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Exchange Rate Movements and Adjustment in Financial Markets: Quarterly Estimates for Major Currencies

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Summary

The large sustained swings in real exchange rates among the major industrial countries that have characterized the past decade have created substantial uncertainty regarding the sustainable levels of these rates. Consequently, departures of market exchange rates from their longer-run equilibrium levels may not generate large enough speculative shifts in financial portfolios to restore equilibrium. This paper develops a model of portfolio behavior in which it is assumed that market participants act as if they always expected exchange rates to move in line with expected inflation differentials. Other features of the model are that the supply of assets denominated in foreign currencies is endogenous in major industrial countries and that domestic money stocks are determined by the monetary authorities' reaction functions. In the solution of this model, actual portfolio allocations, and thereby actual exchange rate movements, are determined by real interest rate differentials and the cumulated balance of external payments. In the long run, the equilibrium level of the exchange rate is determined by relative price levels and the underlying equilibrium of the balance of payments.

There are two important empirical differences between this model and most other models based on the asset-market approach to exchange rate determination: first, relative money stocks do not play a direct role; and second, in the short run the real interest differential determines the rate of change in the exchange rate, rather than its level. This second point implies that the real interest differential does not need to keep widening in order to generate a continuing flow of funds

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into a currency. The model is tested econometrically, using quarterly data from 1973 to 1983 for the five largest industrial economies: the United States, Japan, the Federal Republic of Germany, the United Kingdom, and France. These tests indicate that the model provides a reasonably good statistical fit for all of these countries' exchange rates, except for the pound sterling. Interest rate differentials are found to have a clearer short-run relationship to exchange rate changes than to exchange rate levels. In post-sample predictions for 1982-83, this model outperforms both random-walk models and a version of the monetary/portfolio-balance model.

I. Introduction

The large swings in exchange rates among the currencies of the major industrial currencies during the past decade have proved so far to be elusive of empirical analysis. Neither the monetary approach nor the portfolio-balance approach has led to robust estimates of models explaining changes in the market values of these currencies. The purpose of this study is to test a model that incorporates the hypothesis that sustained departures of market-determined exchange rates from their longer-term equilibrium levels can occur because risk-averse market participants do not have enough information (or enough confidence in available information) to induce a sufficient amount of stabilizing speculation.

The model set out below is a portfolio-balance model in which private agents allocate net financial wealth to three markets: money, domestic securities, and assets denominated in foreign currencies. Changes in interest rates and exchange rates are determined by the excess demands in these markets. Monetary growth is endogenously determined by the authorities' decisions about the desired rate of growth and by the current values of domestic and foreign interest rates. Uncovered portfolio shifts occur between domestic securities and foreign-currency assets, so that exchange rate expectations are an important determinant of realized asset prices. Market participants are assumed not to know the fundamental equilibrium value of the real exchange rate; instead, they act as if the current level were always the equilibrium rate. Expectations regarding nominal exchange rate movements are determined by relative inflation rates, but they are not affected by departures of real exchange rates from historical norms.

Section II describes the theoretical model corresponding to the assumptions just outlined. The empirical results are set out in Section III, followed by a comparison with an alternative model and some out-of-sample forecasts in Section IV. The conclusions of the exercise are contained in Section V.

II. The Theoretical Model

The structural model can be described by the following eight equations, which are assumed to be linear in terms of ratios and rates of change:

$$m^d = \ell_o - \ell_1 r + \ell_2 y \qquad (1)$$

$$m^s = m_o + m_1\mu + m_2(r-\pi) - m_3(r^f-\pi^f) \qquad (2)$$

$$f^d = f_o - f_1(r - r^f - e) \quad (3)$$

$$f^s = g_o + g_1(r - r^f - e) - g_2 k \quad (4)$$

$$e = \pi - \pi^f \quad (5)$$

$$\Delta k = -\kappa \cdot \ell n(E \cdot P^f / P)_{-1} \quad (6)$$

$$\Delta \ell nE = \lambda_1 (f^d - f^s) + (\pi - \pi^f) \quad (7)$$

and

$$\Delta r = \lambda_2 (m^d - m^s) \quad (8a)$$

or

$$\Delta m = \lambda_3 (m^d - m_{-1}) \quad (8b)$$

where E = domestic price of foreign exchange

e = expected rate of change in E

f = ratio of foreign currency assets to private financial wealth (W)

k = cumulated balance of private capital flows, as ratio to W

m = stock of money, as ratio to W

P, P^f = domestic and foreign deflators for private domestic demand

r, r^f = domestic and foreign nominal interest rates

y = private domestic demand, as ratio to W

μ = target value of money stock, as ratio to W

π, π^f = expected domestic and foreign inflation rates

and the superscripts d and s refer to quantities demanded or supplied. All of the parameters are hypothesized to be positive; for notational convenience, error terms and time subscripts have been suppressed. Domestic demand and the levels of and expected changes in domestic demand deflators are exogenous, as are targeted money stocks.

