Macroeconomic determinants of international commodity prices

Jeffrey Frankel

Harpel Professor Capital Formation & Growth

Harvard University

Keynote Address

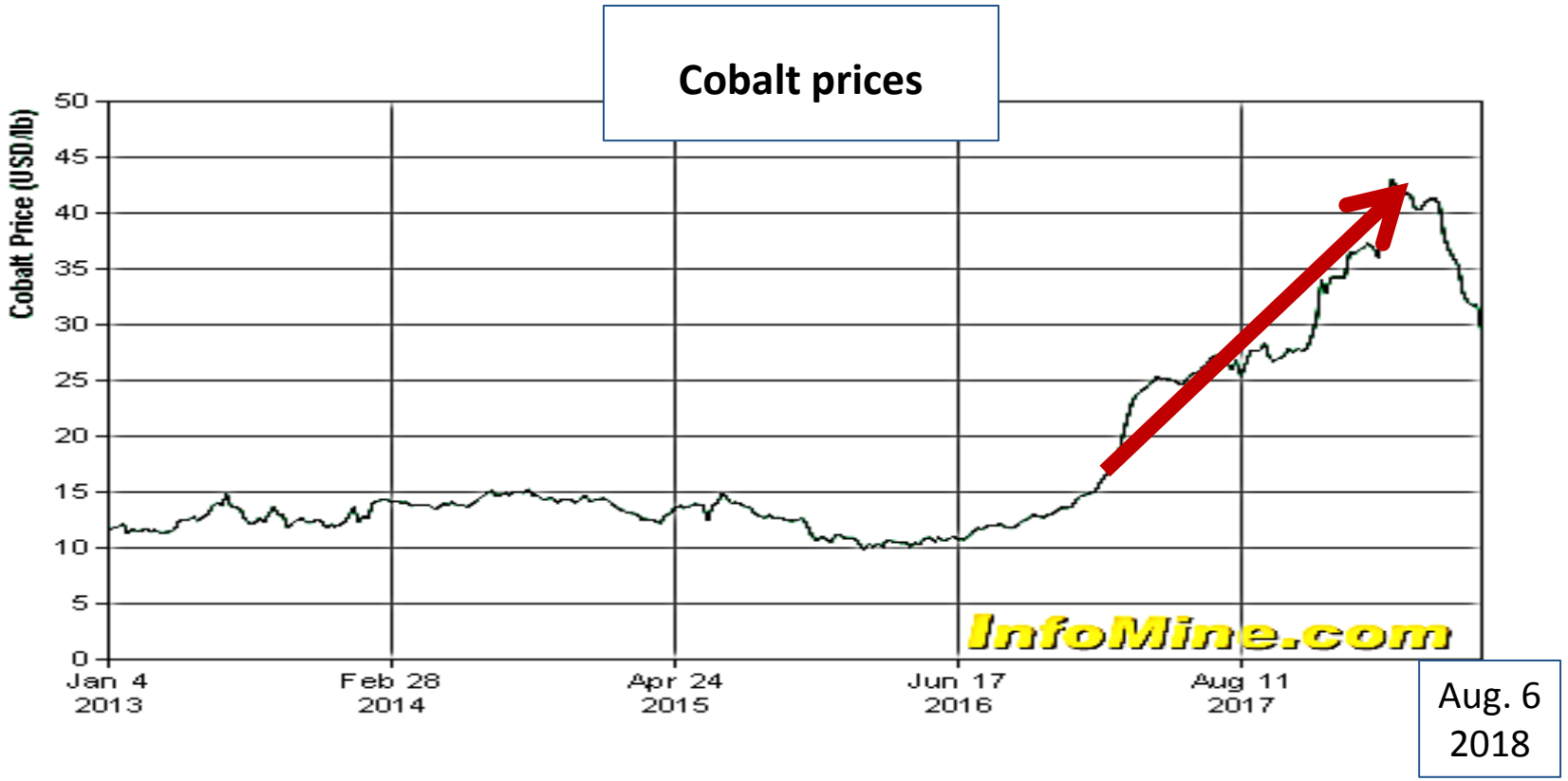
JPMCC International Commodities Symposium,

University of Colorado Denver Business School

August 13-15, 2018

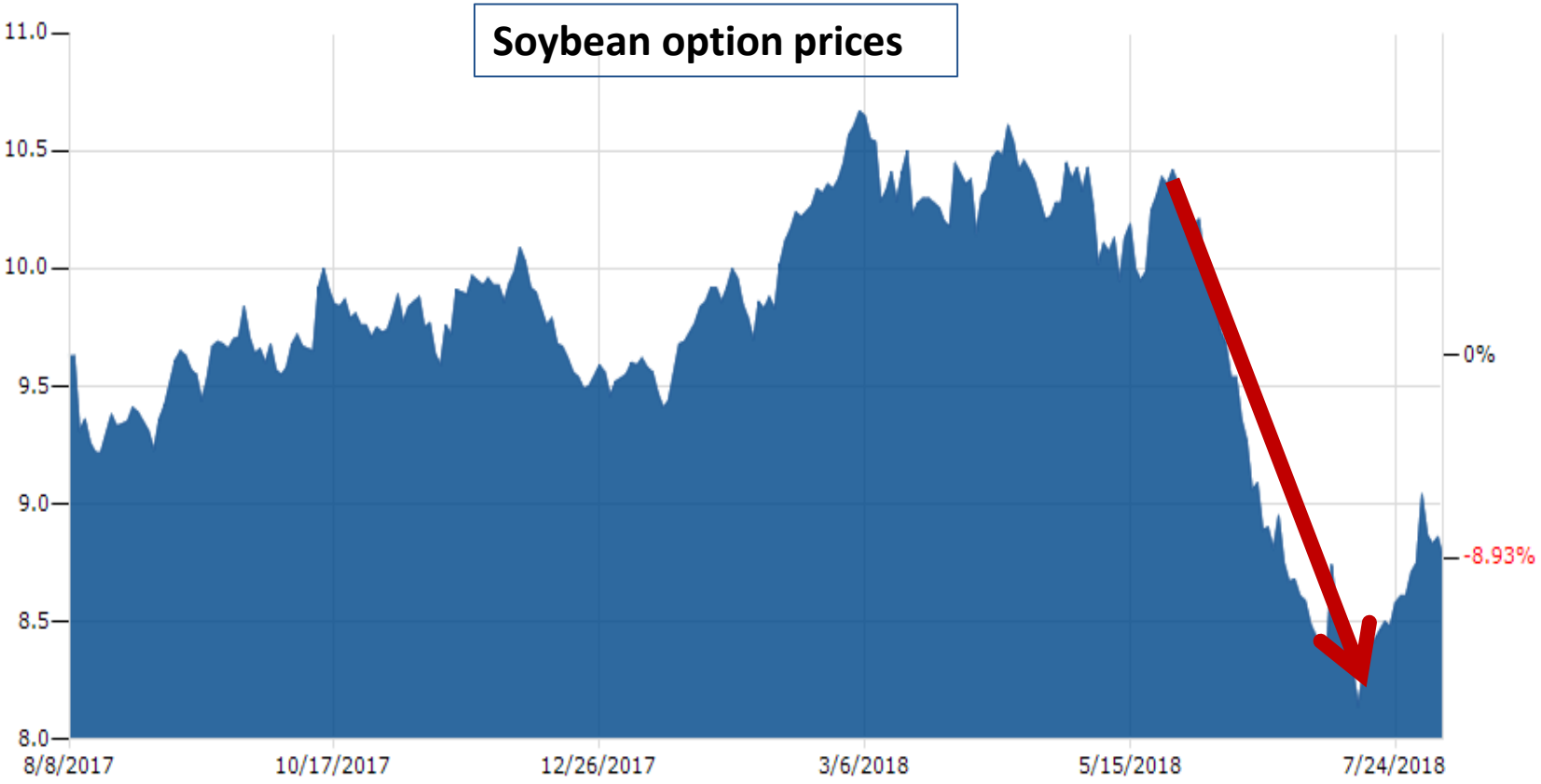
What drives commodity prices?

