

Macroeconomic Determination of Prices of Agricultural and Mineral Commodities

Jeffrey Frankel, Harvard University, and
Andrew Rose, University of California, Berkeley

First draft of a paper written for the Reserve Bank of Australia. To be presented at pre-conference June 16-17, Muenster, Germany, June 2009. We would like to thank Ellis Connolly, Marc Hinterschweiger, Imran Kahn and Frederico Meinberg for research assistance.

Abstract

Motivated in part by the 2008 peak in prices of agricultural and mineral commodities, this paper restates a theory that allows a role for macroeconomic determinants of real commodity prices. The model includes GDP and the real interest rate as macroeconomic factors and inventory levels, risk measures and the spot-futures spread as other factors. The complete equation is subject to a large battery of econometric tests, using individual commodity time series, panel studies, and aggregate price indices. The variables that seem to have the most consistent and strongest effects are inventories, volatility, and the spot-future spread.

The determination of prices for oil and other mineral and agricultural commodities has always fallen predominantly in the province of microeconomics. Nevertheless there are periods when so many commodity prices are moving so far in the same direction at the same time that it becomes difficult to ignore the influence of macroeconomics. The decade of the 1970s was one such time. The decade of the 2000s was another. A rise in the price of oil might be explained by “peak oil” fears, or by a risk premium on Gulf instability, or by political developments in Russia, Nigeria or Venezuela. Some agricultural prices might be explained by drought in Australia or shortages in China or ethanol subsidies in the United States. But it cannot be coincidence that almost all commodity prices rose generally together during much of the decade, and peaked abruptly together in mid-2008. (Even if the simple answer were “it’s all rising demand from China,” that itself is a macroeconomic explanation.)

During 2003-2008, three theories (at least) competed to explain the widespread ascent of commodity prices.

- First, and perhaps most standard, was the *global growth explanation*, including the recovery of Japan and Germany from a decade of stagnation but most particularly including the arrival of China, India and other new entrants on the list of important economies, and the prospects of continued high growth in those countries in the future. This growth entailed rapidly increasing demand for raw materials.
- The second explanation, also highly popular, at least outside of academia, was *destabilizing speculation*. Most of these commodities are highly storable (though not

necessarily all, in the case of some agricultural products). Perhaps a majority are traded on futures markets. We can define speculation as the purchases of the commodities — whether in physical form or in the form of contracts traded on an exchange -- in anticipation of financial gain at the time of resale. There is no question that speculation, so defined, is a major force in the market. However, the second explanation is more specific: that speculation was a major force pushing the commodity prices *up* during the period 2003-2008. As a general phenomenon, this would be destabilizing speculation or a speculative bubble. The alternative possibilities include that speculation was stabilizing during this period (that speculators were short on average, in anticipation of a future reversion to more normal levels, and that thereby kept prices lower than they otherwise would be), or that it did not consistently point in either direction. A variety of evidence has been brought to bear to see if speculators contributed to the price rise, including whether futures prices lay above or below spot prices and whether their net open position was positive or negative.¹ A particularly convincing point against the destabilizing speculation hypothesis is that commodities that feature no futures markets have experienced as much volatility as those that have them. Historical efforts to ban speculative futures markets have failed to reduce volatility.

A central criterion is inventory behavior, which seems to undermine further the hypothesis that speculators contributed to the 2003-08 run-up in prices. The argument was that since inventories were not historically high, and in some cases were historically low, speculators could not have been betting on price increases and could not have added to the current demand. A counterargument, especially in the case of oil, is that what is measured in inventory data is small compared to the reserves under the ground. The decision by producers whether to pump oil today or to leave it underground for the future is more important than the decisions of oil companies or downstream users whether to hold higher or lower inventories.

- The third explanation, less prominent than the first two, is that low *real interest rates* were at least one of the factors contributing to either the high demand for commodities or the low supply. Conversely, high real interest rates drove prices down in the early 1980s. At that time, real interest rates rose sharply, especially in the US. One effect was that this raised the cost of holding inventories. Lower demand for inventories contributed to lower total demand for oil. A second effect of the higher interest rates was that they undermined the incentive for oil-producing countries to keep oil under the ground; by pumping instead, they could invest the proceeds at interest rates that were higher than the return to leaving it in the ground. Higher rates of pumping increased supply. Lower demand, higher supply – the result was that oil prices fell. After 2000, the process was run in reverse. The Fed cut real interest rates sharply in 2001-2004, and again in 2008. Each time, it lowered the cost of holding inventories, thereby contributing to an increase in demand.

¹ Expectations of future oil prices on the part of typical speculators, if anything, initially lagged behind contemporaneous spot prices. Speculators have often been “net short” (sellers) on commodities rather than “long” (buyers). In other words they may have delayed or moderated the price increases, rather than initiating or adding to them. Commodities that feature no futures markets have experienced as much volatility as those that have them. Historical efforts to ban speculative futures markets have failed to reduce volatility.

Critics of this interest rate theory as an explanation of the boom that peaked in 2008 have pointed out that it implies that inventory levels are high, which was said not to be the case. This is the same point that has been raised in objection to the destabilizing speculation theory. For that matter, it could be applied to most theories. Explanation #1, the global boom theory, is often phrased in terms of expectations of China's future growth path, not just its currently-high level of income; but this factor, too, should if operating in the market place in theory work to raise demand for inventories.

How can high demand for commodities be reconciled with low inventories? One possibility is that researchers are looking at the wrong inventory data. Standard data inevitably exclude various components of inventories, such as those held by users, those in faraway countries, and especially deposits, crops, or herds that lie in or on the ground. In other words, the lower real interest rates of 2001-2005 and 2008 reduced the incentive for oil producers to pump oil, relative to what it would otherwise be. The King of Saudi Arabia said at this time that his country might as well leave the reserves in the ground for its grandchildren. Higher demand, lower supply – the result was upward pressure on oil prices.

In 2008, enthusiasm for explanations (2) and (3), the speculation and interest rate theories, increased, at the expense of theory (1), the global boom. Previously, rising demand from the global expansion, especially the boom in China, had seemed the obvious explanation for rising commodity prices. But the sub-prime mortgage crisis hit the United States in August 2007. Every month thereafter, forecasts of growth were downgraded, not just for the United States but for the rest of the world as well, including China. Meanwhile commodity prices, far from declining as one might expect from the global demand hypothesis, climbed at an accelerated rate. For the year following August 2007, at least, the global boom theory was clearly out of contention. That left explanations (2) and (3). In both cases – increased demand arising from either low interest rates or expectations of capital gains -- detractors pointed out that they implied that inventory holdings should be high and argued that this was not the case. (Among others, Krugman, 2008, and Kohn, 2008.) A counterargument, especially in the case of oil, is that what is measured in inventory data is small compared to the reserves under the ground. The decision by producers whether to pump oil today or to leave it underground for the future is more important than the decisions of oil companies or downstream users whether to hold higher or lower inventories.

The paper presents a theoretical model of the determination of prices for storable commodities that gives full expression to such macroeconomic factors as economic activity and real interest rates. It then some offers some up-to-date econometric estimates of the model

1. The theory of macroeconomic determination of commodity prices

Most agricultural and mineral products are differentiated from other goods and services in that they are both storable and relatively homogeneous. As a result, they are hybrids of assets – where price is determined by supply and demand of stocks – and goods for which flow supply and flow demand matter.²

² E.g., Frankel (1984).

The elements of an appropriate model have long been known.³ The monetary aspect of the theory can be reduced to its simplest algebraic essence as a claimed relationship between the real interest rate and the spot price of a commodity relative to its expected long-run equilibrium price. This relationship can be derived from two simple assumptions. The first one governs expectations. Let

$s \equiv$ the spot price,

$\bar{s} \equiv$ its long run equilibrium,

$p \equiv$ the economy-wide price index,

$q \equiv s-p$, the real price of the commodity, and

$\bar{q} \equiv$ the long run equilibrium real price of the commodity,

all in log form. Market participants who observe the real price of the commodity today lying above or below its perceived long-run value expect it in the future to regress back to equilibrium over time, at an annual rate that is proportionate to the gap:

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

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

Following the classic Dornbusch overshooting paper, which developed the model for the case of exchange rates, we begin by simply asserting the reasonableness of the form of expectations in these equations: a tendency to regress back toward long run equilibrium. But, as in that paper, it can be shown that regressive expectations are also rational expectations, under certain assumptions regarding the stickiness of prices of other goods (manufactures and services) and certain restrictions on parameter values.⁴

The second equation concerns the decision whether to hold the commodity for another period – either leaving it in the ground or on the trees or holding it in inventories – or to sell it at today's price and deposit the proceeds in the bank to earn interest. The arbitrage condition is that the expected rate of return to these two alternative courses of action must be the same:

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

where $c \equiv cy - sc - rp$

³ E.g., Frankel (1986, 2008), among others.

⁴ Frankel (1986).

$cy \equiv$ convenience yield from holding the stock (e.g., the insurance value of having an assured supply of some critical input in the event of a disruption, or in the case of gold the psychic pleasure component of holding it)

$sc \equiv$ storage costs (e.g., costs of security to prevent plundering by others, rental rate on oil tanks or oil tankers, etc.),

$rp \equiv$ risk premium, which is positive if being long in commodities is risky, and

$i \equiv$ the interest rate.⁵

There is no reason why the convenience yield, storage costs, or risk premium should be constant over time. If one is interested in the derivatives markets, one often focuses on the forward discount or slope of the futures curve, $f-s$ in log terms (also sometimes called the spread or the roll). For example, the null hypothesis that it is an unbiased forecast of the future change in the spot price has been tested extensively. As in the (even more extensive) tests of the analogous propositions in the forward exchange markets and the term structure of interest rates, the null hypothesis is usually rejected. Appendix 1 to this paper reviews this literature. The issue does not affect the questions addressed in this paper, however. Here we note only, that one need not interpret the finding of bias in the futures rate as a rejection of rational expectations; it could be due to a risk premium. The spread is given by:

$$f-s = i-cy+sc, \text{ or equivalently by } E \Delta s - rp. \quad (4)$$

On average $f-s$ tends to be negative. This phenomenon, called “normal backwardation,”⁶ apparently suggests that convenience yield on average outweighs the interest rate and storage costs.

