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Exchange Rates, Country Preferences, and Gold

Prepared by Michael P. Dooley, Peter Isard, and Mark P. Taylor 1/

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Abstract

This paper provides indirect tests of the hypothesis that exchange rate movements may be largely coterminus with changes in preferences for holding claims on different countries. It is argued that changes in country preferences will be reflected systematically in the price of gold and, hence, that gold price movements, under the maintained hypothesis, should have explanatory power with respect to exchange rate movements over and above the effects of monetary shocks. The paper applies multivariate vector autoregression and cointegration modeling techniques to test for the short- and long-run influence of gold prices on exchange rates conditional on other monetary and real macroeconomic variables, and applies the resulting error correction exchange rate equation to out-of-sample forecasting exercises.

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1/ The views expressed in this paper are solely those of the authors and do not necessarily reflect those of the International Monetary Fund.

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Summary

This paper tests indirectly the hypothesis that exchange rate movements may largely reflect changes in preferences for holding claims on different countries. It is argued that changes in country preferences will be reflected systematically in the price of gold and, hence, that gold price movements should have power to explain exchange rate movements over and above the predicted effects of monetary shocks. The argument is based on the concept of gold as "an asset without a country," which suggests that shocks that change relative preferences for holding claims on different countries will also change preferences for holding gold relative to holding claims on any particular country.

The paper applies multivariate vector autoregression and cointegration modeling techniques to test for the short- and long-run influence of gold prices on exchange rates conditional on other monetary and real macroeconomic variables, and applies the resulting error-correction exchange rate equation in out-of-sample forecasting exercises. It also compares the apparent explanatory power of movements in the price of gold with that of movements in the price of wheat, which is not generally held as an asset. The paper's investigations yield quite strong support for the hypothesis.

I. Conceptual Background

Most exchange rate models that have emerged since the early 1970s have involved "asset market views," recognizing that international capital movements are not exogenous. 1/ A widely employed taxonomy divides the asset market models into two broad classes: the monetary approach and the portfolio balance approach. 2/ The key distinction is whether portfolio holders are assumed to regard domestic and foreign assets as perfect substitutes--in which case the model represents the monetary approach--or, equivalently, whether the uncovered interest parity condition (UIP) is assumed to hold continuously. 3/

For those subclasses of the monetary approach in which UIP enters the model structure explicitly, and for virtually all portfolio balance models, closed-form solutions can be derived for the expected rate of change of the exchange rate, but the current level of the exchange rate cannot be explained independently of its expected future level at some horizon. One approach to modeling expectations about future nominal exchange rates is to adopt a conventional model of expected inflation factors, and to assume that expectations about future real exchange rates are based on perceptions of some kind of goods market or balance of payments constraint. 4/ The balance of payments constraint need not be precisely defined. 5/ The key point, as Dooley (1982) has emphasized, is that the nature of any balance of payments constraint essentially reflects perceptions of a country's creditworthiness, and that changes in perceived creditworthiness will have predictable effects on both the tightness of the constraint and the real exchange rate consistent with meeting the constraint. The bottom line is that the expected future level or time path of a country's real exchange rate will presumably change systematically in response to revisions in expectations about the prospective relative returns on assets located in that country, or on financial claims held against that country.

Strong but casual empirical support for this line of argument is provided by observing that nominal exchange rates have shifted dramatically

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1/ See MacDonald and Taylor (1992). For this reason, the "traditional view" in which the exchange rate simply equilibrates current account flows to an exogenous capital account balance within a single-period horizon is now regarded as inappropriate.

2/ See Frankel (1983) for a discussion of the taxonomy and MacDonald and Taylor (1992) for a recent survey of the empirical evidence on the main classes and subclasses of models.

3/ See Isard (1991) for perspectives on the validity of the UIP assumption.

4/ See Dooley and Isard (1983).

5/ Indeed, the concept of balance of payments sustainability has proved difficult to define precisely.

during episodes involving major changes in the relative attractiveness of holding assets in different countries. For example, the outbreak of the international debt crisis in 1982 led to very substantial real depreciations of the currencies of debt-burdened developing countries. 1/ More rigorous empirical support has been difficult to muster, however, mainly because it is difficult to find time series of suitable quality and length on variables that indicate the relative attractiveness of holding claims on different countries. 2/

This paper attempts to fill this void by providing indirect empirical evidence based on the relationship between exchange rates and the price of gold. The basic line of argument is that changes in relative country preferences should be systematically reflected in the price of gold, which we view as "an asset without a country." Hence, if the effects of monetary shocks can be isolated, evidence that residual changes in the price of gold are capable of "explaining" residual changes in exchange rates might be regarded as indirect evidence that exchange rate behavior reflects changes in country preferences.

II. Theoretical Priors and Summary of Empirical Findings

Consider a world consisting of two countries, A and B, and three types of assets: net claims on A, net claims on B, and gold. Claims on A may be physical assets located in country A or net financial claims against the government or private sector of country A. The key distinguishing feature is that the prospective returns on these net claims depend on economic and political developments in country A. Adverse macroeconomic shocks to country A, other things equal, will reduce prospective yields on net claims on A. Similarly, political developments that portend higher tax rates on claims on A, other things equal, will reduce the relative attractiveness of these net claims.

