The Relationship Between Primary Commodity Prices and Macroeconomic Variables

by

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THE RELATIONSHIP BETWEEN PRIMARY COMMODITY PRICES AND MACROECONOMIC VARIABLES

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The effects of macroeconomic variables, more specifically the effects of monetary variables and exchange rates, on agricultural commodity prices, exports and inventories have been analyzed in Chambers and Just (1982), Batten and Belongia (1986), Gilbert (1989), and Gilbert and Palaskas (1989). Recent structural models of commodity price behavior defined by Frankel (1986) and Boughton and Branson (1988, henceforth BB) have emphasized the important role in the price formation process of expectations concerning macroeconomic disturbances. The prices of most primary commodities are determined in flexible "auction" markets, actually financial markets that trade contracts. This permits commodity prices to react immediately to "news" about changes in macroeconomic disturbances, whereas manufactured goods prices do not. 1/ Frankel and Hardouvelis (1985) and Barnhart (1989) have undertaken empirical work to investigate how commodity markets react in the short run to expectations concerning macroeconomic disturbances. Frankel has formalized the effects of monetary disturbances on commodity prices by extending the Dornbusch (1974) overshooting model of exchange rates. He argued that unanticipated, permanent shocks in the money supply cause short-run changes in interest rates and consequently in real commodity prices because prices of other goods are sticky. However, if changes in the real interest rates cause real commodity prices to overshoot in the short-run, they can still have a fixed or stationary relationship over the long run.

Only a few studies have examined the existence of long-run relationships between commodity prices and macroeconomic variables. Durand and Blondal (1988) and BB test the inverse hypothesis to that analyzed by Frankel. That is, commodity price movements are indicators of consumer prices (in this case of the major seven OECD countries' inflation rates). Their results suggest that, though there is no clear quantitative long-run relationship, a temporal causality and feedback effect exists between rates of inflation and commodity prices. Powell (1989), applying integration and co-integration tests, has shown that it is not possible to reject the hypothesis that the terms of trade between commodity prices and manufactured goods prices is stationary.

The purpose of this paper is to employ integration and co-integration tests to investigate the hypothesis of a long-run relationship between commodity market prices at the aggregate and disaggregate levels and several macroeconomic variables--focusing on interest rates and money supply and inflation, but including also industrial production and exchange rates. Section II discusses the ideas underlying co-integration, the integration and co-integration tests and their implications. Section III reports on the integration and co-integration tests and, where a co-integrating relationship is established, in Section IV the short-run and long-run dynamics of this relationship are analyzed by estimating error correction models (ECM). Finally, Section V analyzes the results and draws conclusions.

1/ Shown empirically by Bordo (1980).

II. LONG RUN RELATIONSHIPS: TESTS

The first question to be analyzed is whether there exists a stable, long-run relationship between the level of commodity prices PC_t and the level of interest rates (r_t). If so, it may be possible to make quantitative inferences about future commodity prices from observations of changes in interest rates.

As a first step we examine the stationarity of commodity prices and the interest rate, employing the integration test, since the co-integration test begins with the premise that for a long-run equilibrium relationship to exist between two variables it is necessary that they have the same intertemporal characteristics. The dynamic property of a time series can be described by how often it needs to be differenced to achieve time-invariant linear properties and provide a stationary process. A series that has at least invariant mean and variance and whose autocorrelation has "short memory" is called I(0), denoting "integrated of order zero". 1/ A series which needs to be differenced Δ times to become I(0) is said to be integrated of order Δ, denoted as I(Δ).

The order of integration is inferred by testing for unit roots. The most widely applied unit root tests are: (a) the Durbin-Watson test of Sargan and Bhagrava (1983) (CRDW); and (b) the Dickey-Fuller test (DF) or Augmented Dickey-Fuller test (ADF) (Dickey and Fuller 1979, 1981). All test the null hypothesis that the series are I(1) : Ho : $X_t \sim I(1)$. The three statistics employed are calculable by least squares regression 2/ as follows:

CRDW : $X_t = a + e_t$

Ho : X_t is I(1) if DW. is below a critical value

DF : $\Delta e_t = a + \beta e_{t-1} + v_t$

H_o : X_t is I(1) if β is negative and its t-statistic is below a critical value. 3/

ADF : $\Delta e_t = a + \beta e_{t-1} + \sum_{i=1}^{n} \gamma_t \Delta e_{t-1} + v_t$

H_o : X_t is I(1) if β is negative and its t-statistic is below a critical value.

1/ With "short memory" a small number of lagged observations explains current behavior.

2/ Their critical values with one, two and three variables are provided by Engle and Granger (1987) and Granger and Newbold (1989).

3/ The test statistic is the t-statistic for Beta, but the standard t-distribution is not appropriate.

where e_t are the residuals from the X_t regression and n is selected to be large enough to ensure that the residuals v_t are white noise. A statistically significant, negative coefficient β signifies that changes in X_t or e_t can be reversed over time and that their levels are stable over the long term.

