Interest Rates and Commodity Prices

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Abstract. *The theory of storage and arbitrage approaches fully incorporate nominal interest rates in far-near commodity price spreads Alternative frameworks admit a relationship between interest rates and commodity own rates of interest, and as a result, the commodity price spread would not completely incorporate the nominal interest rate This study examines the views on interest rate-commodity price relationships, the potential role of nonneutralities, and empirical evidence on the relationships The evidence does not support the hypothesis of a close relationship between commodity own rates and the real interest rate*

Keywords. *Theory of storage, arbitrage, interest rates, commodity own rates, risk premium, nonneutralities*

Much recent research has focused on the relationship between interest rates and commodity prices Most studies are based on, and support, the theory of storage Under a strict interpretation, the theory of storage indicates that the percentage difference between simultaneously quoted prices for contracts of different delivery dates completely incorporates nominal interest costs Recently, however, some analysts have suggested that the commodity own rate, an implicit rate of return to commodities, is positively related to the real interest rate, and as a result, the far-near commodity price spread would not incorporate the full nominal interest cost

Interest rate-commodity price relationships are key in examining macroeconomic linkages to primary commodity sectors like agriculture (*24*) [1] The relationships are particularly important for examining nonneutral monetary impacts Nominal money supply changes produce no real economic impacts, only nominal price effects, with money neutrality With nonneutralities, money supply changes induce changes in the real interest rate and real prices The real price impacts may be particularly strong for primary commodities due to the highly flexible nature of their prices Examinations of the importance of real interest rates in the determination of commodity prices and expected commodity price dynamics can, therefore, provide important information for understanding nonneutral monetary impacts.

Theoretical Issues and Relationships

The literature on the relationship between commodity prices and interest rates has a long history. For example, Keynes examined futures prices and the relationships among commodity prices, commodity own rates, and the money rate of interest (*15, 16*) Many of these relationships have also been used in a well-developed literature on the theory of storage [2] The theory of storage is the basis of the arbitrage approach used by Frankel (*7, 8*) and examined by Kitchen and Denbaly (*18*) Kitchen and Denbaly, and Fama and French (*6*), used essentially identical approaches, giving results that support the role of interest rates as specified in the theory of storage and the arbitrage approach According to Fama and French (*6*, p 55), "the theory of storage is not controversial "

In a dynamic world of uncertainty, Working's theory of storage is a self-contained but static formulation of intertemporal price relationships (*28*) A conceptual inconsistency in Working's hypothesis was demonstrated by Weymar (*27*) who used Muth's (*19*) rational expectation hypothesis to show that the spread between futures prices for two different dates of delivery should depend on expected stocks, not stocks already in existence Expectations about stock relationships, and the way such expectations are formed, critically affect storable commodity prices In contrast, Working stated, "It is only supplies already in existence which have any significant bearing on current intertemporal price relationships "

There appears to be some controversy about whether the far-near commodity price spread exactly incorporates the nominal interest rate Cornell and French (*2*) showed empirical results that suggest that commodity price spreads (the commodity basis as they define it) adjust to money shocks by an amount that is less than the adjustment in the nominal interest rate Cornell and French theorize that this smaller adjustment of the commodity basis is due to the relationship between commodity own rates and the economywide real interest rate Gordon introduced similar concerns by suggesting that the convenience yield is related to the nominal interest rate (*13*)

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[1] Italicized numbers in parentheses cite sources listed in the References section at the end of this article

[2] See (*27*), and for more recent reviews, see (*21, 10,* and *6*)

The General Case

A general formulation, which admits a host of special cases, presents the basis or price spread as

$$\ln F(t,t+j) - \ln S(t) = a_1\, i(t,j) + a_2\, sc(t,j) - a_3\, cy(t,j) + a_4\, p(t,j) + a_5\, ar(t,j), \quad (1)$$

where ln represents the natural logarithm, $F(t, t+j)$ is the futures contract price in period t for a commodity to be delivered in period t+j, $S(t)$ is the spot price in period t, $i(t,j)$ is the j-period nominal rate of interest in period t, $sc(t,j)$ is the j-period physical storage cost percentage in period t, $cy(t,j)$ is the j-period convenience yield in period t, $p(t,j)$ is the j-period risk premium in period t, and $ar(t,j)$ is the j-period arbitrage cost in period t The parameters a_1 a_5 are assumed to have two settings, zero or one, depending on the specifications of each alternative case