Gold is viewed as an asset without a country. Gold can be held outside the jurisdiction of all tax authorities, and the return on gold is not subject to the country-specific uncertainties that surround claims on future output. Any type of shock that reduces the attractiveness of holding claims on A, other things equal, will increase the demands for other assets--both claims on B and gold--leading to changes in market-clearing prices. Such adjustments will result in higher currency A prices for both gold and currency B (i.e., a depreciation of currency A against currency B). The currency B price of gold may rise or fall, depending on the relative strengths of the different substitution effects.

1/ See the evidence provided in Dooley (1989) and Dooley and Isard (1991).

2/ See Dooley and Isard (1986) and Isard (1988) for some initial attempts based on spreads between the yields on dollar-denominated claims on Mexico (Brazil) and the yields on similar claims on the World Bank.

One way of formalizing the argument is as follows. The level of the exchange rate, s, can be thought of as being determined by two components--monetary fundamentals and country preferences:

$$s_t = \beta' x_t + z_t \tag{1}$$

In equation (1), x_t is a vector of monetary fundamental variables, and z_t is an unobservable variable measuring the attractiveness of the home country's assets relative to those of the foreign country. The term $\beta' x_t$ may be thought of as a standard exchange rate model. Since z_t is unobservable, we suggest proxying it (or rather, proxying its inverse) by the domestic-currency price of gold. Thus, the empirically implementable counterpart to equation (1) that we suggest is:

$$s_t = \beta' x_t + \kappa g_t \tag{2}$$

If s_t is the foreign price of domestic currency and g_t is the domestic price of gold, we expect κ to be negative--a rise in g_t, other things equal, represents a relative decline in the attractiveness of domestic assets and will therefore tend to be associated with a depreciation of the domestic currency.

The specification of equations (1) and (2) reflects the assumption that there are only two types of shocks: monetary shocks, and shocks that affect country preferences. We refer to the latter as real shocks. A deeper analysis would distinguish between different types of monetary and real shocks--in particular, between global real shocks that might increase the attractiveness of gold vis-à-vis both claims on A and claims on B, and country-specific real shocks that affect the attractiveness of gold vis-à-vis claims on A differently than the attractiveness of gold vis-à-vis claims on B. By implicitly assuming that all real shocks are country specific, our methodology appears to make it more difficult to find statistically significant evidence that movements in the price of gold contain information capable of explaining movements in the exchange rate between currencies A and B.

We think of monetary shocks as shocks that have no effects on the relative attractiveness of holding assets in different countries. These include both global and country-specific inflationary shocks accompanied by monetary policy responses that essentially hold constant the expected real yields on claims on A and claims on B. Such shocks generally lead to changes in nominal interest rates and, hence, the nominal carrying cost of gold, which in turn lead to jumps in the nominal price of gold. Since our objective is to extract from the price of gold only information that can be taken to reflect changes in country preferences, our econometric methodology must be capable of isolating movements in the price of gold that cannot be attributed to monetary shocks.

In the empirical model suggested in equation (2), the monetary fundamentals represented by x_t typically include relative money supplies, relative interest rates, and so on. Accordingly, the estimate of κ should only reflect variation in the gold price that is not common to these monetary fundamentals. This point becomes even more obvious if we apply the so-called Frisch-Waugh theorem (see e.g., Maddala, (1977), p. 462). Suppose we regress g_t onto x_t and retrieve the residuals, $\tilde{g}_t$ say:

$$\tilde{g}_t = g_t - \hat{\alpha}' x_t \tag{3}$$

where $\hat{\alpha}$ represents the least squares estimate. If we then regress s_t onto $\tilde{g}_t$:

$$s_t = \kappa \tilde{g}_t \tag{4}$$

the least squares estimate of κ obtained from estimation of (4) is identical to that obtained from least squares applied to (2). 1/ Thus, by including monetary fundamentals in our estimating equations, we can isolate co-variation in exchange rates and gold that is not attributable to movements in the monetary fundamentals.

We have conducted a variety of empirical tests, focusing on end-of-month exchange rates between the U.S. dollar and four other major currencies (the pound sterling, the Japanese yen, the deutsche mark, and the French franc), as well as on the mark/yen exchange rate, over the period 1976-90. In light of the prominent attention earned by the work of Meese and Rogoff (1983a, 1983b, 1988), we begin by investigating how their general exchange rate equation specification 2/ performs when the price of gold is added to the set of explanatory variables. We find that the price of gold is the most significant explanatory variable in-sample for an equation explaining logarithmic changes in the exchange rate. As a test of whether the information contained in the price of gold indeed reflects the prominent role that gold has played as an asset, we also present a set of results in which the price of gold is replaced by the price of wheat.

We then move from single-equation tests to tests based on a vector autoregression (VAR) system. This is followed by a third line of investigation, which uses the VAR system to examine the long-run relationships between the exchange rate, the price of gold, and the other variables in the system. We find that the long-run relationship between the exchange rate and the price of gold is highly significant with the anticipated sign. The estimated cointegration relationships are then used to find dynamic error correction equations, and we again apply recursive tests of predictive ability.

