	Apr	222.46	712.38	177.60	143.81	713.54	156.84	242.26
Major Exporters 4/	Mar	22.22	221.10	6.16	64.00	149.75	76.00	23.73
	Apr	22.22	221.10	6.16	65.50	151.60	75.30	22.58
Argentina	Mar	0.25	18.00	0.01	0.10	5.50	12.50	0.26
	Apr	0.25	18.00	0.01	0.10	5.20	12.80	0.26
Australia	Mar	4.37	21.50	0.15	3.40	6.80	16.00	3.22
	Apr	4.37	21.50	0.15	3.40	6.80	16.00	3.22
Canada	Mar	6.84	30.00	0.50	3.50	8.70	22.50	6.14
	Apr	6.84	30.00	0.50	3.50	8.70	22.50	6.14
European Union 5/	Mar	10.77	151.60	5.50	57.00	128.75	25.00	14.12
	Apr	10.77	151.60	5.50	58.50	130.90	24.00	12.97
Major Importers 6/	Mar	152.30	202.53	96.13	31.93	278.99	7.01	164.97
	Apr	154.20	203.36	95.48	32.80	279.03	6.83	167.18
Brazil	Mar	2.26	4.26	7.80	0.50	12.10	0.60	1.62
	Apr	2.26	4.26	7.30	0.50	12.00	0.30	1.52
China	Mar	111.05	129.77	4.00	13.50	117.00	1.00	126.82
	Apr	111.05	129.77	4.00	13.50	117.00	1.00	126.82
Sel. Mideast 7/	Mar	13.03	19.42	18.25	5.36	40.57	0.94	9.19
	Apr	14.93	19.33	18.20	5.36	39.67	1.01	11.78
N. Africa 8/	Mar	13.92	18.15	27.85	2.18	45.08	0.74	14.11
	Apr	13.92	18.99	27.35	2.25	45.08	0.79	14.41
Pakistan	Mar	4.35	26.50	0.03	1.00	25.00	1.20	4.68
	Apr	4.35	26.60	0.03	1.00	25.00	1.20	4.78
Southeast Asia 9/	Mar	5.61	0.00	27.20	8.39	25.14	1.07	6.60
	Apr	5.61	0.00	27.40	9.14	26.09	1.07	5.85

2.2. Market Structure

- For a useful introduction into the trading of commodities, see Pirrong (2012).

- Financial trade takes place via futures, where settlement can happen via physical delivery of the commodity. To avoid physical settlement, many traders close their original position before expiration by taking an opposite position in the futures market.

- Commodity trading firms trade the physical commodity in the spot market, but they are also active in the futures market.

- Interestingly, many commodity trading firms are large and privately owned.

- Perspective: Apple's revenue in 2017 was $263 billion. Vitol's revenue, one of the largest energy and commodities traders, in 2018, was $231 billion, not that far behind. Vitol's 2023 revenue: $400 billion.

- We know little about commodity trading firms, in part because these are private firms.

- An interesting and important research question is to understand better their role in commodities markets.

2.3. *Forward Prices and Returns*

- We often cannot trade in spot markets and the spot price is often not even observed.

  ⇒ Most of the empirical work uses futures prices.

- The basis at date t is defined as the difference between the spot price and the futures price: $S_t - F_{t,T}$

- The spot and the futures price are related by the cost of carry formula, a no-arbitrage relationship:

$$
\begin{aligned}
F_{t,1} &= S_t(1 + r_f) + w_t - c_t, \\
(1 + r_f)S_t - F_{t,1} &= c_t - w_t \equiv \delta_t S_t
\end{aligned}
$$

  where w_t is the unit storage cost, c_t is the convenience yield from an additional unit of inventory, and δ_t the (interest-adjusted) basis expressed as a percent of the spot price.

- If the futures price is higher than the spot price, the normal situation for most commodities, the basis is negative and the commodity is said to be in **contango**.
  When the basis is positive, the spot is more expensive than the futures contract, and the commodity is in **backwardation**.

- Convenience yield captures a direct benefit from owning physical inventory of the commodity (e.g., interest on gold bullion) as well as the option value due to positive probability of an inventory *stock-out*; see Routledge, Seppi, and Spatt (2000).

- Or it captures a **commodity risk premium**.

- How do we compute returns?
- If you buy a futures contract, you need to put up collateral X.
- The gross return is then given by

$$R_{t+1} = \frac{S_{t+1} - F_t + X(1 + r_f)}{X},$$

  where we assume that the collateral earns the risk-free rate.

- If the trade is fully collateralized, then $X = F_t$ and

$$R_{t+1} = \frac{S_{t+1}}{F_t} + r_f.$$

- The net excess return is

$$r^e_{t+1} = \frac{S_{t+1} - F_t}{F_t}.$$

- By changing X, we change the leverage of the position.
- The commodity risk premium is

$$E_t[r^e_{t+1}] = \frac{E_t[S_{t+1}] - F_t}{F_t}.$$

2.4. *Facts*

2.4.1. Average Return on Commodities and the Correlation with Other Asset Classes

- Erb and Harvey (2006) document several basic facts about commodities futures:

  1. The average return of the GSCI is about the same as the S&P500 and it is similarly volatile:

Table 1. Return and Risk, December 1969–May 2004

Entity	Annualized Compound Return	Annualized Standard Deviation	*t*-Statistic[a]
U.S. inflation	4.79%	1.15%	—
Three-month U.S. T-bill return	6.33	0.83	—
Intermediate-term government bond return	8.55	5.82	2.23
S&P 500 return	11.20	15.64	1.83
GSCI return	12.24	18.35	1.89
50% S&P 500/50% GSCI return	12.54	11.86	3.07

Notes: The GSCI inception date is December 1969. The GSCI return is a total return that includes the return on collateral (the T-bill return). During this time period, the S&P 500 and the GSCI had a monthly return correlation of –0.03. This low correlation drives the lower standard deviation for a rebalanced portfolio.

[a]Test of whether excess return is different from zero.

2. The correlation with bonds and stocks is fairly low:

Table 2. Return and Risk over a Common Time Period, January 1991–May 2004

Index	Compound Total Return	Standard Deviation	Correlation				
			GSCI	DJ-AIGCI	CRB	Wilshire 5000	EAFE
GSCI	6.81%	17.53%					
DJ-AIGCI	7.83	11.71	0.89				
CRB	3.64	8.30	0.66	0.83			
Wilshire 5000	11.60	14.77	0.06	0.13	0.18		
EAFE	5.68	15.53	0.14	0.22	0.27	0.70	
Lehman Aggregate	7.53	3.92	0.07	0.03	–0.02	0.07	0.03

Notes: The comparison of annualized index returns starts in 1991 because this is the earliest common time period for all three commodity indices. EAFE is the MSCI Europe/Australasia/Far East Index. The T-bill return was 4.14 percent over this period.

- DJ-AIGCI = Dow Jones AIG commodities index, tracks weighted avg. of 22 commodities futures, now known as the Bloomberg Commodity Index.
- CRB = Commodity Research Bureau index, initially made up of 28 commodities, now known as the Thomson Reuters Core Commodity CRB Index made up of 19 commodities.

3. Correlation among commodities, historically (1982-2004), is low as well.

	GSCI	Nonenergy	Energy	Livestock	Agriculture	Industrial Metals	Precious Metals
Sector							
Nonenergy	0.36						
Energy	0.91	0.06					
Livestock	0.20	0.63	0.01				
Agriculture	0.24	0.78	0.01	0.12			
Industrial metals	0.13	0.31	0.03	–0.02	0.17		
Precious metals	0.19	0.20	0.14	0.03	0.08	0.20	

Notice the high correlation between the GSCI and energy commodities.

4. Since May 2004, commodities have been on a roller coaster ride:
   - the GSCI first nearly doubled from 5,200 to 9,200 in April 2008,
   - then crashed to 3,350 in March 2009,
   - recovered to 5,765 in May 2011,
   - and then went on a persistent decline to 2,500 in December 2019.
   - Another big crash followed with Covid-19 in April 2020 to 1400. Back to 2,000 in Nov 2021.
   - Over the 11/21-11/22 period: +16.5%
   - Peaked in June 2022. Fell 25% by June 2023.
   - Stable between June 2023 and April 2024.


S&P GSCI (Index Points) 4885.25 -105.17 (-2.11%)
9000
8000
7000
6000
5000
4000
3000
1877.49
1000
1980
1990
2000
2010
2020
1Y 5Y 10Y 25Y 50Y All
% num dif


S&P GSCI
596.95
↑34.04% +151.61 5Y
Apr 15, 3:41:22 PM UTC-4 · INDEXSP · Disclaimer
1D 5D 1M 6M YTD 1Y 5Y MAX
900
800
700
600
500
400
300
200
2020
2021
2022
2023
2024

5. Many of the price dynamics in the GSCI since 2004 are mimicked in crude oil prices
    - Wild drop from $60 in Jan 2020 to $20 in March 2020
    - Oil prices rebounded sharply to $120 in June 22 before coming back down to $70 at the end of 2022.
    - Oscillating between $70-$90 since then.

2.4.2. Cross-sectional Predictability: The Basis or Carry

- The basis is the traditional predictor of commodity returns, which is a special case of the more general concept of carry

$$C_t = \frac{S_t - F_t}{F_t} = \frac{S_t}{F_t}(\delta_t - r_f) \simeq \delta_t - r_f,$$

  where we used the cost of carry no-arbitrage formula

$$F_{t,1} = (1 + r_f)S_t - \delta_t S_t$$

  see Koijen, Moskowitz, Pedersen, and Vrugt (2018).

- Rewrite the expected excess return on commodities:

$$E_t[r^e_{t+1}] = \frac{E_t[S_{t+1} - S_t]}{F_t} + \frac{S_t}{F_t} - 1 = \frac{E_t[\Delta S_{t+1}]}{F_t} + C_t = \frac{E_t[\Delta S_{t+1}]}{F_t} - r_f + \delta_t.$$

- Yang (2013) studies the predictability of the basis (δ_t) for the cross-section of commodity returns and shows that there is a factor structure in the portfolios sorted on the basis.

- Commodities that are included in the exercise (1970-2008):

Table 1
Summary statistics of commodity futures for every individual commodity in the sample.
The sample includes monthly close quotes of futures of maturities up to 12 months of 31 commodities from January 1970 to December 2008. N is the number of monthly observations available for a commodity. The basis column reports the historical average basis of a commodity. The "freq. of bw." column reports the frequency of a commodity futures curve that is in backwardation. A commodity is defined as being in backwardation if its basis is positive. Columns $E(R^e)$ and $\sigma(R^e)$ report the annualized historical average and standard deviation of futures excess returns of individual commodities with many maturities.

