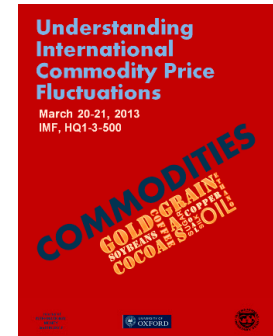


# Estimated Effects of Speculation & Interest Rates in a “Carry Trade” Model of Commodity Prices



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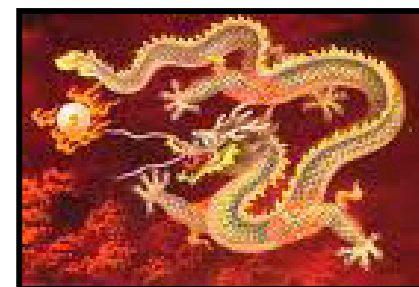
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# Three explanations for big recent increases in the prices of oil, minerals & agricultural commodities

- (1) *global growth*

- especially China



- (2) *speculation*

- defined as purchases of commodities, whether in physical form or via financial contracts, in anticipation of gain at the time of resale.

- Includes:

- not only possible destabilizing speculation (bandwagons),
- but also the possibility of stabilizing speculation.



- (3) *easy monetary policy*

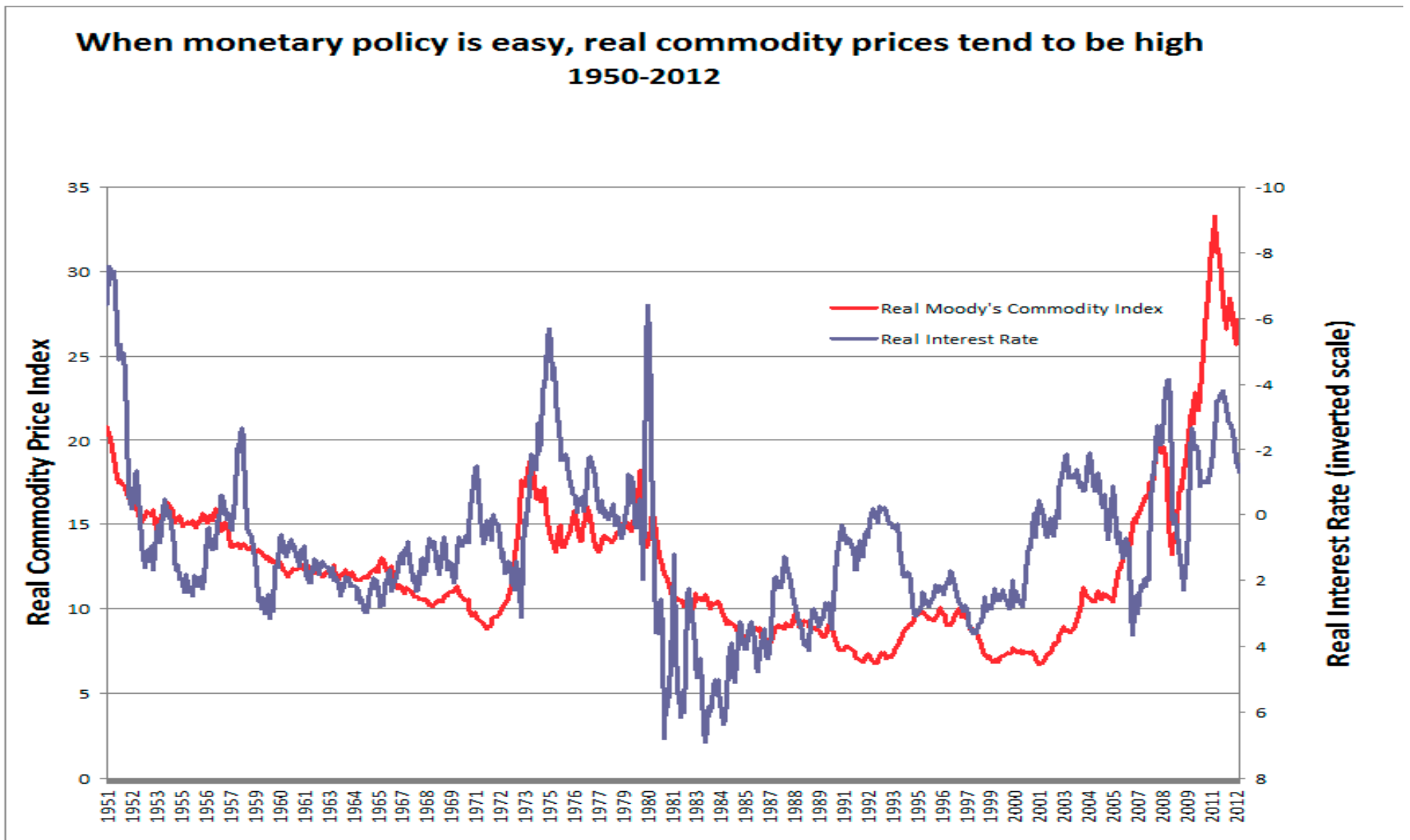
- reflected in low real interest rates.



# 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 the rates at which oil is pumped, copper mined, forests logged, or livestock herds culled.
- ✕ by decreasing firms' desire to carry inventories
  - think of oil inventories held in tanks.
- ✕ by encouraging speculators to shift out of spot commodity contracts, and into treasury bills
  - the famous “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.