- Individual commodities are of course influenced by individual micro causes.
  - E.g., why did cobalt prices quadruple in 2017-18?
    - Rising EV battery demand;
    - Congo-concentrated supply hit by instability & sanctions.



What drives commodity prices?

- Individual micro causes.
  - Why did soybean prices fall by 20% in June-July, 2018?
  - Chinese retaliation against Trump tariffs.



Source: *Business Insider*, 8/7/2018

What drives commodity prices?

- Individual micro causes.
  - Why did oil prices rise in June?
  - In part, US sanctions on Iran after withdrawing from JCPA.

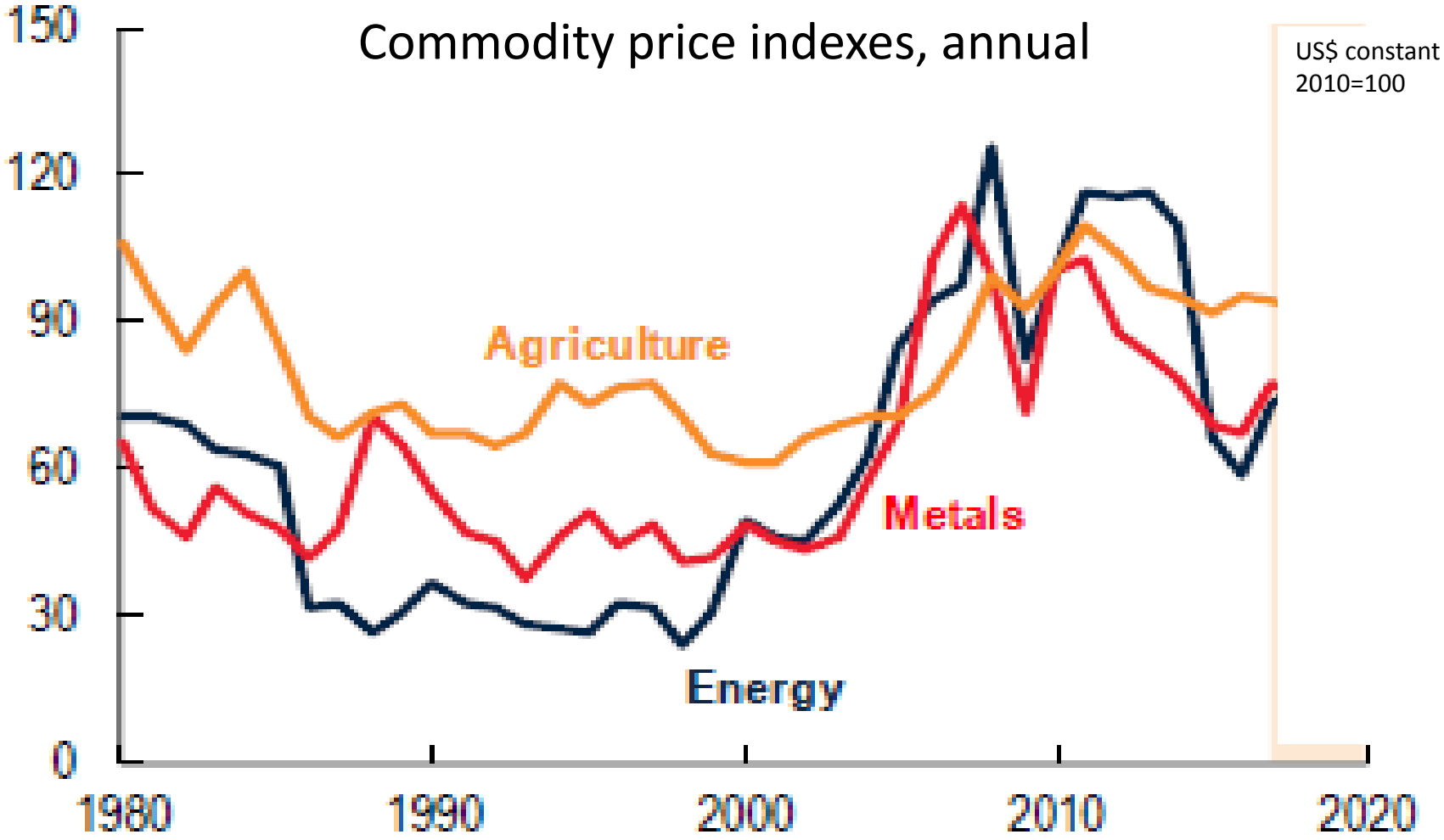
Crude Oil Price: WTI – Cushing, OK, Daily

FRED, Aug. 8, 2018

What drives commodity prices?

- But the extent to which prices of different commodities move together is striking.
    - E.g., Robert Pindyck & Julio Rotemberg, 1990, "The Excess Co-Movement of Commodity Prices," *The Economic Journal*.
- There are direct microeconomic linkages among some of them, to be sure.
- But the correlation is broader than that.

Fig. 1: Commodity prices are (i) volatile & (ii) correlated.



Source: *Commodity Markets Outlook*, World Bank Group, Oct. 2017

Some macroeconomic factors influence commodity prices jointly.

1. Economic Activity: GDP

2. Monetary policy: real interest rate.

   The overshooting model
   theory & evidence.

3. What about exchange rates?

4. Other determinants of net convenience yield
   - Inventories
   - Risk premium

The "carry trade" model.

1. First macro factor: overall economic activity

- as measured by US GDP or a global counterpart.
  - Probably China's growth rate has mattered more for global commodity demand than that of other countries,
    - e.g., Kilian & Hicks (2013).

- Some of the big price swings since 2000 can be explained by GDP.
- But there is more going on.

2. Second macro factor: monetary policy

- The claim: An increase in the real interest rate *r*, has a negative effect on real commodity prices,
  - even controlling for GDP.

- E.g., why did commodity prices:
  - (i) continue to rise sharply mid-2007 – mid-2008?
    - Aggressive Fed easing in 2008.
  - (ii) fall sharply in mid-2014?
    - The end of QE in 2014.
- I have been making this case for over 30 years.
  - "Overshooting model" (1984, 1986, 2006, 2008):
    - effect of *r* on real commodity prices.
  - "The carry-trade model" (2010, 2014):
    - add in also convenience yield & its determinants.