The critical values for the three different tests at the 99%, 95% and 90% significance level are presented below. The critical values for the DF and ADF test statistic were obtained through Monte Carlo simulations, under the assumption that Δe_t is identically and normally distributed.

Critical Value of Unit Root Tests

Tests	Levels of Significance		
	90%	95%	99%
CRDW	0.322	0.386	0.511
DF	3.03	3.37	4.07
ADF	2.84	3.17	3.77

Source: Engle and Granger (1987).

In the case of non-autocorrelation in the residuals Δe_t, the ADF test is misspecified and less powerful than the DF test since it estimates parameters that are truly zero. In the case of autocorrelation, the DF is misspecified and less powerful than the ADF test. The CRDW test performs better overall in both the non-autocorrelated and autocorrelated cases according to the power calculations of Engle and Granger (1987). However, its critical values are quite sensitive to the particular parameters within the null hypothesis as well as to the sample size. In summary, and in order to avoid midleading results from these tests all three tests are applied.

After establishing that commodity prices and interest rates are integrated, the next step is to see if they are also co-integrated. Two variables are said to be co-integrated if there exists a constant K such that $Z_t = PC_t - Kr_t$ is integrated of order zero I(0) (where Z_t is the residual, unexplained error). Z_t is then stationary with a positive, finite spectrum at zero frequency. This is a rather special condition, because it implies that both series have extremely important long-run components. However, in forming Z_t these long-run components cancel out. To test whether the series are cointegrated, a two-stage test similar to that applied to test for integration is followed. In the first stage, the coefficient K is estimated by OLS; in the second stage the resulting series $Z_t = PC_t - Kr_t$ is tested for I(0) using the same three integration tests described previously. If the series are co-integrated, a robust estimate for K (the long-run co-integrator) can be expected. Phillips (1986) has shown that the estimated parameters of cointegrated variables converge in the limit to constants. Another important implication of co-intergration is that the long-run optimal forecast of the co-integrated variables PC_t and r_t will "hang together" and therefore will produce better forecasts than any other univariate forecast (see Yoo (1986). Finally, since PC_t is an I(1) variable and r_t is an I(1) policy controllable variable, then PC_t and r_t will be co-integrated if optimal control is applied (see Nickell (1985)).

III. INTEGRATION AND COINTEGRATION TEST RESULTS

(a) Integration Test

Tables 1 and 2 report the Sargan-Bhagrava (CRDW), Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) test statistics for the 13 series listed. The first five series are price indices for various primary commodity groups and are expressed in deflated terms. All other series are also expressed in real terms. The ADF test was also carried out after fitting various lags to the data, where the number of lags were sufficient to ensure that the residual v_t is white noise (these results are in column 5 of Tables 1 and 2). Results of the Lagrange Multiplier test for third order residual autocorrelation, LM(3)--distributed as chi-squared in large samples, under the null hypothesis that there is no autocorrelation--are presented in the sixth column of the tables (the critical value at 95% level of significance chi-squared is 7.81).

The integration tests of the untransformed data (Table 1) showed that all the series, regardless of the sample period, are non-stationary at the 99% level of significance. Therefore, we tested whether the rate of change of the variables was stationary. From the test results on the first-differenced series in Table 2 it appears that all the series, apart from the first difference of the consumer price index for the major 7 OECD countries, CPIG7, are stationary at the 99% level. The CPIG7 series must be differenced twice to become stable at the same level of significance. Thus, CPIG7 is integrated of order two, I(2), while all the other series have a unit root. Therefore, a long-run relationship cannot be established between the levels of the commodity price and consumer price series.

(b) Co-integration Test Results

The critical values of the co-integration tests, shown in Table 3, indicate that a stationary long-run relationship exists between the levels of the aggregate commodity price index (ICP 33) and the sub-indices of the deflated commodity prices (agriculture, metals and agriculture non-food) and the levels of real interest rates as represented by the rates on 3-month US Treasury Bills. No such relationship was found between real interest rates and the price index for agricultural foods (according to the DF and ADF tests). However, in this case, co-integration is accepted when the real oil price (POIL) is included in the regression. 1/ For the other price indices tested, the negative co-integrated coefficient on the real interest rate

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1/ Holthan (1989) has suggested that the use of macro-economic variables may have a role in establishing co-integration. This is not a result which is used later.