Figure 1a: Real commodity price index (Moody's) and real interest rates



# Figure 1b: Real commodity price index (Moody's) and real interest rates

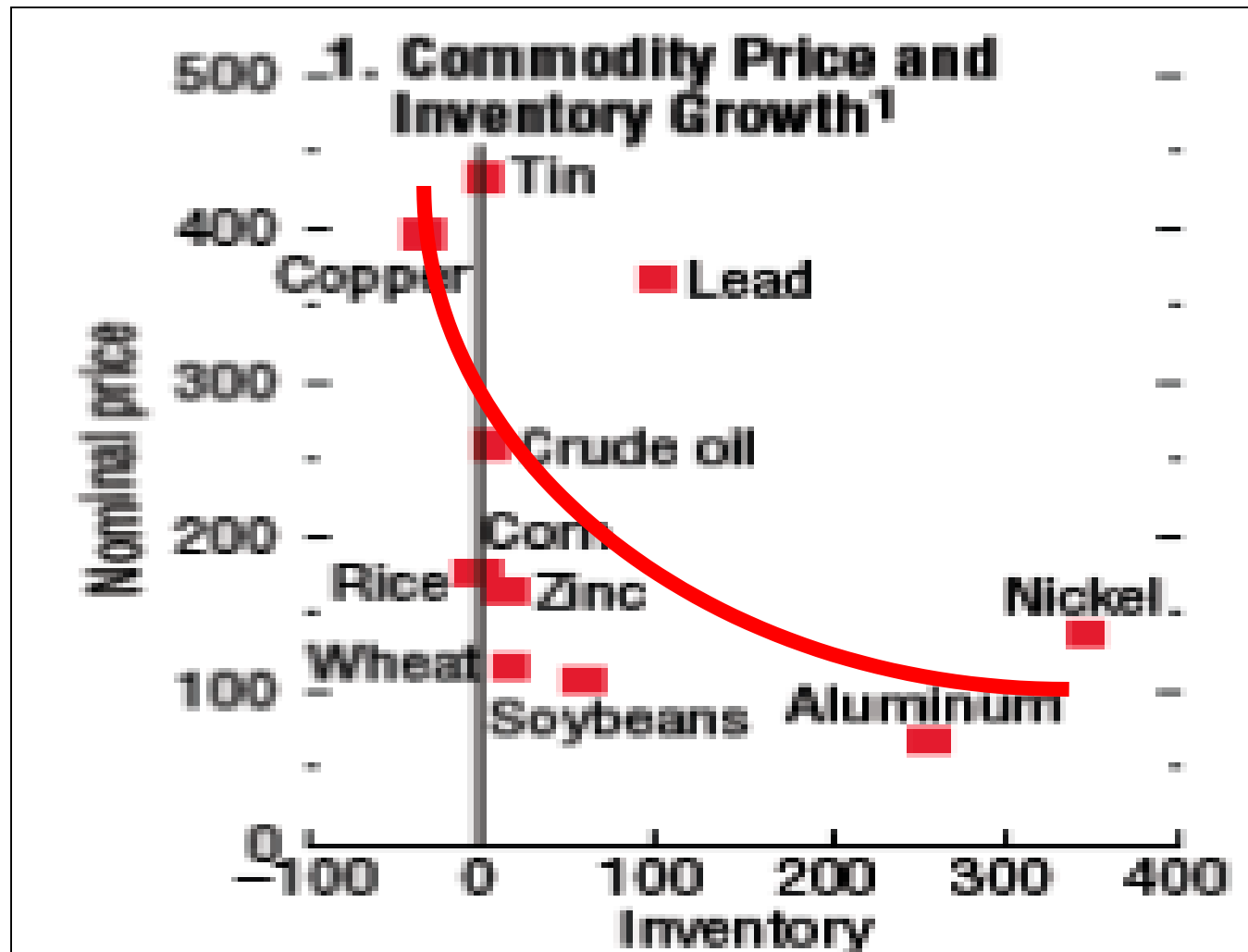
real\_interest\_rate



# The 2008 spike in commodity prices

- Explanation (1) didn't fit:
  - Growth had already begun to slow by 2008 1<sup>st</sup> half
  - while the commodity price rise *accelerated*,
- leaving explanations (2) & (3):
  - Speculation & low interest rates.
- But many argued that inventory data belied them:
  - if speculators were betting on future price increases, inventory demand should be high.
  - The same if the cause were low interest rates.
  - But, it was claimed, inventory levels were not high.
  - E.g.. Kohn (2008), Krugman (2008a, b) & Wolf (2008).

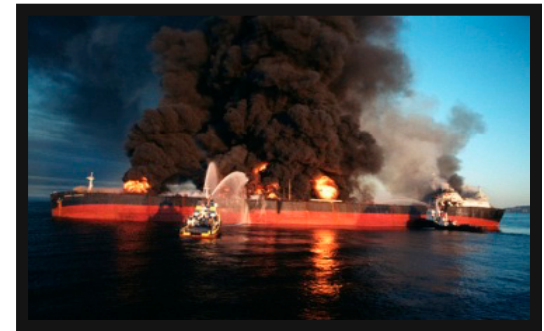
When inventories rise, the commodity price falls.



<sup>1</sup>Cumulative percent change from 2003 to 2011.

# Literature on oil inventories

- We need systematic study of inventories,
  - E.g., Working (1949), Abosedra & Radchenko (2003), Ye, Zyren & Shore (2002,05,06)
  - and role of speculation and interest rates.
- Some have found evidence in inventory data for an important role for speculation,
  - driven by geopolitical fears:
    - disruption to the supply of Mideastern oil.
  - Kilian & Murphy (2013); Kilian & Lee (2013).
- But the speculative factor is inferred implicitly
  - rather than measured explicitly.
  - The inference may be invalid
    - when inventory changes stem from other causes,
    - such as convenience yield.





# Empirical innovations of this paper

- Relative to past attempts to capture the roles of speculation or interest rates via inventories:
  - How to measure speculation, market expectations of future commodity price changes?
    - Survey data collected by *Consensus Forecasts*
    - from “over 30 of the world's most prominent commodity forecasters.”
  - How to measure perceived risk to commodity availability?
    - Volatility implicit in options prices.



## 1<sup>st</sup> assumption: regressive expectations

$$E[ \Delta q ] = - \theta (q - \bar{q}) \quad (1)$$

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

where

- $s \equiv$  natural logarithm of the spot price,
- $p \equiv$  (log of) economy-wide price index,
- $q \equiv s - p$ , the (log) real price of the commodity, and
- $\bar{q} \equiv$  long run (log) equilibrium real price of the commodity.

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

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

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

where:  $c \equiv cy - sc - rp$ .

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

$$\Rightarrow q = - (1/\theta) (i - E(\Delta p) - c) \quad (4).$$

- $q$  is inversely proportionate to the real interest rate,
  - if  $\bar{q}$  and  $c$  are constant.

