

# Macroeconomic determinants of international commodity prices

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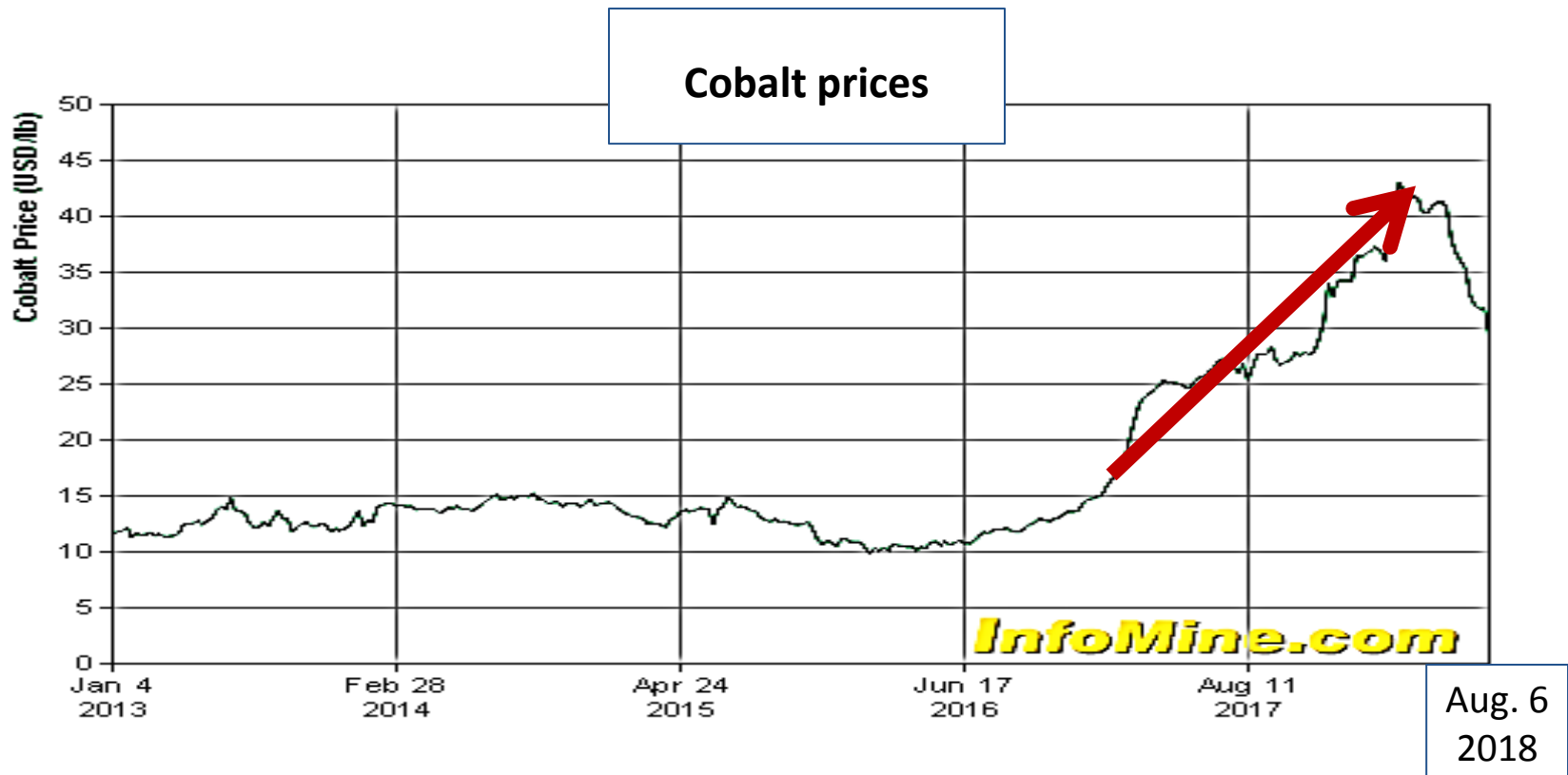