1/ Taylor (1984) demonstrates that this also holds for instrumental variables estimation.

2/ This specification corresponds to the Frankel (1979) real interest rate differential variant of the monetary model.

III. Empirical Results

1. Data

The data are taken from the International Monetary Fund's IFS data tape and run from January 1976 through December 1990. In particular, the exchange rate used is line ag; money is M1, line 34; the short-term interest rate is line 60c; consumer prices are from line 64; and the income measure is industrial production, line 66c. The money supply, price, and industrial production series are seasonally adjusted. The countries considered are the United States, the United Kingdom, France, Germany and Japan. We consider US dollar bilateral exchange rates, as well as the yen/mark rate.

2. Improving upon a standard empirical specification

We started by estimating an equation of the form:

$$\Delta s_t = \alpha_1\Delta(m-m^*)_t + \alpha_2\Delta(y-y^*)_t + \alpha_3\Delta(r-r^*)_t + \alpha_4\Delta(\pi-\pi^*)_t \qquad (5)$$

where s_t is the foreign currency price of the U.S. dollar (or the mark price of yen); m, y, r and π denote, respectively, US narrow money, industrial production, short-term interest rate and inflation rate; and an asterisk denotes the corresponding foreign variable. 1/

Equation (5) is a general monetary model formulation, which nests the real interest differential formulation of Frankel (1979) ($\alpha_1<0,\alpha_2>0,\alpha_3>0,\alpha_4<0$); a simple "overshooting" empirical model ($\alpha_1<0,\alpha_2>0,\alpha_3>0,\alpha_4=0$); and the basic, flexible-price monetary model ($\alpha_1<0,\alpha_2>0,\alpha_3<0,\alpha_4=0$). 2/ In order to provide an indirect test of the hypothesis outlined above, we also estimated equations including (the logarithms of) the dollar price of gold and the dollar price of wheat. 3/

The results are reported in Table 1. As was expected, equation (5) performs badly as a model of exchange rate determination, with most coefficient estimates insignificantly different from zero and low overall explanatory power. Adding the gold variable to this equation, however, produces spectacular results: the gold price is, in every case, strongly significant and of the expected sign (negative), the R^2 rises by an average factor of six, and the Durbin-Watson statistic improves dramatically. Moreover, this success is not repeated when the price of wheat variable is

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1/ For the mark/yen regression, unstarred variables are associated with Japan and the yen. All variables, except interest rates, were put into logarithms. The inflation rate was computed as the first difference of the logarithm of the price series.

2/ See MacDonald and Taylor (1992) for a discussion of these restrictions.

3/ or, in the mark-yen regressions, the yen price of gold and of wheat.

Table 1. **Estimates of a Single Equation Monetary Model Including and Excluding Gold and Wheat Prices** 1/

Exchange Rate	Δ(m-m*)	Δ(y-y*)	Δ(r-r*)	Δ(π-π*)	Δg	Δw	R^2	D.W.
UK£/US$	-0.464	0.203	-0.158	0.449	--	--	0.03	1.86
	(-1.437)	(1.235)	(-0.617)	(1.180)				
	-0.387	0.213	-0.282	0.501	-0.176	--	0.15	1.86
	(-1.275)	(1.382)	(-1.171)	(1.405)	(-5.002)			
	-0.465	0.202	-0.158	0.450	--	-0.638E-2	0.03	1.86
	(-1.435)	(1.229)	(-0.617)	(0.381)		(-0.101)		
DM/US$	-0.104	0.142	0.572	-0.887	--	--	0.04	2.15
	(-0.409)	(1.167)	(1.964)	(-1.276)				
	0.135	0.121	0.289	0.200	-0.219	--	0.22	2.08
	(0.579)	(1.096)	(1.080)	(0.307)	(-6.288)			
	-0.103	0.142	0.572	-0.886	--	0.318E-2	0.04	2.15
	(-0.400)	(1.164)	(1.959)	(-1.269)		(0.051)		
¥/US$	-0.017	-0.145	0.738	-0.718	--	--	0.04	1.87
	(-0.070)	(-0.789)	(2.336)	(-1.659)				
	0.018	-0.109	0.561	-0.771	-0.138	--	0.12	1.80
	(0.079)	(-0.613)	(1.817)	(-1.845)	(-3.700)			
	0.014	-0.160	0.749	-0.703	--	-0.075	0.05	1.87
	(0.058)	(-0.872)	(2.371)	(-1.625)		(-1.151)		
FFR/US$	0.040	0.202	0.362	-0.605	--	--	0.03	2.07
	(0.208)	(1.412)	(1.405)	(-0.944)				
	0.077	0.205	0.187	0.066	-0.201	--	0.20	2.08
	(0.435)	(1.581)	(0.792)	(0.112)	(-6.077)			
	0.039	0.200	0.367	-0.604	--	-0.018	0.03	2.08
	(0.203)	(1.398)	(1.416)	(-0.941)		(-0.299)		
DM/¥	-0.278	0.025	-0.398	-0.342	--	--	0.02	1.89
	(1.369)	(0.256)	(0.875)	(-0.877)				
	-0.181	0.020	-0.420	0.158	-0.187	--	0.19	2.01
	(-0.972)	(0.227)	(-1.010)	(0.433)	(-6.039)			
	-0.232	0.022	-0.378	-0.322	--	0.063	0.03	1.89
	(-1.118)	(0.226)	(-0.830)	(-0.824)		(1.112)		