**THE OVERSHOOTING MODEL**

# THE OVERSHOOTING MODEL (1950-2012)

$q$  is inversely proportionate to the real interest rate  
 Regression of real commodity price indices against real interest rate

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	<b>-0.041***</b> (0.007)	<b>-0.034***</b> (0.006)	<b>-0.071**</b> (0.005)	<b>-0.075***</b> (0.007)
Constant	0.900*** (0.017)	0.066*** (0.016)	2.533*** (0.011)	0.732*** (0.018)
Observations	739	739	739	513
R <sup>2</sup>	0.04	0.04	0.25	0.18
*** p<0.01 (Standard errors in parentheses.)				

## Derivation of inventory demand equation

$$E(\Delta s) + cy - sc - rp = i \quad (3)$$

$$\text{or } sc = [E(\Delta s) - i] + cy - rp. \quad (7)$$

3<sup>rd</sup> assumption: Storage costs rise with the extent to which inventory holdings strain existing storage capacity:  $sc = \Phi(\text{INVENTORIES})$ .

$$\text{Invert: } \text{INVENTORIES} = \Phi^{-1}\{sc\}.$$

And combine with the arbitrage condition (7):

$$\text{INVENTORIES} = \Phi^{-1}\{[E(\Delta s) - i] + cy - rp\} \quad (8)$$

## **THE CARRY TRADE MODEL**

### Table 4: Oil Inventory Equation (1995-2011, quarterly<sup>†</sup>)

Petroleum stocks Millions of barrels	(3)	(4)	(1)	(2)
Carry trade: $E\Delta s - i$	0.12*** (0.03)	0.12*** (0.03)	0.02* (0.01)	0.02* (0.01)
Actual US IP growth	0.56*** (0.15)	0.56*** (0.15)	0.02 (0.08)	0.01 (0.08)
US Industrial Prod. $\log$		-0.01 (0.07)		0.01 (0.04)
Forecast 2-yr IP growth	-0.674** (0.318)	-0.671** (0.318)	0.003 (0.146)	0.000 (0.146)
Oil Stocks lagged $\log$			0.91*** (0.05)	0.91*** (0.05)
Trend	0.004*** (0.000)	0.004*** (0.000)	0.000 (0.000)	0.000 (0.000)
<b>Constant</b>	<b>7.313***</b> (0.008)	<b>7.356***</b> (0.316)	<b>0.653</b> (0.392)	<b>0.600</b> (0.481)
Observations	58	58	58	58
R <sup>2</sup>	0.84	0.84	0.97	0.97

# Complete equation for determination of price

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

$$c \equiv cy - sc - rp \quad (3)$$

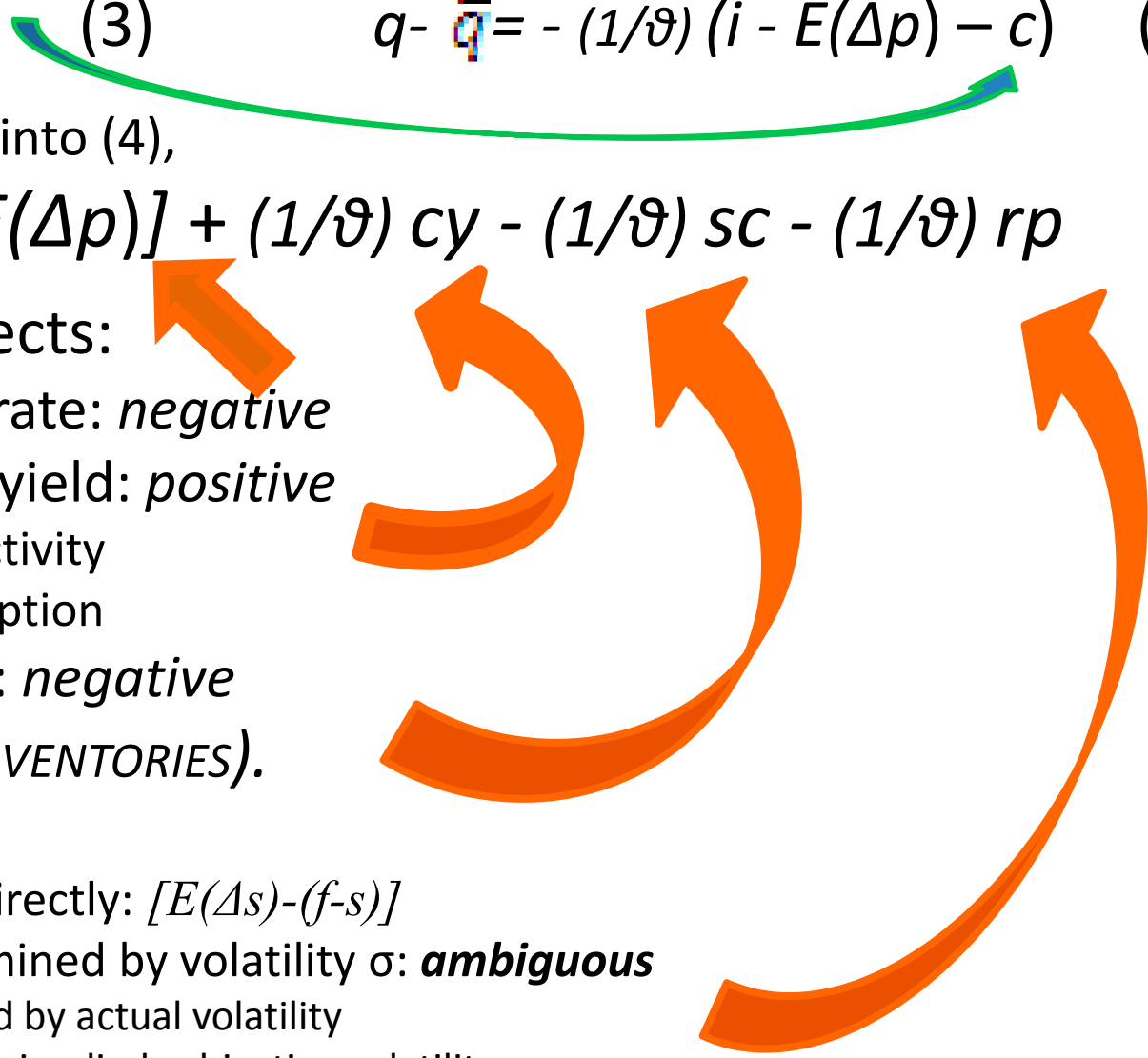
$$q - \bar{q} = - (1/\vartheta) (i - E(\Delta p) - c) \quad (4)$$