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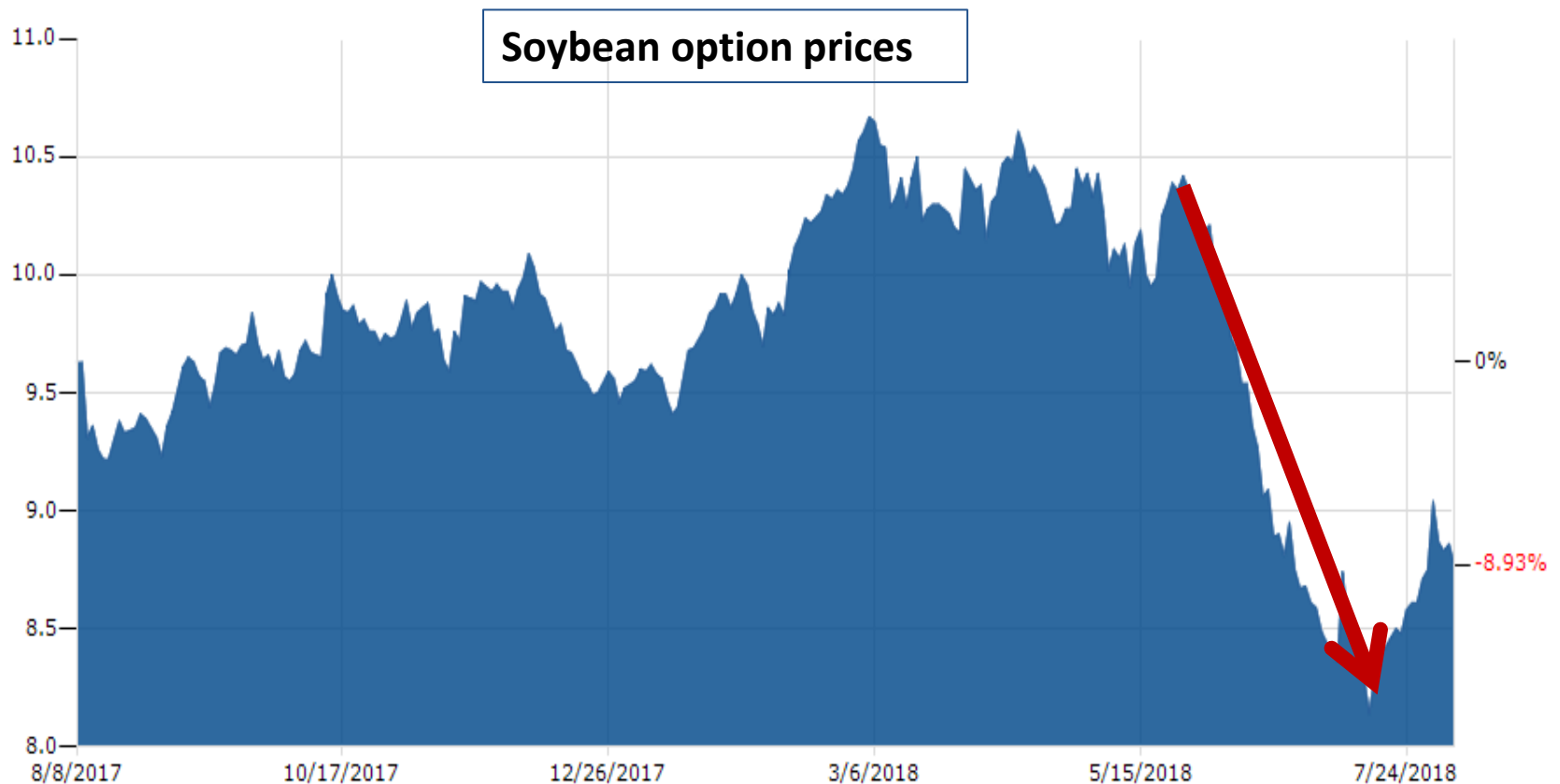
# What drives commodity prices?

- 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.

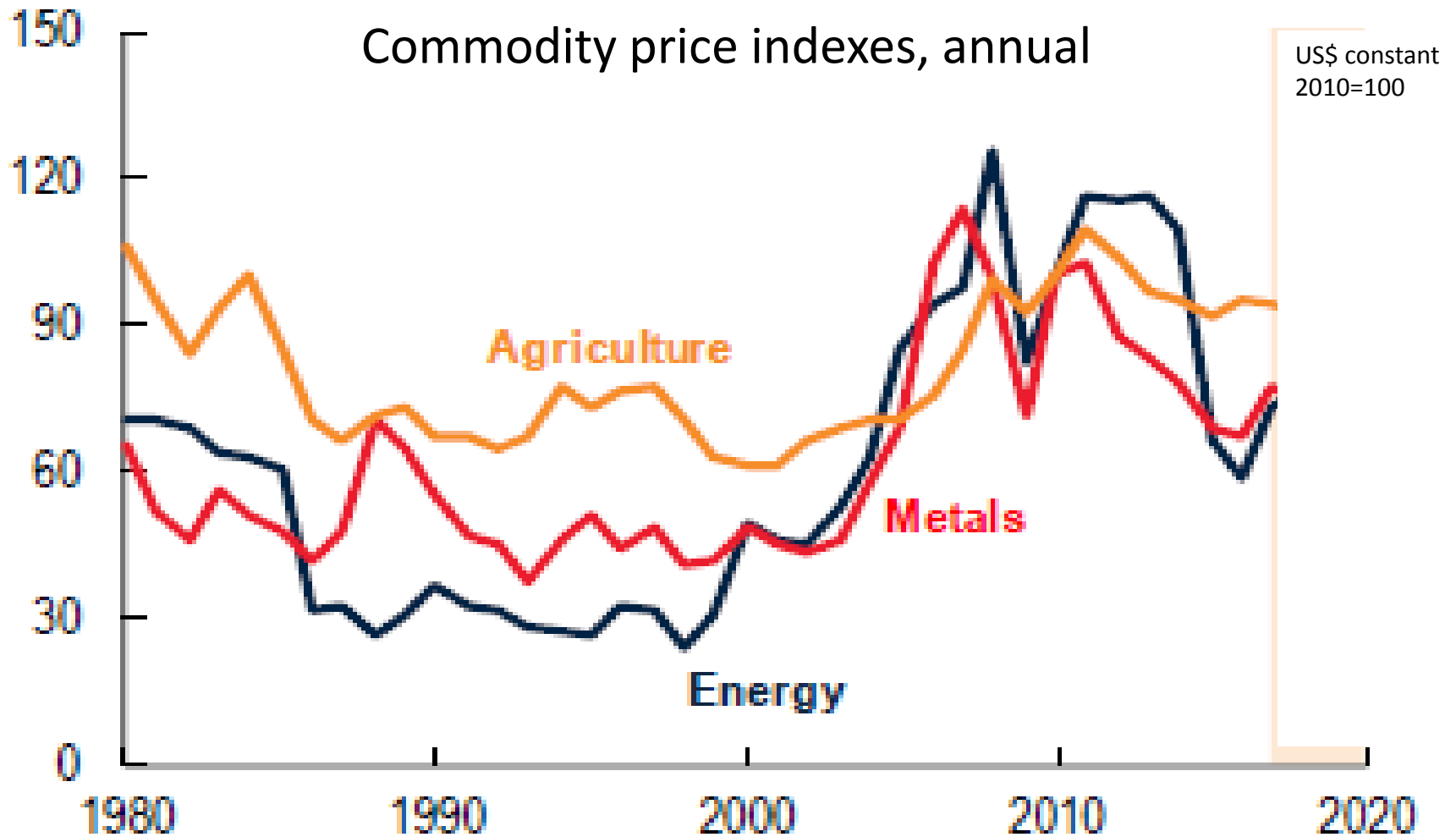
**Crude Oil Price: WTI – Cushing, OK, Daily**



## 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,
  - even if the price hasn't fallen in terms of foreign currency.

