Arbitrage Conditions, Interest Rates, and Commodity Prices

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Abstract. *This research examines the arbitrage condition between financial markets and commodity markets. According to the standard arbitrage condition, for risk-neutral investors to be indifferent between holding securities or commodities, the expected commodity price appreciation, adjusted for physical storage costs, must equal the rate of return on financial assets. For agricultural commodities, however, the convenience yield drives a wedge between the interest return and the commodity price spread. Empirical results support this position, but also provide evidence that the commodity price spread properly incorporates interest costs.*

Keywords. *Commodity prices, interest rates, arbitrage*

Over the past decade there has been increased interest in examining the response of flexible prices to macroeconomic shocks. International economists have theoretically and empirically analyzed the dynamics of flexible exchange rates and have extended the celebrated overshooting model of Dornbusch (*3*) to examine numerous factors affecting temporal exchange rate behavior.[1] A crucial component of these models is the interest parity condition (IPC), which specifies a relationship between interest rates and the implied dynamics of exchange rates.

A rapidly growing literature has extended the IPC and the overshooting-type analysis to primary commodity markets, particularly agricultural commodity markets. Frankel (*4*) has argued for using these models in agricultural research (*5, 6, 7*). Stamoulis, Chalfant, and Rausser (*18*) and Huffman and Langley (*10*) empirically tested the overshooting of agricultural prices, and Rausser (*17*) emphasized the importance of applying the overshooting response to agricultural models to explain the pricing behavior.[2]

The IPC is important in both exchange rate overshooting models and commodity price overshooting models. Given (1) the interest in the commodity price overshooting models, (2) their importance for policy decisions, and (3) the fundamental importance of the IPC in these models, we examined the IPC for primary commodity markets in greater detail. Although the IPC has been extensively tested for foreign exchange markets,[3] its validity for primary commodity markets has not been explicitly investigated.

Our objective in this study is to answer the following questions. Does commodity price behavior conform to the interest parity condition? If not, to what can we attribute the failure? What are the implications of the observed results for studies and models, like the overshooting analyses, that use the interest parity condition?

Theory

Interest parity conditions (IPC) specify relationships between interest rates and implied asset price dynamics such that risk-neutral investors are indifferent between holding a financial instrument and an alternative asset. If the IPC is a correct characterization of market behavior, a systematic violation of the IPC would provide for riskless profits and the market would be inefficient. For example, in the foreign

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[1]Italicized numbers in parentheses refer to items in the References at the end of this article.

[2]Overshooting analyses examine the dynamics of price reactions to money shocks. "Overshooting" is variously defined in the literature as a more than proportionate response of the spot price relative to (1) the money shock, (2) the expected future spot price, or (3) the (unobservable) current period "equilibrium" spot price (*14*). Note that with the first two definitions, given specific conditions or policies, undershooting is a possibility. For a discussion, literature review, and empirical information on overshooting versus undershooting, see Kitchen and Denbaly (*12*).

[3]Studies by Frenkel and Levich (*9*) and by Mishkin (*13*) are among many that demonstrate that covered interest rate parity holds in a static sense for interest rates and exchange rates. Husted and Kitchen (*11*), in their money announcement study, provide information on the implied dynamic responses of interest rates and exchange rates. They show that responses to money shocks are consistent with the covered interest parity condition. See Bilson (*1*) for a discussion on the failure of uncovered arbitrage to hold in international financial markets.

exchange market, the IPC specifies a relationship between interest rates and exchange rates such that investors are indifferent between holding domestic- and foreign-currency-denominated assets Similarly, in commodity markets, the IPC specifies a relationship between interest rates and commodity prices such that investors are indifferent between holding commodities and financial instruments