Substituting from (3) into (4),

$$q = \bar{q} - (1/\vartheta) [i - E(\Delta p)] + (1/\vartheta) cy - (1/\vartheta) sc - (1/\vartheta) rp \quad (5)$$

Hypothesized effects:

- Real interest rate: *negative*
- Convenience yield: *positive*
  - Economic activity
  - Risk of disruption
- Storage costs: *negative*
  - $sc = \Phi (INVENTORIES)$ .
- Risk premium
  - Measured directly:  $[E(\Delta s) - (f - s)]$
  - Or as determined by volatility  $\sigma$ : **ambiguous**
    - Measured by actual volatility
    - Or option-implied subjective volatility



# Estimation of determination for real prices, commodity-by-commodity, 1950-2012

Table 2a -- 1 <sup>st</sup> half	(1)	(2)	(3)	(4)	(5)
Commodity:	<b>Copper</b>	<b>Corn</b>	<b>Cotton</b>	<b>Live cattle</b>	<b>Live hogs</b>
Real interest rate	<b>-0.07***</b>	<b>-0.05*</b>	0.01	<b>-0.05***</b>	<b>-0.04***</b>
	(0.02)	(0.03)	(0.01)	(0.02)	(0.01)
Log World GDP	-0.46	0.62	0.56	2.26	-2.62**
constant 2000US\$ ; WDI	(0.57)	(0.57)	(0.58)	(1.48)	(1.12)
Log Inventories	<b>-0.19***</b>	<b>-0.07</b>	<b>-0.13</b>	1.12	<b>0.42*</b>
	(0.06)	(0.17)	(0.12)	(0.78)	(0.24)
Spread, %	0.000	<b>-0.006</b>	<b>-0.001</b>	<b>-0.007***</b>	<b>-0.004***</b>
Future-Spot	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)
Volatility: Std.dev.	<b>3.04***</b>	<b>0.94</b>	<b>0.20</b>	<b>-0.27</b>	<b>-1.02</b>
of log price over past year	(0.72)	(0.91)	(0.53)	(0.78)	(0.61)
Linear trend	-0.00	<b>-0.04**</b>	<b>-0.04*</b>	<b>-0.08*</b>	0.05
	(0.02)	(0.02)	(0.02)	(0.04)	(0.03)
Constant	16.94	<b>-20.26</b>	<b>-14.94</b>	<b>-81.65</b>	<b>74.87**</b>
	(17.29)	(16.54)	(17.29)	(51.77)	(33.00)
Observations (annual) †	50	51	51	32	39
R <sup>2</sup>	0.55	0.66	0.76	0.51	0.80

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1 (Robust standard errors in parentheses.) † Some commodities have shorter sample periods.



# Estimation of determination for real prices, commodity-by-commodity, 1950-2012, continued

Table 2a -- 2 <sup>nd</sup> half	(6)	(7)	(8)	(9)	(10)	(11)
Commodity:	Oats	Petroleum	Platinum	Silver	Soybeans	Wheat
Real interest rate	-0.04** (0.016)	-0.02 (0.071)	0.08*** (0.015)	-0.02 (0.025)	-0.04** (0.016)	-0.003 (0.021)
Log World GDP (constant 2000 US\$);WDI	1.56** (0.500)	-4.42 (4.984)	3.38*** (0.750)	3.63* (2.012)	0.38 (0.837)	0.33 (0.702)
Log Inventories	-0.31** (0.13)	-2.82 (4.43)	-0.24*** (0.03)	0.01 (0.11)	0.04 (0.09)	-0.45* (0.24)
Spread, % Future-Spot	-0.015* (0.003)	-0.002 (0.003)	-0.000 (0.001)	-0.010** (0.004)	-0.007** (0.003)	-0.001 (0.003)
Volatility: Std.dev. of log price over past year	0.91 (0.66)	-0.08 (0.69)	1.10*** (0.36)	5.15*** (0.67)	1.86** (0.87)	1.81*** (0.65)
Linear trend	-0.09*** (0.03)	0.17 (0.14)	-0.12*** (0.03)	-0.12* (0.06)	-0.04 (0.03)	-0.03 (0.02)
Constant	-45.54*** (16.33)	156.65 (142.65)	-98.36*** (22.41)	-111.77* (60.57)	-13.65 (24.71)	-7.09 (20.18)
Observations (annual)	50	29	47	44	48	51
R <sup>2</sup>	0.63	0.34	0.73	0.62	0.71	0.74

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1 (Robust standard errors in parentheses.) † Some commodities have shorter sample periods.

# A panel across all 11 commodities offers hope for greater statistical power

Table 3a

(492 annual observations)

Dependent variable: real commodity prices (log)

	(1)	(6)	(7)
<b>Real interest rate</b>	<b>-0.02*</b> (0.01)	<b>-0.03**</b> (0.01)	0.01 (0.01)
<b>Log World GDP</b> (constant 2000 US\$) WDI	<b>0.01</b> (0.24)		<b>3.45***</b> (0.77)
<b>Global Business Cycle</b> (HP-Filtered World GDP)		<b>7.22***</b> (1.08)	
Quadratic Trend			0.001*** (0.000)
<b>Log Inventories</b>	<b>-0.14***</b> (0.03)	<b>-0.14***</b> (0.02)	<b>-0.13***</b> (0.02)
<b>Future-Spot Spread, %</b>	<b>-0.003***</b> (0.001)	<b>-0.003***</b> (0.001)	<b>-0.003***</b> (0.000)
<b>Volatility: Standard deviation</b> of log spot price of past year	<b>1.81***</b> (0.52)	<b>1.92***</b> (0.51)	<b>1.77***</b> (0.47)
Linear Trend	-0.02* (0.01)	-0.02*** (0.00)	-0.19*** (0.04)
Constant	0.01 (7.01)	0.32 (0.23)	-101.90*** (22.93)
R <sup>2</sup>	0.46	0.49	0.51