Table 1: INTEGRATION TESTS FOR THE LONG RUN: UNTRANSFORMED DATA

Series	Unit Root Test			No. of Lags in ADF	Serial Correlation Test
	CRDW (crit. value 99% : 0.532 95% : 0.386 90% : 0.322)	DF (crit. value 99% : -4.07 95% : -3.37 90% : -3.03)	ADF (crit. value 99% : -3.77 95% : -3.17 90% : -2.84)	$\sum_{i=1}^{n} \gamma \Delta e_{t-i}$	LM(3) : χ^2_3 for ADF
LnICP33	0.398	-1.981	-1.108	5	0.424
LnICPAG	0.355	-1.767	-1.187	5	1.375
LnICPMM	0.360	-2.039	-1.152	5	0.602
LnICPAGF	0.423	-1.972	-1.413	4	2.559
LnICPAGNF	0.363	-1.854	-1.262	4	1.960
TRB	0.192	-1.687	-1.431	3	1.737
LnIIP	0.022	-1.008	-2.226	4	1.326
LnCPIG7	0.009	2.329	-0.431	7	4.889
LnCPIG7T 1/	0.050	-1.547	-3.054	7	4.047
LnPOIL	0.126	-1.076	-1.373	4	2.818
LnEXR	0.092	-0.253	-0.669	4	0.096
LnGNP7	0.011	0.377	-2.354	7	1.326
LnMS	0.008	4.151	-0.204	5	1.885

Definitions: ICP33 is the World Bank's 33-commodity price Index, ICPAG is the agricultural commodity price index, ICPMM is the metals and minerals price index, ICPAGF is the agricultural food price index, ICPAGNF is the agricultural non-food index; TRB is the 3-month Treasury Bill interest rate series in real terms; IIP is the industrial production index for the G-7 countries; CPIG7 is the GNP-weighted consumer price index for the G-7 countries; POIL is the crude oil price index; EXR is the aggregate of the real Yen, DM and Pounds sterling exchange values to the US dollar weighted by GNP; GNP7 is gross national product of the G-7 countries; MS is M2 of the United States plus reserves of US dollars held by foreign central banks. The price indices have been deflated by the index of unit values for manufactured exports from developed to developing countries. The GNP series were deflated by the GNP deflator for the respective countries.

1/ The CPIG7 variable includes a trend which is proven in the estimation:

$$CPIG7 = -2.827\ (0.049) + 0.050T\ (0.002) + e_t \qquad R^2 = 0.942 \qquad D.W. = 0.050.$$

In this case we can proceed to test CPIG7 for a unit root either by allowing the trend to be included in the e_t or [illegible] for CPIG7 and CPIG7T, respectively.

Table 2: INTEGRATION TESTS FOR THE LONG-RUN: FIRST DIFFERENCED DATA

Series	Unit Root Test: CRDW (crit. value 99% : 0.532, 95% : 0.386, 90% : 0.322)	Unit Root Test: DF (crit. value 99% : -4.07, 95% : -3.37, 90% : -3.03)	Unit Root Test: ADF (crit. value 99% : -3.77, 95% : -3.17, 90% : -2.84)	No. of Lags in ADF $\sum_{i=1}^{n} \gamma \Delta e_{t-1}$	Serial Correlation Test LM(3) : χ_3^2 for ADF
Δ LnICP33	1.939	-5.892	-4.255	3	2.056
Δ LnICPAG	2.030	-6.177	-4.237	3	2.044
Δ LnICPMM	1.558	-4.737	-3.555	3	0.304
Δ LnICPAGF	1.950	-6.604	-3.919	3	0.152
Δ LnICPAGNF	2.116	-6.472	-5.817	3	2.396
Δ TBR	1.706	-5.246	-3.341	3	0.898
Δ LnIIP	2.389	-7.988	-3.783	3	4.781
Δ^2 LnCPIG7	0.420	-2.384	-1.540	5	0.454
Δ LnCPIG7T 1/	1.867	-9.906	-4.111	3	4.336
Δ LnPOIL	1.787	-5.399	-3.606	1	0.762
Δ LnEXR	1.048	-3.606	-4.140	3	0.862
Δ LnGNP7	2.057	-6.562	-2.084	6	2.006
Δ LnMS	0.807	-3.915	-1.698	3	2.240

1/ It was not necessary to include the trend in the first and second order integration test for the CPIG7, because it was not significant.

Notes: For variable definitions see Table 1.

Δ indicates that the first difference of the variables has been taken. Δ^2 indicates second differencing.

variable is significant at the 99% confidence interval. This result implies that interest rates are good indicators of the movements of commodity prices.

Because the lags used in the ADF test are significant, the ADF test becomes more reliable than the DF test. The CRDW test values are much higher than the upper-bound critical value at the 99% confidence interval, while the ADF test results are significant at the 95% interval. The DF test results are significant only at the 90% interval for the reason given. The statistical significance of the co-integration coefficient and the size of the parameter varies between the commodity price indices indicating differences in responses to interest rate changes. These differences are probably due to differences in the nature of the commodities as inputs in the production process, in consumpton and in stockholding. Therefore, it is more appropriate to consider the commodity price indices separately than as an aggregate index.

The introduction of the money supply variable into the commodity price-interest rate relationship, $PC_t = f(r_t, MS_t)$, as suggested by Frankel (1986), did not provide any additional information about the long-run relationship. It can be concluded, therefore, that any effect on commodity prices is passed through interest rates. In fact, the collinearity between money supply and interest rates is very strong, resulting in a change in the sign of the coefficient on the interest rate variable when the money supply variable is added to the equation. 1/ Money supply and commodity price indices were found not to be co-integrated (see Table 4).