1/ The dependent variable is the change in the logarithm of the exchange rate. Unstarred explanatory variables in the exchange rate equations for the US$ (or in the DM/¥ equations) are associated with the United States and the dollar (or Japan and the yen). In particular, m is the logarithm of the U.S. narrow money stock, y is the logarithm of U.S. industrial production, r is a short-term dollar interest rate, π is the U.S. rate of inflation over the previous 12 months, g is the logarithm of the price of gold in dollars, and w is the logarithm of the price of wheat in dollars (g and w are expressed in yen in the DM/¥ equations). Starred explanatory variables are associated with the other country/currency. R^2 and D.W. denote the coefficient of determination and Durbin-Watson statistic respectively; figures in parentheses are t-ratios.

included: it enters in each case with an estimated coefficient which is statistically insignificant from zero.

This set of tests, therefore, provides strong initial support for our conjecture that gold price movements should have explanatory power with respect to exchange rate movements, over and above the effects of monetary shocks.

3. Forecasting the exchange rate

We next tested to see whether knowledge of the gold price would enhance our ability to forecast the exchange rate. Rather than conduct this experiment within the very narrow empirical framework of the previous section, however, we chose to use a less restrictive, vector autoregressive (VAR) framework. Accordingly, we estimated sixth-order, unrestricted VARs, which included domestic and foreign money supplies, output, interest rates, and inflation, as well as the exchange rate, and used this to forecast the exchange rate dynamically from one to twelve months ahead. Starting with an initial VAR, estimated using data for 1976(1)-1988(12), we sequentially added one extra data point and forecast the exchange rate dynamically, using a Kalman filter algorithm to update the coefficient estimates as each new data point was added. Finally, we computed the root mean square error (RMSE) of the forecast at each horizon. As a benchmark for this exercise, we considered the resulting RMSEs relative to that produced by a random walk forecast; the resulting measure is known as Theil's U-statistic. If the U-statistic is less than unity, a superior performance to the random walk is indicated; a value greater than unity implies an inferior performance to the random walk forecast.

The results are reported in Tables 2a-2e. Each of these tables reports four variants of this exercise plus two additional cases for the system excluding gold. The different variants distinguish between cases in which the VAR was used to forecast the values of the "exogenous" variables (money, inflation, output, and interest rates) and gold, and cases in which the actual values of these exogenous variables were used to forecast future values. We also distinguish between cases in which forecast rather than actual prices of gold were used in the forecasts.

For horizons of one to three months, the results are mixed, although it is possible that many of the U-statistics for these horizons are insignificantly different from unity. 1/ For forecast horizons beyond three months, however, a VAR system including gold always gives the lowest U-statistic -- for all exchange rates.

1/ Formal tests of significance have only been developed for the case of non-serially correlated, independent standard normal forecast errors (Granger and Newbold (1977)).

Table 2a. Theil's U-Statistic for VAR Exchange Rate Forecasts 1/

		System Including Gold				System Excluding Gold	
		Actual Future Values of Exogenous Variables		Forecast Values of Exogenous Variables		Actual Future Values of Exogenous Variables	Forecast Values of Exogenous Variables
Exchange Rate	Months Ahead	Actual Future Gold Price	Forecast Gold Price	Actual Future Gold Price	Forecast Gold Price		
UK£/US$	1	1.42	1.42	1.42	1.42	1.27*	1.28
	2	1.59	1.58	1.38	1.42	1.23*	1.28
	3	1.67	1.66	1.24	1.30	1.14*	1.23
	4	1.63	1.63	1.03	1.01*	1.08	1.09
	5	1.60	1.62	0.92	0.86*	1.06	1.01
	6	1.61	1.66	0.87	0.80*	1.16	0.96
	7	1.62	1.66	0.85	0.75*	1.27	0.91
	8	1.59	1.59	0.88	0.77*	1.35	0.91
	9	1.67	1.62	0.88	0.74*	1.51	0.89
	10	1.73	1.63	0.93	0.76*	1.59	0.89
	11	1.79	1.64	0.96	0.77*	1.72	0.88
	12	1.82	1.64	0.94	0.73*	1.84	0.83

1/ The VAR systems included domestic and foreign money supplies, output, interest rates, and inflation as well as the exchange rate. Theil's U-Statistic as the ratio of the root mean square error (RMSE) of the VAR forecast to the RMSE of the random walk forecast. An asterisk denotes minimum U-statistic for that forecast horizon.