# Panel across all 11 commodities; First differences guard against non-stationarity

Table 3b

Dependent variable:  $\Delta$  real commodity prices (log)

	(1)	(6)	(7)
$\Delta$ Real interest rate	-0.021 (0.013)	-0.001 (0.006)	-0.029** (0.012)
<b>Global Business Cycle</b> (HP-Filtered World GDP)		6.765*** (1.035)	
Forecast 2-yr.US GDP growth (Consensus Forecasts monthly)	8.575*** (1.978)		11.365*** (2.178)
Quadratic trend			0.002*** (0.000)
$\Delta$ Log Inventories	-0.004 (0.001)	-0.08 (0.0461)	-0.008 (0.056)
$\Delta$ Future-Spot Spread, %	-0.001*** (0.000)	-0.002*** (0.0005)	0.002*** (0.000)
$\Delta$ Volatility: Std.dev. of log spot price of past year	-0.067 (0.184)	0.192 (0.213)	0.068 (0.208)
Linear Trend	0.010*** (0.002)	0.002*** (0.000)	-0.024*** (0.005)
Constant	-0.314*** (0.068)	-0.043*** (0.009)	-0.271*** (0.071)
Observations	216	486	216
R <sup>2</sup>	0.22	0.17	0.27

# In conclusion...

- The model can accommodate each of the explanations for recent increases in commodity prices: economic activity, speculation, and easy monetary policy.
  - Based on “carry trade”: arbitrage relationship between expected price change and costs of carry: interest rate, storage costs, and convenience yield.
  - And on “overshooting”: prices are expected to regress gradually back to long-run equilibrium
- Specialized data sources:
  - Inventory holdings, as a determinant of storage costs;
  - Survey data on forecasts, as a measure of market expectations of future prices;
  - Option-implied volatility, as a measure of risk perceptions,
    - to supplement actual volatility

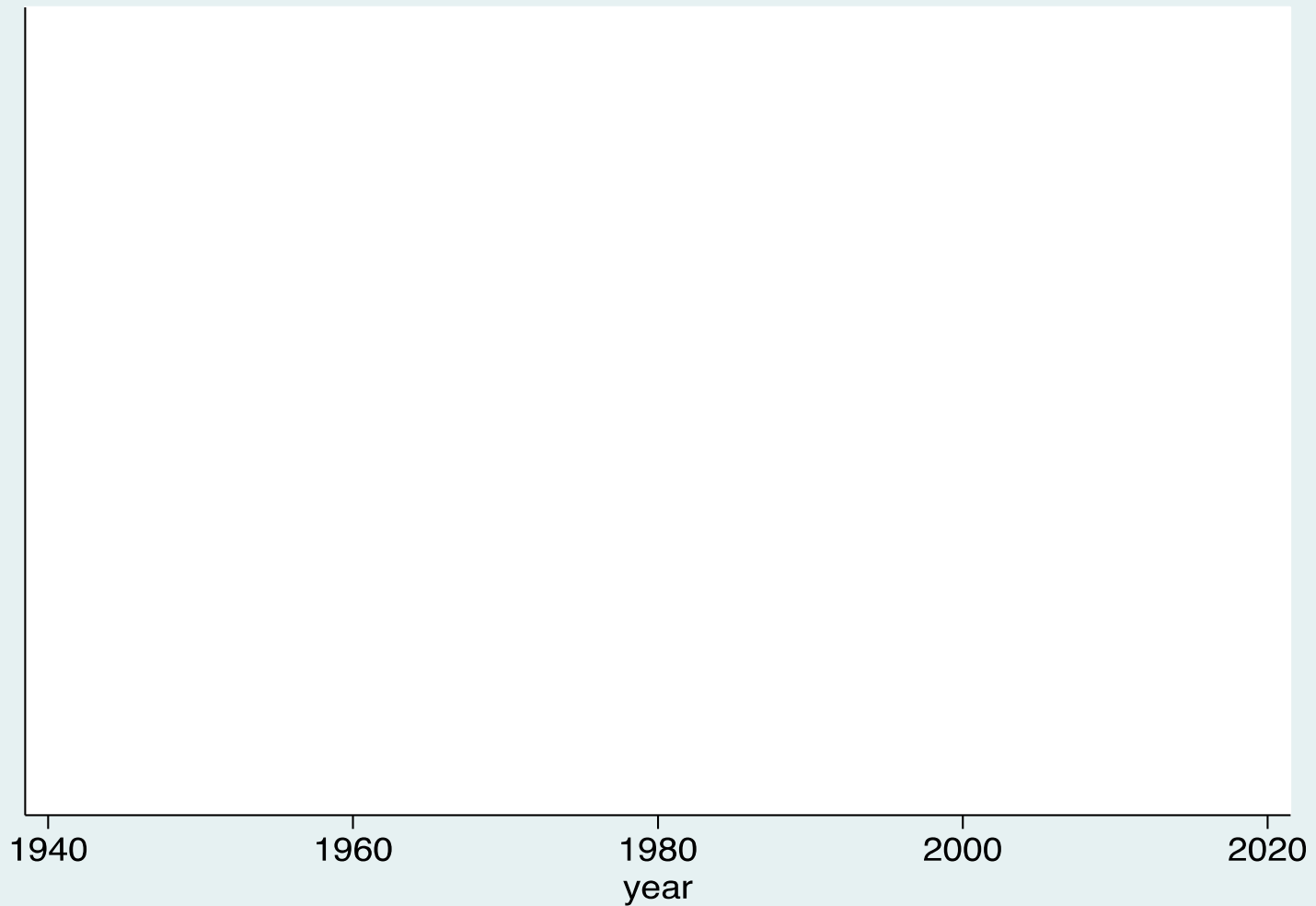
# Empirical findings

- Support for Carry Trade approach:
  - Negative effect of inventory levels on commodity price;
  - Negative effect of interest rate
    - on inventory demand and so on commodity price;
  - Positive effect of expected price increase
    - on inventory demand and so on commodity price.
- More specifically, the overshooting model:
  - negative effect of real interest rate on real commodity prices.
- Also some (limited) support for other relevant variables:
  - economic activity
  - forward-spot spread
  - volatility.