To get our main result, we simply combine equations (2) and (3):

$$\begin{aligned} -\theta (q-\bar{q}) + E(\Delta p) + c &= i && \Rightarrow \\ q-\bar{q} &= -(1/\theta) (i - E(\Delta p) - c) . \end{aligned} \quad (5)$$

Equation (5) says that the real price of the commodity (measured relative to its long-run equilibrium) is inversely proportional to the real interest rate (measured relative to a constant term that depends on convenience yield). When the real interest rate is high, as in the 1980s, money flows out of commodities, just as it flows out of foreign currencies, emerging markets, and other securities. Only when the prices of these alternative assets are perceived to lie sufficiently below their future equilibria will the arbitrage condition be met. Conversely, when the real interest rate is low, as in 2001-05 and 2008, money flows into commodities [just as it flows into foreign currencies (“the carry trade”), emerging markets, and other securities]. Only

⁵ Working (1949) and Breeden (1980) are classic references on the roles of carrying costs and the risk premium, respectively, in commodity markets. Yang, Bessler and Leatham (2001) review the literature.

⁶ E.g., Kolb (1992).

when the prices of these alternative assets are perceived to lie sufficiently above their future equilibria will the arbitrage condition be met.

2. Preliminary data explorations

Figures 1a and 1b each plot the real interest rate against an aggregate index of commodity prices (deflated into real terms), over the last 58 years. An inverse relationship is clearly visible, offering some motivation for the view that the real interest rate is a major influence on commodity prices. The empirical core of Frankel (2008) is estimation of equation (5). The results are generally supportive, at least when a lot of data from different commodities are brought to bear at once, by means either of aggregate commodity price indices or of a panel study of individual commodity prices. Large residuals are also clearly visible, however, in both the figures and the regressions, illustrating that a lot has been left out.

Figure 1a

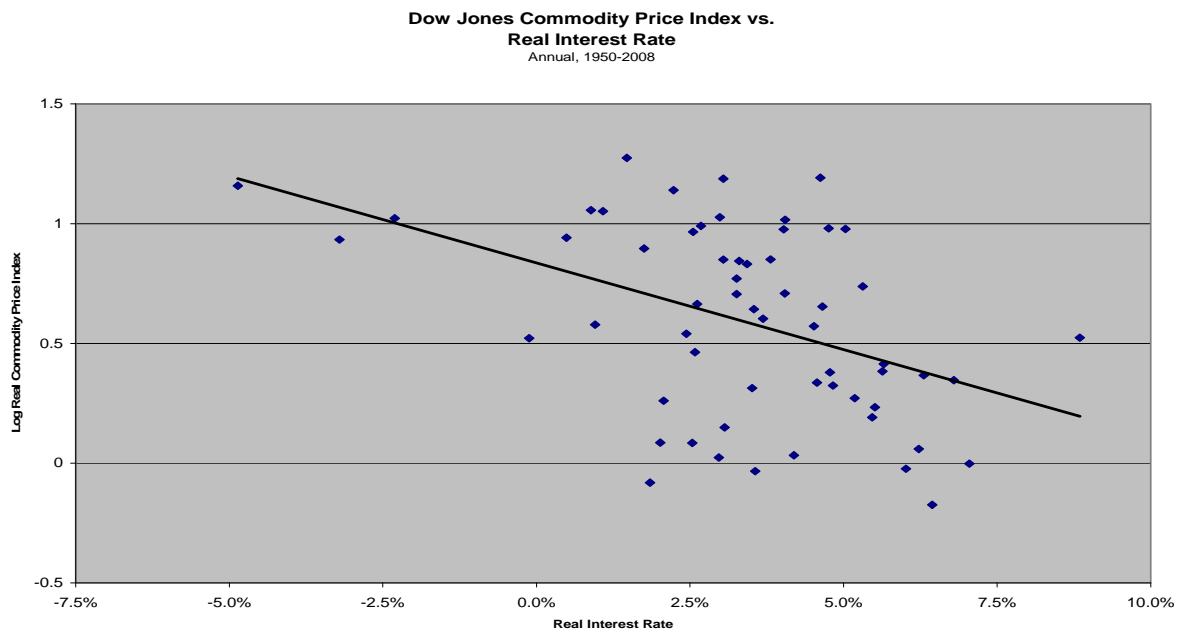
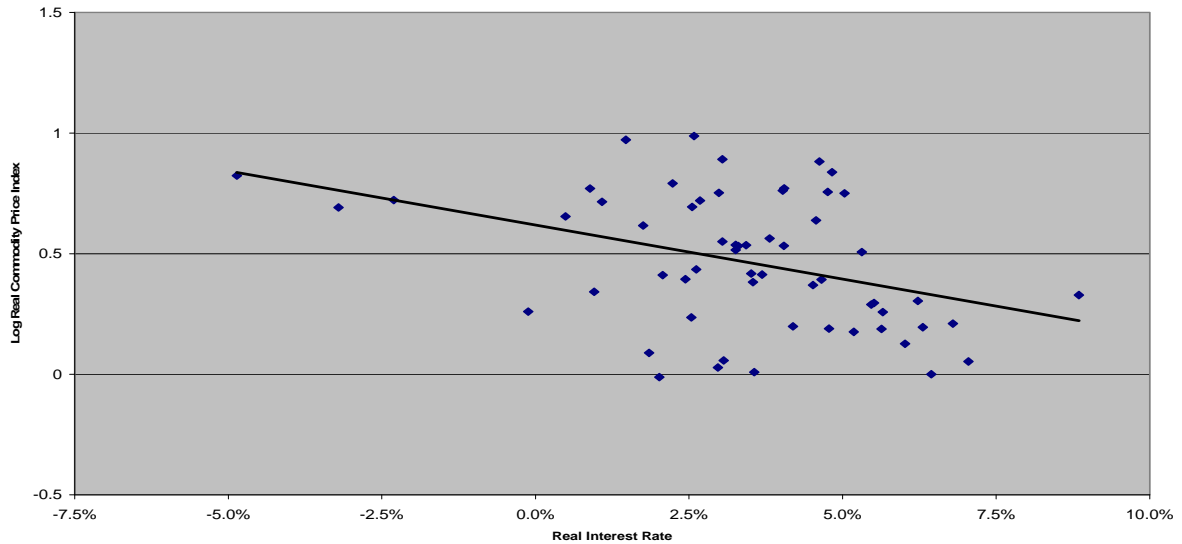


Figure 1b

**Moody's Commodity Price Index vs.
Real Interest Rate**
Annual, 1950-2008



We would expect from the theory that the simple price - interest rate relationship does indeed leave a lot out. As noted, there is no reason for the “constant term” in equation (5) to be constant.

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

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

$$q = \bar{q} - (1/\theta) [i - E(\Delta p)] + (1/\theta) cy - (1/\theta) sc - (1/\theta) rp . \quad (6)$$

Thus, even if we continue to take the long-run equilibrium \bar{q} as given, there are other variables in addition to the real interest rate that determine the real price: convenience yield, storage costs, and risk premium.⁷

⁷ One way to isolate monetary effects on commodity prices is to look at jumps in financial markets that occur in immediate response to government announcements that change perceptions of the macroeconomic situation, as did Federal Reserve money supply announcements in the early 1980s. The experiment is interesting, because news regarding supply disruptions and so forth is unlikely to have come out during the short time intervals in question. Frankel and Hardouvelis (1985), for example, used Federal Reserve money supply announcements to test the monetary implications of the model.

Translating into empirically usable form, there are four or five measurable determinants of the real commodity price:

- Inventories. Storage costs rise with the extent to which inventory holdings strain existing storage capacity: $sc = \Phi (INVENTORIES)$.
If the level of inventories is observed to be at the high end historically, then storage costs must be high (absent and large recent increase in storage capacity), which has a negative effect on commodity prices. Substituting into equation (6),

$$q = \bar{q} - (1/\theta) [i - E(\Delta p)] + (1/\theta) cy - (1/\theta) \Phi (INVENTORIES) - (1/\theta) rp. \quad (7)$$

If one wished to estimate an equation for the determination of inventory holdings:

$$INVENTORIES = \Phi^{-1}(sc) = \Phi^{-1}(cy - i - (s-f)) \quad (8)$$

We see that low interest rates should predict not only high commodity prices but also high inventory holdings.

- Real GDP (Y) or industrial production, representing the transactions demand for inventories, is a determinant of the convenience yield cy . Higher economic activity should have a positive effect on the demand for inventory holdings and thus on prices. Let us designate the relationship $\gamma(Y)$.
- Medium-term volatility (σ), measured either as the standard deviation of the spot price over the last year or as the implicit forward-looking expected volatility that can be extracted from options prices. Volatility is a determinant of convenience yield, cy , which should have a positive effect on the demand for inventories and therefore on prices. It may also be a determinant of the risk premium.
- Risk (political, financial, and economic), in the case of oil for example, is measured by a weighted average of political risk among 12 top oil producers. The theoretical result is ambiguous: Risk is another determinant of cy (especially to the extent that risk concerns fear of disruption of availability), whereby it should have a positive effect on inventory demand and therefore on commodity prices. But it is also a determinant of the risk premium rp , whereby it should have a negative effect on commodity prices. (In the measure we use, a rise in the index represents a decrease in risk.)

Announcements that were interpreted as signaling tighter monetary policy indeed induced statistically significant decreases in commodity prices: Money announcements that caused interest rates to jump up would on average cause commodity prices to fall, and vice versa.