IV. ERROR CORRECTION MODEL

An important implication of the co-integration theorem presented by Engle and Granger (1987) is that, if a long-run relationship has been established between a pair or set of variables, there always exists a dynamic error correction model (ECM) of the relationship (see Davidson, Hendry, Sbra and Yoo (1978)).

Derivation of the ECM involves two steps. The first consists of the integration and cointegration tests as they have been reported above. In the next step the residuals (Z_t) from the co-integrated regression are entered into the error correction model.

Not only must the co-integrated variables, in this case PC_t and r_t, follow an error correction model, but also the error correction model must be co-integrated (i.e., its residuals have to be I(0)). Since both PC_t and r_t are integrated of order one and their differences are I(0) then so is every term in the error correction model, provided Z_t is I(0). The value of Z_t in the ECM at any point in time shows the distance of the system from its equilibrium level.

1/ When money supply was regressed on interest rates (excluding the constant) a positive relationship between the two variables was found (a 1% change in MS is associated with a 10% increase in TRB). The R^2 of the regression is 0.8.

Table 3: CO-INTEGRATION TEST: REAL COMMODITY PRICE INDICES AND REAL INTEREST RATES

	Independent Variable			Co-integration Tests		
Dependent variable	Intercept	TRB	LnPOIL	CRDW	DF	ADF
LnICP33	4.889	-3.729		0.892	-3.311	-3.822
	(0.046)	(0.803)				
LnICPAG	4.902	-4.044		0.784	-2.887	-3.337
	(0.051)	(0.893)				
LnICPMM	4.946	-3.795		0.703	-3.043	-3.854
	(0.059)	(1.031)				
LnICPAGF	4.857	-3.458		0.759	-2.823	-2.910
	(0.050)	(0.879)				
LnICPAGF	4.687	-4.782	0.072	0.855	-3.079	-3.080
	(0.096)	(1.195)	(0.045)			
LnICPAGNF	5.081	-6.548		0.929	-3.315	-3.968
	(0.070)	(1.223)				

Notes: Standard errors are in parenthesis. Critical values for CRDW: $0.369 < CRDW < 0.570$ at 95% confidence interval and $0.515 < CRDW < 0.720$ at 99% confidence interval (see Sargan and Bhargava, 1983). Critical values for DF and ADF as in Table 1.

Table 4: CO-INTEGRATION TEST: REAL COMMODITY PRICE INDICES AND MONEY SUPPLY

	CRDW	DF	ADF	$\sum_{t=1}^{h} \gamma \Delta e_{t-i}$
LnICP33	0.519	-2.381	-1.406	5
LnICPAG	0.588	-2.477	-1.212	5
LnICPMM	0.360	-1.971	-1.247	5
LnICPAGF	0.676	-2.700	-1.634	5
LnICPAGNF	0.520	-2.321	-0.911	5

Notes: See Table 3.

Given co-integration between commodity prices and the real interest rate we proceed to the second stage of the Engle and Granger (1987) procedure. In this stage the residuals defined as $Z_{it} = PC_{jt} - K\ TRB_t$ and derived from the equations presented in Table 3, are entered into the dynamic error correction formulations.

Initially, the error correction formulation of the dynamic model is specified using only the real commodity price indices and the real interest rate variables. Following the 'general-to-simple' modelling methodology [Hendry (1986)], a parsimonious representation (as few variables as possible) of the data-generating process was obtained (Table 5). The main finding from the estimated dynamic model is that the error correction term Z_t is statistically very significant in each of the equations. Tests for serial correlation, normality and out-of-sample forecasting performance indicate strongly that the models have been specified correctly. As a test of their forecasting stability, the equations were also estimated after excluding the last ten periods and used to forecast the last 10 periods. The results are graphed in Annex A with the error bars showing standard errors at 5%. The forecasting performance of the equations is excellent except in the 1985-87 period, when the actual price of each commodity index is considerably lower than the forecast. This may be due to the weakening of the dollar in this period. This hypothesis is tested later in the paper.

To establish the degree of reliability of the error correction specification of the model, the restrictions implied by the prior co-integrated parameter (Z_t) can be relaxed and a free error correction equation estimated by including the lagged values of the commodity price indices and the interest rate. That is, the term Z_{t-1} is replaced by the lags t-1 of the two co-integrated variables. The results of estimation of the unrestricted model are presented in Table 6. The findings from these equations are very close to those of Table 5. The diagnostic tests suggest no evidence of autocorrelation or non-normality. It is also interesting to note that the out-of-sample stability test results indicate considerable parameter stability for these equations. Moreover, the F-test fails to reject the hypothesis that the estimations of the restricted and unrestricted equations are significantly different.