High real interest rates reduce the price of storable commodities through 4 channels:

- ¤ by increasing the incentive for extraction today
  - rather than tomorrow.
  - Think of rates at which oil is pumped, copper mined, or forests logged.
- ¤ by decreasing firms' desire to carry inventories.
  - Think of oil inventories held in tanks or cattle in feed lots.
- ¤ by encouraging speculators to shift out of spot commodity contracts, and into treasury bills.
  - Think of the “financialization" of commodities..
- ¤ by appreciating the domestic currency
  - and so reducing the price of internationally traded commodities in domestic terms.

Derivation of the overshooting model

The relationship can be derived from 2 simple assumptions.

- 1st assumption: "regressive expectations."
- Let:
  $s \equiv$ the log of the spot price of the commodity,
  $p \equiv$ the (log of the) economy-wide price index,
  $q \equiv s-p$, the (log) real price of the commodity, and
  $\bar{q} \equiv$ the long run equilibrium (log) real price of the commodity.
- Market participants observe the real commodity price q today lying either above or below its long-run equilibrium value $\bar{q}$. They expect it to return to equilibrium over time, at an annual rate proportionate to the gap:
- $E[\Delta q] \equiv E[\Delta(s-p)] = -\theta(q-\bar{q})$ (1)
  or $E(\Delta s) = -\theta(q-\bar{q}) + E(\Delta p)$. (2)

$$E(\Delta s) = -\theta (q - \bar{q}) + E(\Delta p) \qquad (2)$$

+ 2nd assumption, speculative arbitrage:

$$E(\Delta s) + c = i, \qquad (3)$$

where $c \equiv$ *net convenience yield.**

$$\Rightarrow \quad -\theta (q - \bar{q}) + E(\Delta p) + c = i$$

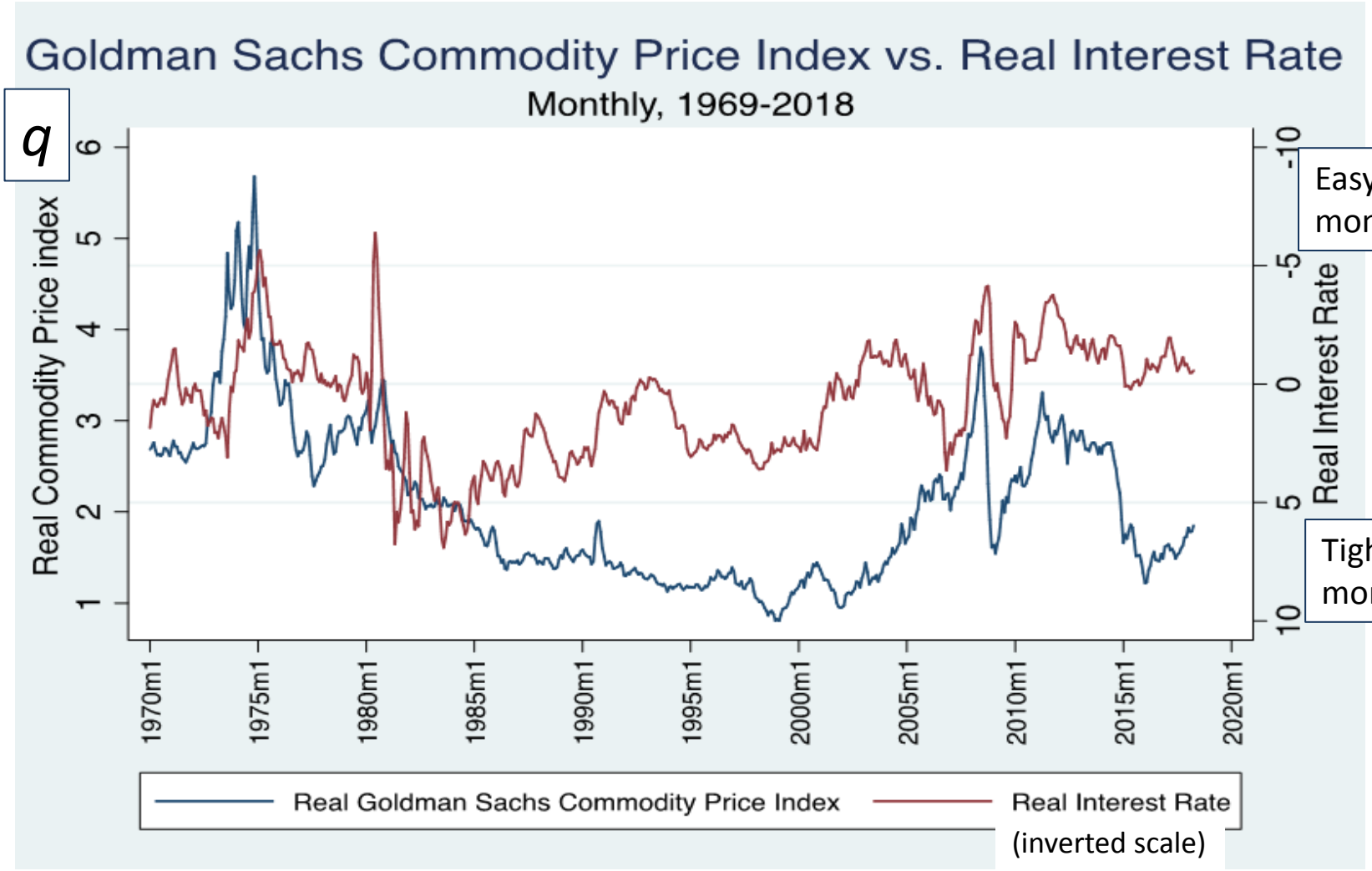
$$\Rightarrow \quad q - \bar{q} = -(1/\theta)(r - c) \qquad (4).$$

- So q responds negatively to the real interest rate, $r \equiv i - E(\Delta p)$,
  - holding $\bar{q}$ & c constant.

* $c \equiv cy - sc - rp \equiv$ *convenience yield – storage cost – risk premium.*