# Derivation of the overshooting model

The relationship can be derived from 2 simple assumptions.

- 1<sup>st</sup> 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)

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

+ 2<sup>nd</sup> assumption, speculative arbitrage:

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

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

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

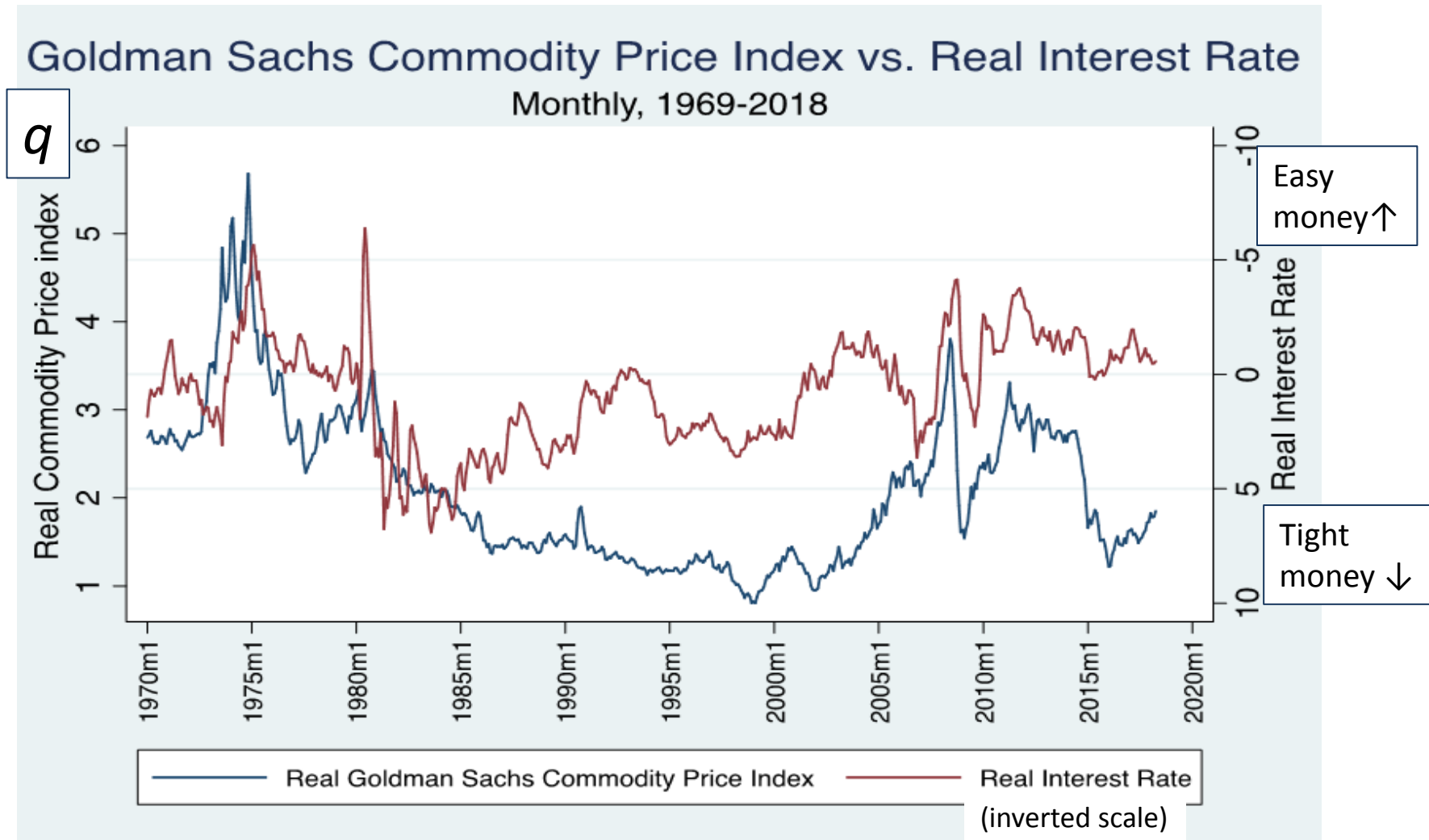
$$\Rightarrow q - \bar{q} = -(1/\theta)(r - c) \quad (4).$$