Sector	Commodity	Symbol	N	Basis	Freq. of bw.	$E[R^e]$	$\sigma[R^e]$	Sharpe ratio
Agriculture	Barley	WA	235	−3.66	27.66	−0.24	19.62	−1.21
	Butter	02	141	−3.68	33.33	3.66	27.22	13.46
	Canola	WC	377	−2.98	33.16	−0.18	19.82	−0.89
	Cocoa	CC	452	−2.61	25.22	4.52	30.32	14.90
	Coffee	KC	420	−2.57	36.90	6.00	36.52	16.44
	Corn	C-	468	−6.03	23.08	−0.01	23.35	−0.04
	Cotton	CT	452	−1.75	36.50	3.60	22.96	15.69
	Lumber	LB	468	−5.63	33.55	−1.13	22.80	−4.98
	Oats	O-	468	−5.65	31.20	0.44	28.90	1.53
	Orange juice	JO	448	−3.08	36.61	2.32	29.56	7.86
	Rough rice	RR	265	−7.56	26.04	−1.50	25.01	−6.01
	Soybean meal	SM	468	0.20	44.87	7.80	28.63	27.25
	Soybeans	S-	468	−0.58	37.18	5.99	26.25	22.81
	Wheat	W-	468	−2.88	38.68	2.79	23.76	11.72
Energy	Crude oil	CL	295	4.25	66.78	10.56	27.87	37.89
	Gasoline	RB	275	8.09	70.91	12.82	30.18	42.47
	Heating oil	HO	345	1.49	55.65	9.50	28.65	33.15
	Natural gas	NG	216	−3.63	43.06	8.66	34.63	25.00
	Propane	PN	247	5.53	55.47	14.28	34.18	41.77
	Unleaded gas	HU	250	8.62	71.20	16.02	29.24	54.78
Livestock	Broilers	BR	19	4.58	52.63	1.49	7.28	20.53
	Feeder cattle	FC	443	0.35	53.27	4.43	14.28	31.01
	Lean hogs	LH	468	2.66	59.40	7.98	22.34	35.70
	Live cattle	LC	468	0.46	50.64	4.55	14.92	30.46
Metals	Aluminum	AL	215	1.06	35.35	5.46	19.11	28.56
	Coal	QL	85	−1.55	34.12	6.20	30.02	20.65
	Copper	HG	412	0.52	41.75	4.62	25.50	18.12
	Gold	GC	400	−6.24	0.00	0.43	19.88	2.18
	Palladium	PA	362	−2.16	30.66	10.21	35.19	29.01
	Platinum	PL	410	−3.21	23.66	3.69	27.81	13.27
	Silver	SI	419	−6.51	1.19	0.44	32.09	1.37

- The basis (log difference of spot to futures price) and average realized excess returns are positively related: 9.4% return spread between high-basis and low-basis commodity portfolios.

Table 2
Key moments of the seven commodity portfolios sorted by basis.
The upper panel reports the moments of portfolio excess returns relative to the risk-free rate. The lower panel reports the historical averages and standard deviations of portfolio-level basis. Portfolios are rebalanced in the last trading day of every month. Futures excess return is defined as the fully collateralized return of longing a futures contract. Portfolio excess return is computed as the equally weighted futures excess return across all commodities within a portfolio. Basis measures the slope of a futures curve. It is defined as the annualized difference between log futures prices with the shortest maturity and the longest maturity available. Portfolio-level basis is computed as the equally weighted mean across all commodities within a portfolio. The t-stats report the statistical significance of the portfolio excess returns. They are adjusted using a Newey-West correction.

	Low	2	3	4	5	6	High	HML
	Futures excess return							
Mean	1.83	2.98	2.28	5.06	6.08	8.92	11.25	9.42
Std	20.67	18.99	17.02	19.01	17.23	18.20	21.90	27.12
Sharpe ratio	8.84	15.69	13.41	26.63	35.28	49.01	51.35	34.74
t-Stat	0.58	0.95	0.76	1.52	2.00	2.89	2.94	2.15
	Basis							
Mean	−18.59	−10.79	−6.57	−3.03	1.26	7.50	19.38	
Std	21.68	13.86	13.95	15.83	18.61	24.59	37.67	

Detour: Carry in Global Asset Classes

- Carry, which can be computed consistently for any asset, predicts returns (both in the time series and in the cross section) for equities, government bonds, corporate bonds, commodities, currencies, and options.

- Carry is the traditional predictor in currency markets and equals the basis in commodity markets.

- Part of a new literature that connects predictability across asset classes and countries

  - Momentum and value: Asness, Moskowitz, and Pedersen (2013).
  - Time-series momentum: Ooi, Moskowitz, and Pedersen (2012).
  - Low-beta anomaly: Frazzini and Pedersen (2014).
  - Carry: Koijen, Moskowitz, Pedersen, and Vrugt (2018).

- If the same economic concept works across markets, then data mining is less likely.

- Moreover, it makes asset-class specific explanations less likely.

- Intuitively, **carry** is the "return you make if market conditions do not change."

- Using the notation from before, the excess return on a fully-collateralized futures position is

$$r^e_{t+1} = \frac{S_{t+1} - F_t}{F_t}.$$

- If market conditions do not change, then $S_{t+1} = S_t$, implying

$$r^e_{t+1} = \frac{S_t}{F_t} - 1 = C_t.$$

- We can write realized excess returns now as

$$r^e_{t+1} = \frac{S_{t+1} - S_t + S_t - F_t}{F_t} = \underbrace{C_t + E_t\left(\frac{\Delta S_{t+1}}{F_t}\right)}_{E_t(r_{t+1})} + u_{t+1},$$

- Carry is observed ex-ante without any modeling assumptions.

- Empirically, the question is "how much the market takes back" from the carry.

- Interpretation of carry in different asset classes:
  - Currencies:
    * CIP: the no-arbitrage price of a currency forward contract with spot exchange rate S_t, local interest rate r_t (funding rate), and foreign interest rate $r_t^\star$ (investment rate) is $F_t = S_t(1 + r_t)/(1 + r_t^\star)$.
    * The carry of the currency is

$$C_t = \frac{S_t - F_t}{F_t} = (r_t^\star - r_t)\,\frac{1}{1 + r_t} \simeq r_t^\star - r_t,$$

      i.e., the carry is the interest rate differential. Historically, you borrow in Japan and invest in Australia.
  - Equities:
    * The no-arbitrage price of a futures contract, $F_t = S_t(1 + r_t^f) - E_t^Q(D_{t+1})$, depends on the current equity value S_t, the expected future dividend payment D_{t+1} computed under the risk-neutral measure Q, and the risk-free interest rate r_t^f in the country of the equity index.
    * The equity carry can be written as

$$C_t = \frac{S_t - F_t}{F_t} = \left(\frac{E_t^Q(D_{t+1})}{S_t} - r_t^f\right)\frac{S_t}{F_t},$$

      i.e., the carry depends on the expected dividend yield relative to the risk-free rate.
    * Terms are on the same order of magnitude.

– Treasuries:

  * The carry of a $\tau-$period government bond is

$$C_t(\tau) = \frac{(1+y_t(\tau))^\tau}{(1+r_t^f)(1+y_t(\tau-1))^{\tau-1}} - 1$$
$$\simeq \underbrace{(y_t(\tau) - r_t^f)}_{\text{slope}} \underbrace{-D^{mod}(y_t(\tau-1) - y_t(\tau))}_{\text{roll down}}.$$

  * If applied to bonds with different maturities, scale the bonds to a constant duration by dividing the carry by duration.

– Options:

  * Consider a synthetic 1-month future that gives the obligation to buy an option that currently has maturity τ with futures price $F_t^\tau = (1+r_t^f)G^j(\tau, K; S_t, \sigma_{t,\tau})$.
  * The carry of an option is then

$$C_t^j(\tau, K) = \frac{G^j(\tau-1, K; S_t, \sigma_{t,\tau-1})}{(1+r_t^f)G^j(\tau, K; S_t, \sigma_{t,\tau})} - 1,$$

which we can approximate by

$$C_t^j(\tau, K) \simeq \frac{-\theta_t^j + \nu_t^j(\sigma_{\tau-1} - \sigma_\tau)}{G^j(\tau, K; S_t, \sigma_{t,\tau})} - r^f,$$

where θ is the option's theta, the derivative with respect to maturity and ν the option's vega, the derivative with respect to the implied volatility.

  * The option's carry therefore depends on the time decay (negative) and the "roll down" on the implied volatility curve.

- Average returns on carry strategies, the “market return” (EW), and the typical predictor in each asset class.
- Carry1-12 is the 12m MA to remove seasonalities.

Panel A: Carry1M trades by security within an asset class

Asset class	Strategy	Mean	St.dev.	Skewness	Kurtosis	Sharpe ratio
Global equities	Carry	9.58	10.48	0.24	5.14	0.91
	EW	5.21	15.73	−0.63	3.86	0.33
	D/P	4.22	11.81	−0.14	5.39	0.36
Fixed income 10Y global (level)	Carry	3.85	7.45	−0.43	6.66	0.52
	EW	5.04	6.85	−0.11	3.70	0.74
	Yield	3.55	7.73	−0.81	10.13	0.46
Fixed income 10Y-2Y global (slope)	Carry	0.68	0.66	0.33	4.92	1.03
	EW	0.01	0.43	−0.28	4.08	0.01
US Treasuries (maturity)	Carry	0.46	0.67	0.47	10.46	0.68
	EW	0.69	1.22	0.58	12.38	0.57
Commodities	Carry	11.22	18.78	−0.40	4.55	0.60
	EW	1.05	13.45	−0.71	6.32	0.08
	Basis	11.22	18.78	−0.40	4.55	0.60
Currencies	Carry	5.29	7.80	−0.68	4.46	0.68
	EW	2.88	8.10	−0.16	3.44	0.36
	Carry	5.29	7.80	−0.68	4.46	0.68
Credit	Carry	0.24	0.52	1.31	18.18	0.47
	EW	0.37	1.09	−0.03	7.10	0.34
	Yield	0.04	0.51	0.43	9.24	0.07
Call options	Carry	63.55	171.51	−2.82	14.49	0.37
	EW	−73.23	313.46	1.15	3.88	−0.23
	Short vol.	5.88	18.00	−7.07	75.58	0.33
Put options	Carry	178.90	99.30	−1.75	10.12	1.80
	EW	−298.89	296.36	1.94	7.11	−1.01
	Short vol.	5.88	18.00	−7.07	75.58	0.33
All asset classes (global carry factor)	Carry	7.18	5.96	−0.03	5.40	1.20
	EW	2.80	6.99	−0.43	9.28	0.40

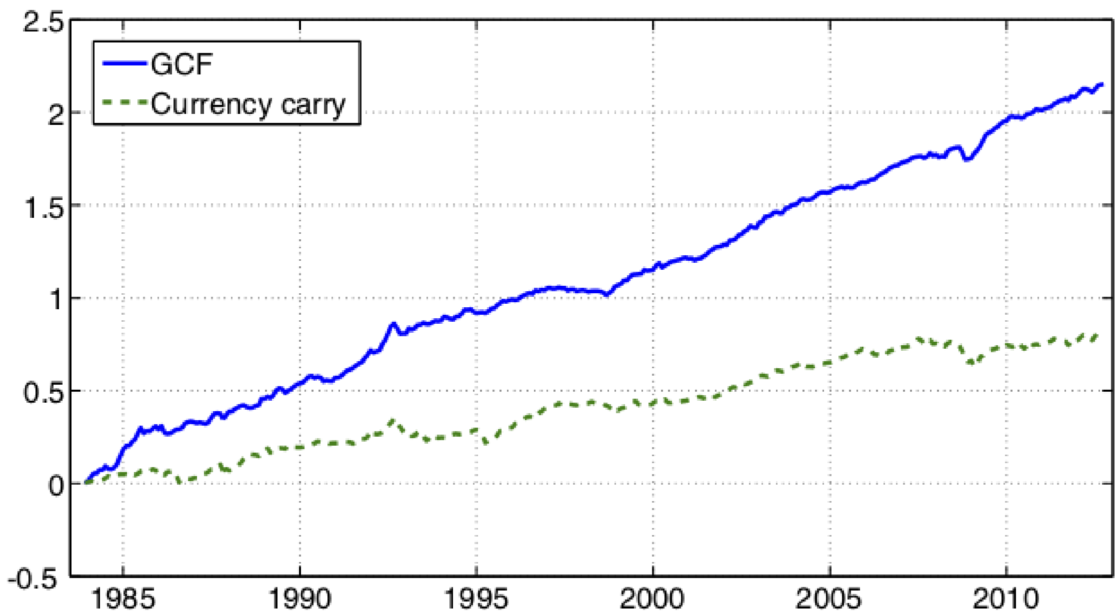
Panel B: Carry1M trades by region or group within an asset class

Asset Class	Strategy	Mean	St.dev.	Skewness	Kurtosis	Sharpe ratio
Global equities	Carry	5.95	10.95	0.45	4.23	0.54
	EW	4.79	14.67	−0.65	3.92	0.33
Fixed income 10Y	Carry	3.71	8.50	−0.37	5.22	0.44
	EW	5.09	6.91	−0.07	3.70	0.74
Fixed income 10Y-2Y	Carry	0.59	0.70	0.12	4.83	0.85
	EW	0.02	0.43	−0.34	3.98	0.04
Commodities	Carry	14.97	31.00	−0.04	4.93	0.48
	EW	1.37	16.15	−0.56	5.86	0.09
Currencies	Carry	4.76	10.73	−1.00	5.31	0.44
	EW	2.68	7.00	−0.05	3.34	0.38