- The spot-futures spread. Intuitively the futures-spot spread reflects the speculative return to holding inventories.⁸ It is one component of the risk premium (along with expected depreciation). A higher spot-futures spread (normal backwardation), or lower future-spot spread, signifies a low speculative return and should have a negative effect on inventory demand and on prices.⁹

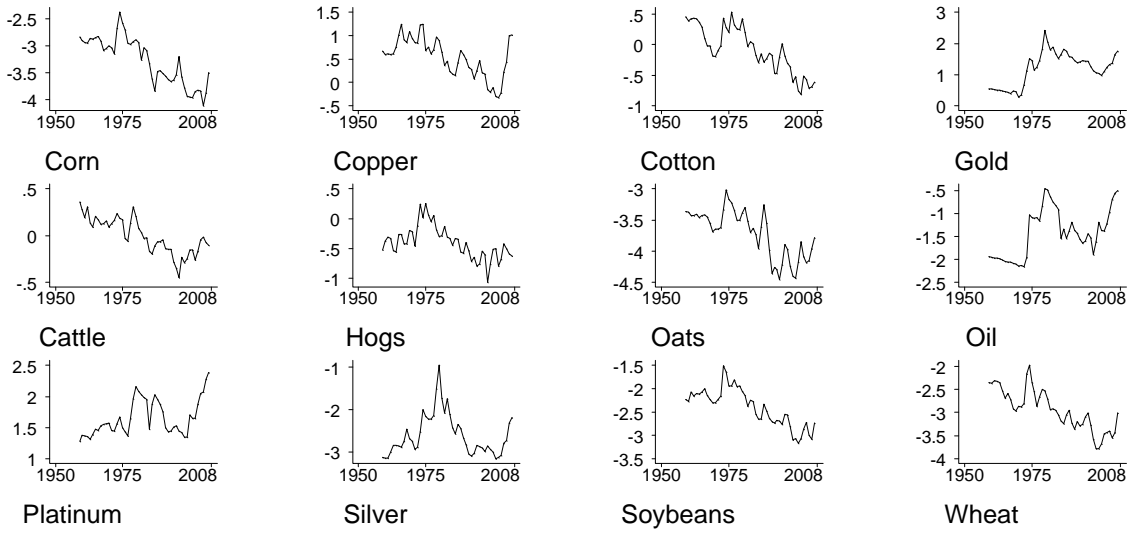
$$q = \bar{q} - (1/\theta) [i - E(\Delta p)] + (1/\theta) \gamma(Y) - (1/\theta) \Phi(INVENTORIES) + (1/\theta) \Psi(\sigma) \quad (9)$$

Frankel (2008), by omitting determinates of convenience yield and risk, stopped short of estimating the full price equation (6). But that paper did include all four variables in an equation to explain inventories of oil, as in equation (8). We begin by using the same data to replicate the results for inventories and then to see if the same variables can explain the price of oil. The results are reported in Appendix 2. The implications for inventories are born out in Tables A2i and A2ii. The latter table includes lagged inventories on the list of determinants, motivated by a stock adjustment model. The hypothesized effects are all there: the positive effect of industrial production, the negative effect of the real interest rate, and the positive effect of risk (which shows up as a negative effect of our inverted risk measure). Tables 2Aiii moves into new territory by trying to explain the real price of oil by means of the same variables. The macroeconomic variables show up with the hypothesized sign and very highly significant: economic activity appears to have a positive effect on the real price of oil and real interest rates to have a negative effect, as the theory says. The other control variables, however, do not show up as hypothesized.

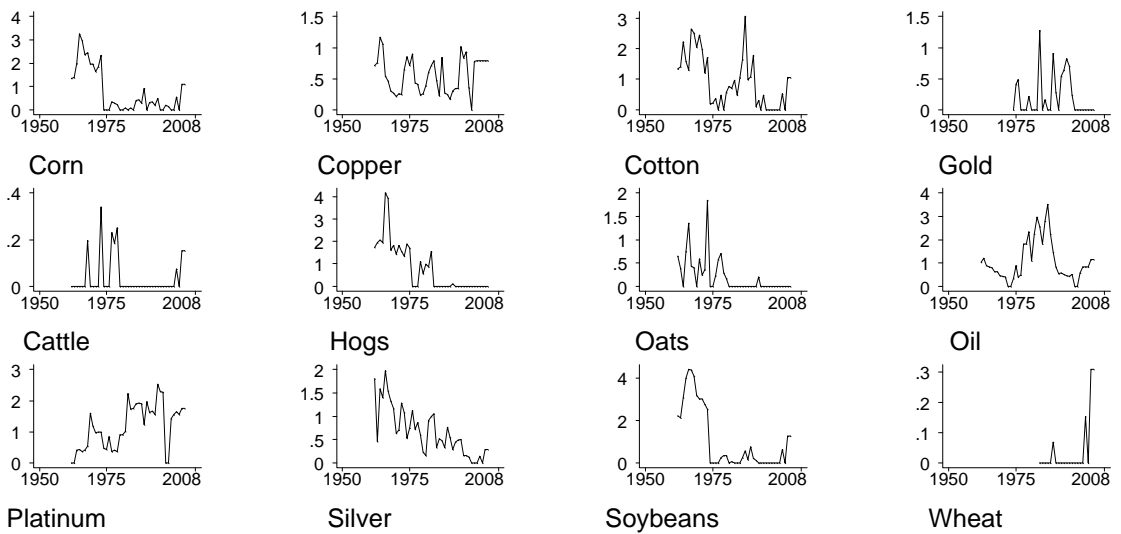
The Figures illustrate the raw times series data. As one can see, the risk variable is somewhat limited in availability. The log of the real price shows the boom of the 1970s in most commodities and the second boom that culminated in 2008 – especially in the minerals: copper, gold, oil and platinum. According to our inventory data, some commodities show inventories that in 2008 were fairly high historically after all: corn, cotton, hogs, oil, and soybeans. For our real activity variable, we sometimes use industrial production (whether for the US alone or advanced countries in the aggregate), which has the advantage of being available monthly, or GDP, which has the advantage of being available for such countries as China. Of course all economic activity variables have positive trends/ one must detrend them to be useful measures of the business cycle. The real interest rate hits bottom in 1975 and hits top in the early 1980s, both of which are as expected. (The data in the graph don't go far enough to include the dramatic easing of 2008.) Imaginative eyeballing can convince one that oil producers show high risk around the time of the 1973 Arab oil embargo and the aftermath of the 2001 World Trade Center attack.

⁸ E.g., see the discussion of Figure 1.22 in the *World Economic Outlook April 2006*, International Monetary Fund, Washington, DC.

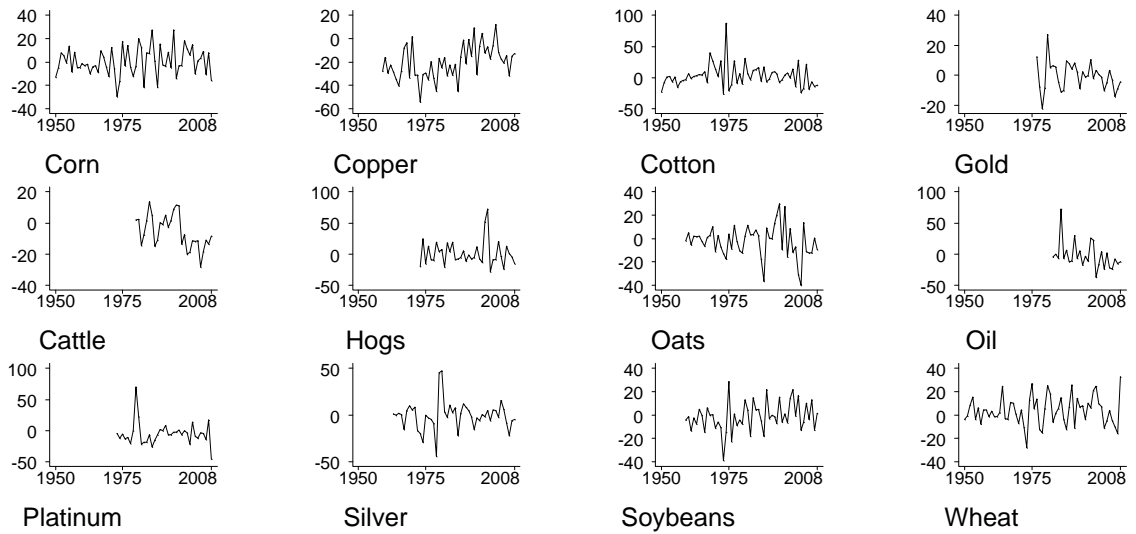
⁹ In theory, if one is estimating equation (9), and one has inventories already in the equation, one does need to add the spread separately. But it is unlikely that any available measure of inventories is complete, which may offer a reason to include the spread separately -- a measure of speculative demand .