The Strict Arbitrage View

In the arbitrage studies conducted by Frankel (*7, 8*) and Frankel and Hardouvelis (*9*), the general formulation is simplified by setting $a_1, a_2 = 1$ and $a_3, a_4, a_5 = 0$, or

$$\ln F(t,t+j) - \ln S(t) = i(t,j) + sc(t,j) \quad (2)$$

This formulation suppresses the convenience yield and potential risk premium and arbitrage cost components Frankel's work concentrates on the expected change in the commodity price (thus replacing $F(t,t+j)$) with $E_t S(t+j)$, where E_t represents the rational expectation formed in period t [3] In this setting, the nominal interest cost would be completely reflected in the contracted commodity price change

Expectations and the Risk Premium

An alternative view addressed by Fama and French (*6*) splits the futures price into the expected spot price change plus a risk premium associated with price uncertainty, $p(t,j) = \ln F(t,t+j) - \ln E_t S(t+j)$, shown as

$$\ln F(t,t+j) - \ln S(t) = \ln E_t S(t+j) - \ln S(t) + p(t,j), \quad (3)$$

so that $a_5 = 0$ and $a_1, a_2, a_3, a_4 = 1$ This formulation imposes a joint efficient markets-rational expectations constraint in the determination of $\ln E_t S(t+j)$, such that the spread between the current spot price and the expected future spot price is determined by the convenience yield and carrying cost Fama and French examined equation 2 and found great variation in the relationships across commodities For example, in the case of crop and animal product commodities, futures prices had forecast power for subsequent spot prices, while for precious metals, there was little forecast power The relationship between the risk premium and futures prices was also highly variable across commodities For some commodities, futures price variation was related to variation in the premium, while for others, particularly precious metals, no evidence related futures prices to time-varying premiums Fama and French gave marginal evidence that the premium was nonzero on average, interpreting this result as consistent with the "normal backwardation" in future prices suggested by Keynes (*15*) With normal backwardation, the premium in equation 3 would tend to be less than zero, $p(t,j) < 0$, and futures prices would be downward-biased predictors of subsequent spot prices [4]

Commodity Own Rates

Keynes (*16*, pp 226-27) carefully examined the various components of the returns to commodities as revealed in the commodity own rate of interest and in the commodity rate of money interest [5]

> It follows that the total return expected from the ownership of an asset over a period is equal to its yield minus its carrying cost plus its liquidity premium, i e to $q - c + 1$ That is to say, $q - c + 1$ is the own-rate of interest of any commodity, where q, c, and 1 are measured in terms of itself as standard To determine the relationships between the expected returns on different types of assets which are consistent with equilibrium, we must also know what the changes in relative values during the [period] are expected to be

Cornell and French (*2*) specify the commodity own rate by using the equation

$$\ln F(t,t+j) - \ln S(t,j) = i(t,j) - k(t,j), \quad (4)$$

where $k(t,j)$ is the j-period commodity own rate From equations 1 and 4, we see that the commodity own rate may be comprised of various components

$$k(t,j) = -\alpha_2\, sc(t,j) + \alpha_3\, cy(t,j) - \alpha_4\, p(t,j) - \alpha_5\, ar(t,j) \quad (5)$$

[3]Frankel (*7*, p 565) downplayed the importance of the risk premium "With conventional estimates of the coefficient of risk aversion and the variances of asset prices, the [Capital Asset Pricing] model suggests that the risk premium cannot be much more than a few basis points "

[4]See (*1, 3, 6,* and *14*) for more details

[5]The commodity own rate of interest and the commodity rate of money interest are apparently the real and nominal rates of interest in commodity markets referred to by Telser (*26*, p 214)