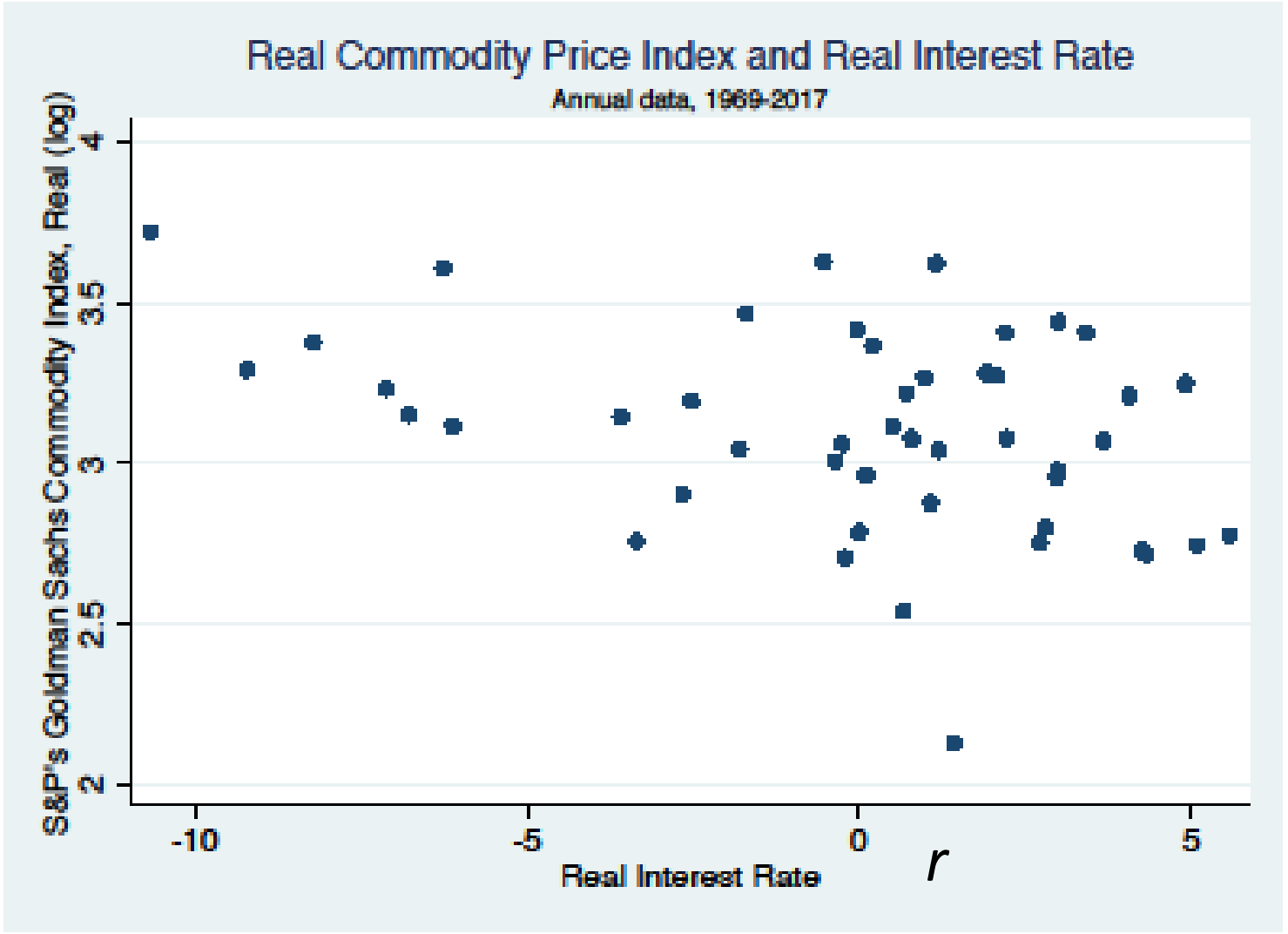
The overshooting equation: $q = \overline{q} - (1/\vartheta)(r-c)$

q is negatively related to the real interest rat r.



Thanks to Marco Martinez del Angel.

The real commodity price index is negatively related to the real interest rate.



Thanks to Shruti Lakhtakia

OLS estimates of the overshooting equation

Regression of real commodity price indices against real interest rate (1950-2012)

Table 1	Dependent variable: log of commodity price index, deflated by US CPI			
VARIABLES	CRB index	Dow Jones Index	Moody's index	Goldman Sachs Index
Real interest rate	**-0.041*** **	**-0.034*** **	**-0.071*** **	**-0.075*** **
	(0.007)	(0.006)	(0.005)	(0.007)
Constant	0.900***	0.066***	2.533***	0.732***
	(0.017)	(0.016)	(0.011)	(0.018)
Observations	739	739	739	513
R^2	0.04	0.04	0.25	0.18
*** p<0.01 (Standard errors in parentheses.)				

Updated estimates of overshooting model

Commodity price indices are significantly negatively correlated with real interest rates.

	Feb 1951-Apr.2018	Feb 1951-Feb 2014	Feb 1951-Apr.2018	Dec1969-Apr.2018
	(1)	(2)	(3)	(4)
	Dependent variable: Log of Real Commodity Price Index			
VARIABLES	CRB (BLS) Foods Price Index	Dow Jones-AIG Commodity Price Index	Moody's Commodity Price Index	Goldman Sachs Commodity Price Index
Real Interest Rate	**-0.026*** **	**-0.026*** **	**-0.088*** **	**-0.071*** **
	(0.007)	(0.007)	(0.005)	(0.006)
Constant	0.847***	0.043**	2.594***	0.713***
	(0.017)	(0.017)	(0.013)	(0.016)
Observations	807	757	807	581
R^2	0.018	0.022	0.295	0.172
***** p<0.01, ** p<0.05.**		**(Heteroskedastic robust standard errors in parentheses.)**		

•REAL INTEREST RATE (Month X, YEAR T) = [3-TBILL(Month X, YEAR T)/100 - INFLATION (Month X-1, YEAR T)]*100 for months (Feb-Dec) ; for Jan we take INFLATION (Month X-1, YEAR T-1). • INFLATION (Month X, Year T) =Log CPI (Month X, Year T) – Log CPI (Month X, Year T-1).
•Source for 3-month treasury bill rates: FRB of St. Louis. Source for Commodity Price Indexes: Global Financial Data

Thanks to S.Lakhtakia

3. What about exchange rates and commodity prices in other currencies?

- The limiting case of a small country in an integrated global commodity market:
  - a 1% exchange rate change translates into an immediate 1 % commodity price change expressed in terms of local currency.
  - even if the price hasn't fallen in terms of foreign currency.
- Even for the US, $ depreciation => commodity price↑
  - (though smaller & slower than for other countries):
  - $ ↓ => global demand for commodity ↑, global supply ↓,
- Regardless the country, the exchange rate is endogenous.
- Real interest differentials move real exchange rates,
  - & so move local-currency real commodity prices,
  - relative to the real $ commodity price.

Determining commodity prices in non-$ currencies.

Dependent variable: Log real CRB commodity price index in local currency				
	Short Rates: **US r**	**r diff.**	Long Rates: **US r**	**r diff.**
Australia	**-0.023***	**-0.076***	**-0.057***	**-0.067***
1/1950-8/2005.	(0.006)	(0.003)	(0.005)	(0.004)
Brazil	**-0.024***	**-0.006***	**-0.161***	**0.001**
7/65-12/89, 1/95-8/05	(0.007)	(0.002)	(0.019)	(0.001)
Canada	**-0.047***	**-0.065***	**-0.073***	**-0.076***
1/1950-9/2005	(0.005)	(0.005)	(0.004)	(0.006)
Chile	**-0.063***	**-0.021***	**-0.092***	**-0.018***
7/1997-9/2005	(0.006)	(0.004)	(0.014)	(0.003)
Mexico	**0.055***	**-0.017***	**0.047***	**0.000**
1/1978-9/2005	(0.013)	(0.002)	(0.011)	(0.003)
NZ	**0.001**	**-0.067***	**-0.081***	**-0.075***
3/1978-8/2005	(0.009)	(0.004)	(0.006)	(0.004)
Switzerland	**0.034***	**-0.054***	**-0.171***	**-0.095***
1/1980-9/2005	(0.016)	(0.009)	(0.013)	(0.012)
UK	**-0.053***	**-0.086***	**-0.106***	**-0.023***
1/1950-9/2005	(0.010)	(0.007)	(0.007)	(0.006)

* indicates coefficient significant at the 5% level of significance. (Robust standard errors.)