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

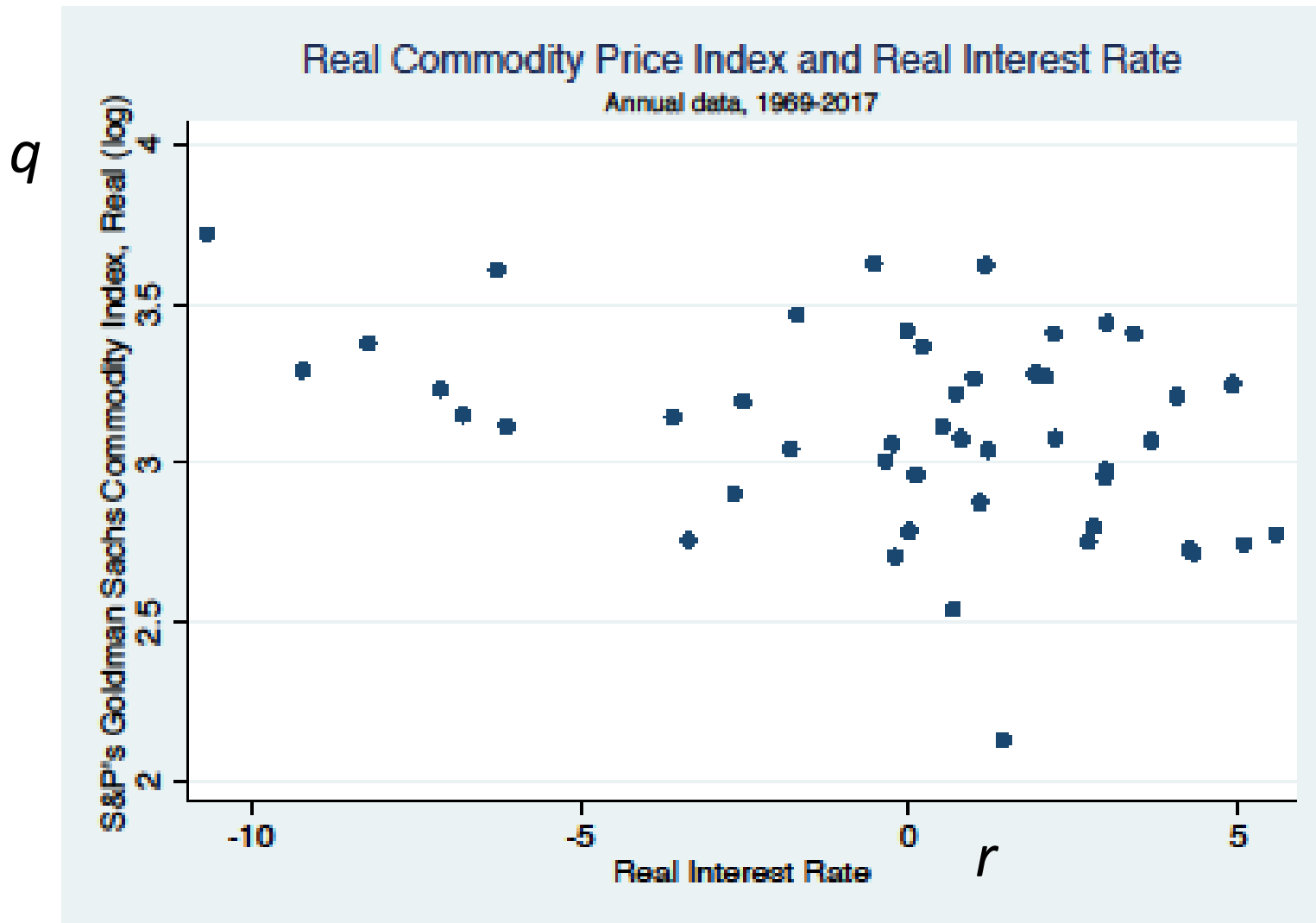
\*  $c \equiv cy - sc - rp \equiv$  convenience yield – storage cost – risk premium.

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

$q$  is negatively related to the real interest rate  $r$ .



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



# OLS estimates of the overshooting equation

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

<b>Table 1</b>	<b>Dependent variable: log of commodity price index, deflated by US CPI</b>			
<b>VARIABLES</b>	<b>CRB index</b>	<b>Dow Jones Index</b>	<b>Moody's index</b>	<b>Goldman Sachs Index</b>
<b>Real interest rate</b>	<b>-0.041***</b>	<b>-0.034***</b>	<b>-0.071***</b>	<b>-0.075***</b>
	(0.007)	(0.006)	(0.005)	(0.007)
<b>Constant</b>	<b>0.900***</b>	<b>0.066***</b>	<b>2.533***</b>	<b>0.732***</b>
	(0.017)	(0.016)	(0.011)	(0.018)
<b>Observations</b>	739	739	739	513
<b>R<sup>2</sup></b>	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	<b>-0.026***</b>	<b>-0.026***</b>	<b>-0.088***</b>	<b>-0.071***</b>
	(0.007)	(0.007)	(0.005)	(0.006)
Constant	<b>0.847***</b>	<b>0.043**</b>	<b>2.594***</b>	<b>0.713***</b>
	(0.017)	(0.017)	(0.013)	(0.016)
Observations	807	757	807	581
R <sup>2</sup>	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