Panel C: Carry1-12 trades by security within anasset class

Asset class	Strategy	Mean	St.dev.	Skewness	Kurtosis	Sharpe ratio
Global equities	Carry1-12	5.90	10.12	0.22	3.73	0.58
Fixed income 10Y global (level)	Carry1-12	3.11	6.81	−0.11	4.59	0.46
Fixed income 10Y-2Y global (slope)	Carry1-12	0.24	0.67	−0.11	6.26	0.35
US Treasuries (maturity)	Carry1-12	0.47	0.60	0.27	8.33	0.78
Commodities	Carry1-12	12.69	19.40	−0.82	5.70	0.65
Currencies	Carry1-12	4.25	7.71	−0.96	6.08	0.55
Credit	Carry1-12	0.27	0.58	−0.07	21.20	0.46
Call options	Carry1-12	42.62	158.81	−1.95	8.71	0.27
Put options	Carry1-12	136.13	89.37	−1.22	7.98	1.52
All asset classes (global carry factor)	Carry1-12	6.54	5.84	−0.15	6.23	1.12

- Comparison of a global carry strategy to the currency carry strategy:



- Part of the improved performance is due to the relatively modest correlation between carry strategies in different asset classes (p-values in parentheses):

	EQ	FI 10Y	FI 10Y - 2Y	Treasuries	COMM	FX	Credit	Calls	Puts
EQ		0.16	0.09	0.09	−0.03	0.05	0.06	0.11	−0.09
FI 10Y	(0.01)		−0.07	0.09	0.05	0.15	−0.02	−0.07	0.06
FI 10Y - 2Y	(0.13)	(0.22)		0.20	0.09	−0.01	0.18	−0.06	0.03
Treasuries	(0.14)	(0.09)	(0.00)		0.12	−0.05	0.12	0.08	−0.06
COMM	(0.60)	(0.32)	(0.09)	(0.02)		0.02	0.04	−0.15	0.08
FX	(0.36)	(0.01)	(0.82)	(0.34)	(0.69)		0.21	−.014	0.11
Credit	(0.32)	(0.69)	(0.00)	(0.01)	(0.40)	(0.00)		−0.04	0.09
Calls	(0.13)	(0.31)	(0.37)	(0.26)	(0.04)	(0.05)	(0.55)		0.15
Puts	(0.24)	(0.39)	(0.66)	(0.44)	(0.25)	(0.13)	(0.21)	(0.03)	

- Carry not only predicts returns in the cross-section but also in the time series: strategy is long or short depending on whether carry is above 0 (above sample mean until then) or below it:

Asset class	Reference point	Mean	St.dev.	Skewness	Kurtosis	Sharpe ratio
Global equities	0	7.69	18.66	0.34	4.41	0.41
	Mean	12.75	16.92	0.12	5.00	0.75
Fixed income 10Y global	0	7.09	10.93	−0.16	4.05	0.65
	Mean	6.82	9.89	−0.11	4.56	0.69
Fixed income 10Y-2Y global	0	0.33	0.75	−0.45	5.55	0.44
	Mean	0.34	0.75	−0.37	5.52	0.46
US Treasuries (maturity)	0	1.36	2.28	−0.48	14.51	0.60
	Mean	0.59	1.93	−1.26	22.34	0.31
Commodities	0	8.28	20.78	0.13	5.56	0.40
	Mean	12.20	16.24	−0.34	3.57	0.75
Currencies	0	7.86	10.01	−0.72	5.63	0.78
	Mean	5.04	9.50	−0.50	4.35	0.53
Credit	0	1.27	2.00	−0.24	8.00	0.64
	Mean	1.15	1.95	−0.30	8.69	0.59
Options calls	0	146.45	626.92	−1.15	3.88	0.23
	Mean	−35.66	264	−2.12	13.35	−0.14
Options puts	0	597.76	592.72	−1.94	7.11	1.01
	Mean	233.12	244.04	2.61	22.49	0.96
All asset classes (*GCF*)	0	6.03	6.45	0.72	12.89	0.93
	Mean	5.89	6.27	0.09	18.66	0.94

- Carry is not explained by other factors:

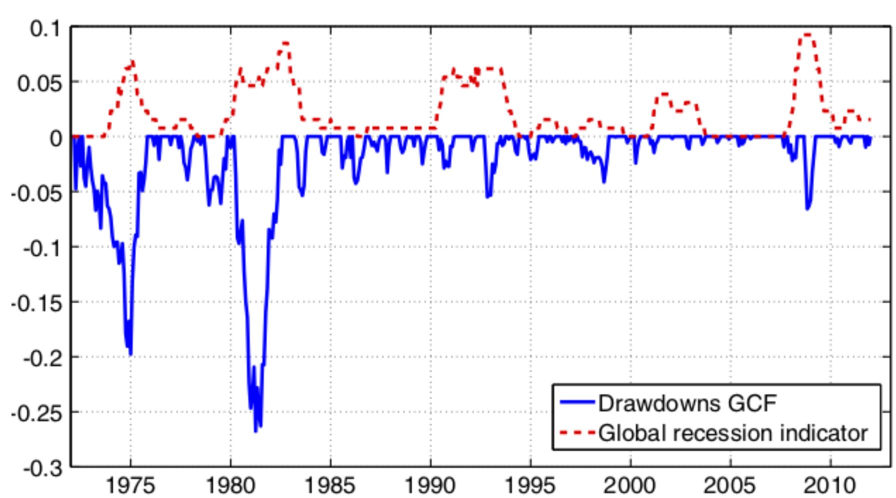
	Global equities		FI 10Y global		FI 10Y-2Y global		US Treasuries		Commodities	
α	0.82	0.82	0.35	0.33	0.06	0.05	0.03	0.02	0.93	0.64
	(4.70)	(4.71)	(3.06)	(3.08)	(5.53)	(5.01)	(3.38)	(2.74)	(3.43)	(2.57)
Passive long	−0.06	−0.06	−0.07	−0.18	−0.02	0.07	0.16	0.12	0.01	−0.02
	(−1.15)	(−1.21)	(−0.94)	(−2.10)	(−0.22)	(0.67)	(2.57)	(3.51)	(0.12)	(−0.31)
Value		0.17		0.07		−0.01		0.00		−0.21
		(1.82)		(0.51)		(−0.81)		(−0.67)		(−2.96)
Momentum		0.04		0.56		−0.01		0.00		0.29
		(0.44)		(4.26)		(−0.65)		(0.04)		(3.81)
TSMOM		−0.04		0.03		−0.00		0.00		−0.04
		(−1.66)		(1.82)		(−0.62)		(0.80)		(−0.45)
R^2	0.01	0.03	0.00	0.16	0.00	0.01	0.08	0.07	0.00	0.20
IR	0.95	0.95	0.57	0.61	1.03	1.01	0.54	0.64	0.60	0.47

	Currencies		Credits		Call options		Put options		*GCF*	
α	0.40	0.30	0.02	0.02	3.21	6.93	13.02	12.55	0.57	0.51
	(3.31)	(2.31)	(2.85)	(1.70)	(1.07)	(2.15)	(4.74)	(4.55)	(7.19)	(6.74)
Passive long	0.17	0.22	0.02	0.14	−0.34	−0.35	−0.08	−0.09	0.11	0.17
	(2.47)	(3.46)	(0.50)	(2.31)	(−5.90)	(−6.07)	(−1.85)	(−2.10)	(1.36)	(2.15)
Value		0.11		0.01		−5.96		2.82		0.05
		(1.08)		(0.82)		(−2.14)		(0.98)		(0.80)
Momentum		0.03		0.00		−4.32		2.14		0.08
		(0.31)		(−0.21)		(−2.54)		(1.01)		(1.40)
TSMOM		0.01		0.00		−0.92		−0.77		−0.02
		(0.25)		(−1.42)		(−1.00)		(−1.07)		(−0.82)
R^2	0.03	0.05	0.00	0.07	0.39	0.43	0.05	0.07	0.02	0.04
IR	0.63	0.47	0.45	0.39	0.29	0.64	1.61	1.56	1.16	1.55

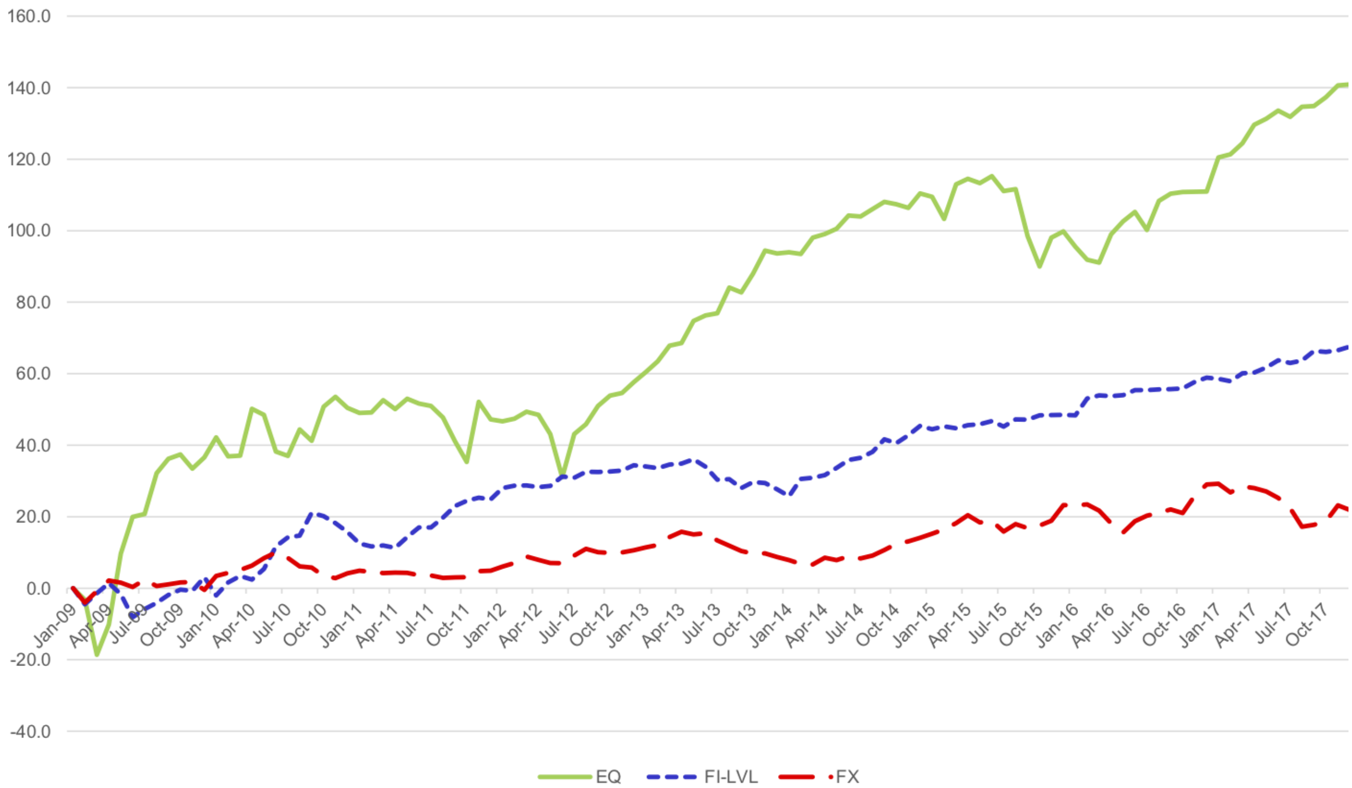
- Potential explanations for the currency carry:
  - Downside (crash) risk. Works well for commodities!
  - Liquidity risk.
  - Volatility risk.
- These factors work for currencies and commodities, but not for other asset classes. The most challenging is Treasuries, as the Treasury carry strategy does well when (i) volatility spikes and (ii) liquidity dries up.