Frankel (2008)

4. Determinants of net convenience yield

Now, complete the "carry trade" equation

There is no reason for the net convenience yield, *c*, to be constant.

$$q - \bar{q} = -(1/\theta)(r - c) \qquad (4)$$

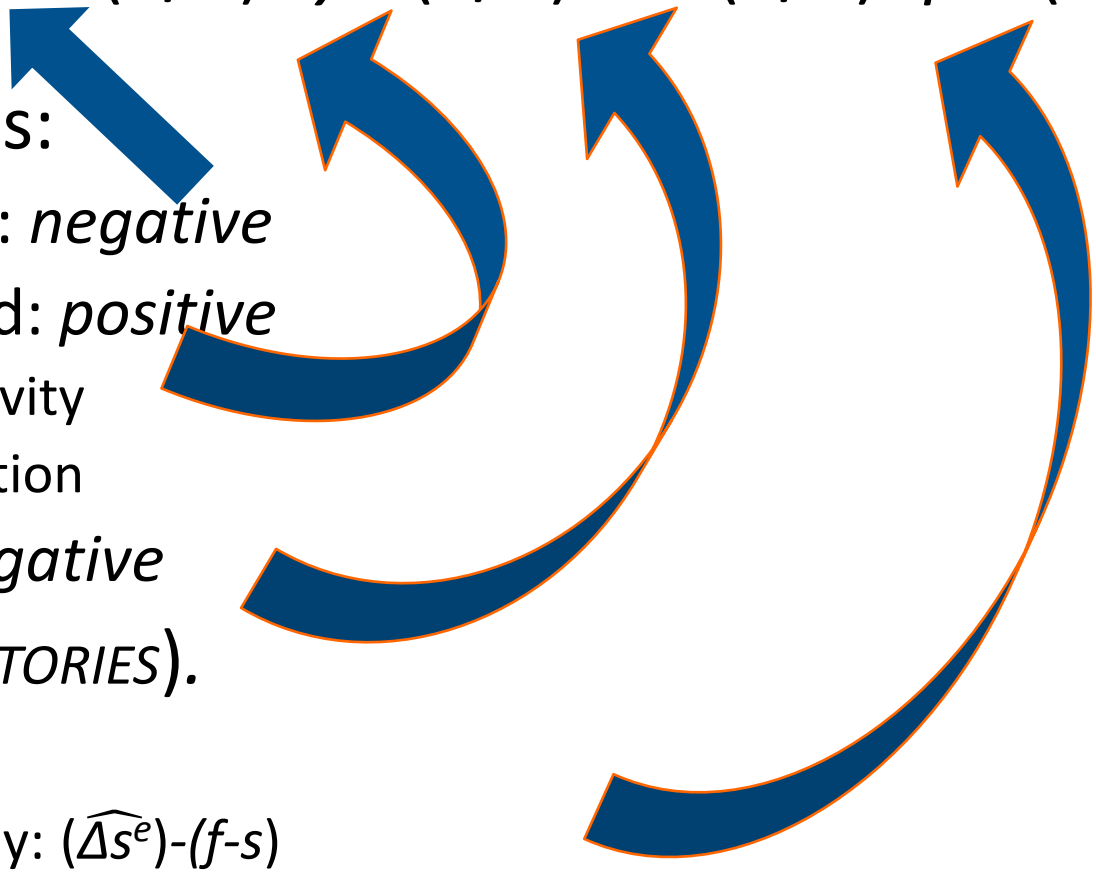
$$c \equiv cy - sc - rp$$

Substituting into (4),

$$q = \bar{q} - (1/\theta)\, r + (1/\theta)\, cy - (1/\theta)\, sc - (1/\theta)\, rp \qquad (5)$$

Complete “carry trade” equation for price determination, continued

$$q = \bar{q} - (1/\theta)\, r + (1/\theta)\, cy - (1/\theta)\, sc - (1/\theta)\, rp \quad (5)$$



Hypothesized effects:

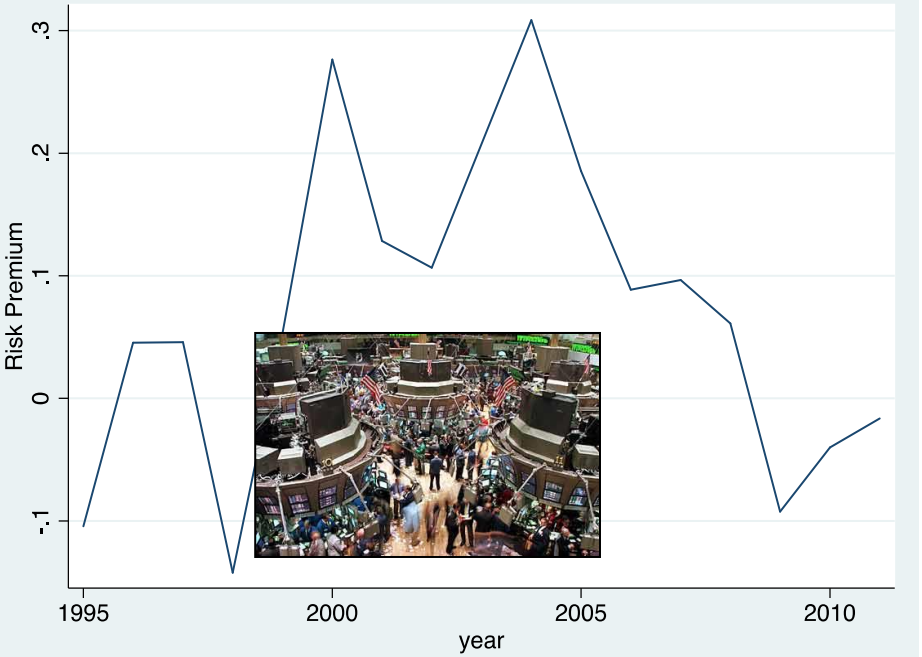
- Real interest rate: *negative*
- Convenience yield: *positive*
  - <= Economic activity
  - <= Risk of disruption
- Storage costs: *negative*
  - $sc = \Phi\,(INVENTORIES)$.
- Risk premium *rp*
  - Measured directly: $(\widehat{\Delta s^e})$-$(f$-$s)$
  - Or as determined by volatility (*ambiguous sign)*
    - measured by actual volatility
    - or by option-implied subjective volatility.

Estimation of the carry-trade equation.

- My 2014 paper estimated for the period 1950-2012 the complete equation that included the micro variables:
  - commodity-specific data on inventories, volatility,
  - and survey expectations of future price changes.
- I found the real interest rate had particularly strong negative effects on the prices of copper, cattle, hogs, oats & soybeans.
- Inventories had a particularly strong negative effect on the prices of copper, oats, & platinum.
- For a complete panel across the 11 commodities where all data were available, all four variables of interest appeared significant: real interest rate, global business cycle, inventories, and volatility.
  - When the equation was estimated on first differences, significance was lost, in particular, for inventories & volatility.