### 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 for the US, \$ depreciation => commodity price  $\uparrow$ 
  - though smaller & slower than for other countries.
- 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.			
<b>Australia</b> 1/1950-8/2005.	<b>-0.023*</b> (0.006)	<b>-0.076*</b> (0.003)	<b>-0.057*</b> (0.005)	<b>-0.067*</b> (0.004)		
<b>Brazil</b> 7/65-12/89, 1/95-8/05	<b>-0.024*</b> (0.007)	<b>-0.006*</b> (0.002)	<b>-0.161*</b> (0.019)	<b>0.001</b> (0.001)		
<b>Canada</b> 1/1950-9/2005	<b>-0.047*</b> (0.005)	<b>-0.065*</b> (0.005)	<b>-0.073*</b> (0.004)	<b>-0.076*</b> (0.006)		
<b>Chile</b> 7/1997-9/2005	<b>-0.063*</b> (0.006)	<b>-0.021*</b> (0.004)	<b>-0.092*</b> (0.014)	<b>-0.018*</b> (0.003)		
<b>Mexico</b> 1/1978-9/2005	<b>0.055*</b> (0.013)	<b>-0.017*</b> (0.002)	<b>0.047*</b> (0.011)	<b>0.000</b> (0.003)		
<b>NZ</b> 3/1978-8/2005	<b>0.001</b> (0.009)	<b>-0.067*</b> (0.004)	<b>-0.081*</b> (0.006)	<b>-0.075*</b> (0.004)		
<b>Switzerland</b> 1/1980-9/2005	<b>0.034*</b> (0.016)	<b>-0.054*</b> (0.009)	<b>-0.171*</b> (0.013)	<b>-0.095*</b> (0.012)		
<b>UK</b> 1/1950-9/2005	<b>-0.053*</b> (0.010)	<b>-0.086*</b> (0.007)	<b>-0.106*</b> (0.007)	<b>-0.023*</b> (0.006)		

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

## 4. Other determinants of net convenience yield

### Now, complete the “carry trade” equation

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

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

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



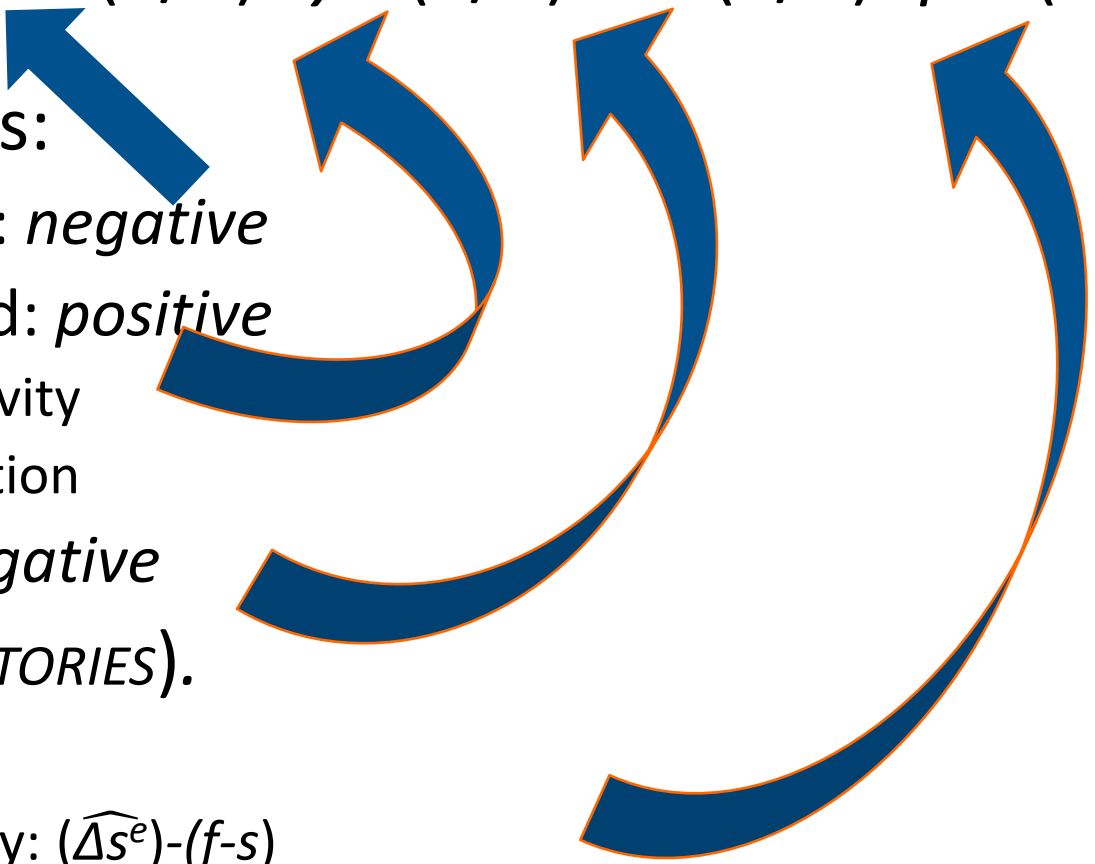
Substituting into (4),

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

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:

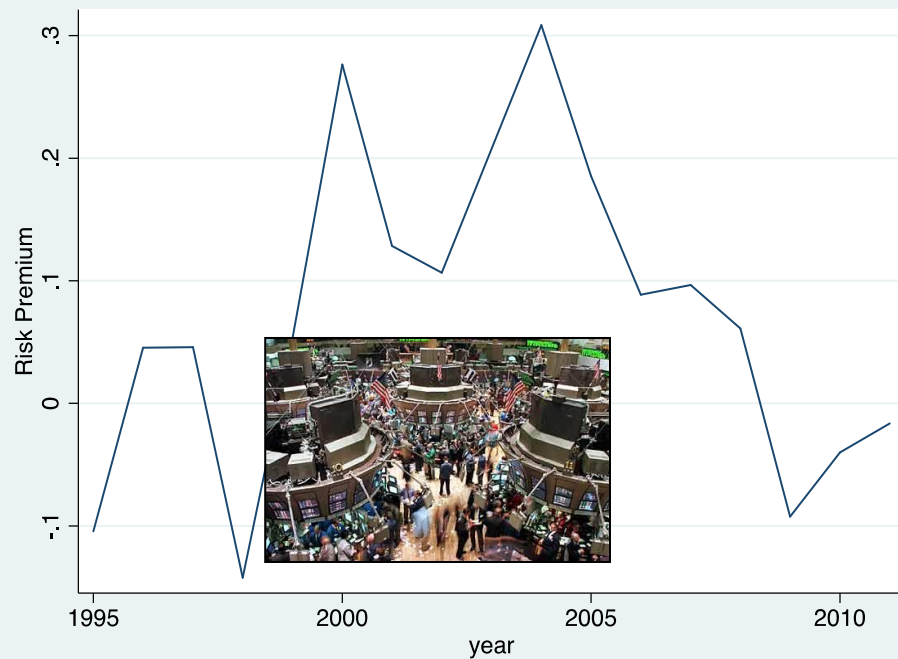
- Real interest rate: *negative*
  - Convenience yield: *positive*
    - $\leq$  Economic activity
    - $\leq$  Risk of disruption
  - Storage costs: *negative*
    - $sc = \Phi (INVENTORIES)$ .
  - Risk premium  $rp$ 
    - Measured directly:  $(\widehat{\Delta s^e}) - (f - s)$
    - Or as determined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