Asset class	Exposure to (t-statistic) liquidity shocks	Exposure to (t-statistic) volatility changes	Alpha (t-statistic)
Equities global	0.70 (1.43)	0.00 (0.01)	0.71% (4.09)
Fixed income 10Y global	0.41 (0.76)	−0.12 (−2.11)	0.07% (0.47)
Fixed income 10Y-2Y global	0.84 (1.52)	−0.03 (−0.92)	0.61% (3.67)
US Treasuries	−0.29 (−0.37)	0.10 (2.37)	0.94% (5.98)
Commodities	0.51 (1.26)	−0.08 (−2.19)	0.26% (1.59)
Currencies	2.19 (3.01)	−0.15 (−4.46)	−0.08% (−0.64)
Credit	3.89 (3.34)	−0.01 (−0.15)	−0.31% (−5.46)
Call options	−0.25 (−0.95)	−0.04 (−1.57)	0.19% (0.90)
Put options	1.26 (2.01)	−0.13 (−2.00)	0.70% (4.14)
	Risk prices (t-statistic)		
Liquidity	0.16 (3.53)		
Volatility	−2.28 (−2.65)		

- Some evidence of comovement with the global business cycle, but too weak to explain the magnitude of carry premia.



• Carry in the low-rate environment (2009-2017)



• The currency carry has been fairly flat given the compression in short rates.

• Carry for global equities and fixed income continued as before.

. . . now back to commodities.

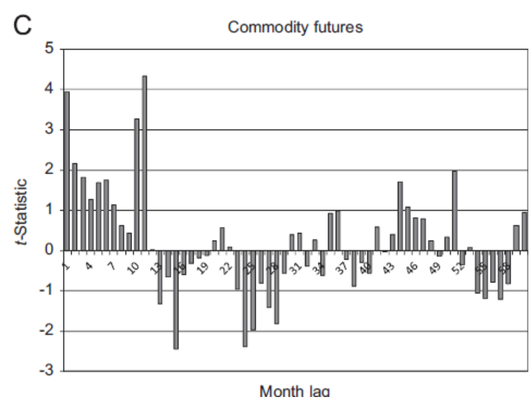
2.4.3. Time-Series Predictability

Time-Series Momentum

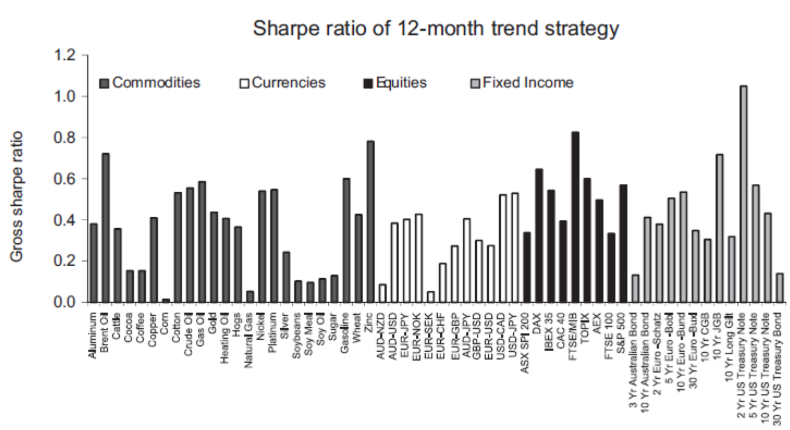
- Moskowitz, Ooi, and Pedersen (2012) look at time-series momentum:

$$r_t/\sigma_{t-1} = \alpha + \beta_h r_{t-h}/\sigma_{t-h-1} + \epsilon_t.$$

- Different from traditional momentum, which is cross-sectional in nature (out-performance relative to other securities)
- The t-statistics of the slope coefficients:



- Sharpe ratios:



2.4.4. Holdings Data

- Commodity Futures Trading Commission (CFTC) publishes data on the positions of futures traders in the Commitment of Traders Reports. Available since January 1986.

- Large traders are classified as *Commercials* and *Non-commercials*

- Smaller traders are called *Nonreportables*.

- Academic literature views *Commercials* as hedgers and *Non-commercials* as speculators. That's because *Commercials* tend to be short the commodity in the futures market, hedging an underlying long position in the spot market.

- A commodity's hedging pressure is defined as the ratio of short positions taken by *Commercials* to open interest, the number of outstanding futures contracts. More on hedging theories below.

- Table and graph below show that *Commercials*' positions show a lot of variation over time, so that they are both long and short, as well as in the cross-section of commodities.

- A new group of (non-commercial) traders, Commodity Index Traders (CITs), a.k.a. index speculators, has grown dramatically since 2004. More on this at the end of the lecture under the topic of financialization.

Table X. Summary of positions of traders, January1986–October 2011

The table summarizes the positions of traders in commodity futures markets according to the classifications employed in *Commitments of Traders Reports* published by the CFTC: For each category (Commercials, Noncommercials, and Nonreportables), positions are measured as net long and expressed as a percentage of open interest. The columns report the sample average position, the standard deviation of the position, the fraction of the months the position is long, and the first-order autocorrelation (ρ) of the position. The end of the sample period is October 2011 except for Propane, whose last month of the sample period is May 2000. The first month of the sample period is indicated in the column labeled "Start".

		Net long positions of traders as percent of open interest											
		Commercials				Noncommercials				Nonreportables			
Commodity	Start	Average	St dev	Long (%)	ρ	Average	St dev	Long (%)	ρ	Average	St dev	Long (%)	ρ
Metals													
Copper	198601	−13.1	23.0	31.0	0.80	6.3	17.1	63.5	0.79	6.8	8.8	76.5	0.83
Platinum	198601	−43.6	24.2	5.8	0.75	29.3	23.1	86.8	0.79	14.3	7.3	98.1	0.79
Softs													
Cotton	198601	−6.3	21.9	35.8	0.73	1.2	19.2	56.1	0.76	5.2	5.8	85.8	0.76
Cocoa	198601	−11.0	16.1	25.2	0.80	5.3	13.6	62.9	0.80	5.7	5.4	89.7	0.88
Orange juice	198601	−18.7	25.4	21.6	0.79	10.6	19.1	70.6	0.77	8.1	12.4	85.8	0.86
Lumber	198601	−9.7	19.2	36.1	0.76	4.6	15.4	63.2	0.66	5.1	11.4	66.8	0.74
Coffee	198601	−17.2	14.6	14.5	0.60	8.1	13.4	74.2	0.61	9.2	5.7	96.8	0.85
Grains													
Wheat	198601	−6.3	15.8	41.3	0.77	3.5	12.0	57.4	0.74	2.8	8.7	55.5	0.84
Corn	198601	−1.0	14.0	46.5	0.80	8.0	11.7	72.3	0.79	−7.0	5.5	9.0	0.83
Soybeans	198601	−11.2	16.5	24.8	0.86	9.1	13.0	75.8	0.83	2.1	8.1	55.8	0.91
Soybean oil	198601	−13.0	17.3	27.4	0.74	6.0	12.6	66.5	0.76	7.0	6.9	86.5	0.74
Soybean meal	198601	−16.0	14.9	17.7	0.73	7.4	11.3	72.9	0.77	8.7	5.4	95.2	0.68
Oats	198601	−34.4	17.2	4.5	0.77	12.6	12.0	88.7	0.79	21.8	14.4	94.5	0.86
Live cattle	198601	−7.0	11.3	31.6	0.86	8.8	10.3	78.1	0.76	−1.8	10.2	39.0	0.90
Lean hogs	198601	0.7	11.3	47.1	0.70	5.7	14.1	67.4	0.68	−6.4	7.8	14.5	0.61
Feeder cattle	198601	8.6	11.3	76.8	0.74	10.5	13.3	78.4	0.73	−19.1	13.4	11.6	0.88
Milk	199710	9.4	16.4	69.8	0.88	0.4	12.4	47.3	0.85	−9.8	8.6	11.2	0.80
Energies													
Heating oil	198601	−9.4	9.2	15.8	0.61	2.8	6.3	66.5	0.61	6.5	5.2	91.3	0.74
Crude oil	198601	−1.2	8.2	40.3	0.69	1.3	6.3	59.0	0.71	−0.2	3.1	49.0	0.59
Unleaded gas	198601	−11.4	11.9	19.4	0.67	9.2	9.7	80.6	0.76	2.2	4.1	75.8	0.38
Propane	198708	−9.9	11.8	19.5	0.72	−0.6	6.0	27.9	0.71	10.5	10.3	82.5	0.65
Natural gas	199004	−2.7	11.2	37.5	0.84	−3.1	10.2	43.6	0.86	5.9	3.2	98.5	0.79

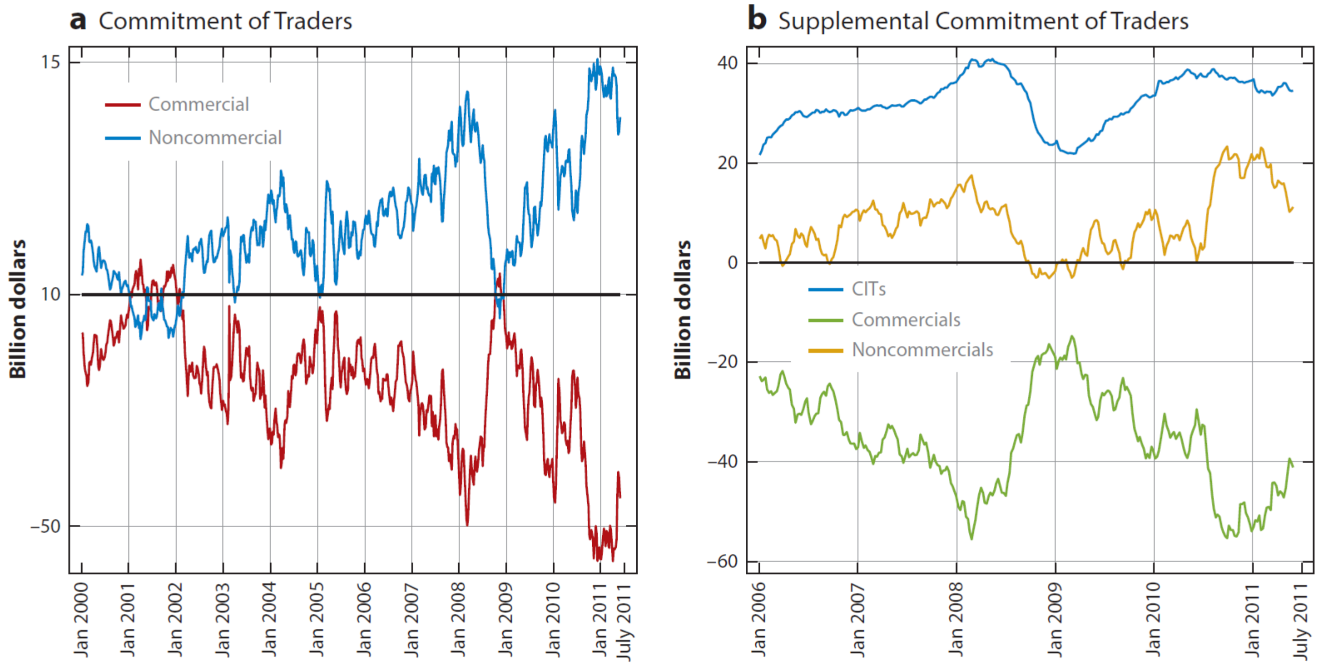


Figure 5

Panel *a* plots the aggregate net notional value for trader groups in the COT report in the 18 GSCI commodities tracked. Panel *b* plots the same for trader groups in the SCOT report for the 12 agricultural commodities tracked. Notional values are calculated using fixed prices as of December 15, 2006. Data source: Bloomberg, CFTC COT reports. Abbreviations: CFTC, Commodity Futures Trading Commission; COT, Commitment of Traders; GSCI, Goldman Sachs Commodity Index; SCOT, Supplemental Commitment of Traders.