Interest parity conditions have been extensively examined and tested in the exchange rate literature The uncovered (or open) IPC for exchange rates is

$$\ln(E_tS_{t+j}) - \ln S_t = \ln(1 + i_{t,j}) - \ln(1 + i^*_{t,j}) \quad (1)$$

where $i_{t,j}$ and $i^*_{t,j}$ are the domestic and foreign j-period nominal interest rates, respectively, S_t is the spot exchange rate, E_tS_{t+j} represents the rational expectation of the spot price in period t+j formed in period t, and ln is the natural logarithm The exchange rates are specified as the domestic currency price of the foreign currency The covered (or closed) IPC for exchange rates is

$$\ln X_{t,t+j} - \ln S_t = \ln(1 + i_{t,j}) - \ln(1 + i^*_{t,j}) \quad (2)$$

where $X_{t,t+j}$ is the forward exchange rate for contracts to be delivered in period t+j If the equality in equation 2 did not hold and there were no transactions costs, riskless profits could be made For example, suppose that the left-hand-side (LHS) is greater than the right-hand-side (RHS)—that is, that the contracted rate of appreciation of the domestic currency is less than the difference in the rates of return on domestic and foreign bonds In terms of a specific currency, the rate of return on foreign bonds would exceed that on domestic bonds Domestic bonds could be sold at rate $i_{t,j}$ and one could use the domestic funds received from that sale to purchase the foreign currency at the spot rate S_t and the foreign funds could then be invested at rate $i^*_{t,j}$ Simultaneously, a forward contract to sell the foreign currency at rate $X_{t,t+j}$ would be made In period t+j the funds from the foreign investment would be converted into the domestic currency at rate $X_{t,t+j}$ The resulting domestic funds would exceed the amount required to pay off the original loan, the difference representing the riskless profit

As noted earlier, the direct application of the IPC to agricultural commodities for studying macroeconomic impacts is a fairly new procedure for agricultural economists However, the concept was not unknown, it was discussed in a similar context in the "theory of the price of storage" of the agricultural marketing literature[4] The theory of the price of storage indicates that, so long as supplies of a storable commodity are relatively large, the difference between the simultaneously quoted far- and near-term futures prices of the commodity will equal the full storage cost In the literature, the full cost of storage is defined as the cost of warehousing and insurance plus the financial costs associated with implicit interest (opportunity) costs

Assuming risk neutrality, the uncovered (or open) IPC for a storable commodity can be written as

$$\ln(E_tP_{t+j}) - \ln(P_t + C_{t,j}) = \ln(1 + i_{t,j}) \quad (3)$$

where

- E_tP_{t+j} = the rational expectation formed in period t for the spot price in period t+j,
- P_t = the spot price in period t,
- $C_{t,j}$ = the j-period physical storage cost in period t, and
- $i_{t,j}$ = the j-period rate of interest observed in period t

The covered (or closed) IPC requires that a future delivery price be specified in the current period, thus eliminating the risk associated with uncertainty about changes in the spot price over the holding period This condition is represented as

$$\ln F_{t,t+j} - \ln(P_t + C_{t,j}) = \ln(1 + i_{t,j}) \quad (4)$$

where $F_{t,t+j}$ is the price for a futures contract to be delivered in period t+j as set in period t The covered arbitrage condition specified here differs from the uncovered case because there is a *contracted* rate of commodity price appreciation rather than just an *expected* rate The covered IPC indicates that, if the LHS in equation 4 were greater than the RHS, funds could be borrowed at rate $i_{t,j}$ and that, simultaneously, the commodity would be purchased at the spot price P_t and a futures contract would be sold at the futures price $F_{t,t+j}$ The commodity would be stored at cost $C_{t,j}$ over the j-period horizon to delivery In period t+j the commodity would be delivered, and price $F_{t,t+j}$ would be received The funds received would exceed the cost of the original loan, and riskless profits would be made This scenario is extreme in the sense that only a small percentage of futures contracts are ever delivered However, the relationship is the exact

[4]See Peck (*16*) for a concise summary

linkage that constrains futures markets to be closely tied to spot markets [5]