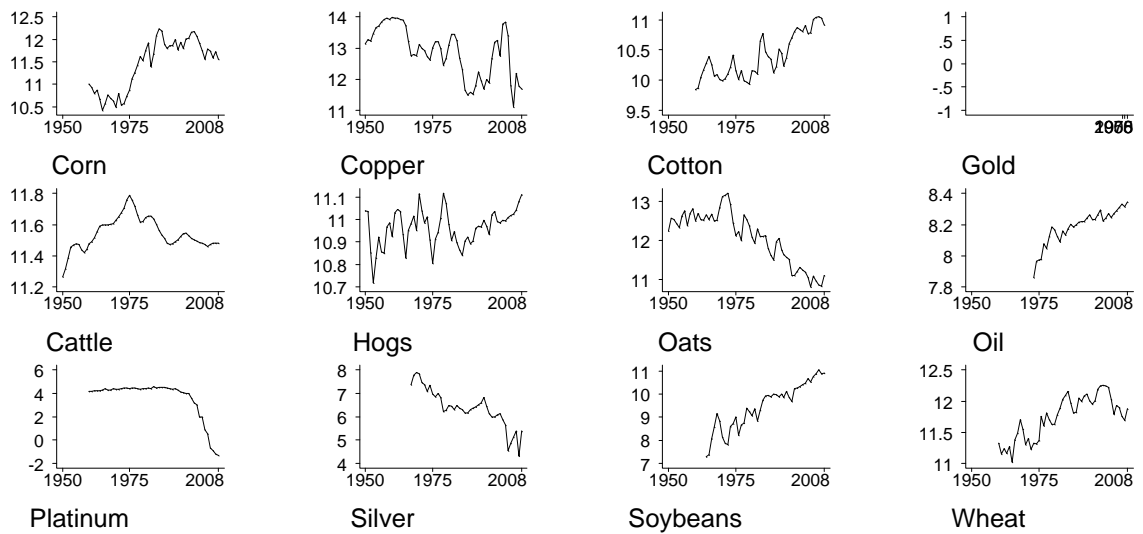
Log Real Spot Price



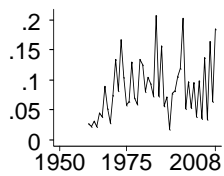
Risk



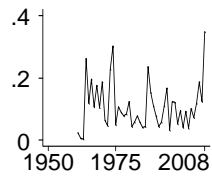
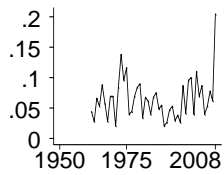
Future-Spot Spread



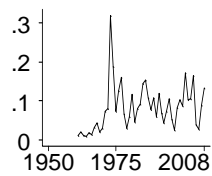
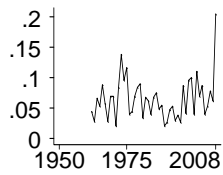
Log Inventory



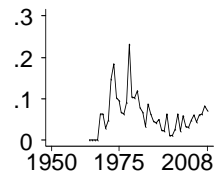
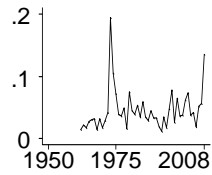
Corn



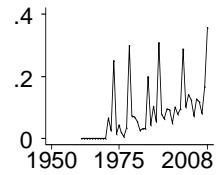
Copper



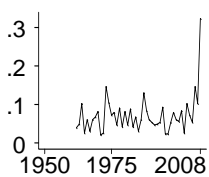
Cotton



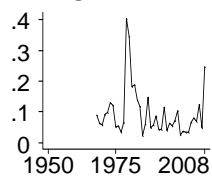
Gold



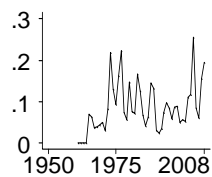
Cattle



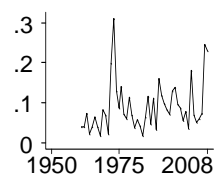
Hogs



Oats



Oil



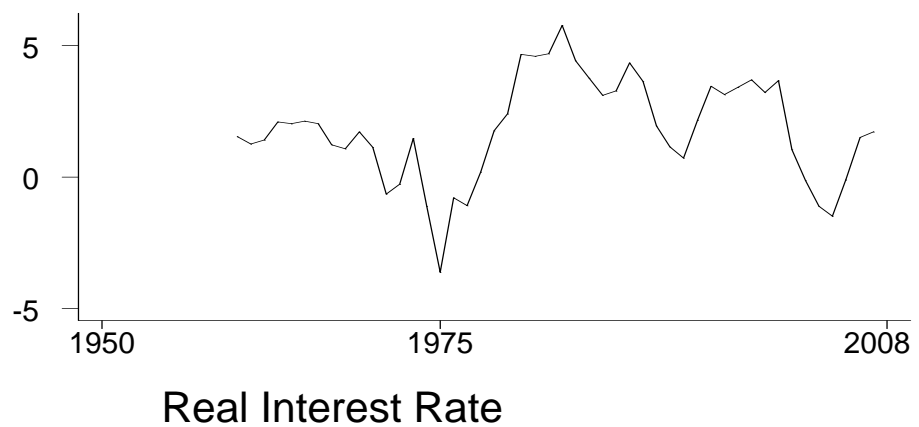
Platinum

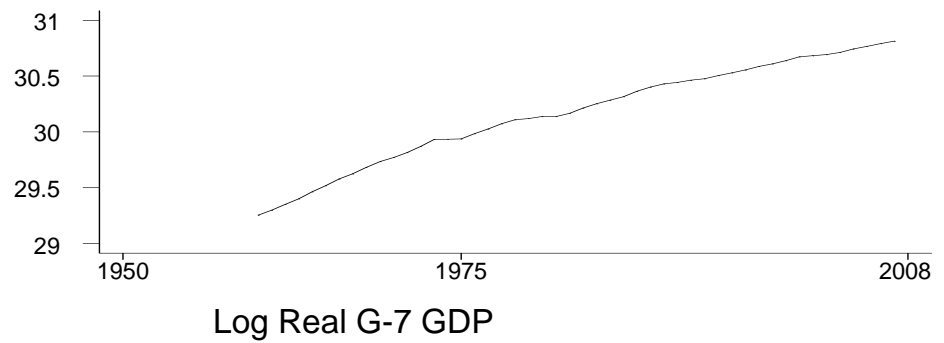
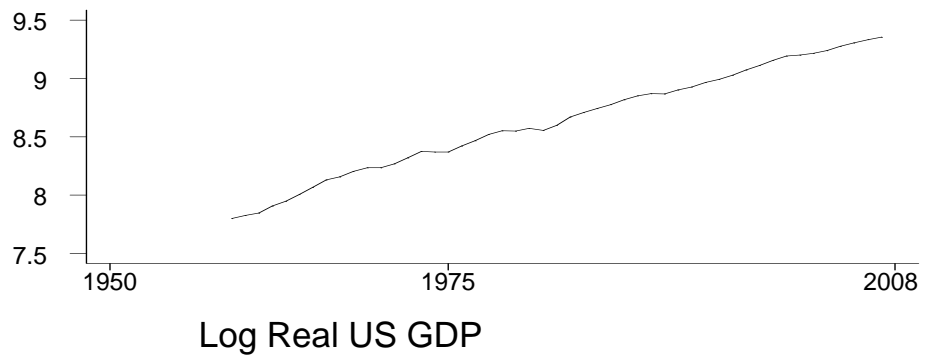
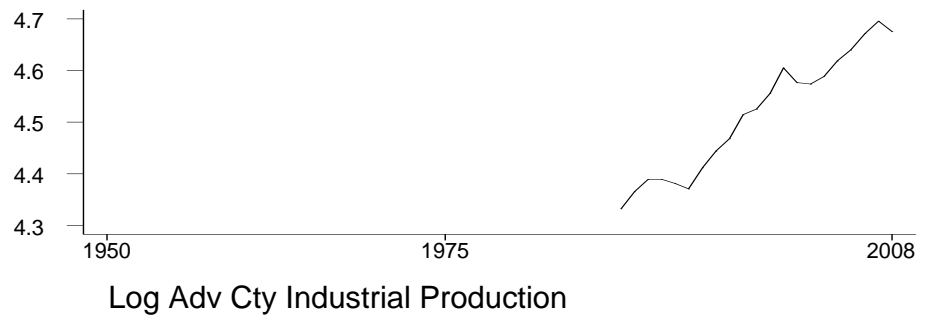
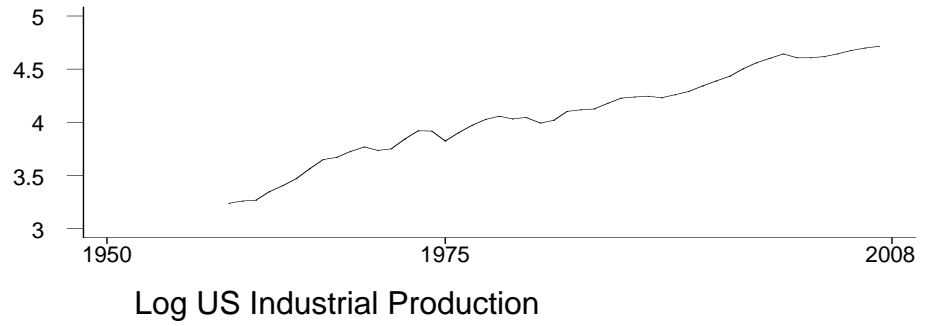
Silver

Soybeans

Wheat

Volatility





3. Estimation of the equation for commodity price determination

As a further warm-up, Table 1a reports results of bivariate regressions. Surprisingly, real GDP (which we use in place of industrial production so as to have more comprehensive coverage). Volatility and inventories both have their hypothesized signs and are significant for about half the commodities. The bivariate relationship between real oil prices and GDP is weaker than one would expect. The real interest rate, too, is usually not significant, although it has the hypothesized sign slightly more than half the time. When the same tests are run in terms of first differences in Table 1b, the results improve a bit. GDP is always of the right sign, but not always significant. Volatility and inventories again show up as hypothesized.

The theory made it clear that prices depend on a variety of independent factors, so bivariate tests tells us little. Table 2a presents the multivariate estimation of equation (8).¹⁰ The volatility, spread, and inventories data are usually of the hypothesized sign, and often significant, but not always. The macroeconomic variables are less successful. When the regressions are run on first differences, in Table 2b, the coefficient estimates are more often of the right sign, including for the macro variables a majority of the time. Indeed the estimates are never significantly of the wrong sign. But the significance levels tend to be low.

It is not surprising that tests run on one commodity at a time do not always produce the relationships we are looking for, because each has too few observations to produce significant estimates. We know we have not captured all the weather events that led to bad harvests in some agricultural regions or the political unrest that closed mines in other parts of the world. As in earlier research, we can hope to learn more when data from different commodities are combined. Tables 3a and 3b pool data from different commodities together into one large data set. This helps a lot with significance. The inventory measure is always statistically significant and of the hypothesized negative sign -- with or without time effects, commodity effects, or both. (Intuitively, high inventory levels mean that storage costs are high, so demand is low.) Similarly the spot-futures spread is always statistically significant and of the hypothesized negative sign. Volatility is always positive, and is statistically significant when commodity effects are included (with or without time effects); this suggests that high volatility leads to a high demand for inventories. When political risk is included, in table 3b, the results are mixed. Its presence, however, does seem to help the equation work better. Specifically, economic activity (GDP among major industrialized countries) has a significantly positive effect, as hypothesized.