Table 2b. Theil's U-Statistic for VAR Exchange Rate Forecasts 1/

Exchange Rate	Months Ahead	System Including Gold: Actual Future Values of Exogenous Variables: Actual Future Gold Prices	System Including Gold: Actual Future Values of Exogenous Variables: Forecast Gold Prices	System Including Gold: Forecast Values of Exogenous Variables: Actual Future Gold Prices	System Including Gold: Forecast Values of Exogenous Variables: Forecast Gold Prices	System Excluding Gold: Actual Future Values of Exogenous Variables	System Excluding Gold: Forecast Values of Exogenous Variables
DM/US$	1	1.45	1.45	1.45	1.45	1.35*	1.35*
	2	1.53	1.49	1.56	1.53	1.38*	1.38*
	3	1.60	1.45	1.65	1.59	1.40*	1.41
	4	1.56	1.36*	1.63	1.54	1.39	1.38
	5	1.48	1.25*	1.56	1.49	1.34	1.35
	6	1.37	1.16*	1.49	1.44	1.34	1.42
	7	1.26	1.06*	1.42	1.37	1.39	1.53
	8	1.16	0.95*	1.32	1.28	1.41	1.61
	9	1.01	0.82*	1.22	1.20	1.47	1.71
	10	0.87	0.70*	1.18	1.17	1.49	1.81
	11	0.80	0.72*	1.16	1.18	1.52	1.84
	12	0.70	0.73*	1.15	1.18	1.53	1.86

1/ See note to Table 2a.

Table 2c. Theil's U-Statistic for VAR Exchange Rate Forecasts 1/

		System Including Gold				System Excluding Gold	
		Actual Future Values of Exogenous Variables		Forecast Values of Exogenous Variables		Actual Future Values of Exogenous Variables	Forecast Values of Exogenous Variables
Exchange Rate	Months Ahead	Actual Future Gold Prices	Forecast Gold Prices	Actual Future Gold Prices	Forecast Gold Prices		
¥/US$	1	1.21	1.21	1.21	1.14*	1.15	1.21
	2	1.20	1.19	1.17	0.99*	1.06	1.15
	3	1.11	1.06	1.10	0.92*	0.97	1.05
	4	1.05	1.00	1.08	0.91*	0.93	1.02
	5	1.04	0.98	1.06	0.89*	0.93	1.00
	6	1.11	1.08	1.03	0.91*	1.00	0.98
	7	1.15	1.16	0.98	0.86*	1.02	0.92
	8	1.12	1.17	0.90	0.79*	0.97	0.88
	9	1.07	1.08	0.81	0.70*	0.87	0.78
	10	1.06	0.96	0.73	0.59*	0.74	0.64
	11	1.02	0.87	0.68	0.59*	0.64	0.64
	12	0.97	0.76	0.63	0.59*	0.65	0.63

1/ See note to Table 2a.

Table 2d. Theil's U-Statistic for VAR Exchange Rate Forecasts 1/

		System Including Gold				System Excluding Gold	
		Actual Future Values of Exogenous Variables		Forecast Values of Exogenous Variables		Actual Future Values of Exogenous Variables	Forecast Values of Exogenous Variables
Exchange Rate	Months Ahead	Actual Future Gold Prices	Forecast Gold Prices	Actual Future Gold Prices	Forecast Gold Prices		
FFR/US$	1	1.31	1.32	1.31	1.31	1.27*	1.27*
	2	1.45	1.42	1.32	1.30*	1.39	1.33
	3	1.61	1.43	1.35	1.33*	1.44	1.35
	4	1.57	1.33	1.33	1.26*	1.42	1.29
	5	1.49	1.23	1.31	1.18*	1.40	1.25
	6	1.43	1.20	1.27	1.12*	1.38	1.24
	7	1.37	1.18	1.21	1.01*	1.38	1.15
	8	1.28	1.16	1.12	0.91*	1.33	1.05
	9	1.23	1.16	1.04	0.84*	1.31	0.97
	10	1.18	1.12	0.99	0.81*	1.28	0.92
	11	1.04	1.11	0.81*	0.84	1.25	0.91
	12	0.84	1.11	0.62*	0.88	1.24	0.91

1/ See note to Table 2a.

Table 2e. Theil's U-Statistic for VAR Exchange Rate Forecasts 1/

		System Including Gold				System Excluding Gold	
		Actual Future Values of Exogenous Variables		Forecast Values of Exogenous Variables		Actual Future Values of Exogenous Variables	Forecast Values of Exogenous Variables
Exchange Rate	Months Ahead	Actual Future Gold Prices	Forecast Gold Prices	Actual Future Gold Prices	Forecast Gold Prices		
DM/¥	1	1.20	1.10*	1.20	1.10*	1.20	1.20
	2	1.03	0.96	1.01	0.92*	1.03	1.02
	3	0.95	0.88	0.99	0.82*	0.95	0.95
	4	0.94	0.86*	1.08	0.89	0.96	1.06
	5	0.89	0.83*	1.19	0.96	0.96	1.22
	6	0.90	0.83*	1.25	0.99	0.93	1.29
	7	0.88	0.82*	1.24	0.99	0.94	1.31
	8	0.81	0.77*	1.19	0.96	0.85	1.33
	9	0.82	0.80*	1.15	0.95	0.85	1.41
	10	0.83	0.81*	1.15	0.94	0.86	1.45
	11	0.85	0.81*	1.19	0.94	0.88	1.46
	12	0.88	0.82*	1.28	0.96	0.89	1.47

1/ See note to Table 2a.