Keynes' "yield" and "liquidity premium" terms together comprise the convenience yield, cy(t,j), in our notation, while the carrying cost is analogous to sc(t,j) Keynes (*16*, p 240) stated

> The liquidity premium is partly similar to the risk premium, but partly different, however, in calculating the own-rate of interest we must allow for both

Thus, Keynes also acknowledged the importance of the risk premium, p(t,j), as a component of the own rate

Commodity Own Rates and the Real Interest Rate

While the commodity own rate examined by Cornell and French (*2*) is not a new idea, their concept of the commodity own rate being related to, even determining, the real interest rate in the economy is new The Cornell and French theory specifies the real interest rate in the economy as a weighted average of the k(t,j) own rate terms across commodities (weighted by the commodity expenditure share) Their analysis concentrated on commodity own rates as a measure of the real interest rate and also on the far-near commodity price spread (the commodity basis) as a measure of expected inflation, the expected change in the value of commodities relative to money

The difference between the Cornell and French view and the strict arbitrage view centers on the fact that the arbitrage approach implicitly assumes that, in addition to the inflation component of the nominal interest rate, the real interest rate is also completely incorporated in the far-near commodity price spread The Cornell and French approach requires a relationship between the variables of the right-hand side of equation 5 and the real interest rate, while the theory of storage does not specify any relationship

We are left with two different interpretations Cornell and French view commodity own rates (or the component parts liquidity premiums, convenience yields, carrying costs, or risk premiums) as positively related to the real interest rate The alternative interpretation from the theory of storage and the arbitrage studies views commodity convenience yields and liquidity and risk premiums as commodity-specific and unrelated to the interest rate, that is, own rates are unrelated to the real interest rate

Empirical Evidence in the Recent Literature

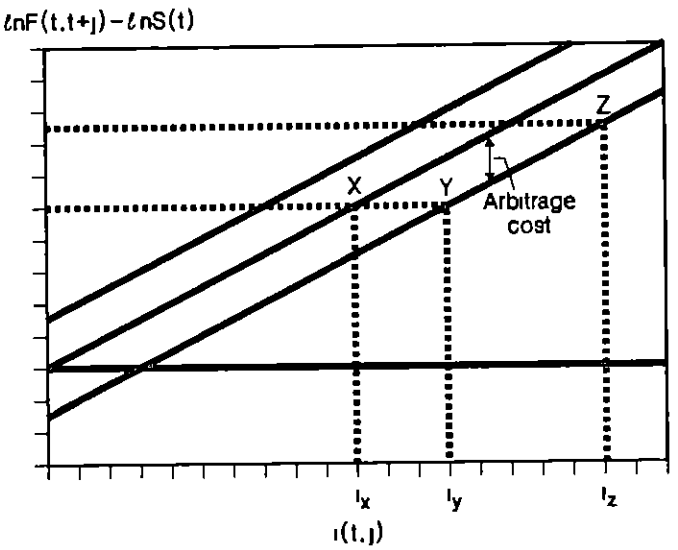
The empirical results of Cornell and French showed that, in response to money shocks during 1980-82, the nominal interest rate change was greater than the change in the far-near commodity price spread (the commodity basis) Their results, in conformance to their theory, suggested that commodity own rates and the real interest rate are related However, since Cornell and French did not account for arbitrage costs and nonneutralities, their empirical results are subject to other interpretations

Transactions and other arbitrage costs can lead to problems and potential bias in estimating parameters based on arbitrage relations [6] If the cost of arbitrage between financial and commodity markets (represented in equation 1 as the percentage ar(t,j)) is large relative to the change in interest rates, there may be no profit incentive to produce a response in the commodity price spread.