Tables 4a and 4b run the regressions in terms of first differences,. The results are similar. Again the strongest three variables are volatility, the spread, and inventories.¹¹

Tables 5a and 5b report the results for a variety of prominent indices each of which aggregates commodity prices. In table 5a the real GDP coefficient always has the hypothesized

¹⁰ We exclude the risk measure. It gives generally unclear results, perhaps in part because its coverage is incomplete, perhaps because of the possible theoretical ambiguity mentioned earlier. Volatility seems to be better at capturing risk. A useful extension would be to use implicit volatility from options prices, which might combine the virtues of both the volatility and political risk variables.

¹¹ The significance of the inventory variable suggests that the data and relationship are meaningful, notwithstanding fears that it is an incomplete measure.

positive sign, if not always statistically significant. The volatility coefficient is often statistically greater than zero. The spot-futures spread coefficient is usually negative, if not always significant. The inventory coefficient is usually negative, and sometimes significant. The real interest rate is almost always insignificant.

Although we have already reported results of regressions run in first differences, a complete analysis requires that we examine the stationarity or nonstationarity of the series formally. Tables 6a and 6b test for unit roots in our individual variables by means of Phillips-Perron tests, and Table 6c tests for unit roots in the entire panel. The tests often fail to reject unit roots. One school of thought would doubt on a priori grounds that a variables such as volatility or the real interest rate could truly follow a random walk (which would imply that they eventually hit +100% or -100%). Another school of thought says that one must go wherever the data instruct. Here we pursue the implication of unit roots to be safe, as a robustness check if nothing else.

Tables 7a – 7c report tests of cointegration, and generally find it. Table 8 reports a vector error correction model. As in so many of the previous tests, the variables that are most consistently significant and of the hypothesized sign are the spread and the volatility, and to a lesser extent inventories.

Table 1a -- Commodity by Commodity Bivariate Results, Levels

Ln (real price)	ln(G-7 Real GDP) +	Volatility +	Sp-Fut. Sprd -	Inventories -	Real Int rate -
Corn	1.29* (.50)	1.55 (.84)	-.004 (.003)	-.12 (.11)	-.02 (.02)
Copper	.72 (1.01)	2.39** (.69)	-.008* (.003)	-.26** (.04)	-.03 (.02)
Cotton	1.09* (.48)	1.08** (.39)	-.002 (.002)	-.25 (.13)	.01 (.01)
Cattle	-2.06* (.90)	-.38 (1.18)	-.007** (.002)	.05 (.43)	-.03 (.02)
Hogs	-4.49** (1.07)	1.68 (1.13)	-.004* (.001)	.08 (.48)	-.04** (.01)
Oats	.91 (.53)	3.63* (1.68)	-.007* (.003)	-.24* (.11)	-.02 (.02)
Oil	-11.5** (3.1)	-.98 (.96)	-.005 (.003)	-4.60 (3.36)	.01 (.06)
Platinum	-3.73 (2.23)	3.31* (1.40)	.003 (.003)	-.15** (.03)	.02 (.02)
Silver	2.56 (2.05)	4.20** (.81)	.003 (.008)	-.70** (.21)	.04 (.03)
Soybeans	2.00** (.50)	3.12** (.44)	-.007 (.003)	-.06 (.10)	-.02 (.02)
Wheat	-3.46 (2.48)	1.87 (.96)	-.008* (.004)	-.97** (.21)	.00 (.04)

Each cell is a slope coefficient from a bivariate regression of the real price on the relevant regressor, and intercept and a trend.

Annual data:

robust standard errors in parentheses;

** (*) means significantly different from zero at .01 (.05) significance level.

Table 1b -- Commodity by Commodity Bivariate Results, First-Differences

Ln(rl price)	ln(G-7 Real GDP) +	Volatility +	Sp-Fut. Sprd -	Inventories -	Real Int rate -
Corn	1.75 (2.63)	.92 (.54)	-.002 (.001)	-.24* (.12)	.02 (.02)
Copper	9.05** (2.40)	.84* (.42)	-.004* (.002)	-.16 (.10)	.08** (.03)
Cotton	2.68 (1.74)	1.10** (.40)	-.001 (.001)	.01 (.12)	.05* (.02)
Cattle	2.53* (1.15)	-.97 (.49)	-.005** (.001)	-2.11* (.88)	-.01 (.01)
Hogs	1.54 (2.78)	.48 (1.12)	-.004** (.001)	-1.05* (.51)	-.01 (.02)
Oats	.45 (2.47)	1.46 (.96)	-.003 (.002)	-.46** (.11)	.00 (.03)
Oil	9.20* (3.63)	-.40 (.60)	-.004** (.001)	-1.40 (1.24)	.04 (.03)
Platinum	1.93 (1.93)	1.27* (.52)	.000 (.001)	-.02 (.08)	.04 (.02)
Silver	1.07 (4.19)	1.83** (.47)	.001 (.003)	-.06 (.14)	.01 (.05)
Soybeans	5.22** (1.83)	1.89** (.43)	-.003* (.001)	-.00 (.10)	.03 (.02)
Wheat	1.39 (3.39)	.78 (.63)	-.001 (.003)	-.65* (.24)	.01 (.02)

Annual data.

Each cell is a slope coefficient from a bivariate regression of the real price on the relevant regressor, and intercept and a trend.

Robust standard errors in parentheses;

** (*) means significantly different from zero at .01 (.05) significance level.

Table 2a -- Commodity by Commodity Multivariate Results, Levels

Ln(rl price)	ln(G-7 Real GDP) +	Volatility +	Sp-Fut. Sprd -	Inventories -	Real Int rate -
Corn	1.31 (.52)	1.09 (.76)	-.002 (.003)	-.1 (.15)	-.01 (.02)
Copper	-.55 (.85)	1.48* (.63)	-.006* (.003)	-.23** (.06)	-.02 (.01)
Cotton	.24 (.69)	1.20 (.59)	-.002 (.002)	-.18 (.16)	.02 (.01)
Cattle	-4.00 (2.71)	-.76 (.86)	-.005** (.001)	-1.59 (1.48)	-.00 (.03)
Hogs	-3.45** (.98)	.17 (.92)	-.004* (.001)	.28 (.26)	-.02* (.01)
Oats	2.22** (.67)	2.45* (1.16)	-.007** (.002)	-.60** (.10)	-.01 (.01)
Oil	-12.7** (3.51)	.22 (1.260)	-.004 (.003)	1.23 (3.73)	.03 (.05)
Platinum	.58 (1.92)	.81 (1.63)	.002 (.002)	-.23** (.05)	.08** (.01)
Silver	-.01 (1.58)	2.91** (.86)	.001 (.004)	-.48** (.17)	.03 (.03)
Soybeans	1.60** (.53)	2.55** (.38)	-.001 (.002)	-.04 (.07)	-.01 (.01)
Wheat	-3.02 (1.59)	1.47** (.51)	.004 (.004)	-1.05** (.26)	.02 (.02)

Annual data.

Robust standard errors in parentheses;

** (*) means significantly different from zero at .01 (.05) significance level.

Intercept and linear time trend included, not recorded.

OLS, commodity by commodity.

Table 2b -- Commodity by Commodity Multivariate Results, First-Differences

Ln(rl price)	ln(G-7 Real GDP) +	Volatility +	Sp-Fut. Sprd -	Inventories -	Real Int rate -
Corn	.41 (2.49)	.91* (.54)	-.001 (.001)	-.21 (.11)	.01 (.02)
Copper	4.59 (2.57)	.55 (.32)	-.002 (.001)	-.10 (.08)	.04 (.02)
Cotton	-.52 (2.36)	1.02** (.36)	-.001 (.001)	.01 (.12)	.04 (.03)
Cattle	1.95 (1.99)	-.49 (.56)	-.004* (.002)	-.98 (1.00)	-.00 (.01)
Hogs	1.68 (2.52)	-1.05 (1.08)	-.004** (.001)	-.55 (.49)	-.02 (.02)
Oats	2.00 (1.56)	1.51* (.65)	-.005** (.001)	-.68** (.12)	-.01 (.02)
Oil	9.54 (5.46)	-.53 (.55)	-.003* (.001)	-.61 (1.23)	-.01 (.03)
Platinum	-.31 (2.97)	1.21 (.65)	.000 (.001)	-.01 (.08)	.03 (.03)
Silver	-1.07 (4.03)	2.41** (.64)	.004 (.002)	.06 (.14)	.00 (.04)
Soybeans	3.64* (1.79)	1.65** (.34)	-.001 (.001)	.01 (.08)	-.01 (.02)
Wheat	1.26 (3.83)	.94 (.54)	.003 (.003)	-.90* (.23)	-.00 (.04)

Annual data

Robust standard errors in parentheses;

** (*) means significantly different from zero at .01 (.05) significance level.

Intercept and linear time trend included, not recorded.

OLS, commodity by commodity.

Table 3a -- Panel Results, levels

Ln(rl price)	Ln(G-7 Real GDP) +	Volatility +	Sp-Fut. Sprd -	Inventories -	Real Int rate -
Pooled	.56 (.34)	2.24 (1.55)	-.022** (.006)	-.20** (.03)	.02 (.04)
Time Effects	n/a	2.00 (1.85)	-.026** (.007)	-.20** (.01)	n/a
Commodity Effects	-.01 (.36)	2.03** (.52)	-.003* (.001)	-.15** (.02)	-.00 (.01)
Both	n/a	1.54** (.30)	-.002* (.001)	-.14** (.01)	n/a

Annual data

robust standard errors in parentheses;

** (*) means significantly different from zero at .01 (.05) significance level.

Intercept and trend (for pooled and commodity effects rows) included, not recorded.