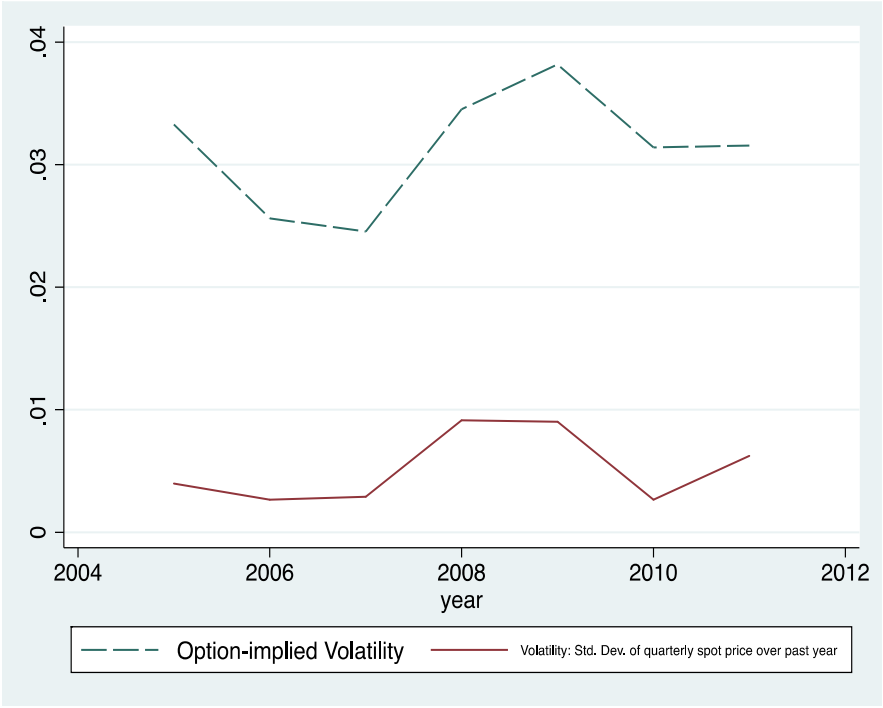
Risk premium

$(f\text{-}s) - \widehat{E\Delta s}$



2 measures of volatility

option-implied & actual volatilities



The positive risk premium seemed to have disappeared after 2005 ($\widehat{E\Delta s}$ measured by survey data), despite no decline in volatility.

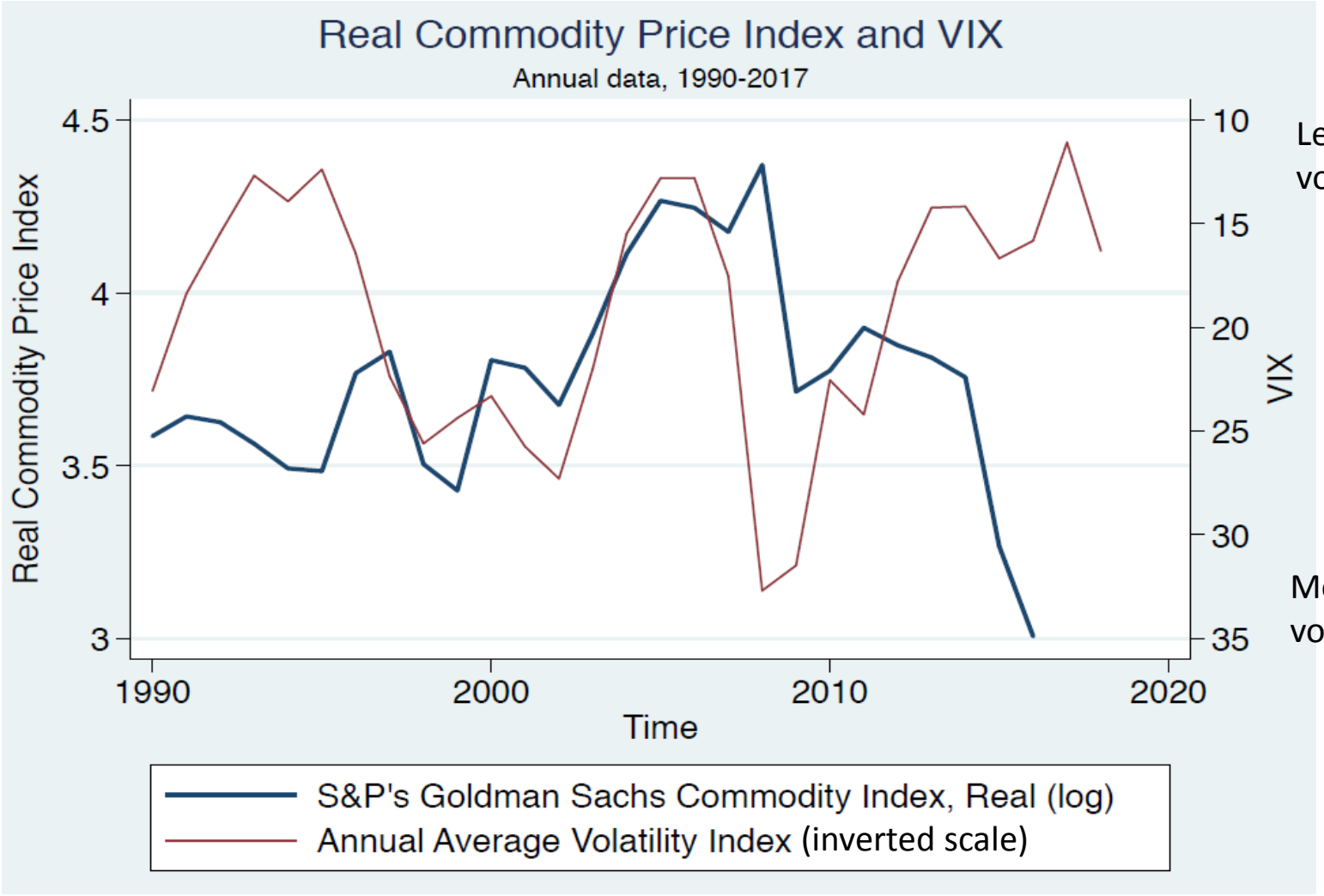
Consistent with Hamilton &Wu's (2013) interpretation of the financialization hypothesis: Investors in commodity indices took the long side of the futures market after 2005.

From Frankel (2014)

5. Updated tests

- There is some negative correlation between perceived volatility as measured by the VIX and the commodity price index.
  - E.g., prices high in 2006, when VIX low ("risk on"),
  - & prices low in 2009, when VIX high ("risk off").
- But the VIX is not a significant determinant
  - when controlling for *r* and GDP.

VIX-implied volatility appears negatively correlated with real commodity price index.