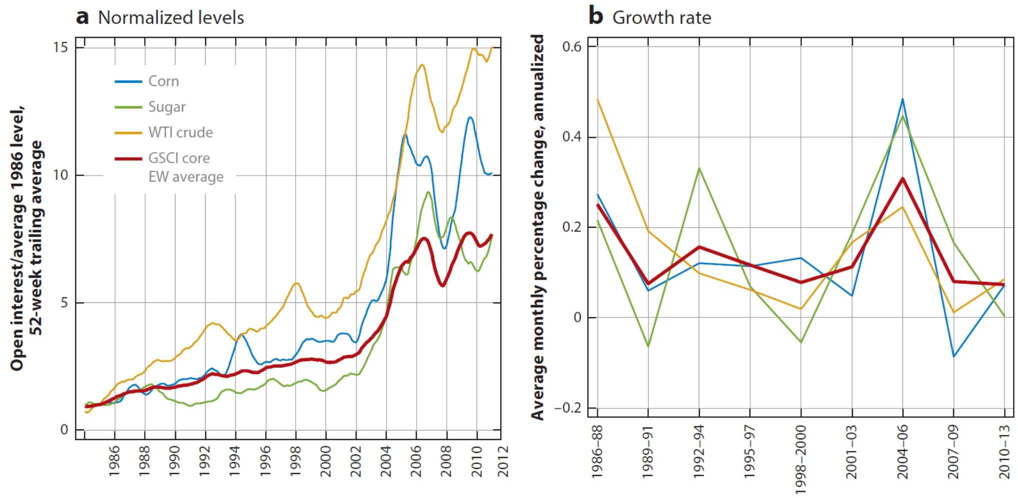


Figure 4

Panel *a* plots open interest in corn, sugar, oil and GSCI normalized to the average 1986 open interest. Panel *b* plots annualized average monthly percentage changes in open interest for three-year periods beginning in 1986. The GSCI core equal-weighted average is the equal-weighted commodity average within the GSCI commodities that have data going back to 1986. All values are 52-week trailing averages. Data source: CFTC COT reports. Abbreviations: CFTC, Commodity Futures Trading Commission; COT, Commitment of Traders; EW, equal-weighted; GSCI, Goldman Sachs Commodity Index; WTI, West Texas Intermediate.

3. Interpreting the Facts

3.1. Factor Models

- Yang (2013) finds that 2 factors explain 75% of the variation in the 7 commodity portfolio returns sorted on carry: a level (market) factor and a slope (carry) factor which buys high-basis and shorts low-basis commodities.

- He proposes a reduced-form pricing model with a level and slope factor HML_C and shows that it prices the cross-section of commodity portfolios sorted on basis. This is similar to Lustig, Roussanov, and Verdelhan (2011) for currencies.

- Yang (2013) also shows that the slope factor HML_C is negatively related to the empirical proxies for the investment-specific technology shocks from Papanikolaou (2011) . The two-factor model with the commodity market factor and the IST shock proxy works nearly as well to explain the commodity portfolio returns. This leads to the structural model we will discuss below.

3.2. Structural Asset Pricing Models

3.2.1. Hedging Pressure and Storage Theories

- The first classical theory explaining the predictability of commodity futures returns, the **Theory of Normal Backwardation** dates back to Keynes (1923, 1930) and Hicks (1939).
  - Speculators who take long positions in futures demand a positive risk premium from producers/hedgers (commercials), who short the futures to lock in their future profits. Their hedging pressure pushes down futures prices and raises the basis (positive basis = backwardation).
  - de Roon, Nijman, and Veld (2000) empirically link hedging pressure to future excess returns and the basis.
- The second classical theory, the **Theory of Storage**, postulates that futures prices are driven by optimal inventory management, and dates back to Kaldor (1939) and Working (1948,1949).
  - Introduces the notion of a convenience yield (c_t) to explain the holding of inventory in periods when spot prices are expected to decline. Recall:

$$(1 + r_f)S_t - F_{t,1} = c_t - w_t \equiv \delta_t S_t$$

  - Routledge, Seppi, and Spatt (2000) introduce a futures market in the optimal inventory management model of Deaton and Laroque (1992), and show that time-varying convenience yields can arise with risk neutral agents.
- These theories are not mutually exclusive and the modern commodities literature often combines the two strands.

- Hirshleifer (1990) constructs an equilibrium model where speculators and hedgers interact. For hedging demand to affect prices and quantities, two frictions are necessary:

  1. Speculators must face barriers to entry in futures market (here, because of fixed setup costs)
  2. Producers cannot market the revenues from the physical commodity (because they are not able to issue equity on their future cash flows) $\Rightarrow$ Segmentation between equity and commodities markets.

  In this segmented markets setting, the commodity futures risk premium contains a component related to the volatility of spot prices beyond traditional systematic risk.

  This theory has **no role for storage, i.e., inventories**.

- Acharya, Lochstoer, and Ramadorai (2013) extend the model to incorporate optimal inventory management. They relate risk premia to the hedging demand of producers (driven by changes in producer default risk) in a model where speculators also have limited capital.

  – Show empirically that increases in aggregate default risk predict future commodity returns, esp. in periods where broker-dealer balance sheets are shrinking.

- Similarly, Etula (2013) relates commodity futures risk premia to the risk-bearing capacity of broker-dealers (the speculators).

- Gorton, Hayashi, and Rouwenhorst (2013) look at the relationship between the basis, risk premia and inventories in a simple equilibrium model that combines elements of the theory of storage and the theory of hedging pressure.

- Main result is that **basis and risk premium are high when inventories are low**. Find empirical support for this model.

- Model assumptions:

  - Two-period model: $t = 0, 1$.
  - Interest rates are zero.
  - Agents: Speculators and hedgers.
  - Spot market in period 0 and 1. A futures market in period 0 with contracts maturing in period 1.
  - All investors have mean-variance preferences.
  - Hedgers (producers, commercials):
    * Endowed with I units of the commodity; decide to store (inventory) $x \Rightarrow$ Sells $I - x$ in the spot market.
    * The time-0 profit is $\Pi_0 = S_0(I - \overline{x}) \times (I - x)$, where spot price $S_0(\cdot)$ is the inverse demand function and $\overline{x}$ is the average over all hedgers.
    * The hedgers also sell N contracts forward at price F $\Rightarrow$ A long position corresponds to a negative N.
    * The hedger will sell in period 1 in the spot market

      $$z + (1 - \delta)x - N,$$

      where z is the stochastic period-1 endowment and δ is the depreciation rate of the commodity.

* The economy-wide supply in period 1 is $z + (1 - \delta)x$.
* The hedgers maximize their utility over $x \geq 0$ and N

$$\max_{x,N} \Pi_0 + E[\Pi_1] - \frac{\alpha}{2} Var(\Pi_1),$$

where $\Pi_1 = S_1 \times (z + (1 - \delta)x - N) + FN$

* The first-order conditions imply that, when $x > 0$,

$$S_0 - F = -\delta F.$$

The wedge between the spot and the future, the basis, equals minus the storage cost, $-\delta F$. This is the standard no-arbitrage *cost-of-carry* condition.

* When $x = 0$ (*stock-out* occurs, no inventory), then

$$S_0 - F > -\delta F,$$

i.e., the spot price is “too high” relative to the future to store anything. The basis is higher than -the cost of storage, i.e., the *convenience yield* is strictly positive.

- Speculators:
  - End-of-period wealth given initial endowment e_0

$$e_0 + (S_1 - F)N.$$

  - Given mean-variance preferences with risk aversion β, their FOC w.r.t. N is:

$$N = \frac{E[S_1] - F}{\beta Var(S_1)}$$

  - Speculators require risk premium for accommodating hedgers.
- Under further regularity conditions, the model predicts a negative relationship between basis and inventories and between risk premia and inventories

- Empirical test: Basis should be high when inventory I is low relative to normal level $I^\star$. Convex relationship, use spline $h(\cdot)$

  Basis $=$ Linear function of seasonal dummies + $h(I/I^\star)$ + error.

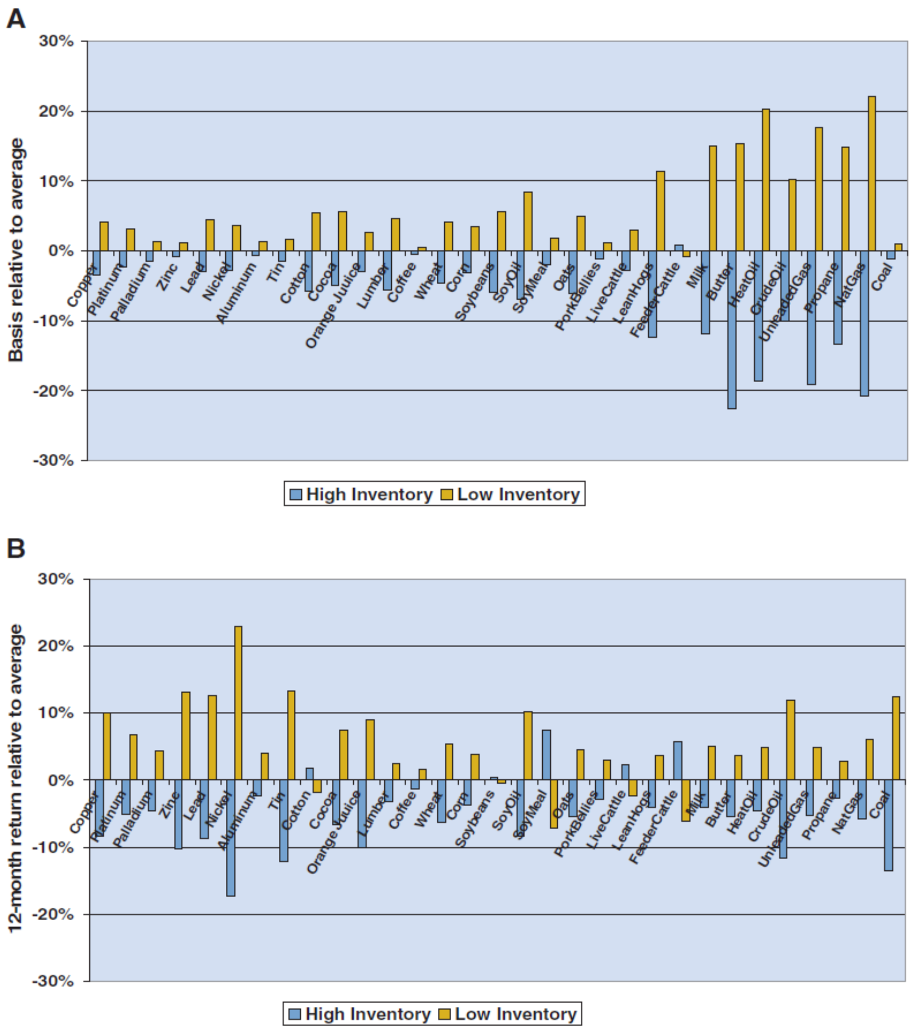


Figure 5. Inventories and price-based signals.