Table 3b-- Panel Results, levels with risk included

Ln(rl price)	Ln(G-7 Real GDP) +	Risk -	Volatility +	Sp-Fut. Sprd -	Inventories -	Real Int rate -
Pooled	.82* (.38)	.21 (.11)	2.24 (1.57)	-.021** (.006)	-.16** (.04)	.02 (.04)
Time Effects	n/a	.43** (.15)	2.04 (1.93)	-.026** (.007)	-.13** (.02)	n/a
Commodity Effects	.57* (.21)	-.06 (.04)	1.75* (.58)	-.003* (.001)	-.15** (.03)	.00 (.01)
Both	n/a	-.01 (.02)	1.49** (.31)	-.003* (.001)	-.12** (.01)	n/a

Annual data,

Robust standard errors in parentheses;

** (*) means significantly different from zero at .01 (.05) significance level.

Intercept and trend (for pooled and commodity effects rows) included, not recorded.

Table 4a -- Panel Results, first-differences

Ln(rl price)	Ln(G-7 Real GDP) +	Volatility +	Sp-Fut. Sprd -	Inventories -	Real Int rate -
Pooled	1.07 (.78)	.77** (.18)	-.002** (.001)	-.12** (.04)	.02 (.01)
Time Effects	n/a	.60** (.19)	-.002** (.001)	-.08* (.04)	n/a
Commodity Effects	1.49 (.80)	.76* (.27)	-.002** (.001)	-.12* (.05)	.01 (.01)
Both	n/a	.58** (.18)	-.002** (.001)	-.07 (.04)	n/a

Annual data:

robust standard errors in parentheses;

** (*) means significantly different from zero at .01 (.05) significance level.

Intercept and trend (for pooled and commodity effects rows) included, not recorded.

Table 4b -- Panel Results, first-differences with risk included

Ln(rl price)	Ln(G-7 Real GDP) +	Risk -	Volatility +	Sp-Fut. Sprd -	Inventories -	Real Int rate -
Pooled	1.22 (.78)	-.03 (.02)	.69** (.19)	-.002** (.001)	-.16** (.04)	.01 (.01)
Time Effects	n/a	-.02 (.02)	.53** (.19)	-.002** (.001)	-.10** (.04)	n/a
Commodity Effects	1.56 (.81)	-.03 (.02)	.69* (.28)	-.002** (.001)	-.16* (.07)	.01 (.01)
Both	n/a	-.02 (.02)	.53** (.20)	-.002** (.001)	-.10** (.04)	n/a

Annual data:

robust standard errors in parentheses;

** (*) means significantly different from zero at .01 (.05) significance level.

Intercept and trend (for pooled and commodity effects rows) included, not recorded.

Table 5a -- Index Results, in Levels

Weights	Period After	Ln(Real G-7 GDP) +	Volatility +	Sp-Fut. Sprd - -	Inventories -	Real Int rate -
Dow-Jones/AIG	1984	6.39** (1.74)	-.29 (.37)	-.002 (.001)	-.44** (.15)	-.00 (.02)
Dow-Jones/AIG	1973	1.06 (1.36)	1.37* (.48)	.001 (.002)	-.31* (.14)	.01 (.01)
Dow-Jones/AIG	1964	2.53 (1.68)	1.94** (.53)	-.002 (.002)	-.09 (.11)	.01 (.01)
S&P GCSI	1984	9.20* (4.10)	-.49 (.47)	-.002* (.001)	-.96 (.67)	-.01 (.02)
S&P GCSI	1973	1.15 (1.48)	1.04 (.53)	.000 (.002)	-.30 (.15)	.01 (.02)
S&P GCSI	1964	2.22 (1.78)	1.78** (.56)	-.002 (.002)	-.13 (.12)	.01 (.01)
CRB Reuters/Jefferies	1984	7.55* (2.11)	-.62 (.38)	-.002 (.001)	-.48* (.19)	-.00 (.02)
CRB Reuters/Jefferies	1973	.86 (1.67)	1.16* (.47)	.001 (.002)	-.27* (.15)	.02 (.02)
CRB Reuters/Jefferies	1964	1.97 (1.60)	1.88** (.51)	-.002 (.002)	-.13 (.11)	.02 (.01)
Grilli-Yang	1984	2.80 (1.46)	1.39 (.75)	-.002 (.002)	-.23 (.14)	.03 (.02)
Grilli-Yang	1973	.42 (2.13)	1.73** (.56)	-.001 (.002)	-.20 (.15)	.03 (.02)
Grilli-Yang	1964	1.01 (1.99)	1.31** (.48)	-.002 (.002)	-.15 (.13)	.03* (.01)
Economist	1984	2.86* (1.37)	2.12* (.79)	-.001 (.001)	-.21 (.10)	.03 (.03)
Economist	1964	2.27 (1.63)	1.82** (.48)	-.002 (.001)	-.11 (.09)	.02 (.02)
Equal	1984	4.12 (1.97)	1.18 (.75)	-.002 (.002)	-.42** (.12)	.02 (.02)
Equal	1973	.19 (1.71)	1.57* (.73)	.001 (.002)	-.41* (.17)	.02 (.02)
Equal	1964	1.31 (1.63)	1.96** (.54)	-.002 (.002)	-.23 (.12)	.01 (.01)

Annual data:

robust standard errors in parentheses;

** (*) means significantly different from zero at .01 (.05) significance level.

Intercept and trend included, not recorded.

Weighted averages (according to different schemes) of percentage changes/first differences.

Table 5b -- Index Results, in First-Differences

Weights	Period After	Ln(Real G-7 GDP) +	Volatility +	Sp-Fut. Sprd - -	Inventories -	Real Int rate -
Dow-Jones/AIG	1984	.89 (1.66)	1.31** (.20)	-.003 (.002)	-.25 (.19)	.00 (.02)
Dow-Jones/AIG	1973	-.28 (.84)	1.34** (.11)	.001 (.002)	-.31* (.13)	-.01 (.01)
Dow-Jones/AIG	1964	.12 (.68)	1.21** (.15)	-.003* (.002)	-.10 (.14)	-.01 (.01)
S&P GCSI	1984	1.31 (1.86)	.06 (.33)	-.004** (.001)	1.02** (.34)	.01 (.04)
S&P GCSI	1973	-.29 (.90)	1.31** (.11)	.000 (.002)	-.29* (.13)	.01 (.01)
S&P GCSI	1964	.05 (.68)	1.24** (.15)	-.003 (.002)	-.16 (.14)	-.01 (.01)
CRB Reuters/Jefferies	1984	.61 (1.95)	.93* (.26)	-.003 (.002)	.07 (.26)	.01 (.03)
CRB Reuters/Jefferies	1973	-.25 (.95)	1.29** (.11)	-.000 (.001)	-.26 (.13)	-.01 (.01)
CRB Reuters/Jefferies	1964	.14 (.63)	1.27** (.16)	-.003 (.002)	-.15 (.13)	-.01 (.01)
Grilli-Yang	1984	.51 (1.80)	1.37** (.22)	-.001 (.002)	-.27 (.19)	-.00 (.02)
Grilli-Yang	1973	-.46 (1.20)	1.25** (.12)	-.000 (.002)	-.20 (.16)	-.01 (.01)
Grilli-Yang	1964	-.08 (.60)	1.24** (.18)	-.003 (.002)	-.18 (.13)	-.01 (.01)
Economist	1984	.43 (1.53)	1.35** (.18)	-.001 (.002)	-.26 (.15)	-.00 (.02)
Economist	1964	.04 (.63)	1.24** (.16)	-.003 (.002)	-.14 (.13)	-.01 (.01)
Equal	1984	.62 (1.42)	1.55** (.23)	-.003 (.002)	-.45* (.21)	.00 (.02)
Equal	1973	-.30 (.89)	1.37** (.16)	.000 (.001)	-.36 (.18)	-.01 (.02)
Equal	1964	.11 (.54)	1.35** (.17)	-.003 (.002)	-.26 (.13)	-.01 (.01)

Annual data:

robust standard errors in parentheses;

** (*) means significantly different from zero at .01 (.05) significance level.

Intercept and trend included, not recorded.

Weighted averages (according to different schemes) of percentage changes/first differences.

Unit Root Tests

Table 6a Phillips-Perron Tests for Unit Root in Aggregate Time-Series

	Z(rho)	Z(t) (MacKinnon p-value)
Log US Industrial Production	-1.07	-1.59 (.49)
Log Advanced Country Industrial Production	-.67	-.74 (.84)
Log Real US GDP	-.49	-1.52 (.52)
Log Real G-7 GDP	-1.12	-4.84** (.00)
Real Interest Rate	-10.23	-2.32 (.17)

Annual Data. Intercept included. Two lags as controls. * (**) indicates rejection of null hypothesis of unit root at .05 (.01) significance level.

Table 6b Phillips-Perron Tests for Unit Root in Commodity-Specific Time-Series

	Log Real Price	Spread	Log Inventory	Volatility	Risk
Corn	-4.7/-1.6	-61**/-8.6**	-2.6/-1.2	-53**/-6.7**	-6.2/-1.8
Copper	-7.5/1.9	-40**/-5.5**	-8.6/-2.0	-39**/-5.2**	-22**/-3.7*
Cotton	-3.7/-1.4	-77**/-10**	-4.5/-1.5	-24**/-4.1**	-12/-2.6
Live Cattle	-7.0/-2.2	-12.3/-2.7	-7.5/-2.7	-39**/-4.5**	-34**/-5.1**
Live Hogs	-8.2/-2.1	-34**/-6.2**	-23**/-3.5**	-39**/-4.5**	-7.1/-2.0
Oats	-7.3/-2.0	-46**/-6.2**	-2.1/-0.8	-30**/-4.2**	-29**/-4.7**
Petroleum	-4.1/-1.3	-27**/-5.1**	-5.0/-3.4*	-38**/-4.9**	-7.8/-2.0
Platinum	-6.0/-1.4	-29**/-4.6**	4.5/3.6	-40**/-3.6	-13*/-2.9*
Silver	-7.4/-2.0	-35**/-5.4**	-3.1/-1.3	-20**/-3.3*	-15*/-3.2*
Soybeans	-4.0/-1.4	-57**/-8.1**	-4.2/-1.8	-24**/-4.0*	-3.9/-1.5
Wheat	-6.3/-1.9	-49**/-6.5**	-5.0/-1.7	-28**/-4.2**	-5.3/-1.1

Z(rho)/Z(t) statistics reported. Annual Data. Intercept included. Two lags as controls. * (**) indicates rejection of null hypothesis of unit root at .05 (.01) significance level.