An extension of this approach to testing the relationship between commodity prices and interest rates is to specify a model that incorporates both short-run dynamics and long-run solutions. Among the variables expected to be included in the equilibrium solutions are variables indicating shifts in commodity demand--either Gross National Product (GNP), or the Index of Industrial Production (IIP) whenever appropriate, real exchange rates (EXR), and the oil price (POIL).

The time-series behavior of these series in logarithms (Ln) was presented in Table 1 and 2. The three tests CRDW, DF and ADF indicated that the three series are I(1). 1/ Given that each commodity price index has the

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1/ These variables were also tested for co-integration with the commodity price indices. The results indicate that such co-integration exists (see Table 7).

Table 5: ERROR CORRECTION FORMULATION: COMMODITY PRICES AND INTEREST RATES

33 Commodity Index (sample 1952-88)

$$\Delta\, LnICP33 = \underset{(0.012)}{-\,0.015} \underset{(0.103)}{-\,0.459}\, \Delta\, LnICP33_{t-2} \underset{(0.125)}{+\,0.193}\Delta\, LnICP33_{t-3}$$

$$\underset{(1.075)}{-\,1.989}\Delta\, TRB_{t-2} \underset{(0.103)}{-\,0.174}\, Z_{t-1}$$

$R^2 = 0.604$ s.e = 0.073   Serial Correlation LM : F [3,29] = 0.22.

Normality : $\chi^2_{(2)} = 0.085$ Forecast Stability Test : Chow (10,29) = 1.39

Agricultural Commodities (sample 1952-88)

$$\Delta\, LnICPAG = \underset{(0.019)}{-\,0.020} \underset{(0.115)}{-\,0.427}\Delta\, LnICPAG_{t-2} \underset{(0.107)}{+\,0.181}\Delta\, LnICPAG_{t-3}$$

$$\underset{(1.043)}{-\,1.903}\, \Delta\, TRB_{t-2} \underset{(0.093)}{-\,0.186}\, Z_{t-1}$$

$R^2 = 0.604$ s.e. = 0.074   Serial Correlation LM:F [3.29] = 0.47

Normality : $\chi^2_{(2)} = 5.346$ Forecast Stability Test : Chow (10,22) = 1.45

Minerals and Metals (sample 1954-88)

$$\Delta\, LnICPMM = \underset{(0.017)}{-0.003} \quad \underset{(0.176)}{-0.474}\, \Delta\, LnICPMM_{t-2} \underset{(0.172)}{+\,0.432}\Delta\, LnICPMM_{t-5}$$

$$\underset{(1.426)}{-4.839}\quad \Delta\, TRB_{t-5} \underset{(0.104)}{-\,0.210}\, Z_{t-1}$$

$R^2 = 0.552$ s.e. = 0.096   Serial Correlation LM:F [3,27] = 0.67

Normality : $\chi^2_{(2)} = 0.88$ Forecast Stability Test : Chow (10,20) = 0.70

Table 5: (Continued)

Agricultural Foods (sample 1952-1988)

$$\Delta\, LnICPAGF = -\underset{(0.015)}{0.014} - \underset{(0.109)}{0.426}\,\Delta\, LnICPAGF_{t2} - \underset{(0.130)}{0.198}\Delta\, LnIPCAGF_{t-3}$$

$$-\underset{(1.225)}{2.903}\Delta\, TRB_{t-2} + \underset{(0.061)}{0.094}\Delta\, LnPOIL_{t-2} - \underset{(0.109)}{0.198}\, Z_{t-1}$$

$R^2 = 0.551$ s.e.= 0.087 Serial Correlation LM:F [3,28] = 0.68

Normality: $\chi^2_{(2)} = 0.139$ Forecast Stability Test: Chow (10,21) = 1.73

Agricultural Non-Foods (sample 1952-1988)

$$\Delta\, LnICPAGNF = -\underset{(0.018)}{0.052} - \underset{(0.155)}{0.308}\,\Delta\, LnICPAGNF_{t-1} - \underset{(0.128)}{0.321}\Delta\, LnICPAGNF_{t-2} - \underset{(0.133)}{0.286}\Delta\, LnICPAGNF_{t-3}$$

$$-\underset{(1.037)}{1.758}\,\Delta\, TRB_{t-2} - \underset{(0.109)}{0.235}Z_{t-1}$$

$R^2 = 0.632$ s.e. = 0.099 Serial Correlation LM:F [3,28] = 0.23

Normality: $\chi^2_{(2)} = 0.16$ Forecast Stability Test: Chow (10,21) = 2.28

Notes: Standard errors in parenthesis.