Figure 1 shows upper and lower arbitrage boundaries Begin with a case where the strict commodity-financial parity relation holds, as at point X in figure 1 If a change in the interest rate does not exceed the cost of arbitrage, that is i_x to i_y, then no profit incentive would exist to change the commodity price spread, producing a point such as Y Or, suppose the initial position was inside the arbitrage bands (for example, point X) and that the change in the interest rate was relatively large, like i_x to i_z, thus producing a commodity price response (a change to point Z, for example)

[6] See (*11, 22,* and *23*) for more information on the role of transactions costs in foreign exchange and commodity markets

Figure 1
Arbitrage boundaries



This case requires that arbitragers initially have a net long position in the commodity, allowing for the simultaneous spot sale of the commodity, forward purchase of the commodity, and purchase of a security with relevant maturity The analagous opposite case is not as restrictive Arbitragers could either sell off currently held securities or they could borrow funds at the current interest rate In each case, arbitrage costs arise for each of the transactions For example, we have $ar(t_J) = t_s + t_f + t_b$, where t_s, t_f, and t_b are the percentage transaction costs for spot contracts, forward contracts, and securities, respectively

The commodity price spread response is less than the interest rate response in these examples As a result of arbitrage costs we would expect percentage changes in the commodity price spread to be less than the changes in the interest rate

Cornell and French also did not address the issue of nonneutral monetary impacts, which were assumed away (*2*, p 9, note 7) Frankel and Hardouvelis (*9*) and Rausser, Chalfant, Love, and Stamoulis (*25*) discussed the importance of nonneutralities showing that the commodity price response to monetary shocks is consistent with such an interpretation Monetary shocks that drive real interest rate changes also drive real primary commodity price changes

Frankel and Hardouvelis (*9*) examined the response of spot commodity prices to Federal Reserve Board (FRB) monetary stock announcements Spot prices of primary commodities increased in response to a larger than anticipated money stock during periods when the FRB was not committed to strict monetary aggregate targets (1977-79 in the analysis) However, spot prices of primary commodity prices fell in response to a larger than anticipated money stock during periods of monetary aggregate targeting and questions about FRB credibility (1980-82) Their model provides an explanation for both policy periods with the spot commodity price overshooting equilibrium

Figures 2 and 3 show likely paths for prices under the two monetary policy regimes in a steady-growth-state economy with inflation The market learns of a larger than anticipated money stock at time t(0) In periods without commitment to monetary aggregate targeting (fig 2), both the equilibrium price and the (flexible) primary commodity price increase, with the flexible price overshooting the equilibrium With a monotonic adjustment to equilibrium, the deviation is eliminated over a j-period horizon During periods of commitment to monetary aggregate targeting (fig 3), the news of a larger than anticipated money stock triggers a decline in equilibrium prices and the flexible spot commodity price again overshoots the equilibrium

The paths shown in figures 2 and 3 follow a model similar to that of Frankel and Hardouvelis (*9*), where the equilibrium general price level is a monotonic function of the series of log differences of the expected nominal money supply and expected real income Without monetary policy credibility (fig 2), unexpected money stock increases signal that the nominal money stock is expected to be larger relative to real income in future periods, producing an increase in the equilibrium general price level With money stock targeting and policy credibility (fig 3), unexpected money stock increases signal that real income is higher than expected relative to the expected money stock over time, producing a decline in the general price level

Cornell and French saw the response of the commodity basis (the far-near price spread) as a measure of the response of inflation expectations to money shocks Accounting for nonneutralities makes clearer that the commodity basis is actually measuring flex-price inflation rather than general or equilibrium inflation For example, figure 3 shows that flex-price inflation (C to E*) exceeds equilibrium inflation (E′ to E*) Thus, with nonneutralities, the commodity basis cannot be used as an accurate measure of expected (aggregate or equilibrium) inflation A large positive response in the flex-price commodity basis could occur, and yet the aggregate rate of inflation over the horizon