Table 6c Panel Unit Root Tests

	Im, Pesaran, Shin (p-value)	Levin, Lin	Dickey, Fuller	Maddala, Wu
Log Real Price	-1.68 (.24)	-.12 (.15)	68	14.1 (.94)
Risk	-1.68 (.20)	-.33* (.03)	395	24.5 (.44)
Spread	-2.94** (.00)	-1.03* (.02)	153	88.1** (.00)
Log Inventory	-1.05 (.94)	-.06 (.95)	85	27.4 (.20)
Volatility	-2.88** (.00)	-.78 (.19)	161	63.3** (.00)

Annual Data. Intercept included. Two lags as controls. * (**) indicates rejection of null hypothesis of unit root at .05 (.01) significance level.

Cointegration Tests

Table 7a Johansen Tests for Cointegration in Commodity-Specific Models

	Default	1% level	3 Lags	Max Eigenvalue	Add trend	Drop Risk
Corn	0	4	4	0	4	0
Copper	1	1	4	0	1	0
Cotton	3	2	2	0	4	2
Live Cattle	6	5		0	6	0
Live Hogs	4	3	6	0	4	3
Oats	2	2	3	0	2	2
Petroleum						3
Platinum	3	3	4	0	3	2
Silver	1	1	4	0	2	2
Soybeans	2	2	4	0	3	3
Wheat			3			3

Maximal rank from Johansen trace statistic at 5% level unless noted. Annual Data. Intercept included. Two lags included unless noted. * (**) indicates rejection of null hypothesis of unit root at .05 (.01) significance level.

Model of log real commodity price includes six controls (risk, spread, log inventory, volatility, real interest rate, log real G-7 GDP) unless noted.

Table 7b: Panel Cointegration Tests: without Risk

	G_t	G_a	P_t	P_a
Default	-1.65 (.96)	-3.17 (1.0)	-4.73 (.89)	-2.78 (.99)
Only 1 lag	-2.16 (.55)	-4.17 (1.0)	-5.66 (.68)	-3.82 (.96)
Add constant	-1.74 (1.0)	-4.86 (1.0)	-5.53 (.99)	-4.90 (1.0)
Add constant, trend	-1.69 (1.0)	-4.97 (1.0)	-4.95 (1.0)	-4.43 (1.0)
Add lead	-.52 (1.0)	-.76 (1.0)	-1.49 (1.0)	-.54 (1.0)

Default: two lags. P-values (for null hypothesis of no cointegration) recorded in parentheses. Model of log real commodity price includes five controls (spread, log inventory, volatility, real interest rate, log real G-7 GDP).

Table 7c: Panel Cointegration Tests: Including Risk

	G_t	G_a	P_t	P_a
Default	-1.26 (1.0)	-.98 (1.0)	-3.57 (1.0)	-1.02 (1.0)
Only 1 lag	-1.90 (.96)	-3.25 (1.0)	-4.89 (.97)	-3.06 (1.0)
Add constant	-1.69 (1.0)	-2.75 (1.0)	-3.21 (1.0)	-1.62 (1.0)
Add constant, trend	-1.57 (1.0)	-2.31 (1.0)	-2.7 (1.0)	-1.4 (1.0)
Add lead	.08 (1.0)	.22 (1.0)		.01 (1.0)

Default: two lags. P-values (for null hypothesis of no cointegration) recorded in parentheses. Model of log real commodity price includes six controls (risk, spread, log inventory, volatility, real interest rate, log real G-7 GDP).

**Table 8 -- Cointegration Vector Estimates
from Commodity by Commodity Vector Error Corrections**

Ln(rl price)	ln(G-7 Real GDP) +	Volatility +	Sp-Fut. Sprd -	Inventories -	Real Int rate -
Corn	-.60** (.21)	2.98** (.90)	-.049** (.004)	-.26 (.18)	.03 (.03)
Copper	1.48** (.33)	.92 (1.69)	-.078** (.008)	-.36* (.18)	-.09 (.06)
Cotton	-1.09** (.17)	5.30** (.83)	-.048** (.002)	-.79** (.20)	.02 (.02)
Cattle	.62 (.32)	-15.3** (1.4)	-.026** (.003)	2.73** (1.05)	.01 (.03)
Hogs	-.37 (.21)	16.0** (1.8)	-.025** (.003)	-2.68** (.85)	.01 (.02)
Oats	-.64* (.27)	5.29** (1.82)	-.035** (.004)	.21 (.17)	.03 (.03)
Oil	-5.76 (5.67)	24.7** (4.9)	-.187** (.017)	24.1 (16.2)	-.12 (.25)
Platinum	-.77 (.73)	16.6** (4.0)	.057** (.007)	-.10 (.14)	.07 (.06)
Silver	-2.27** (.32)	4.28** (.63)	-.040** (.003)	-.83** (.13)	.04 (.02)
Soybeans	.39 (.41)	.54 (1.04)	-.073** (.005)	-.23 (.16)	.02 (.03)
Wheat	-1.08** (.16)	3.70** (.64)	-.039** (.003)	-.08 (.21)	.02 (.02)

Annual data: standard errors in parentheses;

** (*) means significantly different from zero at .01 (.05) significance level.

Intercept and linear time trend included, not recorded.

VEC estimation, commodity by commodity, one lag.

References

- Abosedra, Salah; and Radchenko, Stanislav (2003), "Oil Stock Management and Futures Prices: An Empirical Analysis", *Journal of Energy and Development*, vol. 28, no. 2, Spring 2003, pp. 173-88
- Balabanoff, Stefan (1995), "Oil Futures Prices and Stock Management: A Cointegration Analysis", *Energy Economics*, vol. 17, no. 3, July 1995, pp.205-10.
- Bessimbinder, Hendrik (1993). "An Empirical Analysis of Risk Premia in Futures Markets" *Journal of Futures Markets*, 13, page 611–630.
- Breeden, Douglas. T.(1980) "Consumption Risks in Futures Markets". *Journal of finance*, vol. 35, page 503-20, May.
- Brenner, Robin J. and Kroner, Kenneth F. (1995). "Arbitrage, Cointegration, and Testing Unbiasedness Hypothesis in financial markets". *Journal of finance and Quantitative Analysis* 30, page 23-42.
- Choe, Boum-Jong(1990). "[Rational expectations and commodity price forecasts](#)," [Policy Research Working Paper Series](#) 435, The World Bank.
- Covey, Ted, & Bessler, David A. (1995). "Asset Storability and the Information Content of Intertemporal Prices". *Journal of Empirical Finance*, 2, page 103-15.
- Dusak, Katherine (1973). "Futures trading and investor returns: An investigation of commodity market risk premiums". *Journal of Political Economy*, 81, page 1387–1406.
- Fama, Eugene, & French, Kenneth R. (1987). "Commodity futures prices: Some evidence on forecast power, premiums, and the theory of storage". *Journal of Business*, 60, page 55–73.
- Fortenbery, Randall T. & Zapata, Hector O. "An Evaluation of Price Linkages Between Futures and Cash Markets for Cheddar Cheese." *The Journal of Futures Markets*, vol.,17, page 279-301.
- Fortenbery, Randall T. & Zapata, Hector O. "Analysis of Expected Price Dynamics Between Fluid Milk Futures Contracts and Cash Prices for Fluid Milk." *Journal of Agribusiness*, vol., 15, page 125-134.
- Frankel, Jeffrey, 1984, "Commodity Prices and Money: Lessons from International Finance," [American Journal of Agricultural Economics](#) 66, no. 5 (Dec. 1984), 560-566.
- Frankel, Jeffrey, 1986 "Expectations and Commodity Price Dynamics: The Overshooting Model," [American Journal of Agricultural Economics](#) 68, no. 2 (May 1986), 344-348. Reprinted in Frankel, *Financial Markets and Monetary Policy*, MIT Press, 1995.
- Frankel, Jeffrey, 2008, "The Effect of Monetary Policy on Real Commodity Prices," in *Asset Prices and Monetary Policy*, John Campbell, ed., U.Chicago Press: 291-327.
- Frankel, Jeffrey, and Gikas Hardouvelis, 1985, "Commodity Prices, Money Surprises, and Fed Credibility" [Journal of Money, Credit and Banking](#) 17, no. 4 (Nov., Part I), 427-438. Reprinted in Frankel, *Financial Markets and Monetary Policy*, MIT Press, 1995.
- Froot, Kenneth. A & Frankel, Jeffrey. A., (1989). "Forward Discount Bias: Is It an Exchange Risk Premium?," *The Quarterly Journal of Economics*, vol. 104(1), pages 139-61, February.

Kolb, Robert W. (1992). "Is normal backwardation normal?" *Journal of Futures Markets*, 12, page 75–91.

Kohn, Donald, 2008, speech on *The Economic Outlook* by the Vice Chairman of the Federal Reserve Board, at the National Conference on Public Employee Retirement Systems Annual Conference, New Orleans, Louisiana, May 20.

Krugman, Paul, 2008, "Commodity Prices," *NYTimes*, March 19, at <http://krugman.blogs.nytimes.com/2008/03/19/commodity-prices-wonkish/>.

Turnovsky, Stephen J., (1983). "The Determination of Spot and Futures Prices with Storable Commodities," *Econometrica*, vol. 51(5), pages 1363-87, September.