Table 6: UNRESTRICTED EQUATION ESTIMATES: COMMODITY PRICES AND INTEREST RATES

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33 Commodity Index (sample 1952-88)

$$\Delta\, LnICP33 = \underset{(0.510)}{0.906} \; \underset{(0.125)}{-0.475}\Delta\, LnICP33_{t-2} + \underset{(0.118)}{0.170}\Delta\, LnICP33_{t-2} - \underset{(1.138)}{1.622}\Delta\, TRB_{t-2}$$

$$- \underset{(0.104)}{0.184}\; LnICP33_{t-1} - \underset{(0.617)}{1.124}\; TRB_{t-1}$$

$R^2 = 0.616$ s.e. = 0.073 Serial Correlation LM:F [3,28] = 0.47

Normality: $\chi^2_{(2)}$ = 0.341 Forecast Stability Test: Chow (10,22) = 1.24

Test against restricted equation F(1,37) = 0.474

Agricultural Commodities (sample 1952-88)

$$\Delta\, LnICPAG = \underset{(0.462)}{0.909} \; \underset{(0.116)}{-0.438}\Delta\, LnICPAG_{t-2} + \underset{(0.107)}{0.169}\Delta\, LnICPAG_{t-3} - \underset{(1.094)}{1.679}\Delta\, TRB_{t-2}$$

$$- \underset{(0.094)}{0.186}\; LnICPAG_{t-1} - \underset{(0.590)}{1.080}\; TRB_{t-1}$$

$R^2 = 0.611$ s.e. 0.075 Serial Correlation LM:F [3,28] = 0.62

Normality: $\chi^2_{(2)}$ = 6.98 Forecast Stability Test: Chow (10.21) = 1.45

Test against the restricted equation F(1,31) = 0.419

Table 6: (Continued)

Minerals and Metals (sample 1954-88)

$$\Delta \text{ LnICPMM} = \underset{(0.522)}{1.072} \underset{(0.178)}{-0.469} \Delta \text{ LnICPMM}_{t-2} + \underset{(0.182)}{0.392} \Delta \text{ LnICPMM}_{t-5}$$

$$\underset{(1.475)}{-4.592} \Delta \text{ TRB}_{t-5} - \underset{(0.104)}{0.213} \text{ LnICPMM}_{t-1} - \underset{(0.74)}{1.259} \text{ TRB}_{t-1}$$

$R^2 = 0.56$ s.e. = 0.097 Serial Correlation LM:F [3,26] = 0.66

Normality: $\chi^2_{(2)} = 0.569$ Forecast Stability Test: Chow [10,19) = 0.77

Test against the restricted equation: F(1,29) = 0.302

Agricultural Foods (sample 1952-88)

$$\Delta \text{ LnICPAGF} = \underset{(0.531)}{0.987} \underset{(0.132)}{-0.452} \Delta \text{ LnICPAGF}_{t-2} + \underset{(0.135)}{0.144} \Delta \text{ LnICPAGF}_{t-3} - \underset{(1.295)}{2.855} \Delta \text{ TRB}_{t-2} + \underset{(0.063)}{0.117} \Delta \text{ LnPOIL}_{t-2}$$

$$\underset{(0.112)}{-0.190} \text{ LnICPAGF}_{t-1} - \underset{(0.974)}{0.783} \text{ TRB}_{t-1} - \underset{(0.027)}{0.022} \text{ LnPOIL}_{t-1}$$

$R^2 = 0.585$ s.e. = 0.087 Serial Correlation LM:F [3,26] = 0.92

Normality test: $\chi^2_{(2)} = 0.286$ Forecast Stability Test: Chow [10,19] = 1.73

Test against the restricted equation: F[1,29] = 0.881

Agricultural Non-Food (sample 1952-88)

$$\Delta \text{ LnICPAGNF} = \underset{(0.566)}{1.143} \underset{(1.158)}{-0.309} \Delta \text{ LnICPAGNF}_{t-1} - \underset{(0.131)}{0.321} \Delta \text{ LnICPAGNF}_{t-2} - \underset{(0.136)}{0.286} \Delta \text{ LnICPAGNF}_{t-3}$$

$$\underset{(0.058)}{-1.769} \Delta \text{ TRB}_{t-2} - \underset{(0.110)}{0.236} \text{ LnICPAGNF}_{t-1} - \underset{(0.919)}{1.473} \text{TRB}_{t-1}$$

$R^2 = 0.632$ s.e. = 0.101 Serial Correlation LM:F[3,27] = 0.23

Normality test: $\chi^2_{(2)} = 0.198$ Forecast Stability test: Chow (10,20) = 2.18

Test against the restricted equation: F(1,30) = 0.606

Table 7: CO-INTEGRATION TESTS: REAL COMMODITY PRICE INDICES AND MACRO-ECONOMIC VARIABLES /a

	CDRW	DF	ADF
LnICP33	1.360	-4.421	-5.049
LnICPAG	1.240	-4.245	-4.328
LnICPMM	1.215	-4.073	-3.018
LnICPAGF	1.187	-4.029	-4.123
LnICPAGNF	1.675	-6.528	-3.306

Note: See Table 1 for variable definitions.