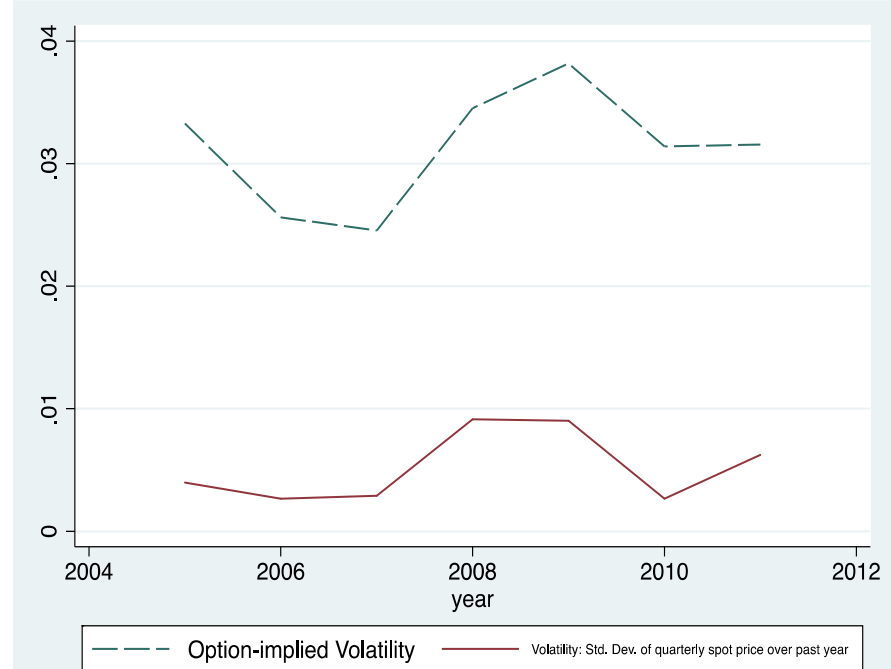
- My 2014 paper estimated for the period 1950-2012 the complete equation that included the micro variables:
  - commodity-specific data on inventories, volatility,
  - and survey expectations of future price changes.
- I found the real interest rate had particularly strong negative effects on the prices 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

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



# 2 measures of volatility *option-implied & actual volatilities*



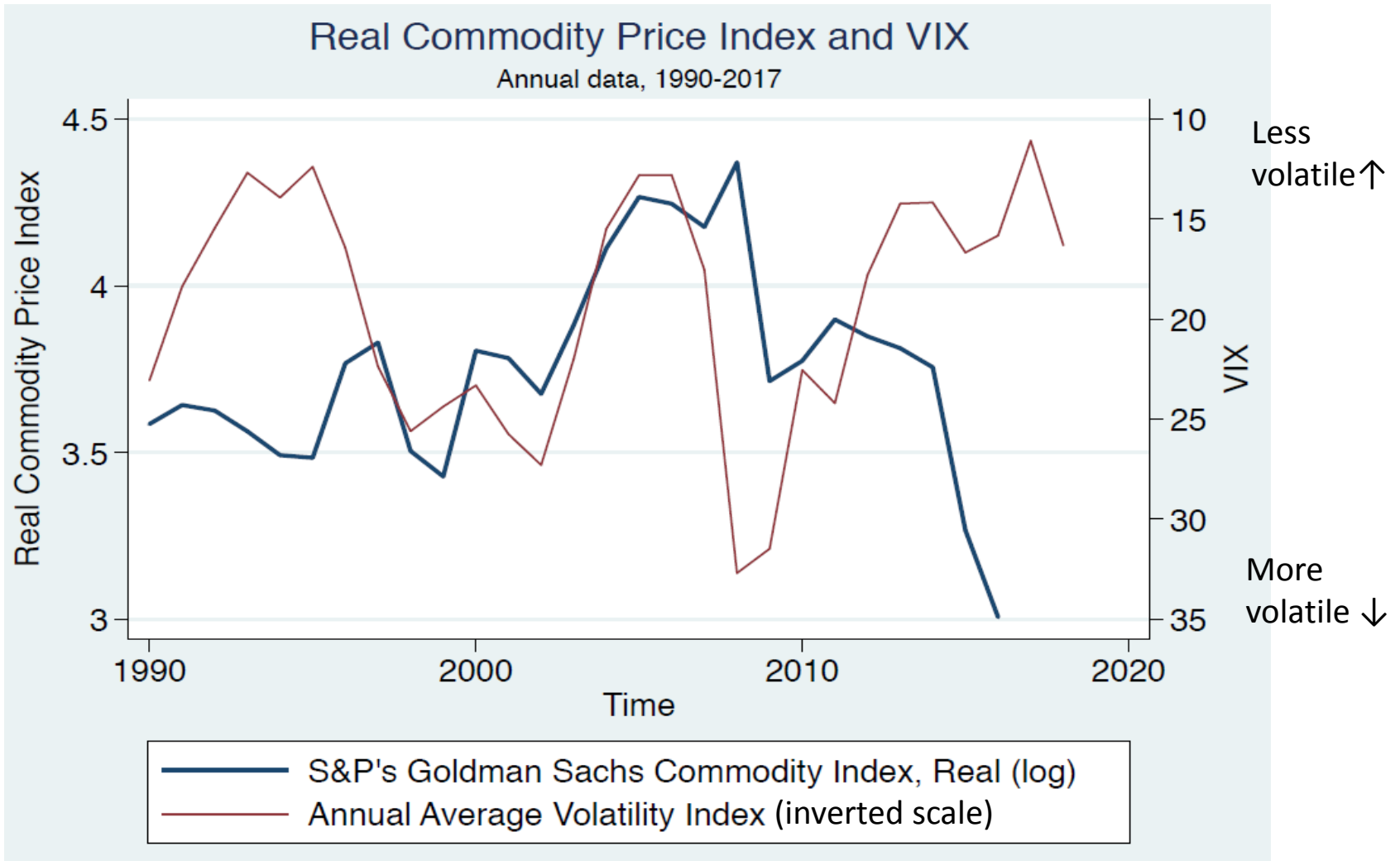
The positive risk premium seemed to have disappeared after 2005 ( $\widehat{E}\Delta s$  measured by survey data), despite no decline in volatility.