Working, Holbrook (1949). "The Theory of Price Storage" *American Economic Review*, vol. 30, page 1254-62, December.

Yang, Jian; Bessler, David A.; and Leatham, David J., (2001). "Asset Storability and Price Discovery in Commodity Futures markets: A New Look" *The Journal of Futures Markets*. vol. 21(3), March.

Appendix 1: Predictive Bias in Commodity Futures Markets

Summary

Although there are a number of studies that explore the existence of risk premium in commodities futures, most of the empirical literature on commodities futures pricing focuses more on exploring the less controversial ‘theory of storage’ which links spot price to futures price of commodities via the net costs of carrying. Most of the papers studying the existence of risk premium or biasness of futures as a forecast of a future spot price found mixed results.

Introduction

Commodity futures can deliver both storage facilitation and forward pricing role in their price discovery function¹². Accordingly there are two main theories in commodity futures price determination.

1. Theory of storage or costs-of-carrying models (Working 1949, Brennan 1958) which explains the difference in the contemporaneous spot price and futures price of commodities by the net costs of carrying stock which composed of 1) interests foregone (had they been sold earlier), 2) warehousing costs, and 3) convenience yield.
2. The view that futures price has two components (Breen 1980, Hazuka 1984): the expected risk premium (Keynes’ “normal backwardation theory”), and the forecast of future spot price. Under this theory the futures price is a biased estimate of future spot price because of the risk premia - insurance being sold by the speculators to the hedgers.

Is the futures price a biased predictor of future spot price?

Much of the empirical literature up to 1980s had emphasized the storage facilitation role of futures markets and thus focused on the costs-of-carrying model rather than the forward pricing role of the future rate (and therefore the use of futures to forecast ahead the spot price). More recent studies during 1990s addressed the question of unbiasedness of futures price to forecast spot price by examining the cointegration between futures and spot prices to deal with problems of non-stationary nature of commodities price (e.g. Covey and Bessler 1995; Brenner and Konner 1995; Fortenbery and Zapata 1997; Yang 2001). Most of these studies found mixed results for storable commodities but no cointegration for non-storable ones.

Following Keynes’ theory of normal backwardation, there are a number studies motivated by the presumed existence of a risk premium in the futures price. The evidence is mixed. For example, Bessembinder (1992) found evidence of risk premia (futures bias) for live cattle, soy beans, and cotton, but much smaller than those in non-agricultural assets such as T-bills. On the other hand, Fama and French (1987) studied 21 commodities and found only weak evidence of time-varying risk premia. A study by Kolb (1992) did not find evidence of risk premia for most of 29 commodities examined. Many of these studies, however, examined the existence of risk premium either by exploring the extra returns earned by the speculators or defining as expected premium the bias of futures price as a forecast of future spot price. None of these studies, except for Choe (1990), address the question of whether the bias in the futures price comes from systematic expectation errors or from a time-varying risk premium.

¹² See Yang et al (2001) for review of the literature.

Is it the risk premium or errors in the expectations?

Choe (1990) attempted to bring an independent expectations measure to bear on the question whether the predictive bias in commodity futures is due to a risk premium or to a failure of the rational expectations methodology, analogous to the approach taken by Frankel and Froot (1989) for the foreign exchange market. To explore commodities including copper, sugar, coffee, cocoa, maize, cotton, wheat, and soybeans, Choe obtained the data on futures prices and then approximated expectations of the future spot price using the forecast conducted by the World Bank International Commodity Market Division (CM). He discovered that:

- Using futures prices for short-term price forecasting is more bias-prone than relying on specialists' forecasts.
- In contrast to the results found by Frankel and Froot (1989), a major part of futures forecast bias comes from risk premia as well as expectational errors. For copper, cocoa, cotton, and soybeans, the expectational errors seem to play a principle role, whereas the existence of risk premia is important for the other of commodities.
- The size of the risk premia can be large compared to the expectational errors. However, the variance of risk premium is larger than that of expected price change only for coffee and wheat.
- The estimated bias from the risk premium is negative while that from expectational error is mixed – negative for half of the commodities examined and positive for the others.

Table I: Data and Sources for Review of Literature on Futures Bias

Authors	Sources
Dusak 1973	US Department of Agriculture
Fama and French 1987	Chicago Board of Trade for Corn, Soy Bean, Soy Oil, Wheat, Plywood, Broilers Chicago Mercantile Exchange for Lumber, Cattle, Hogs, Pork Bellies Commodity Exchange for Copper, Gold, and Silver Coffee, Sugar and Cocoa Exchange for coffee and cocoa New York Cotton Exchange for cotton New York Mercantile Exchange for Platinum
Choe 1990	International Economic Division at the World Bank and DRICOM database from Data Resource Inc: copper, sugar, coffee, cocoa, maize, cotton, wheat, soybeans
Tomek 1997	Chicago Board of Trade
Carter 1999	Commodity Future Trading Commission (CFTC): both cash and future prices
Yang et al. 2001	Data Stream International: data on Chicago Board of Trade and Minneapolis Grain Exchange

Appendix 2 The effect of real interest rates and other control variables on oil inventory demand and on the price of oil

using the same data as in Frankel (2008).

Aug 2008

We begin by replicating the first couple of lines of Table 2 in Frankel (2008) for the case of oil.

* The data set is from the "inventories and interest rates.xls" * The oil price data set is from the "oilprices.xls" * The oil price data turns monthly for some periods of time.

Variable	Obs	Mean	Std. Dev.	Min	Max
Month counter	1265	633	365.3184	1	1265
week	1265	199364.8	699.9613	198141	200552
col3	1265	12376	2557.228	7952	16800
inventories	1201	325.5764	24.17652	263.666	391.907
cpi	1252	143.3593	29.82036	93.2	198.8
Inflation	1199	3.116811	1.082935	1.039326	6.289809
Rate1	1252	6.020673	2.89577	.9	15.26
rrate1	1199	2.587453	2.073909	-1.840134	8.308461
risk	1135	65.83963	6.079567	55.51264	77.78235
ind.prod.	1243	83.79805	11.72833	61.25731	102.4795
oil_sf2	1174	2.213825	3.792078	-16.53524	25.36327
oil_sf3	1083	3.34529	5.229748	-18.26758	31.32576
date	1265	12376	2557.228	7952	16800
close	1110	24.10227	8.770657	10.86	66.71
l_inv	1201	5.782786	.0754349	5.574683	5.971025
l_ip	1243	4.418268	.1438607	4.115083	4.629663
counter2	1265	534041	477637.1	1	1600225
lagl_inv	1201	5.782786	.0754349	5.574683	5.971025
lroilp	1110	-1.837853	.3257896	-2.71478	-1.06331

*

Table A2.i: Determination of oil inventories

Replication of the inventory regressions from Table 2 of Frankel (2008).

. reg l_inv rrate1 oil_sf2 l_ip risk counter counter2

Source	SS	df	MS	Number of obs =
Model	4.40809355	6	.734682259	1126
Residual	1.82012629	1119	.001626565	
Total	6.22821984	1125	.005536195	

F(6, 1119) = 451.68
 Prob > F = 0.0000
 R-squared = 0.7078
 Adj R-squared = 0.7062
 Root MSE = .04033

l_inv	Coef.	Std. Err.	t	P> t
rrate1	-.0039438	.0009769	-4.04	0.000
oil_sf2	-.0082112	.0003243	-25.32	0.000
l_ip	.396612	.0584869	6.78	0.000
risk	-.0017421	.000554	-3.14	0.002
counter	-.0001391	.0000427	-3.26	0.001
counter2	-1.19e-07	1.50e-08	-7.90	0.000
_cons	4.319159	.254002	17.00	0.000

Table A2.ii: Determination of oil inventories, including lagged inventories

. reg l_inv rrate1 oil_sf2 l_ip risk lagl_inv counter counter2

Source	SS	df	MS	Number of obs = 1126	
				F(7, 1118) = 4834.72	
Model	6.02905095	7	.861292993	Prob > F = 0.0000	
Residual	.199168895	1118	.000178147	R-squared = 0.9680	
				Adj R-squared = 0.9678	
Total	6.22821984	1125	.005536195	Root MSE = .01335	

l_inv	Coef.	Std. Err.	t	P> t
rrate1	-.0005557	.0003252	-1.71	0.088
oil_sf2	-.0007923	.0001325	-5.98	0.000
l_ip	.0522222	.0196897	2.65	0.008
risk	.000127	.0001844	0.69	0.491
lagl_inv	.9310542	.0097607	95.39	0.000
counter	-.0000314	.0000142	-2.21	0.027
counter2	-2.78e-09	5.13e-09	-0.54	0.588
_cons	.183803	.0945812	1.94	0.052

*
 * Regression of real oil price against its determinants.¹³
 * Theory indicates a positive effect for IP; negative effects for inventories, real interest rates, risk, and the spread.

Table A2iii Determination of real oil price

```
. reg lroilp l_ip l_inv rrate1 risk oil_sf2 counter counter2
```

Source	SS	df	MS	Number of obs = 1066	
				F(7, 1058) = 407.59	
Model	70.9020652	7	10.1288665	Prob > F = 0.0000	
Residual	26.291911	1058	.024850578	R-squared = 0.7295	
				Adj R-squared = 0.7277	
Total	97.1939762	1065	.091261949	Root MSE = .15764	

lroilp	Coef.	Std. Err.	t	P> t
l_ip	3.444707	.2385354	14.44	0.000
l_inv	.4553318	.1192463	3.82	0.000
rrate1	-.0523439	.0039533	-13.24	0.000
risk	.0365303	.0022475	16.25	0.000
oil_sf2	.0260395	.0016334	15.94	0.000
counter	-.0060037	.0001724	-34.82	0.000
counter2	2.84e-06	6.23e-08	45.52	0.000
_cons	-19.67304	1.143041	-17.21	0.000

6 Aug 2008

¹³ Note: Volatility is missing. Also Autocorrelation is ignored here, and there are missing observations (holidays)