/a The co-integrated macro-economic variables included on the right-hand side of the above tests are: three-month US treasury bill as proxy for the real interest rate, the real price of oil, the real exchange rate and real GDP of the G-7 countries.

same linear properties as the macroeconomic variables under consideration, we proceed to the specification and estimation of restricted and unrestricted dynamic error correction models. The results of estimating the error correction formulation are presented in Table 8. A noteworthy feature of these equations is the significance of the error correction term Z_{t-1}. It indicates that, even after the inclusion of other important macroeconomic variables in the equation, the direction of change in each of the commodity price indices takes into account the size and the sign of the previous equilibrium error, Z_{t-1}. The diagnostic tests for serial correlation, normality and forecast stability suggest no evidence of autocorrelation, non-normal errors or instability. The introduction of the exchange rate variable into the equations eliminates the forecast errors in the period 1985-87.

Changes in exchange rates have an impact on commodity prices after a two or three year lag. This suggests that producer pricing reactions to exchange rate changes are slow--a result consistent with Feenstra (1987) for cars, and Varangis and Duncan (1988) for coffee, cocoa, copper and steel. The index of industrial production gives better results for most of price equations than does use of the GDP variable. This result supports Gilbert's (1989) findings. Also, the oil price variable has significant immediate and lagged effects on commodity prices. The negative asset pricing effect of interest rates is strongly established across all equations.

The diagnostic tests for the unrestricted dynamic model equations and the equilibrium solutions for the interest rate are presented in Table 9. The LM test for serial correlation indicates that only in the agricultural price equation is there some degree of autocorrelation, while the normality test suggests that the errors are normal. The parameters also exhibit a high degree of stability when the last ten observations are excluded from the estimations. The F test compares the restricted equations with the unrestricted equations. This test rejects the hypothesis that the two equations are significantly different. The equilibrium elasticities of these equations are presented at the bottom of Table 9.

Table 8: **ERROR CORRECTION FORMULATION: REAL COMMODITY PRICES AND MACRO-ECONOMIC VARIABLES**

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33 Commodity Index (sample 1952-88)

$$\Delta \, LnICP33 = \underset{(0.009)}{-\,0.023} - \underset{(0.116)}{0.301}\,\Delta^2 LnICP33_{t-2} - \underset{(0.694)}{0.869}\,\Delta^2 TRB_{t-2} - \underset{(0.155)}{0.507}\,\Delta\, LnEXR_{t-2}$$

$$+ \underset{(0.134)}{0.206}\,\Delta^2 LnGNP_{t-1} + \underset{(0.028)}{0.093}\,\Delta^2 LnPOIL_t + \underset{(0.038)}{0.061}\,\Delta\, LnPOIL_{t-2} - \underset{(0.080)}{0.276}\, Z_{t-1}$$

$R^2 = 0.764$ s.e. = 0.059 Serial Correlation LM:F[3,26] = 0.29

Normality: $\chi^2_2 = 1.019$ Forecast Stability Test: Chow (10,19) = 1.08

Test against unrestricted equation: F(1,28) = 0.474.

Agricultural Commodities (sample 1955-88)

$$\Delta \, LnICPAG = \underset{(0.011)}{-\,0.070} - \underset{(0.097)}{0.606}\,\Delta\, LnICPAG_{t-2} - \underset{(1.106)}{1.694}\,\Delta^2\, TRB_{t-3} - \underset{(0.178)}{0.467}\,\Delta^2 LnEXR_{t-2} + \underset{(0.172)}{0.54}\,\Delta\, LnIIP$$

$$\underset{(0.152)}{+0.139}\,\Delta^2\, LnIIP_{t-2} + \underset{(0.152)}{0.304}\,\Delta\, LnIIP_{t-5} + \underset{(0.034)}{0.549}\,\Delta\, LnPOIL_t + \underset{(0.046)}{0.233}\,\Delta\, LnPOIL_{t-2} - \underset{(0.079)}{0.257}\, Z_{t-1}$$

$R^2=0.869$ s.e. = 0.046 Serial Correlation LM:F[3,22] = 1.20

Normality: $\chi^2_{(2)} = 0.305$ Forecast Stability Test: Chow (10,15) = 1.45

Test against unrestricted equation: F(1,24) = 0.533

Minerals and Metals (sample 1959-88)

$$\Delta \, LnICPMM = \underset{(0.028)}{-\,0.079} + \underset{(0.094)}{0.264}\,\Delta^2\, LnICPMM_{t-1} - \underset{(1.564)}{2.129}\,\Delta\, TRB_{t-3} - \underset{(0.328)}{0.647}\,\Delta\, LnEXR_{t-3} + \underset{(0.285)}{0.320}\,\Delta\, LnIIP_t$$

$$\underset{(0.424)}{+0.982}\,\Delta\, LnIIP_{t-3} + \underset{(0.259)}{0.519}\,\Delta\, LnIIP_{t-4} + \underset{(0.039)}{0.129}\,\Delta^2\, LnPOIL_t - \underset{(0.092)}{0.384}\, Z_{t-1}$$