A potential problem arises in applying the IPC to commodity markets If the RHS were greater than the LHS in equation 4, the opportunity for riskless profits would not exist For international financial markets, either currency could be borrowed for immediate use and the debt could be repaid later However, a commodity to be produced in the future cannot be "borrowed" from the future to be sold in the spot market for possession today (If such an activity were possible, it would drive the spot price down relative to the future price, increasing the LHS spread until it equalled the RHS) In the absence of a riskless profit motive, another force might maintain the IPC The requirement is that commodity holders treat the commodity as a portfolio asset In this risk-neutral framework and if one abstracts from transactions costs, if the rate of return on financial assets exceeded the rate of return on commodities, portfolios would be realigned with commodities being sold and financial assets being purchased until the rates of return were equated If commodities were held for purposes other than as portfolio assets (for example, as primary inputs into a production process), the IPC could be systematically violated That is, the condition in equation 4 would then be

$$\ln F_{t,t+j} - \ln(P_t + C_{t,j}) \leq \ln(1 + i_{t,j}) \qquad (4')$$

We would expect that the more a commodity deviated from being simply a portfolio asset, the greater would be the deviation from the IPC

Precious metals are perfectly storable, are continuously produced, and are held primarily as portfolio assets Under these conditions, arbitrage should ensure the equality of the price spread and the interest rate Agricultural commodities, however, are produced seasonally, and supplies can be occasional and relatively small Under relatively small supplies, the price difference can drop below the full cost of storage and may even be negative ("inverse carrying charges") As scarcity increases and as the spot price is driven up relative to the future price, the resulting drop in the price difference creates a disincentive for storage, as the return on storage falls below that required to cover full storage costs Under such conditions, for the IPC to be violated, stockowners must attach intrinsic value to their available stocks and possession of the commodity allows them to meet current use requirements When supplies are relatively small, commodity ownership can provide what is typically called a "convenience yield" (the liquidity premium for the commodity is greater than zero) The convenience yield explains the inequality in equation 4'

Empirical Evidence and Interpretation

The theoretical presentation produced specifications for testing the covered and uncovered versions of the IPC By treating the interest rate as exogenous, we can estimate the following regressions.

$$\ln F_{t,t+j} - \ln(F_{t,t} + C_{t,j}) = a + b\ln(1 + i_{t,j}) + e_{t,j} \quad (5)$$

$$\ln F_{t+j,t+j} - \ln(F_{t,t} + C_{t,j}) = c + d\ln(1 + i_{t,j}) + w_{t+j,j} \quad (6)$$

where $F_{t,t+j}$ is the price in period t of a futures contract to be delivered in period t + j ($F_{t,t}$ and $F_{t+j,t+j}$ are analogously defined) and $i_{t,j}$ is the j-period nominal rate of interest observed in period t In equations 5 and 6 the spot price is represented by the futures price for contracts with current period delivery [6]

The LHS in equation 5 is the contracted rate of change in the commodity price, thus, equation 5 is the regression for testing the covered IPC Using the assumption of rational expectations so that the actual

[5]Equations 3 and 4 are written differently from those generally used in the literature (*5*, p 345, equation 1) First, the IPC equations often use the interest rate directly rather than ln (1+i) This procedure can be justified through an approximate equality in the IPC since $\ln(1+i) \cong i$ when i is "close" to zero Second, in the literature, the storage cost term is usually assumed to be "constant" and to enter additively in logarithms as in

$$(\ln E_t P_{t+j} - \ln P_t) - sc \cong i_{t,j}$$

However, for this equation to be correct, storage costs must be a constant percentage of the spot price, a condition that is systematically violated for agricultural commodities Note that

$$-\ln(P_t + C_{t,j}) \cong -\ln P_t - sc \quad \text{iff} \quad C_{t,j} = sc\, P_t$$

To avoid these problems, we used the formulation of the text with the per unit storage cost entering additively with the level of the spot price