Figure 2
Price reaction to money shock, with no monetary authority credibility

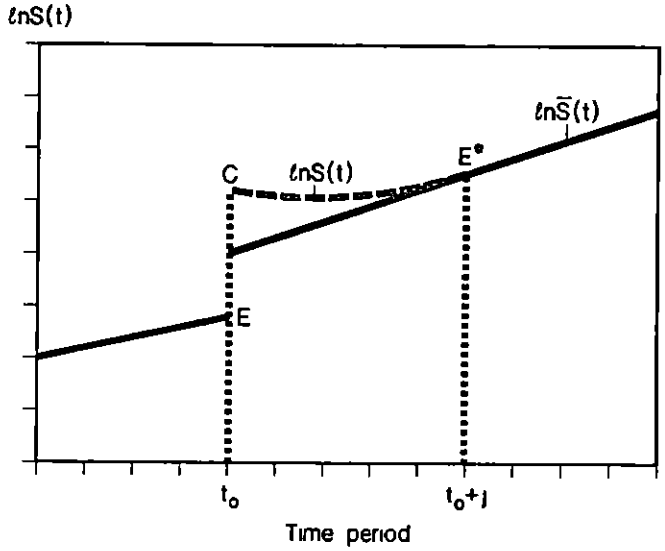
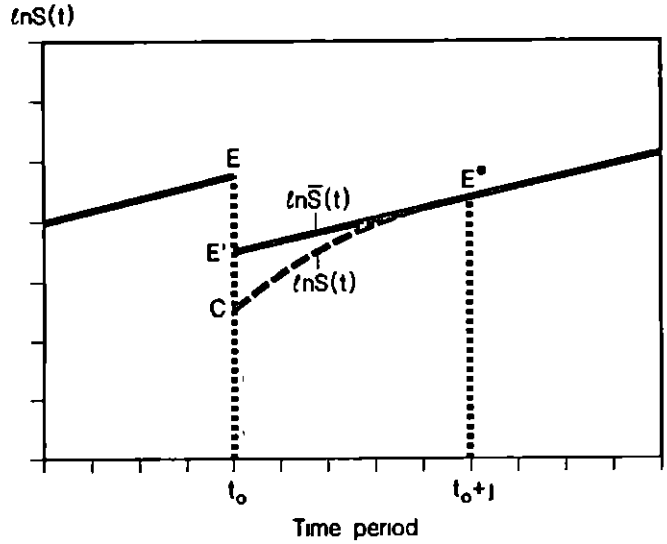


Figure 3
Price reaction to money shock, with monetary authority credibility



could be expected to decline The point is that non-neutralities exist and money shocks can drive real commodity prices The far-near commodity price spread would then incorporate the real interest rate in addition to the inflation expectation components of the nominal interest rate

Additional evidence on the relationship between commodity own rates and the nominal interest rate comes from the empirical results in (*18*) and (*6*) Consider the regressions

$$\ln F(t,t+j) - \ln S(t) = a + b\, i(t,t+j) + e(t,t+j), \text{ and} \quad (6)$$
$$\ln S(t) - \ln F(t,t+j) + i(t,t+j) = c + d\, i(t,t+j) + w(t,t+j), \quad (7)$$

where e(t,t+j) and w(t,t+j) are regression errors, and a, b, c, and d are regression coefficients The following constraints hold for the estimated coefficients (*4, 5*)

$$a + c = 0 \quad (8)$$
$$b + d = 1\ 0 \quad (9)$$

The standard errors of these coefficient estimates are identical across equations, that is, s(a) = s(c) and s(b) = s(d) These contraints *must* hold since the left-hand side (LHS) variables in equations 6 and 7 sum to the right-hand side variable used in each regression Since the LHS variable in equation 7 is simply the commodity own rate examined by Cornell and French, evidence on the relationship between commodity own rates and interest rates is implicitly contained in the regression estimates of equation 6 The c and d coefficients of equation 7 can be derived from the a and b coefficient estimates in equation 6 (table 1) The derived c coefficients reveal that significant non-stochastic own rates of interest (convenience yields) exist for the agricultural commodities No significance of the c coefficients is observed for the metals Contrary to the results observed by Cornell and French, and the relationship between the convenience yield and the interest rate hypothesized by Gordon, the d coefficient estimates reveal no significant relationship between commodity own rates and the interest rate

Direct Evidence on Commodity Own Rates and the Real Interest Rate

By using the definition for the commodity own rate (equation 4), we see that the values of 6-month own rates were calculated for eight primary commodities for sample periods covering the 1970's and 1980's *Ex ante* 6-month real interest rates were also calculated [7]