$R^2=0.685$ s.e. = 0.085 Serial Correlation LM:F[3,24] = 1.44

Normality: $\chi^2_{(2)} = 0.437$ Forecast Stability Test: Chow (10,17) = 1.01

Test against unrestricted equation: F[1,26] = 0.612

Table 8: **(continued)**

Agricultural Foods (sample 1954-88)

$$\Delta\, LnICPAGF = \underset{(0.011)}{-\,0.032} \underset{(0.077)}{-\,0.116}\Delta^2\, LnICPAGF_{t-2} \underset{(0.641)}{-\,1.177}\Delta^2\, TRB_{t-3} \underset{(0.226)}{-\,0.614}\Delta\, LnEXR_{t-3} \underset{(0.206)}{+\,0.910}\Delta\, LnGNP_{t-1}$$

$$\underset{(0.039)}{+\,0.156}\,\Delta\, LnPOIL_t \underset{(0.049)}{+\,0.103}\Delta\, LnPOIL_{t-3} \underset{(0.09)}{-\,0.557}\, Z_{t-1}$$

R^2=0.806   s.e. = 0.061   Serial Correlation LM:F[3,24] = 0.07

Normality: $\chi^2_{(2)}$ = 0.639   Forecast Stability Test: Chow (10,17) = 2.34

Test against unrestricted equation: F(1,26) = 0.881

Agricultural Non Foods (sample 1952-88)

$$\Delta\, LnICPAGNF = \underset{(0.012)}{-\,0.068} \underset{(0.110)}{-\,0.544}\Delta\, LnICPAGNF_{t-1} \underset{(0.083)}{-0.311}\Delta\, LnICPAGNF_{t-2} \underset{(0.092)}{-0.436}\Delta\, LnCPAGNF_{t-3} \underset{(0.827)}{-1.866}\Delta^2\, TRB_{t-2}$$

$$\underset{(0.217)}{-\,0.547}\Delta\, LnEXR_{t-2} \underset{(0.267)}{-\,0.652}\Delta\, LnEXR_{t-3} \underset{(0.156)}{+\,3.365}\Delta^2\, LnIIP_t \underset{(0.039)}{+\,0.151}\Delta^2\, LnPOIL \underset{(0.100)}{-\,0.183}\, Z_{t-1}$$

R^2=0.836   s.e. = 0.071   Serial Correlation LM:F[3,24] = 0.31

Normality: $\chi^2_{(2)}$ = 1.578   Forecast Stability test: Chow (10,17) = 1.90

Test against unrestricted equation: F[1,26] = 0.371

Note: Standard errors are in parantheses.

Table 9: DIAGNOSTICS, TESTS AND EQUILIBRIUM ELASTICITIES OF THE UNRESTRICTED ESTIMATIONS

		LnICP33	LnICPAG	LnICPMM	LnICPAGF	LnICPAGNF
	h	26	22	24	24	24
R^2		0.786	0.881	0.689	0.827	0.845
s.e.		0.058	0.045	0.087	0.059	0.070
LM: test for serial correlation	F[3,h]	0.54	4.28	1.46	0.62	0.76
Normality	$X^2_{(2)}$	1.370	0.365	0.502	1.673	1.642
Forecast Stability Chow: 1979-88	F[10,h]	1.09	1.410	1.300	1.940	1.490
Test against restricted equations 1/	F[1,h]	0.474	0.533	0.612	0.881	0.371
Long-Run Solutions of TRB from the Unrestricted Estimates						
TRB		-5.682	-5.804	-4.630	-4.283	-3.681
LnPOIL					0.016	

Note: h is the number of degrees of freedom for the test.

1/ These results are in Table 7.

CONCLUSIONS

The research reported here has found that the interest rate plays an important role in both short-run and long-run determination of non-fuel primary commodity prices--the World Bank's 33 commodities price index and its sub-indices, agriculture (food and non-food) and minerals and metals. Co-integration and error correction techniques were applied. The central conclusion of these estimations is that the hypothesis that there is a stationary long-run relationship between the levels of commodity prices and interest rates cannot be rejected. These results are in line with the theory of commodities as financial assets and contrast with Powell's (1989) findings that interest rates play "little role in either the short run or the long run".

After establishing the existence of co-integration between commodity prices and interest rates an error correction model was developed for each commodity price index and the interest rate. This estimated relationship confirms the results of the co-integration tests and evidences a remarkable forecasting ability. What is also interesting is the fact that the introduction of the price of oil as a macroeconomic variable in the error correction models has a significant impact in explaining the variation in commodity prices.

The inclusion of the exchange rate variable improved the explaining ability of the error correction models particularly during the 1980s when exchange rate volatility increased. The index of Industrial Production was also found to significantly contribute in explaining commodity price movements particularly for the cases of metals and agricultural non-food commodities. Changes in the money supply were generally not important in explaining commodity price behavior.

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