[6]The price on the current delivery futures contract differs from the spot price by the basis The basis accounts for quality, location, and other differences between the spot and futures markets To assure homogeneity of the commodity for both the near and far term prices across time, we used the current delivery futures price rather than the cash spot price

We did not use storage cost data to adjust the price spread for precious metals Unlike agricultural commodities, which are bulky and have significant storage costs that vary greatly as a percentage of price, precious metals can be stored at a cost that is typically a small and fairly constant percentage of the spot price This storage cost percentage would then be captured in the intercept term in the precious metals regressions

Other variables that explain the LHS price spreads in equations 5 and 6 that are omitted are assumed to be orthogonal to the interest rate price deviates from the prior expectation by a random error, that is,

$$\ln F_{t+j,t+j} = \ln E_tF_{t+j,t+j} + u_{t+j,j}$$

we can use equation 6 to test the uncovered IPC If the IPC is a correct characterization of commodity price behavior, the testable joint hypothesis in each case is (a,b) = (0,1) and (c,d) = (0,1)

Note that the Frankel-type IPC relations do not explicitly account for transactions costs, particularly the margin deposit required for selling the far-term futures contracts for the covered IPC case Incorporating the margin deposit yields

$$\ln (F_{t,t+j}(1+m)) - \ln (F_{t,t} + C_{t,j} + mF_{t,t+j}) = \ln (1 + i_{t,j}) \quad (7)$$

where m is the margin percentage The difference between equations 4 and 7 is the interest cost of the margin deposit Under the IPC, equation 7 can be rewritten as

$$\ln (F_{t,t+j}) - \ln (F_{t,t} + C_{t,j}) = \ln (1 + i_{t,j}) - \ln (1 - mi_{t,j}) \quad (7')$$

The RHS of equation 7′ is slightly *larger* than the RHS of equations 3 and 4, but more important, the omitted variable in regressions like equations 5 and 6 will be correlated with the regressor, leading to possible coefficient bias For estimating regressions based on equation 7 we assumed that m was 10 percent Note, however, that large traders can deposit Treasury bills as margin and the interest would accrue to the trader, so the role of margin interest in the price spread may not be very important

We acquired data for futures prices and interest rates for 1971-86 Futures prices for two types of storable commodities, precious metals and agricultural grains, were taken from the Chicago Board of Trade *Statistical Annual* The sample period for precious metals covers the shorter 1975-86 period [7] To avoid estimation problems associated with overlapping data or the use of period averages, we drew the data for the futures prices from the first business days of March and September for the March and September contracts [8] This procedure establishes the time horizon, j, to be 6 months, thus, there are two observations per year in a time series format For example, for March observations, the futures price at closing on the first business day of March for a March delivery contract is used for the near-term price The far-term, 6-month ahead, price is the futures price for September delivery contracts at closing on the first business day of March September observations are analogous, with September delivery contract prices specifying the near-term price and March delivery contract prices specifying the far-term prices The market yield for 6-month Treasury bills was used for the interest rate We divided the annual yield by two to convert it to a 6-month rate of return The near-term prices for agricultural commodities were adjusted to account the the 6-month physical (noninterest) storage cost The physical storage cost data for the various grains came from the Agricultural Stabilization and Conservation Service (ASCS) [9] We divided the reported annual values by two to obtain a 6-month storage cost

The use of Commodity Credit Corporation (CCC) storage cost data merits further discussion Paul used an approach similar to ours to examine the pricing of binspace in the 1952-65 period (*15*) By (1) adjusting the far-near price spread (the carrying charge) for interest and commission costs, (2) dropping the May-July observations, (3) assuming that the convenience yield on at least one of the five commodities examined was zero in each remaining observation period, and (4) using the largest value of the interest/commission cost-adjusted carrying charge among the five commodites, Paul obtained an estimate of the competitive price of binspace The estimated competitive price varied above and below the CCC storage rate, but on average the estimated price was below the CCC rate (11 6 cents vs 13 8 cents per bushel) This final average result conformed with the conceptual view advanced by Paul that the CCC rate would tend to exceed the competitive price