The 6-month own rate used the 6-month ahead futures price for the value of F(t,t+j) (j=6) and the current delivery futures price for the value of S(t) at the first business day of the observation month The interest rate used was the market yield on Treasury bills with

[7]Mishkin recently presented some statistical analysis of 2-month own rates (*19*) While evidence suggested that the real interest rate process shifted as a result of the October 1979 FRB policy change, Mishkin found no support for a similar shift in commodity own rate processes

Table 1—Implied coefficient estimates for own rate regression[1, 2]

Commodity	c	(c)	d	s(d)
Metals				
Gold	-0 88	1 08	0 13	0 24
Silver	1 34	1 84	- 29	41
Grains				
Corn	4 03	2 60	42	61
Oats	9 08	4 68	0	1 09
Soybeans	8 57	3 29	- 91	71
Wheat	8 81	4 24	- 70	99
Stacked grains	7 62	1 91	- 30	45

[1]ln S(t) – ln F(t,t+j) + i(t,t+j) = c + d i(t,t+j) + w(t,t+j)
[2]These data were derived from results presented in (*17*) Similar estimates for the d coefficient can be obtained from the results presented in (*6*) The results for the intercept and intercept dummies used in (*6*) were not reported, so c coefficients cannot be derived

maturity closest to the first delivery day for the 6-month ahead futures contract February and August contract prices were used in the own rate calculations for gold, hog, pork belly, live cattle, and feeder cattle futures contracts March and September contract prices were used for corn, soybean, and wheat contracts

We calculated the *ex ante* 6-month real interest rate as the 6-month nominal interest rate minus the expected inflation over that period Expected inflation was determined from the Consumer Price Index forecasts reported in the *Economic Outlook Survey* of the National Bureau of Economic Research and the American Statistical Association

Table 2 shows cross-correlations between the individual commodity own rate and the relevant *ex ante* real interest rate series The coefficients reveal that none of the commodity own rates were closely correlated with the real interest rate The own rates of the agricultural commodities were highly volatile over the entire sample period While gold own rates appeared to be more closely correlated with the real interest rate during October 1979-October 1982 than during other periods, there was no obvious relationship that existed between agricultural own rates and the real interest rate during that period This evidence suggests that there is little relationship between commodity own rates and the real interest rate

Conclusions

Subtle differences exist in analyses that link interest rates and intertemporal commodity prices Our analysis suggests that the change in primary commodity basis, contrary to the Cornell and French interpretation, would be a poor measure of the change in (aggregate or equilibrium) inflation expectations And, a change in primary commodity own rates (even in weighted average form) would not be a good signal of a change in the real interest rate in the economy

We are led to these conclusions from several observations First, the pass-through of interest rate effects to commodity prices can be dampened by factors that restrict efficient price adjustment, for example, arbitrage costs Second, the rigidity of the economy's general price level and the highly volatile nature of primary commodity prices together enhance a negative relationship between real primary commodity prices and real interest rates Third, little evidence supports a hypothesized positive relationship between *ex ante* real interest rates and commodity own rates Neither gold nor agricultural commodity own rates were closely correlated with the *ex ante* real interest rate While commodity prices are related to nominal interest rates as suggested by the theory of storage, commodity prices do not communicate precise knowledge about the components of nominal interest rates Commodity futures price spreads do not generally appear to provide clear information about inflation expectations, and commodity own rates are not closely related to the real interest rate

Table 2—Cross-correlation coefficients for commodity own rates and the *ex ante* real interest rate[1]

Commodity	Cor(k(t,j),r(t,j))
Gold	0 064
	(229)
Feeder cattle	504
	(189)
Live cattle	349
	(182)
Live hogs	– 162
	(182)
Frozen pork bellies	– 228
	(182)
Corn	299
	(182)
Soybeans	– 010
	(182)
Wheat	027
	(182)

[1]Numbers in parentheses are standard errors, which are determined by sample size

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