Interestingly, however, better results were generally obtained when forecast rather than actual gold prices were used in the forecasts. For exchange rates not involving the mark, better results were also obtained using forecast values of the exogenous variables. For the mark/dollar and yen/dollar exchange rates, best results were obtained using the actual future values of exogenous variables, combined with the forecast values of the gold price.

We next repeated this experiment, replacing the price of gold with the price of wheat. For exchange rates not involving the mark, the lowest RMSEs were obtained using forecast values of the exogenous variables and of the wheat price; for mark exchange rates, best results were obtained when the actual future values of the exogenous variables were used. We then took the smallest RMSE for each exchange rate, and divided it by the corresponding RMSE obtained using the gold price in the VAR. The results are given in Table 3. An entry greater than unity in Table 3 indicates a superior performance of the system involving gold. For horizons of six months or more ahead, the system involving gold uniformly does better than the system involving wheat, although the superior performance of the gold price is not as striking as it is in the results reported in Table 1. Nevertheless, these results confirm the findings of the previous section, that the price of gold has explanatory power for the exchange rate, even when the monetary fundamentals are controlled for. Moreover, these results appear to be peculiar to gold rather than to commodities in general.

4. Cointegration and error correction

The final step in our analysis was to investigate the long-run relationship between exchange rates and gold--controlling for monetary variables--using cointegration techniques. We also used our estimated cointegrating vectors to form short-run, dynamic error-correction equations for the exchange rate, which were then subjected to post-sample forecasting tests.

In our cointegration tests, we employed the maximum likelihood cointegration technique of Johansen (1988). To do this, we estimated a vector autoregression (VAR) for the variables in question 1/ (in each case a sixth-order VAR was adequate in terms of residual diagnostics).

Let $X_t = (s_t, g_t, m_t, m_t^*, y_t, y_t^*, r_t, r_t^*, p_t, p_t^*)$. Then, excluding the constant terms for expositional purposes, the estimated VAR is of the form:

$$X_t = \sum_{i=1}^{6} \pi_i X_{t-i} + \epsilon_t \qquad (6)$$

1/ Applying unit root tests to the individual series, we could in no case reject the hypothesis of first-difference stationarity.

Table 3. Root Mean Square Error of Exchange Rate Forecasts from VAR System Including Wheat Prices Relative to Root Mean Square Error from VAR System Including Gold Prices

	Forecast Values of Exogenous Variables and Gold/Wheat Price			Actual Future Values of Exogenous Variables, Forecast Gold/Wheat Price	
Months Ahead	£/$	¥/$	FFR/$	DM/$	DM/¥
1	0.89	1.06	0.95	0.94	1.00
2	0.79	1.03	0.91	0.86	1.02
3	0.77	0.95	0.88	0.82	1.00
4	0.87	0.96	0.90	0.79	1.03
5	0.99	0.98	0.97	0.78	1.12
6	1.13	1.02	1.08	0.84	1.11
7	1.15	1.12	1.24	1.00	1.09
8	1.09	1.23	1.35	1.21	1.08
9	1.14	1.37	1.43	1.52	1.01
10	1.14	1.68	1.48	1.96	1.04
11	1.19	1.69	1.46	2.01	1.12
12	1.27	1.59	1.43	2.05	1.22

where the π_i are conformable coefficient matrices and ϵ_t is a white noise innovation vector. The long-run static equilibrium corresponding to (6) is 1/:

$$(I-\sum_{i=1}^{6}\pi_i)X_t=0 \tag{7}$$

The coefficient matrix in (7) can be factorized:

$$(I-\sum_{i=1}^{6}\pi_i)=\alpha'\beta \tag{8}$$

where α and β are 6xr matrices, r ≤ 9, such that each of the linear combinations of X_t formed by the rows of β is stationary, or I(0):

$$\beta_i' X_t \sim I(0) \tag{9}$$

for $\beta' = (\beta_1 \ldots \beta_r)$. Thus, if a stable long-run relationship between the elements of X_t exists, at least one of the β_i vectors must be significantly different from the null vector. If this is the case, then the elements of X_t are said to be cointegrated (Engle and Granger, 1987). Johansen (1988) develops a maximum likelihood technique for estimating α and β and testing for the number of distinct cointegrating vectors, r, as well as for testing linear restrictions on the parameters of the cointegrating vectors, β_i.

The results of applying the Johansen procedure to the data are reported in Table 4. Among the ten variables considered, there are at least six significant cointegrating vectors (seven in the case of sterling/dollar, mark/dollar, and yen/dollar). Moreover, the likelihood ratio statistic for the null hypothesis that gold should be excluded from the cointegrating vector is in every case greatly significant. This therefore indicates that *gold is an important long-run determinant of the exchange rate*, even controlling for the effects of real and monetary variables.