We cannot claim here, by using the CCC rates, that we have an exact proxy for the true competitive physical storage cost We recognize the limitations of its use The CCC rates can be written as the sum of the true competitive physical storage cost plus an error In our estimated regressions the additional error would, as a percentage of the price, enter into the RHS of the relationship Systematic components of the error would be captured in the estimated intercept, and random components would enter into the regression error If the CCC rates were systematically

[7]Data for the most recent futures observations were supplied by an anonymous reviewer

[8]See Cumby and Mishkin (2, pp 6 7) for a discussion of estimation problems associated with overlapping data The sampling technique we used matches the forecasting interval with the sampling interval If we had taken additional observations within the sample, the forecasting and sampling intervals would have "overlapped" and the regression errors would have followed an autoregressive process Although there are estimation procedures that account for these problems, we chose to avoid the error structure problem and thereby preserve the desirable properties of ordinary least squares estimation

[9]We thank Linwood Hoffman of ERS for providing us with the storage cost data The data were Government storage costs from the ASCS Warehouse Division of Commodity Operations

larger than the true competitive price, the intercept estimate would be biased downward However, this information and the data suggest that the magnitude of the bias would be small, ranging from 0 33 for soybeans to 1 19 for oats with an average across the grains of 0 71

Tables 1 and 2 show the results for the covered IPC of equation 5 and the margin-adjusted form based on equation 7 All the coefficient estimates for the interest rate term have correct signs, and t-tests reveal that these estimates do not differ significantly from 1 0, as hypothesized The intercept estimates for precious metals are not significantly different from zero, as hypothesized However, significant negative intercepts are observed for the agricultural grains regressions (the oats and corn intercepts are significant at approximately the 6-percent and 14-percent levels, respectively) The F-statistics for testing the hypothesis that (a,b) = (0,1) indicate that the joint relation for covered IPC cannot be rejected for metals, but the hypothesis is rejected in every case for grains at the 1 percent level The results for the unadjusted and margin-adjusted forms are similar, and the bias does not appear to be that important

Tables 3 and 4 show the results for the uncovered IPC of equation 6 None of the coefficient estimates is significantly different from zero However, the slope coefficient is significantly different from 1 0 only for the stacked grains regression, whereas the joint (0,1) hypothesis is rejected only for corn and oats Therefore, one must conclude the variance of the expectation error is quite large relative to the variance of the true regression error That is, the proper regression would use the actual expectation so that the true version of equation 6 would be

$$\ln E_tF_{t+j,t+j} - \ln(F_{t,t} + C_{t,j}) = c + d\ln(1 + i_{t,j}) + z_{t+j,j} \quad (6T)$$

The difference, as previously stated, is the expectation error $u_{t+j,j}$ By estimating equation 6 and using the proxy LHS, we find that the regression error in equation 6 includes both the true regression error and the expectation error

$$w_{t+j,j} = z_{t+j,j} + u_{t+j,j} \quad (8)$$

Because of the additional component in the regression error, the standard errors in the estimated relationship increase, and hypothesis testing is compromised These relationships help explain the absence of statistical significance in the uncovered IPC results of tables 3 and 4

Note an important characteristic of financial and primary commodity markets the role of "news" Much attention has recently been devoted to models that explicitly account for information and the ways in which new information (the "news") affects prices Frenkel (*8*) and others developed the "news" concept, applying it to international financial markets to examine exchange rate adjustment A whole literature uses "news" frameworks to examine the response of various prices and rates to the weekly money supply announcements Articles by Frankel

Table 1—Covered IPC regressions for precious metals

Commodity	a	b	R^2	DW	F	n
Gold	0 880 (1 081)	0 866** (241)	0 392	1 80	0 57	22
Silver	-1 339 (1 843)	1 293** (411)	310	1 89	27	22
Margin adjusted						
Gold	804 (978)	784** (218)	392	1 80	56	22
Silver	-1 209 (1 673)	1 170** (373)	309	1 89	53	22