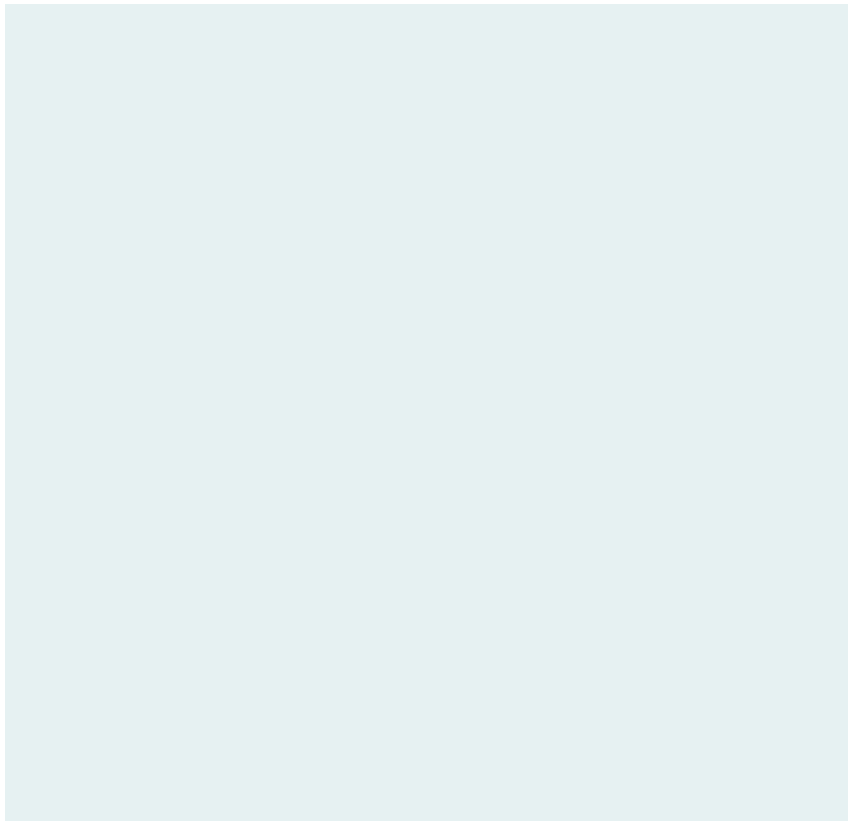
# Appendix: Data graphs

## Real Moody's commodity price index

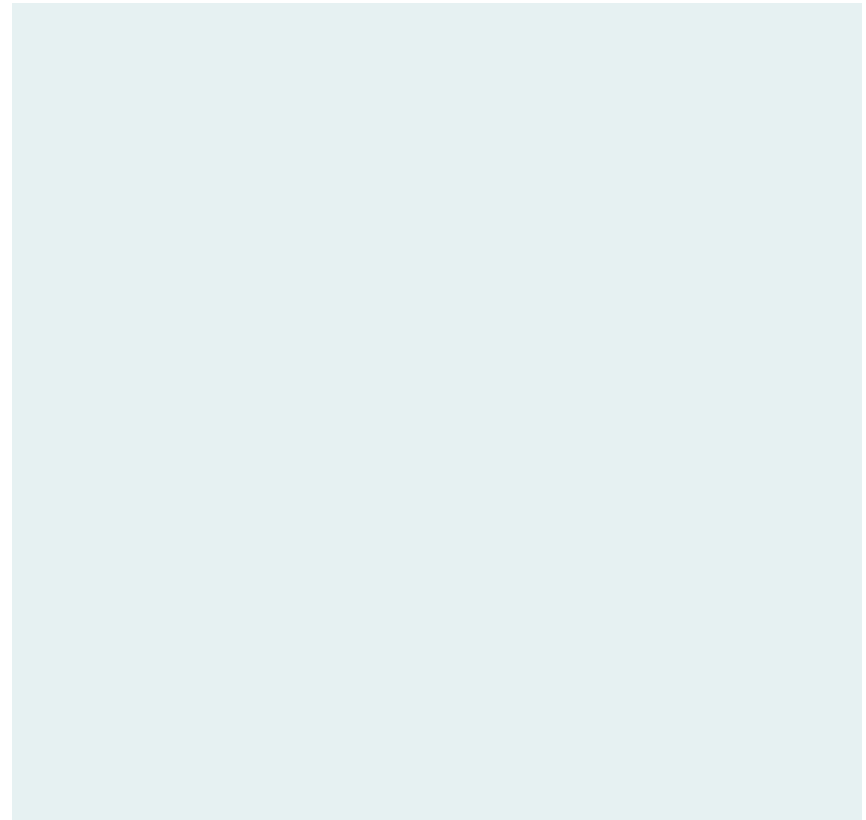


# Real interest rate

**1950-2012**

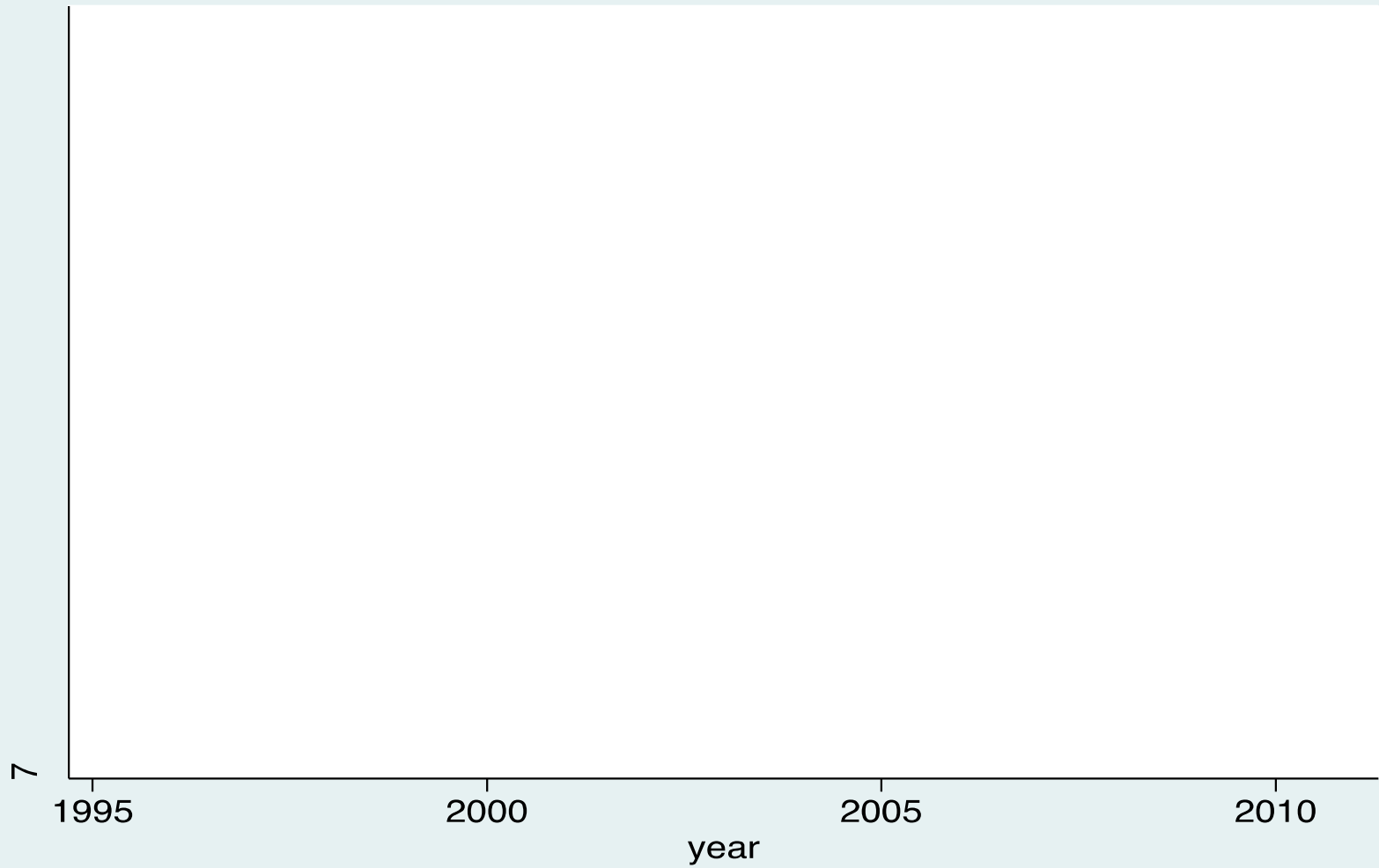