Less volatile ↑

More volatile ↓

Thanks to S.Lakhtakia

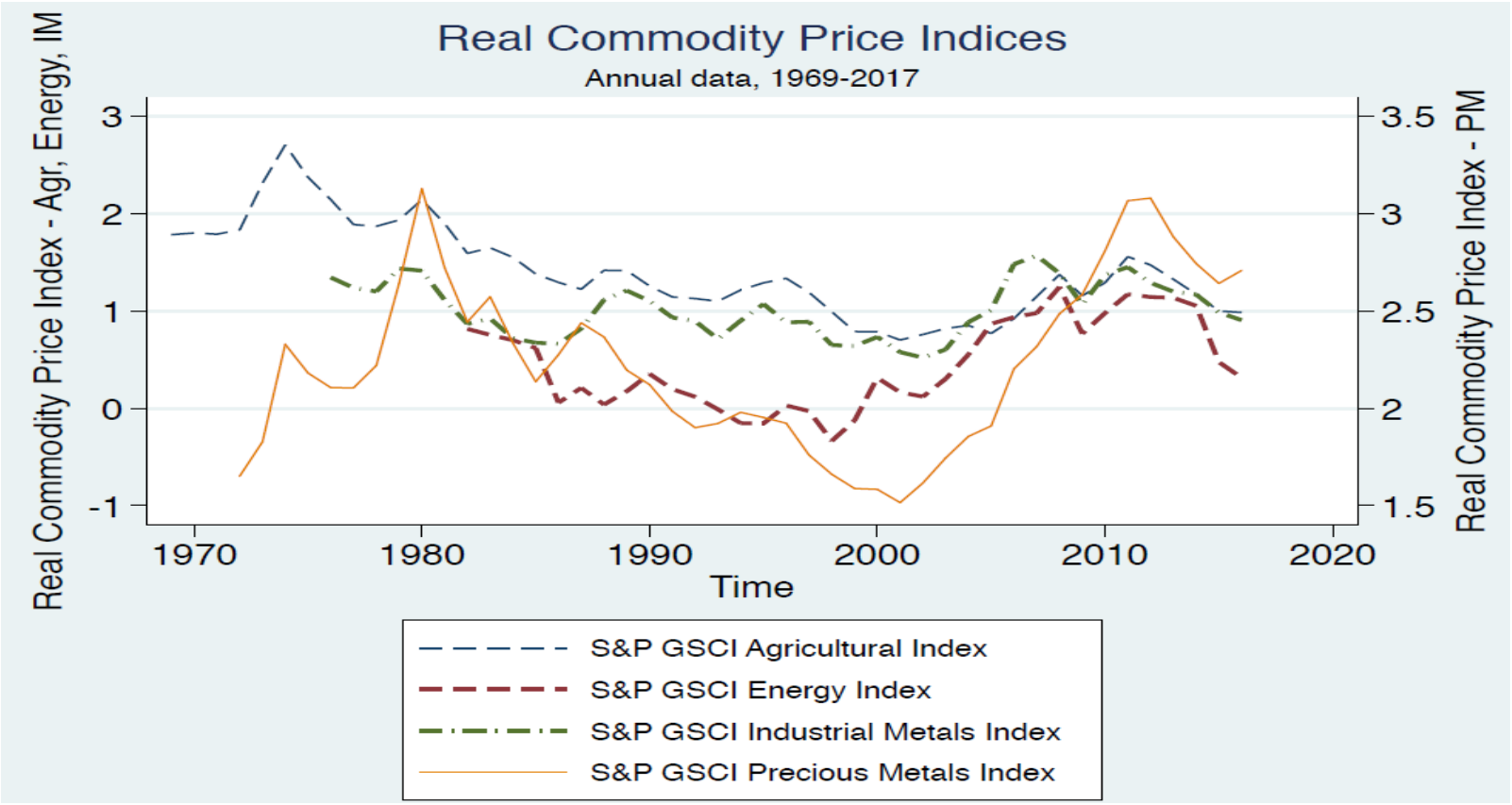
Updated tests for real commodity price index show significant negative effect of *r* and positive effect of GDP.

Dependent variable:	Real Commodity Price Index				
	1	2	3	4	5
Real Interest Rate	-0.035***	-0.015*	-0.023**	-0.029***	-0.013
	(0.010)	(0.009)	(0.009)	(0.010)	(0.008)
Real Commd PI trend	-1.627			-1.817	
	(2.203)			(1.877)	
Lagged Real ComPI		0.689***			0.596***
		(0.153)			(0.147)
Real US GDP			4.676***	4.738***	3.501***
			(1.226)	(1.206)	(0.962)
Constant	8.198	0.958*	3.093***	8.789	1.244***
	(6.928)	(0.476)	(0.040)	(5.897)	(0.455)
Observations	47	46	47	47	46
R^2	0.150	0.497	0.300	0.322	0.587

*** p<0.01, ** p<0.05, * p<0.1 (Robust standard errors in parentheses.)

Thanks to S.Lakhtakia

Consider four components of price index



In regressions for the four price indices,
r has a negative sign for all variations. It is most consistently significant in the case of industrial metals prices.

Thanks to S.Lakhtakia

Stylized macro effects on commodity prices

Period	GDP growth	Monetary ease	*r*	Value of $	$ commodity prices
2004-07	↑	↓	↑	↓	↑
2007-08	↓	↑	↓	↓	↑
2008-09	↓	↑	↓	↑	↓
2010-11	↑	↑	↓	↓	↑
2014-16	↑	↓	↑	↑	↓
Forecast (My guess, as of 2018)			↑	↑	↓

Some references by the author on macroeconomic determination of commodity prices.

The overshooting model: Real interest rates influence real commodity prices.

- "Expectations and Commodity Price Dynamics: The Overshooting Model," 1986, *American Journal of Agricultural Economics* 68, no. 2, May, pp.344-48.
- "Commodity Prices, Money Surprises, and Fed Credibility," with Gikas Hardouvelis, 1985, *Journal of Money, Credit & Banking* 17, no.4, Nov., 427-38.

Determinants of commodity prices in non-$ currencies

- "The Effect of Monetary Policy on Real Commodity Prices," 2008, *Asset Prices and Monetary Policy*, John Campbell, ed. (U.Ch.Press), 291-327. NBER WP 12713.

The "carry trade" model: Determinants of convenience yield matter too.

- "Determination of Agricultural and Mineral Commodity Prices," with Andrew Rose, 2010, in *Inflation in an Era of Relative Price Shocks* (Reserve Bank of Australia), pp. 9-51. HKS RWP 10-038.
- "Effects of Speculation and Interest Rates in a 'Carry Trade' Model of Commodity Prices," 2014, *Journal of International Money and Finance,* vol.42, pp. 88-112. NBER WP 19463.