Ordinary-least-squares estimation
Standard errors appear in parentheses
** = significantly different from zero at the 0 01 level
* = significantly different from zero at the 0 05 level
DW = Durbin-Watson statistic
F = the calculated value of the test statistic used for testing the null hypothesis H_O (a, b) = (0, 1) The critical value is $F_{05, 2, 20} = 3\ 44$
n = number of observations

Table 2—Covered IPC regressions for grain commodities

Commodity	a	b	R^2	DW	F	n
Wheat	-8 809* (4 236)	1 704 (991)	0 090	1 85	8 65**	32
Soybeans	-8 573** (3 295)	1 915** (711)	171	2 04	10 01**	32
Corn	-4 035 (2 601)	583 (609)	030	1 68	20 48**	32
Oats	-9 077 (4 677)	1 003 (1 095)	027	1 57	15 80**	32
Stacked grains	-7 623** (1 905)	1 301** (446)	063	1 69	11 41**	128
Margin adjusted						
Wheat	-8 051* (3 879)	1 552 (908)	089	1 85	9 70**	32
Soybeans	-7 829** (3 030)	1 746** (709)	168	2 04	11 27**	32
Corn	-3 673 (2 374)	528 (556)	029	1 68	23 45**	32
Oats	-8 302 (4 275)	914 (1 000)	027	1 57	17 21**	32
Stacked grains	-6 964** (1 744)	1 185** (408)	063	1 70	12 77**	128

Ordinary-least squares estimation
Standard errors appear in parentheses
** = significantly different from zero at the 0 01 level
* = significantly different from zero at the 0 05 level
DW = Durbin-Watson statistic
F = the calculated value of the test statistic used for testing the null hypothesis H_O (a, b) = (0, 1) The critical value is $F_{01,2\ 20}$ = 5 39 and $F_{01\ 2,126}$ = 4 77
n = number of observations

Table 3—Uncovered IPC regressions for precious metals

Commodity	a	b	R^2	DW	F	n
Gold	9 16 (19 95)	-1 87 (4 34)	0 010	1 82	0 39	21
Silver	25 92 (27 75)	-5 57 (5 94)	040	2 26	0 74	21

Ordinary-least-squares estimation
Standard errors appear in parentheses
** = significantly different from zero at the 0 01 level
* = significantly different from zero at the 0 05 level
DW = Durbin Watson statistic
F = the calculated value of the test statistic used for testing the null hypothesis H_O (a, b) = (0, 1) The critical value is $F_{05,2\ 19}$ = 3 52
n = number of observations

Table 4—Uncovered IPC regressions for grain commodities

Commodity	a	b	R^2	DW	F	n
Wheat	7 03 (10 86)	-2 36 (2 52)	0 029	1 50	2 46	31
Soybeans	15 13 (10 85)	-3 92 (2 51)	077	2 46	2 76	31
Corn	-2 06 (10 26)	- 72 (2 38)	003	1 43	3 57*	31
Oats	-8 00 (9 59)	27 (2 22)	001	1 87	5 62**	31
Stacked grains	3 02 (5 15)	-1 68 (1 19)	016	1 82	2 96	124

Ordinary least squares estimation
Standard errors appear in parentheses
** = significantly different from zero at the 0 01 level
* = significantly different from zero at the 0 05 level
DW = Durbin-Watson statistic
F = the calculated value of the test statistic used for testing the null hypothesis H_0 (c, d) = (0, 1) The critical value is $F_{05, 2\ 29}$ = 3 33 and $F_{01\ 2\ 29}$ = 5 42, $F_{05\ 2\ 122}$ = 3 07
n = number of observations

and Hardouvelis (*6, 7,*) and by Kitchen and Denbaly (*12*) are relevant examples Frankel and Hardouvelis show that commodity prices and interest rates react quickly to the news in the money announcement Kitchen and Denbaly present results that indicate that far-term and near-term commodity prices and interest rates react in a fashion consistent with the covered IPC Given the sensitivity of these prices to new information, it is not surprising that the expectation errors could have relatively large variances (as we suggested above)