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.

## 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.



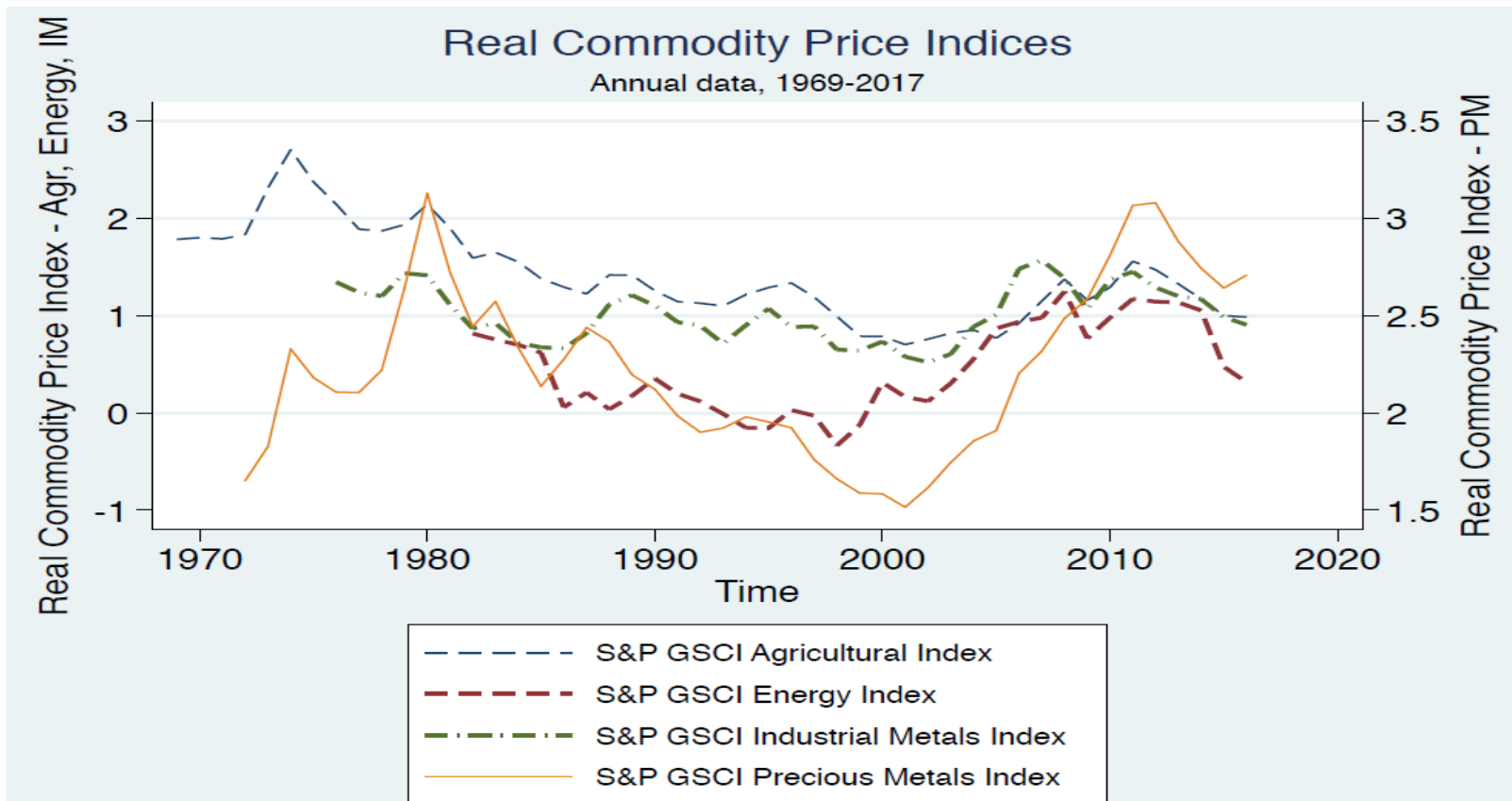
Updated tests for real commodity price index show significant negative effect of  $r$  and positive effect of GDP.