We then took the most significant cointegrating vector for each of the exchange rate groups and used this to find an error-correction form equation. According to the Granger Representation Theorem (Engle and

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1/ Dynamic steady-state equilibrium would simply involve an additional term in the constant vector of steady-state growth rates, which we omit here for expositional purposes.

Table 4: Johansen Co-integration Test Results 1/

a) Johansen Statistics

Trace Statistics

Exchange Rate	H_0:r=0	H_0:r≤1	H_0:r≤2	H_0:r≤3	H_0:r≤4	H_0:r≤5	H_0:r≤6	H_0:r≤7	H_0:r≤8	H_0:r≤9
UK£/US$	440.46	338.00	252.69	179.52	126.56	88.79	55.52	31.25*	14.34*	3.56*
DM/US$	338.36	301.56	225.49	164.21	118.40	80.09	56.76	34.64*	16.75*	3.71*
¥/US$	425.25	332.43	257.73	196.57	143.51	92.69	52.14*	22.68*	9.82*	2.15*
FFR/US$	454.98	325.04	250.98	181.96	131.61	90.42	58.12*	28.86*	12.77*	5.28*
DM/¥	415.67	335.64	268.64	206.82	150.26	104.75	65.97	34.23*	12.51*	0.10*

b) Test for Exclusion Restriction of Gold

	Likelihood Ratio Statistic	Degrees of Freedom
UK£/US$	57.75	7
DM/US$	33.79	7
¥/US$	19.19	6
FFR/US$	34.82	6
DM/¥	40.96	7

1/ An asterisk denotes insignificance at the 5% level. In (b) the statistics are distributed as χ^2 under the null hypothesis, with the indicated degrees of freedom.

Granger (1987)), if a set of first-difference stationary series X_t are cointegrated such that

$$e_t = \beta' X_t \sim I(0) \tag{10}$$

then there exists an error correction representation of the form:

$$\Delta X_t \Psi(L) = -\rho e_{t-1} + \nu_t \tag{11}$$

Further model parsimony may be achieved by imposing insignificant restrictions among the variables (Cuthbertson, Hall, and Taylor (1992)).

In Tables 5a-5d, we report our final estimated equations, obtained for each of the dollar exchange rates using this modelling strategy. In each case, the equations were estimated using data up to the end of 1988, with two years of data retained for tests of forecasting ability. In each case, the error correction exchange rate equation performs well in-sample, with well-determined coefficients. Each equation yields a highly-significant, correctly-signed coefficient on the gold price variable, easily passes a battery of diagnostic tests, and appears to display parameter stability over the remaining two years of data, as measured by the Chow and predictive failure (PF) tests (Hendry (1979)).

Note that we make no attempt to rationalize the form of the short-run dynamics of the equations reported in Tables 5a-5d. It is possible that these result from the interaction of different speeds of adjustment of wages, goods prices, and asset prices, and/or from short-term fads in foreign exchange markets (See MacDonald and Taylor (1992)). For our purposes, however, it is only necessary to note the strong significance of the gold price variable in these equations, even after controlling for complex data dynamics.

As a point of comparison, we also conducted dynamic post-sample prediction tests of the kind reported earlier. That is to say, for the twenty-four observations, 1989(1) - 1990(12), we allowed the parameters to be re-estimated at each data point (although the cointegrating parameter vector was held constant) and computed dynamic forecasts for a number of months ahead. The resulting U-statistics from this exercise are reported in Table 6. Except for the yen/dollar rate, these show a marked improvement over those reported for the VAR system in Tables 2a-2e. This effect is particularly marked for the sterling/dollar exchange rate.

IV. Concluding Remarks

The general conclusion which emerges from the various empirical investigations we have conducted is that gold price movements have

Table 5a. Parsimonious Error Correction Forms 1/

UK£/US$

$$\Delta s_t = \underset{(0.038)}{-0.167}\Delta g_t \underset{(0.009)}{-0.03}e_{t-1} \underset{(0.207)}{-0.404}(\Delta m^{us}_{t-1} - \Delta m^{uk}_t) \underset{(0.301)}{-0.592}(\Delta m^{uk}_{t-1} - \Delta p^{uk}_{t-1})$$

$$+ \underset{(0.702)}{1.387}\Delta p^{us}_{t-1} \underset{(0.266)}{+0.875}\Delta^2 y^{us}_t \underset{(0.148)}{-0.249}\Delta y^{uk}_t \underset{(0.002)}{+0.004}\Delta^2 r^{us}_t$$

$$\underset{(0.003)}{+0.007}\Delta^2 r^{uk}_t \underset{(0.003)}{-0.005}\Delta r^{uk}_{t-2} \underset{(0.004)}{-0.004}$$

$R^2 = 0.36$	$\sigma = 2.8\%$
DW = 1.89	CHOW(24,143) = (1.27) (0.20)
$AR_{1-7}(7,136) = 1.16$ (0.33)	PF(24) = 31.68 (0.14)
ARCH (7,129) = (1.14) (0.34)	NORM(2)=2.23 (0.33)
RESET(1,142)=2.22 (0.14)	$HETX^2(21,121)=1.03$ (0.43)