- Portfolios sorted on lagged inventories $I/I^{\star}$:

Panel A: Statistics about excess return from t to $t+1$	$t=1971/1$–$2010/12$			$t=1986/1$–$2010/12$			$t=1990/12$–$2010/12$		
	High	Low	Long–short	High	Low	Long–short	High	Low	Long–short
Mean	2.03	8.93	−3.45	2.82	9.38	−3.28	1.44	8.86	−3.71
Standard deviation	18.59	15.25	7.58	14.80	13.21	6.27	14.19	13.29	6.02
t-statistic for the mean	0.63	3.21	−2.78	0.88	3.16	−2.55	0.40	2.59	−2.59
Excess return > EW (%)	43	56	43	44	56	41	43	56	42

Panel B: Average portfolio characteristics at t or $t+1$	High	Low	t-statistic for the difference	High	Low	t-statistic for the difference	High	Low	t-statistic for the difference
Basis at t	−4.47	2.31	−7.39	−3.80	2.26	−6.10	−5.53	0.42	−5.72
Prior 12-month excess return at t	3.02	10.62	−4.49	2.31	9.90	−4.88	0.95	9.77	−4.83
Prior 12-month spot return at t	3.93	12.50	−6.77	3.18	12.02	−7.17	3.59	13.25	−6.58
Volatility at $t+1$	31.60	30.64	2.11	31.77	30.67	1.93	31.50	30.93	0.95
Demeaned volatility at $t+1$	0.71	−0.40	2.78	0.29	−0.73	2.57	0.10	−0.75	2.10
Commercials at $t+1$				−10.16	−10.22	0.07	−10.08	−11.04	1.17
Noncommercials at $t+1$				6.11	7.47	−2.86	6.47	8.24	−3.16
Nonreportable at $t+1$				4.05	2.75	2.61	3.61	2.80	1.61

- The results suggest that the state of inventories is negatively related to commodity risk premia.

- Paper also investigates hedging pressure hypothesis. Larger short positions of *Commercials* in the futures market are *contemporaneously* associated with higher futures prices. But no *predictive* relationship, suggesting that hedging pressure is not a good theory for commodity risk premia.

Open Interest Growth

- Hong and Yogo (2012) show that changes in the open interest, the number of futures contracts outstanding, predicts future returns.
- Why does open interest contain information beyond prices (the basis)?
- Fact: open interest = gross (as opposed to net) hedging demand is strongly pro-cyclical
- They develop a simple model with
  - Infinitely risk-averse producers that want to be short futures (i.e., hedge all future price risk).
  - Informed, risk-averse speculators (i.e. limited arbitrage capital).
  - Uninformed, risk-averse investors (consumers) that want to be long futures.
- There is uncertainty about the state of the economy, which informed investors and producers know, but uninformed investors do not.
- In the good state, the futures price could be high or low. If the hedging demand is sufficiently strong, producers put downward pressure on the futures price because of limited arbitrage capital. If consumers have stronger demand, futures prices will be high, again because of limited arbitrage capital.
- Open interest, on the other hand, is always high in the good state and is thus a reliable predictor of high future commodity returns.

- Dynamics of the growth in open interest:

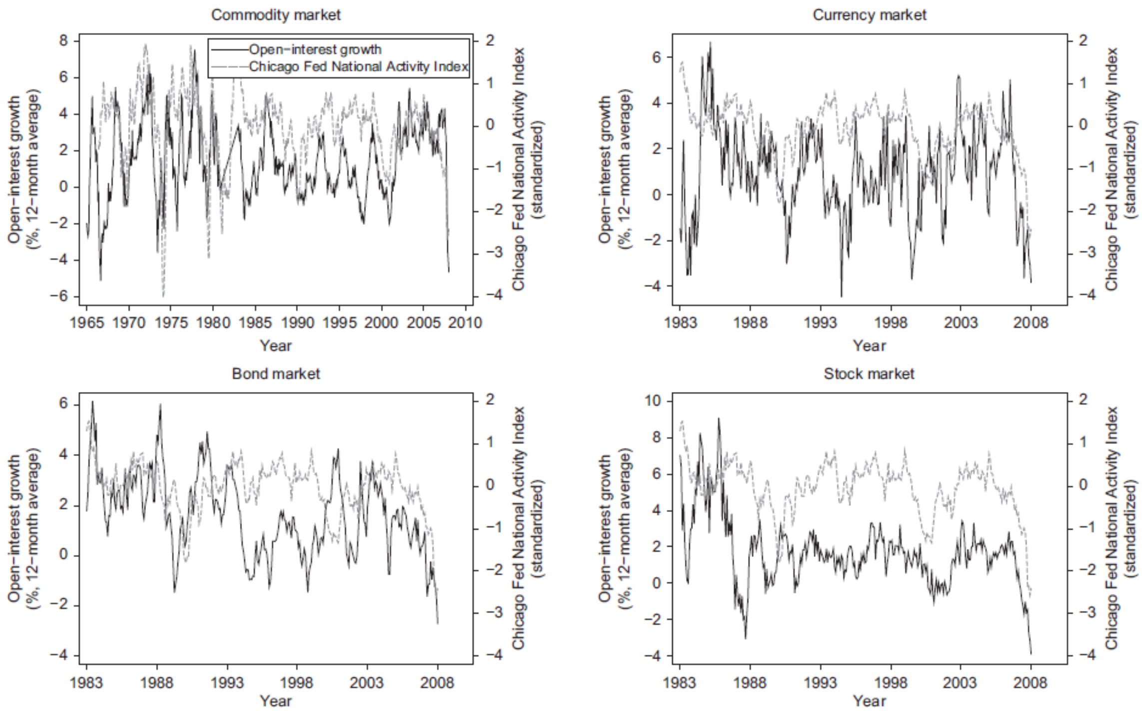


Fig. 2. Growth rate of open interest and the Chicago Fed National Activity Index. The 12-month geometrically averaged growth rate of commodity, currency, bond, and stock market interest is shown. Also the Chicago Fed National Activity Index, which is a weighted average of 85 monthly indicators of US economic activity, is shown. The sample period is 1965:12–2008:12 for the commodity market and 1983:12–2008:12 for the other markets.

H. Hong, M. Yogo / Journal of Financial Economics 105 (2012) 473–490

- Return predictability:

Table 6
Predictability of commodity returns by commodity market interest.
The predictability of monthly excess returns on a portfolio of fully collateralized commodity futures over the one-month T-bill rate is tested. All predictor variables are lagged one month. Standardized coefficients with heteroskedasticity-consistent *t*-statistics in parentheses are reported. The sample period is 1966:1–2008:12.

Predictor variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Short rate	−0.51	−0.48	−0.44	−0.50	−0.55	−0.50	−0.52	−0.55
	(−2.42)	(−1.85)	(−2.10)	(−1.98)	(−2.39)	(−1.99)	(−2.50)	(−2.12)
Yield spread	−0.51	−0.44	−0.37	−0.48	−0.45	−0.42	−0.58	−0.57
	(−2.68)	(−2.03)	(−2.03)	(−2.41)	(−2.17)	(−1.90)	(−2.78)	(−2.54)
Commodity basis	−0.57	−0.52	−0.56	−0.52	−0.59	−0.53	−0.66	−0.62
	(−2.05)	(−1.91)	(−2.01)	(−1.91)	(−2.04)	(−1.92)	(−2.02)	(−1.88)
Commodity market interest		0.73		0.77		0.69		0.68
		(2.50)		(1.85)		(2.42)		(1.88)
Commodity returns			0.32	−0.08				
			(1.39)	(−0.22)				
Commodity market imbalance					0.34	0.12		
					(1.50)	(0.60)		
Chicago Fed National Activity Index							0.47	0.30
							(2.09)	(0.93)
R^2 (%)	2.58	4.96	2.98	4.98	3.01	5.02	4.26	6.20

- In sum, price pressure (= downward-sloping demand curves) is a common theme in the commodities literature.

3.2.2. Production-based Models

- Yang (2013) proposes a GE model of commodity production to rationalize the differences in average returns across commodities sorted by basis.
- Extends Kogan, Livdan, and Yaron (2009) who focus on the term structure of volatility in futures prices.
- N non-storable commodities, each produced by representative firm with capital that is exposed to aggregate IST shocks. Each commodity also exposed to aggregate and idiosyncratic demand shocks. Investment is irreversible.
- SDF M_{t+1} is exogenous with positive price of risk for aggregate demand shock and negative price of risk for IST shock.
- Futures prices with maturity date T for commodity j are given recursively:

$$F^j_{t,T} = E^Q_t[F^j_{t+1,T}] = E_t[M_{t+1}F^j_{t+1,T}]$$

  with boundary condition $F^j_{T,T} = S^j_T$ because futures prices converge to spot prices at maturity.
- High-basis commodities have a more negative exposure to IST shocks, hence higher risk premium.
  - Positive idiosyncratic demand shock prompts high investment in production capacity for commodity j
  - High investment predicts high future supply and hence a low expected future spot rate.
  - High investment also makes commodities producers more sensitive to IST shocks due to irreversibility:
    more negative IST-beta and higher risk premium.

  - Both forces decrease future prices relative to the spot price, hence increase the basis.

$$F_{t,T} = E_t[S_T] - \frac{Cov_t(-M_{t,t+T}, S_T)}{E_t[M_{t,t+T}]}$$

- Model calibration quantitatively generates the observed HML_C spread and the failure of the one-factor commodity CAPM for IST risk price estimated in investment literature.

4. Link Between Commodity Prices and the Macro-economy

- A literature in economics tries to measure supply and demand shocks for specific commodities, for instance, oil and to measure the impact on the macro economy.
- Good example is Kilian (2009).
- He develops a structural VAR to identify demand and supply shocks in oil markets.
- The main VAR contains three series, collected in z_t:
  1. $\Delta prod_t$: percent change in global crude oil production.
  2. rea_t: real economic activity index.
  3. rpo_t: real price of oil.
- Consider three structural shocks:
  1. Supply shocks (ϵ_t^S).
  2. Global demand shocks ($\epsilon_t^{D,G}$).
  3. Oil-specific demand shocks ($\epsilon_t^{D,Oil}$).

- Structural VAR at a monthly frequency:

$$A_0 z_t = \alpha + \sum_{i=1}^{24} A_i z_{t-i} + \epsilon_t,$$

where A_0 is lower triangular.

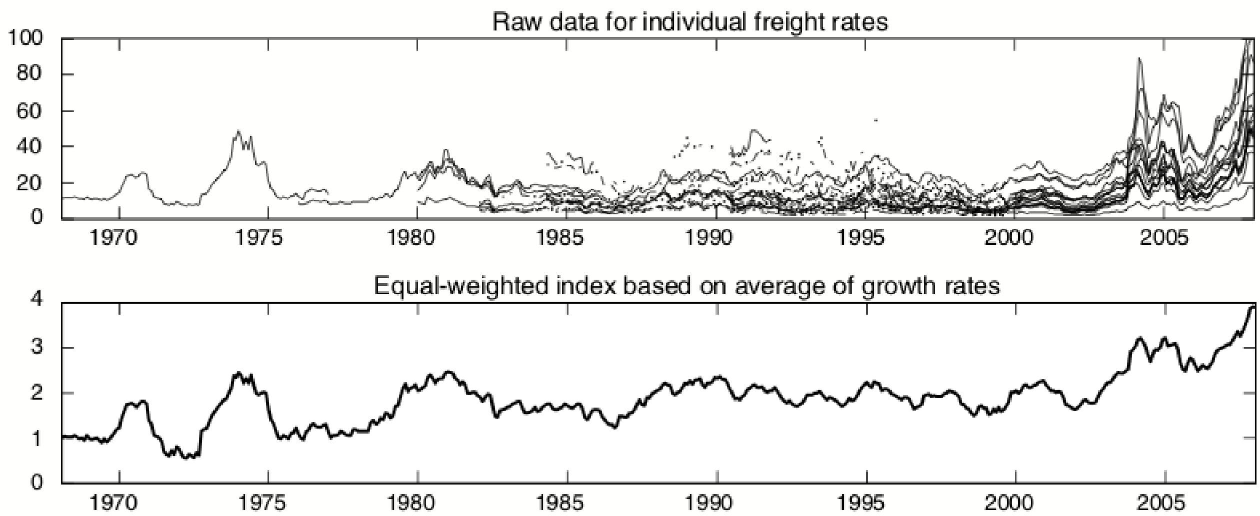
- Identifying assumptions (from this ordering of VAR):

  1. Oil supply curve is vertical in the short run (within a month) and hence unexpected changes in production are identified as supply shocks.
  2. Innovations to global economic activity that cannot be explained by supply shocks are shocks to global demand for industrial commodities ("aggregate demand").
  3. Shocks to the real price of oil that cannot be explained by the previous two shocks are oil-specific demand shocks. This really is just the residual.