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

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

(Robust standard errors in parentheses.)

# 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.

# 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.

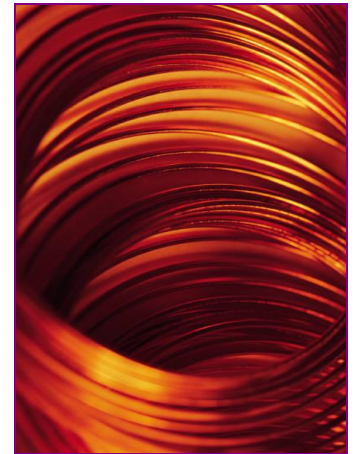
- "Expectations and Commodity Price Dynamics: The Overshooting Model," 1986, *American Journal of Agricultural Economics* 68, no. 2, May, pp.344-48.
- "Commodity Prices, Money Surprises, and Fed Credibility," with Gikas Hardouvelis, 1985, *Journal of Money, Credit & Banking* 17, no.4, Nov., 427-38.

Determinants of commodity prices in non-\$ currencies

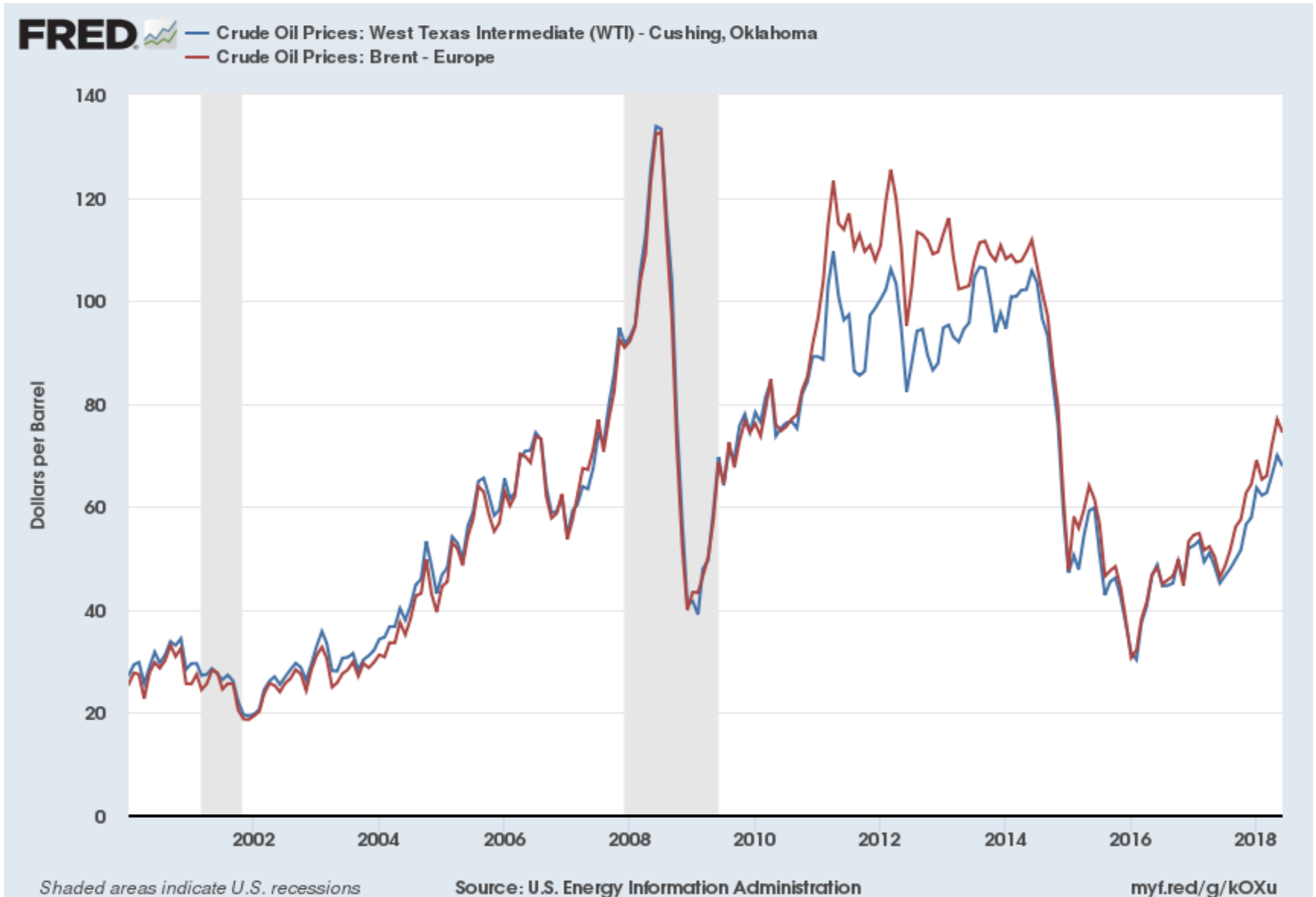
- "The Effect of Monetary Policy on Real Commodity Prices," 2008, *Asset Prices and Monetary Policy*, John Campbell, ed. (U.Ch.Press), 291-327. NBER WP 12713.

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)



# Macroeconomic determinants of commodity prices

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<https://scholar.harvard.edu/frankel>

[www.project-syndicate.org/columnist/jeffrey-frankel](http://www.project-syndicate.org/columnist/jeffrey-frankel)