1/ In this table, e denotes the cointegrating vector corresponding to the largest eigenvalue in the Johansen analysis. Figures in parentheses below coefficient estimates are heteroskedastic-consistent standard errors; those below test statistics are marginal significance levels. R^2 is the coefficient of determination, σ is the standard error of the regression; DW is the Durbin-Watson statistic; AR_{1-7} is a Lagrange multiplier test statistic for up to seventh-order serial correlation; ARCH is a test statistic for up to seventh-order ARCH effects in the residuals; RESET is a general test statistic for functional misspecification; $HETX^2$ is a test statistic for heteroskedasticity based on the squares of the regressors; NORM is the Bera-Jorque test statistic for normality of the residuals; Chow and PF are Chow's (1960) and Hendry's (1979) test statistics for predictive failure when the model is used to forecast over the last 24 data points.

Table 5b. Parsimonious Error Correction Forms 1/

DM/US$

$$\Delta s_t = \underset{(0.046)}{-0.101}\Delta^2 s_{t-1} \underset{(0.031)}{-0.196}\Delta g_t \underset{(0.098)}{-0.002} e_{t-1} + \underset{(0.377)}{1.211}\Delta^2 m_t^{us} + \underset{(0.198)}{0.396}\Delta_2 \Delta m_t^{ge}$$

$$+ \underset{(0.324)}{0.801}\Delta y_t^{us} + \underset{(0.884)}{1.657}\Delta^2 p_t^{us} + \underset{(1.029)}{3.425}\Delta p_{t-1}^{ge} + \underset{(0.003)}{0.007}\Delta r_t^{us} + \underset{(0.351)}{0.631}$$

$R^2 = 0.42$	$\sigma = 2.7\%$
DW = 1.92	CHOW(27,144)=1.24 (0.21)
AR_{1-7}(7,137)=.59 (0.76)	PF(24)=30.96 (0.15)
ARCH(7,130)=.47 (0.85)	NORM(2)=.91 (0.63)
RESET(1,143)=.06 (0.81)	$HETX^2$(18,125)=1.20 (0.27)

1/ See footnote to Table 5a.

Table 5c. Parsimonious Error Correction Forms 1/

¥/US$

$$\Delta s_t = \underset{(0.037)}{-0.146}\Delta g_t \underset{(0.0001)}{-0.0002}e_{t-1} \underset{(0.268)}{+.428}\Delta^2\Delta y_t^{us}$$

$$\underset{(0.003)}{+0.0007}\Delta_t^2 r^{us} \underset{(0.545)}{+0.995}\Delta^2 p_t^{ja} \underset{(0.006)}{+0.002}$$

R^2=0.19	σ = 3.2%
DW=1.97	CHOW(24,148)=1.15 (0.29)
AR_{1-7} (7,141)=1.53 (0.16)	PF(24)=28.8 (0.23)
ARCH(7,134)=0.87 (0.53)	$NORM(2)=5.63$ χ^2 (0.06)
RESET(1,147)=3.81 (0.053)	HETX (11,136)=1.34 (0.21)

1/ See footnote to Table 5a.

Table 5d. Parsimonious Error Correction Forms 1/

FFR/US$

$$\Delta s_t = \underset{(0.068)}{0.174}\Delta s_{t-2} \underset{(0.031)}{-0.210}\Delta g_t \, -0.021 e_{t-1} \underset{(0.347)}{+1.360}\Delta^2 m^{us} + \underset{(0.161)}{0.630}\Delta_2 m^{fr}_{t-1}$$

$$\underset{(0.234)}{+0.730}\Delta^2 y^{us}_t \underset{(0.003)}{+0.009}\Delta r^{us}_t \underset{(0.647)}{+1.278}\Delta p^{us}_t \underset{(0.007)}{-0.008}$$

R^2 = 0.40;	σ = 2.6%
DW = 2.10	CHOW(24,145) = 1.41 (0.11)
AR_{1-7} (7,138) = 0.71 (0.66)	PF(24) = 35.28 (0.06)
ARCH(7,131) = 1.10 (0.37)	NORM(2) = 2.432 (0.30)
RESET(1,144) = 0.66 (0.42)	$HETX^2$(17,127) = 1.26, (0.23)

1/ See footnote to Table 5a.

Table 6. Theil's U-Statistics for Error Correction Equations

Months Ahead

Exchange Rate	1	2	3	6	9	12
UK£/USS	0.94	0.68	0.55	0.37	0.29	0.27
DM/US$	1.01	0.87	0.82	0.78	0.73	0.70
FFR/US$	1.07	0.98	0.89	0.84	0.83	0.79
¥/US$	1.05	0.98	0.91	0.99	1.16	1.27

explanatory power with respect to exchange rate movements, over and above the effects of movements in monetary fundamentals and other variables that enter standard exchange rate models. Based on the concept of gold as "an asset without a country" and the argument that changes in country preferences will be systematically reflected in the price of gold, our empirical findings can be interpreted as indirect evidence that exchange rate movements are largely coterminus with events that change preferences for holding claims on different countries. Further work on this issue might concentrate on developing a more complete theoretical framework capable of suggesting more rigorous, testable restrictions on the data.

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