**1995-2012**





# Petroleum inventories



Risk premium &

$$(f-s) - E(\Delta s)$$

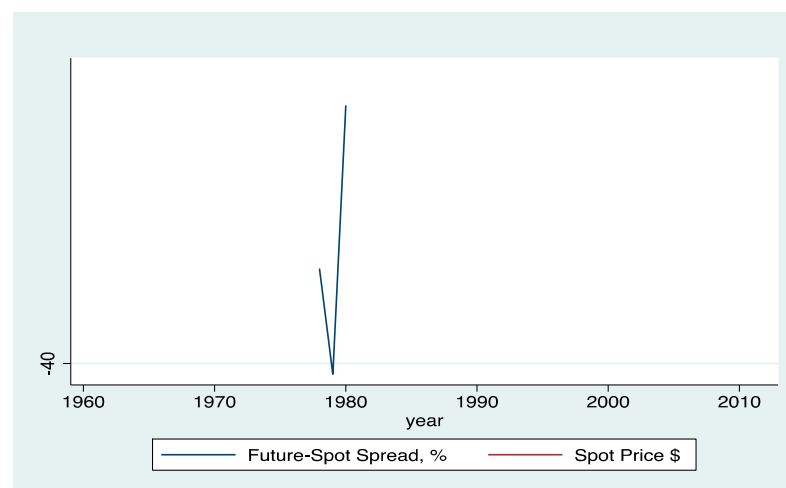
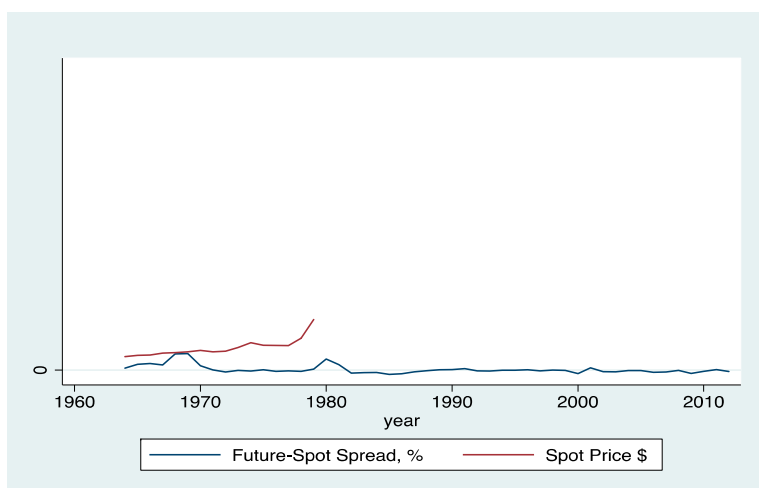
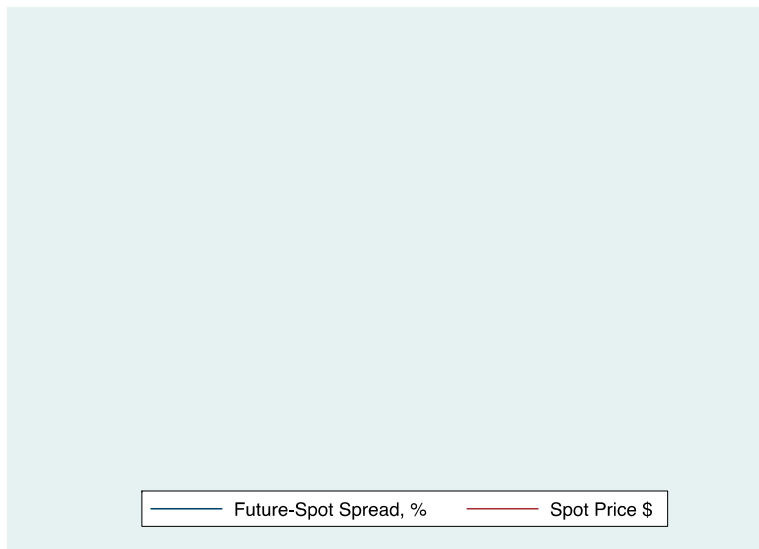
year