- Key innovation: A monthly index of global real economic activity.

- The index of global real economic activity is based on representative single-voyage freight rates available in the monthly report on “Shipping Statistics and Economics” published by Drewry Shipping Consultants Ltd.

- It is based on various bulk dry cargoes consisting of grain, oilseeds, coal, iron ore, fertilizer, and scrap metal.



- Implied shocks:

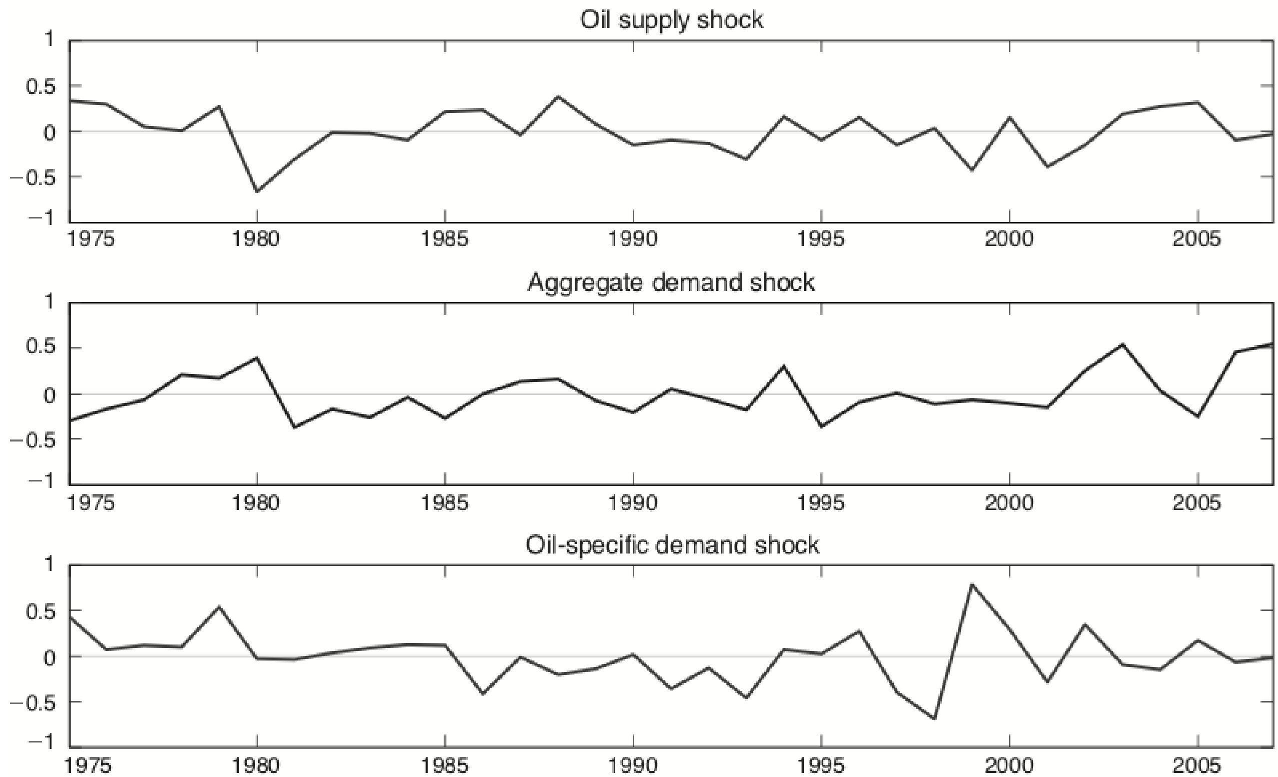


FIGURE 2. HISTORICAL EVOLUTION OF THE STRUCTURAL SHOCKS, 1975–2007

- Large negative supply shock in 1980 corresponds to the Iran-Iraq war.
- Large positive oil-specific demand shocks in the late nineties.

- Impulse responses, where shocks are normalized so they increase the price of oil

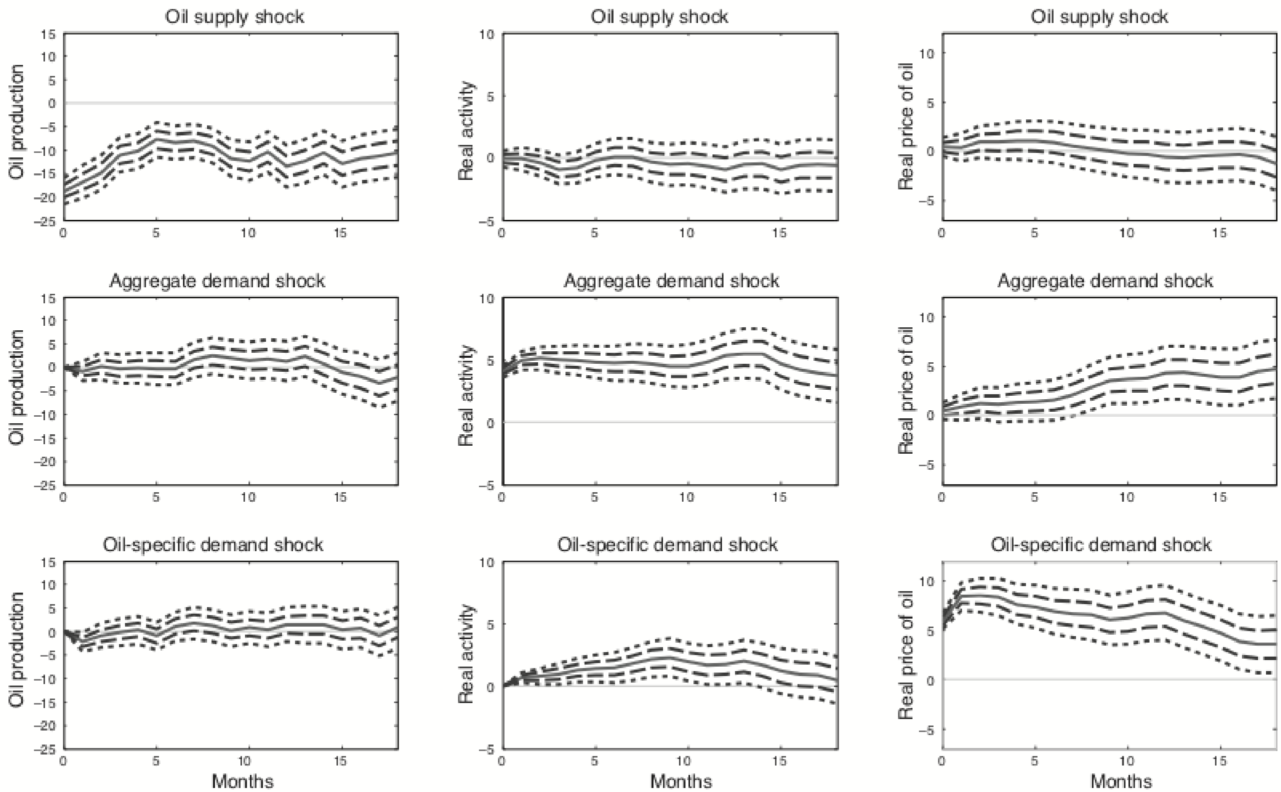


FIGURE 3. RESPONSES TO ONE-STANDARD-DEVIATION STRUCTURAL SHOCKS

  – Supply shock: Short-term decline in production, small transitory decline in economic activity, and small transitory increase in oil prices. This is surprising.

  – Aggregate-demand shock: Persistent effect on economic activity, temporary increase in production, and persistent increase in oil prices.

  – Oil-specific demand shock: Persistent and immediate effect on oil prices, a temporary increase in economic activity, and a small increase in oil production.

- Cumulative effects:

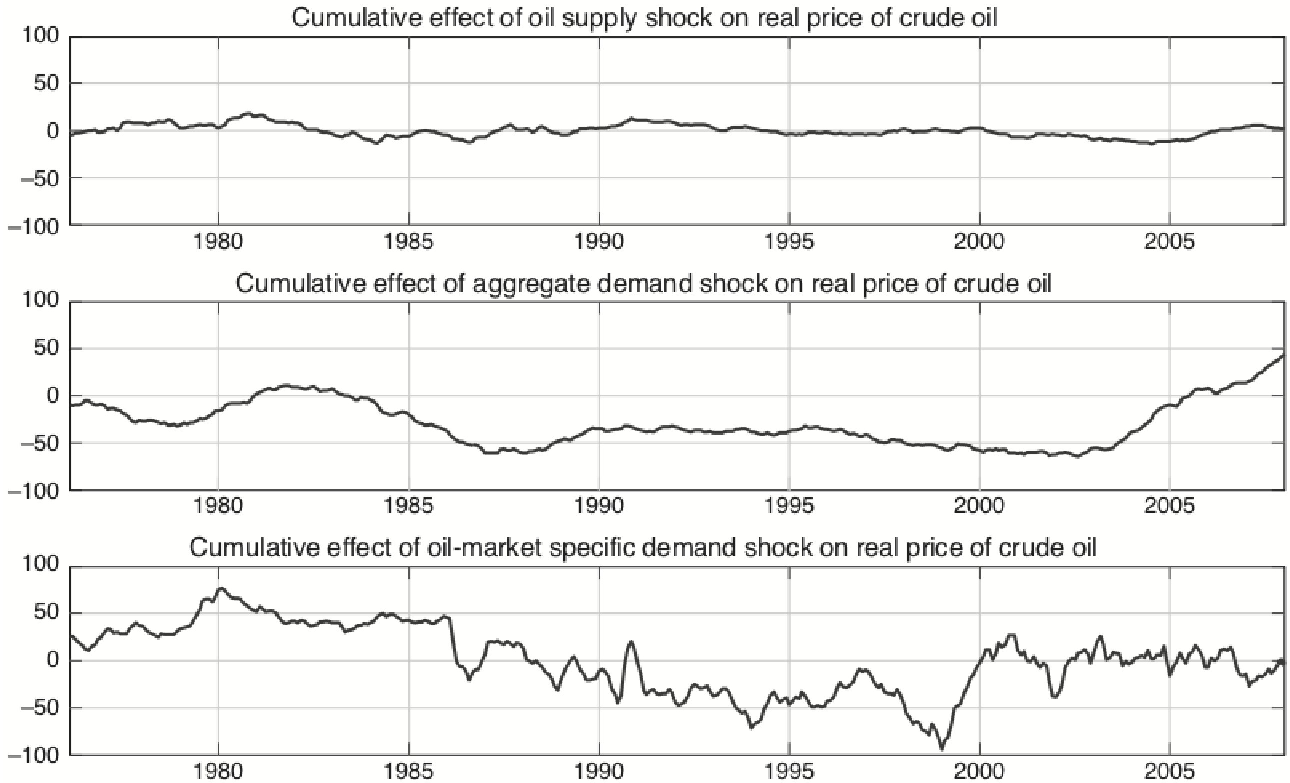


FIGURE 4. HISTORICAL DECOMPOSITION OF REAL PRICE OF OIL

  - Supply shocks have a small impact on oil price fluctuations.
  - Aggregate demand shocks caused low-frequency swings in oil prices.
  - High-frequency dynamics in oil prices due to oil-specific demand shocks, consistent with these being precautionary demand shocks.

- Does it matter for the US economy why the price of real oil increased?