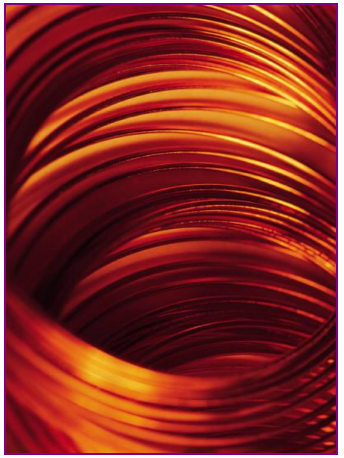




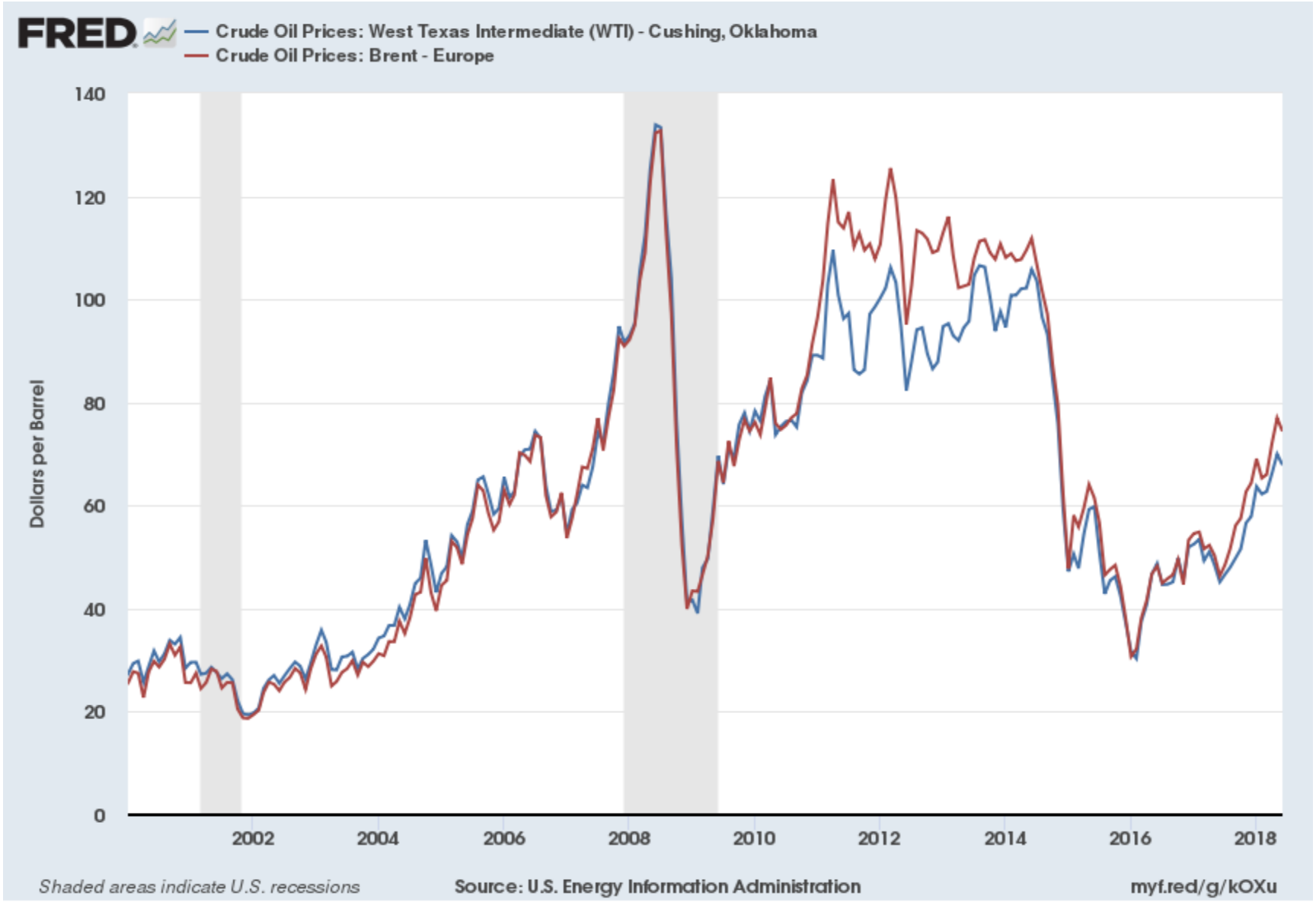




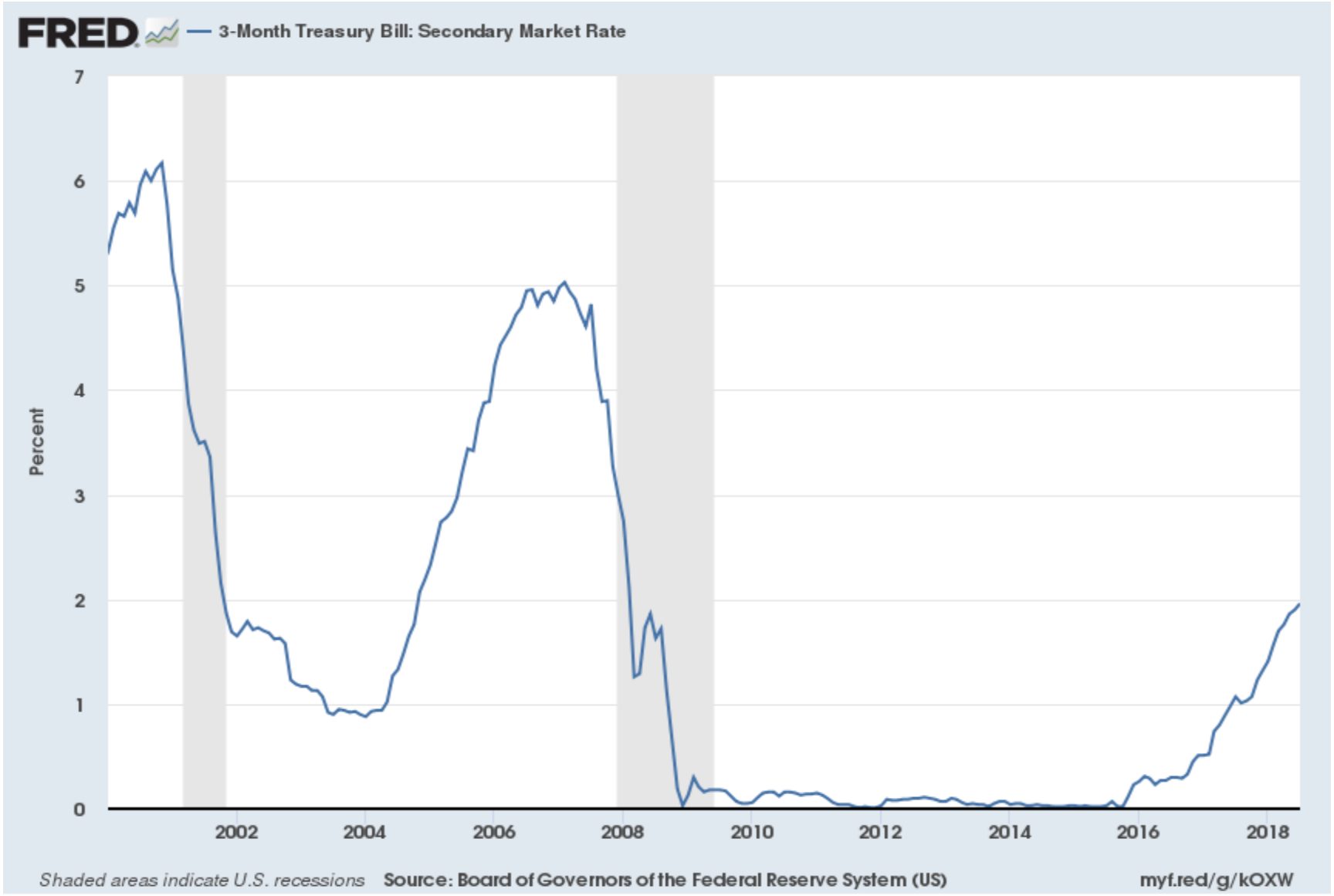



Appendix: Oil prices (Jan. 2000 – June 2018)



Short-term interest rates: Jan. 2000 – July 2018



Value of dollar (Jan. 2000-Aug. 2018)

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Jeffrey Frankel

HARVARD UNIVERSITY
JOHN F. KENNEDY SCHOOL OF GOVERNMENT

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