2 measures of volatility

*option-implied and actual volatilities*

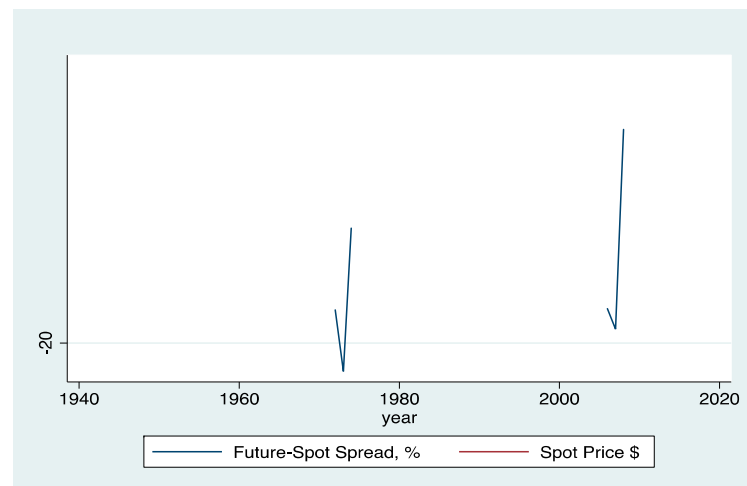
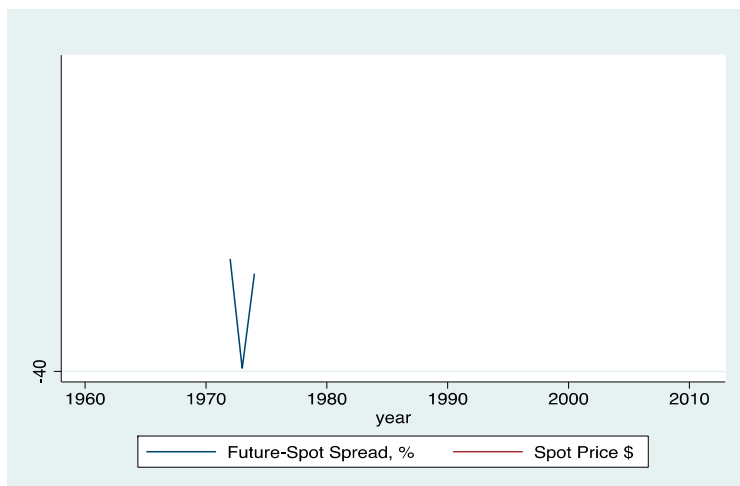
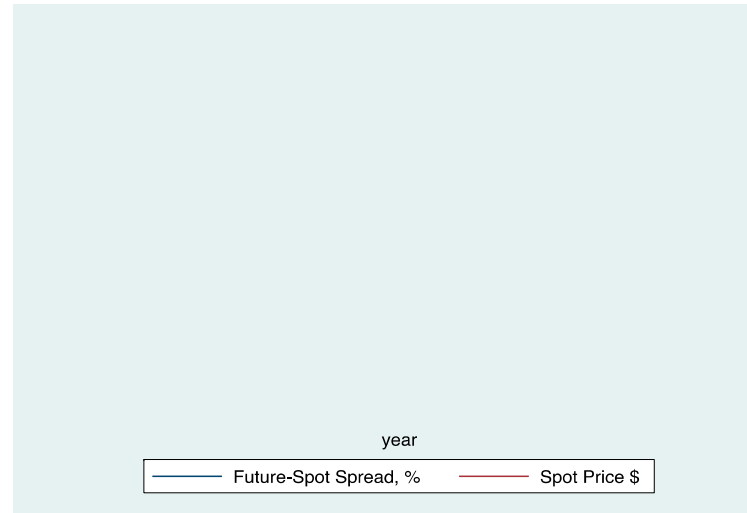
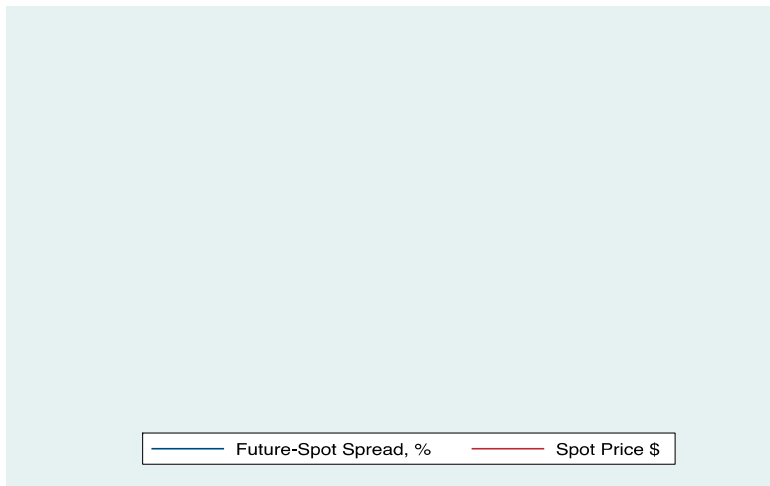
# Spot prices of individual commodities with forward-spot spread

## Minerals



# Spot prices of individual commodities with forward-spot spread

## Food crops



# Spot prices of individual commodities with forward-spot spread

## Other agricultural