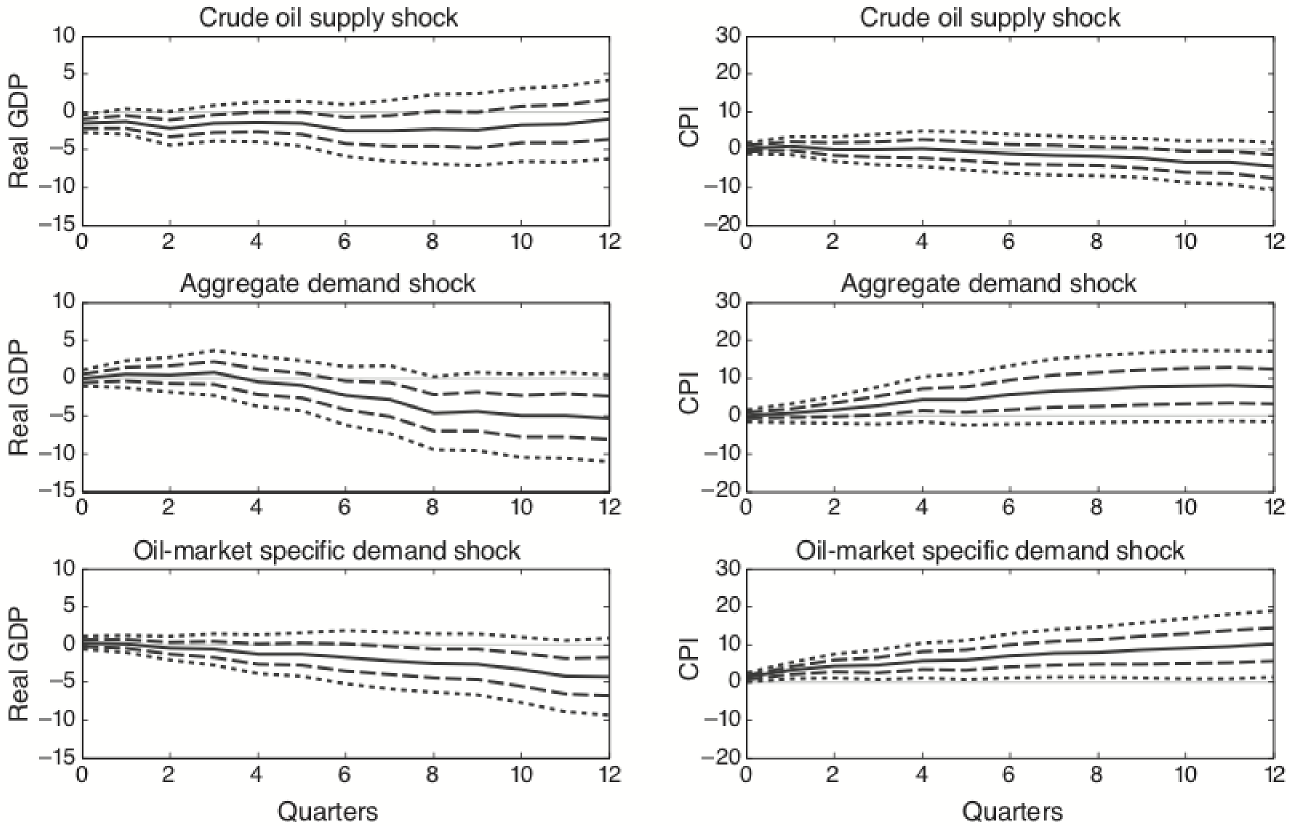


FIGURE 5. RESPONSES OF US REAL GDP AND CPI LEVEL TO EACH STRUCTURAL SHOCK

  - Unexpected reductions in supply cause a temporary decline in GDP and little effect on inflation.
  - Aggregate demand shocks lead to a short-run increase in GDP, but then lower growth in the future due to higher oil prices. Increased economic activity and higher oil prices both lead to higher inflation.
  - Oil-specific demand shocks lower GDP and lead to an increase in inflation.

- These results are controversial. Hamilton (2019) does not like the shipping index, which hinges on a normalization of a base year, and proposes an alternative measure based on world industrial production (OECD+6 major developing countries)
  - 1974-75 looks very different in panel 1 vs. 2
  - recovery after 2008 crisis looks quite different as well

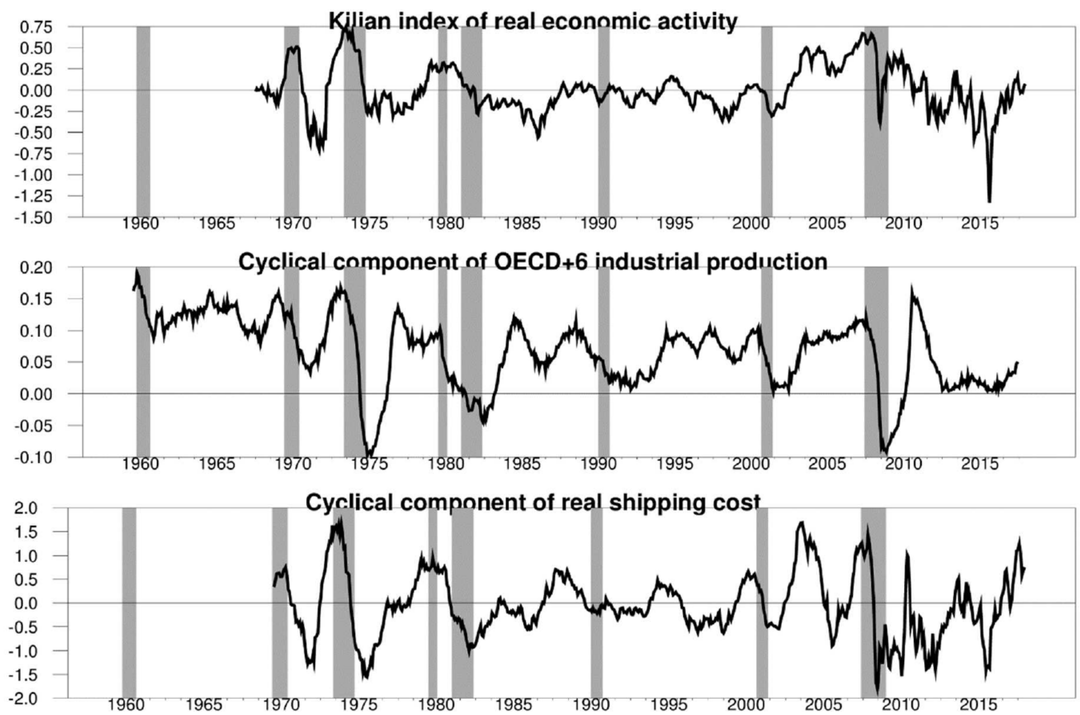


Figure 4. Three different monthly measures of global real economic activity, 1960:1 to 2018:6.

Notes to Figure 4. Top panel: Kilian measure. Middle panel: 2-year change in log of industrial production for OECD countries plus 6 others. Third panel: 2-year change in difference between x_t and the log of the *CPI*.

- Hamilton and Baumeister (2019) also critique the Cholesky decomposition method for shock identification and propose sign restrictions instead for identification.

- Interesting back and forth between these authors.

5. Topic: Financialization of commodities

- Financialization of commodities refers to the fact that there has been a large growth in the amount of capital invested in major commodity indices, like the GSCI. This is now very easy via ETFs.

- This may have made commodities more similar to financial assets and changed the risk properties of commodities.

- On the one hand, by bringing more capital into the commodities market, financialization may mitigate hedging pressure and improve risk sharing (ability of hedgers to hedge cheaply).

- On the other hand, new shocks (outside commodity markets) that hit investors may now be transmitted to the commodities markets, and limit that risk sharing possibly at important times (to the detriment of the commercials).

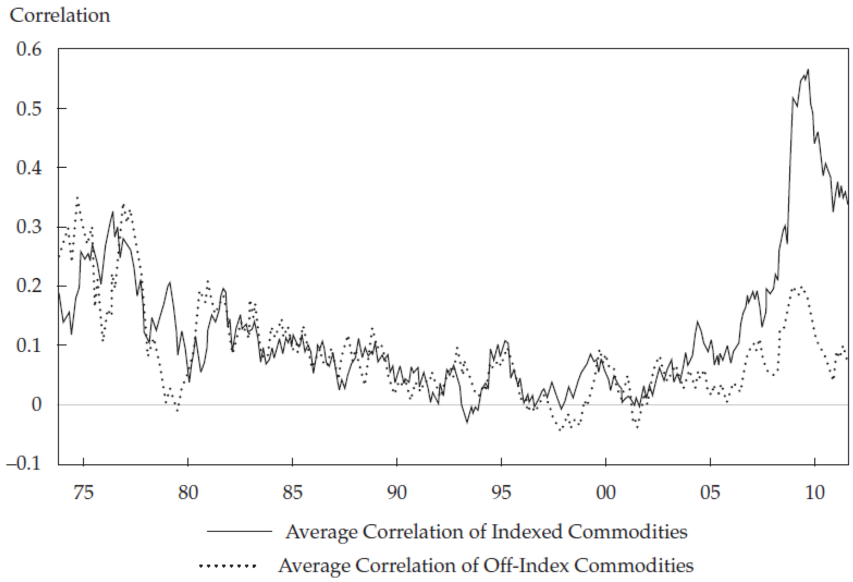
- Basak and Pavlova (2016) provide an equilibrium model of this phenomenon.

- Financialization may also affect information discovery in commodity markets. Maybe investors add noise to futures prices so that they become a less clear signal of global demand as in Sockin and Xiong (2015).

- Cheng and Xiong (2014) provide a survey on financialization of commodities.

- See Tang and Xiong (2012) for empirical work:

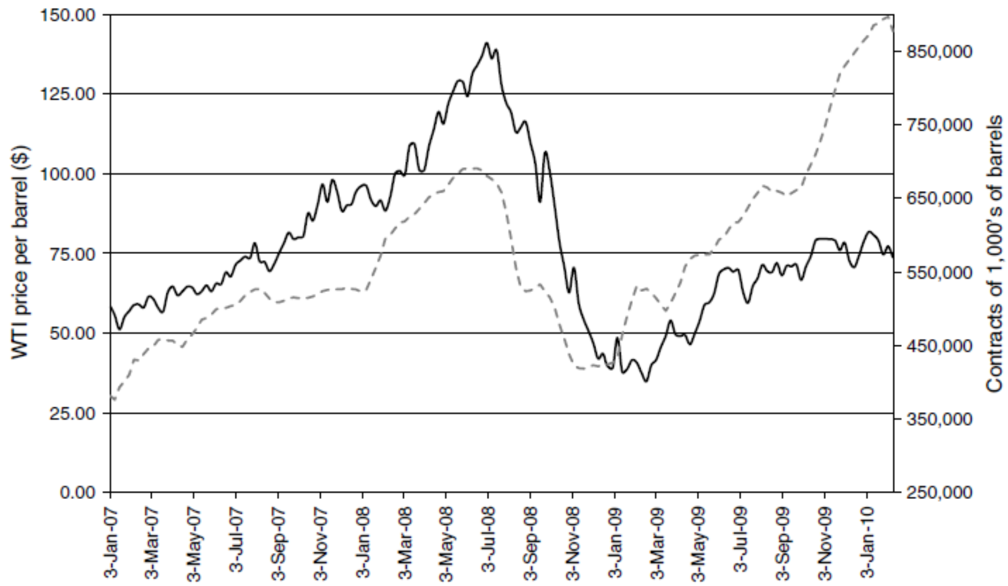
Figure 7. Average Correlations of Indexed and Off-Index Commodities, 1973–2011



Notes: This figure depicts the average return correlations of commodities in the S&P GSCI and DJ-UBSCI and commodities off these indices. We separated the samples of indexed and off-index commodities. In each sample, we constructed an equal-weighted return index for each commodity sector. A commodity is not included in the index until its average daily futures trading volume in a given calendar year is larger than $20 million. Then, for both indexed and off-index commodities, we computed the equal-weighted averages of the one-year rolling return correlations of all sector pairs.

- Singleton (2014) also links investor flows and commodity prices

Figure 1 Commodity Index Long Positions Inferred from the CIT Reports (Dashed Line, Right Sale) Plotted Against the Front-Month NYMEX WTI Futures Price (Solid Line, Left Scale)



- Singleton (2014) finds the largest effect on prices from index positions and managed-money investors (hedge funds).
- Identifying causal effects is challenging.