How should we interpret the results presented here in conjunction with existing evidence? First, the importance of the IPC for commodity price behavior varies greatly across commodities, depending on the extent to which the commodity can be treated as a portfolio asset The covered IPC appears to be an accurate description for gold and silver, but not for grains Second (and related to the first point), the commodity IPC should generally be stated as an inequality as in equation 4′ rather than as a strict equality as in equation 4 The theoretical and empirical evidence supports such an interpretation In fact, Frankel (*5*) and Frankel and Hardouvelis (*6*) acknowledge the potential problems with using the arbitrage condition since in their model the inflation term for primary commodity prices exceeds that for the manufactures prices by an amount equal to the equilibrium real interest rate plus the (invariant percentage) storage cost

> This is a general problem with the commodity arbitrage condition There are two possibilities First, for an agricultural commodity, [the equilibrium commodity price] may gradually increase relative to [the equilibrium manufactures price] (monetary considerations aside) during most of the year, as long as some of the previous harvest peak is being stored, and fall discontinuously when the new harvest comes in Thus, there is no longrun trend in [the difference between the normalized commodity and manufactures equilbrium prices] Alternatively, for a nonperishable, nonrenewable commodity such as gold or oil, there may indeed be a longrun trend in [the difference in equilibrium prices], a la Hotelling (*5*, p 146)

If the IPC for commodities were stated as an inequality, problems with the interpretations in these models would be reduced

Finally, a key point about the overshooting models and analyses and the use of the IPC is that their value lies in their ability to examine the responses of flexible prices to macroeconomic shocks If, in response to macroeconomic shocks, commodity prices react "as if" the IPC were correct—that is, a conditional IPC—one should not discount the value of the IPC It would then be correct to use the IPC in such a context, even if the IPC does not hold exactly for commodity-specific (not macroeconomic) reasons For example, we were unable to reject the hypothesis that the interest rate term had a coefficient of 1 0 so that, *ceteris paribus* (abstracting particularly from systematic convenience yield relationships), changes in the interest rate would be reflected in changes in implied commodity price dynamics The IPC inequality arises from factors other than the interest rate, so the far-near price spread incorporates the interest rate in addition to other nonmonetary components

Conclusions

We have examined and tested the arbitrage condition between financial markets and commodity markets The empirical results confirm the importance of interest costs in the determination of commodity prices Although statistical tests based on regression analysis were unable to reject the covered interest parity condition for precious metals, such tests provided strong evidence for rejecting the covered interest parity condition for agricultural grains For grains, the failure of the condition was interpreted as resulting from a convenience yield (rather than, for example, from market inefficiency) The linkage from interest rates to commodity futures contract prices is consistent with assumptions typically used in examining futures prices—that is, the direct incorporation of interest costs However, the interest rate linkage to price dynamics implied *ex ante* by covered arbitrage does not carry through to actual price dynamics observed *ex post facto* As with exchange rates, uncovered interest parity conditions do not generally hold for commodity prices, so the value of such conditions for purposes of prediction is unclear

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In Earlier Issues

From the algebraic analysis of the free trade model, we can conclude that

- The percentage change in equilibrium price and quantity depend on the elasticities of the excess supply and demand relationships The percentage change in equilibrium price will not exceed the percentage change in the exchange rate, the percentage change in equilibrium quantity traded may or may not exceed the percentage change in the exchange rate
- The percentage change in quantity traded will exceed that of the price change if the elasticity of the excess supply function exceeds one
- The elasticities of excess supply and demand relationships may be elastic even if the underlying domestic supply and demand relationships are inelastic
- Given elastic import demand and export supply relationships, the percentage change in quantity traded due to an exchange rate change may be quite large

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