Equation (1) is a standard money demand function, 1/ with money and income assumed to be linearly homogeneous in net financial wealth. This formulation, which follows that of Tobin (1969), is more convenient from the perspective of the financial-market approach adopted here than is the real-balance form employed in monetary models. Net financial wealth of domestic private nonbank sectors (W) is defined for this purpose as the sum of the outstanding government debt and the cumulated balance on the external current and direct investment accounts. For simplicity, this wealth is assumed to be held only in the form of money balances, government securities, and foreign-currency assets, as defined below. 2/ The external component of wealth is endogenously determined in the model, but wealth is predetermined in the demand and supply functions, both because the cumulated external balance is assumed to depend only on lagged variables and because the stock of wealth is measured at the beginning rather than the end of each period. Money, income, and wealth may be deflated by the level of goods prices, or they may be left in nominal terms, since they enter the model in ratio form. In either case, interest rates are nominal rather than real, reflecting substitution opportunities between money and other financial assets. 3/

Equation (2) assumes that the authorities control the supply of money by reacting to a set of variables in which they have a direct or indirect interest. 4/ First, the desire to keep monetary growth on a stable path is represented by μ, which may be measured by a targeted stock or by observed lagged values. Second, a rise in domestic real interest rates may induce both a rise in the ratio of money to bank reserves (as the banks' incentive to lend is increased) and a rise in the supply of bank reserves (as the authorities accommodate the disturbance that caused the initial increase in interest rates). Third, an increase in foreign real interest rates induces a decline in monetary growth if the authorities attempt to defend the exchange rate. However, as is discussed further below, this formulation is assumed not to apply to the United States.

1/ For convenience, the yield on money balances is ignored. For a more detailed model that incorporates interest rates paid on bank deposits, see Boughton (1983).

2/ The relationship between the sources and uses of financial wealth is described for a detailed set of sectoral balance sheets in Boughton (1983). A simplified version is included in the appendix to this paper.

3/ Substitution between money and goods--which would involve including the expected inflation rate as an argument--is omitted. This omission reflects the simplifying assumption that utility functions are separable between financial and real assets.

4/ This formulation is in contrast to asset-market models such as Frankel (1979) and Hooper and Morton (1982) that treat money stocks as exogenously fixed by the authorities. For examples of other models employing reaction functions, see Branson et al. (1977) and Knight and Mathieson (1983).

The next two equations describe the market for foreign-currency assets, represented by the ratio of such assets to the total financial wealth of the domestic private nonbank sectors. These assets could be a combination of foreign money and securities, but it is assumed that the yield on them can be reasonably approximated by the interest rate on short-term foreign securities. These assets are assumed to be net wealth to the domestic private sector. 1/ The stock of these assets is assumed to be affected by the preferences of the rest of the world as well as those of the domestic sector. It is thus necessary to treat them as endogenously determined in the model and to include a supply function as well as a demand function for them. 2/

In equation (3), the ratio of the demand for foreign-currency assets to wealth is assumed to depend only on the relationship between the expected uncovered yield on assets denominated in foreign currencies and the yield on domestic securities. The absence of foreign interest rates from the money demand function and the absence of income from the demand function for foreign-currency assets omit the possibility of direct substitution between the two markets. These variables can easily be added to the model, but their inclusion turns out to have an insignificant effect on the empirical results shown below.

Equation (4) describes the supply of foreign-currency assets from the rest of the world. This supply depends on domestic and foreign interest rates in the same fashion (with opposite signs) as the demand function. In addition, the ratio of this supply to domestic financial wealth (W) is assumed to depend on the cumulated balance on the private capital account. 3/ For a small country, this balance would be approximately equal to the outstanding stock of foreign-currency assets held by home-country residents, valued at constant exchange rates and interest rates. For a large country, whose external liabilities may be denominated in its own currency, no such equivalence holds. The cumulated balance

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1/ Domestic residents may also issue foreign-currency assets or change the currency composition of existing assets through operations in the forward market, but those transactions would involve "inside" assets and thus would not normally affect relative prices.

2/ The endogeneity of this stock is described further in the appendix.

3/ This variable enters equation (4) as the ratio of the cumulated external capital balance, which may be denoted by K, to domestic financial wealth, W. If K were restricted to be negative, then the supply function could be written in the same form as the demand function, with the supply divided by (-K) as a measure of the home country's claims on the rest of the world. That is, one would have $F^s/(-K) = g'(r-r^f-e)$, where F is the stock of foreign-currency assets. Multiplying both sides of this equation by (-K)/W and dropping the assumption of linear homogeneity--which is necessary to accommodate the possibility of positive values of K--gives the form of equation (4).

nonetheless does represent the net total of assets that are invested by the rest of the world in the home country (if positive) or the net external borrowings of the home country (if negative).

The specification of the market functions for foreign-currency assets reflects a preferred-habitat approach to portfolio allocation based on the assumption that market participants are averse to incurring exchange rate risks. That is, residents of the home country and of the rest of the world hold both domestic- and foreign-currency assets but prefer, in the absence of a yield incentive, to hold assets denominated in their home currency. This approach, which follows that of Dooley and Isard (1982), among others, is clearly more applicable to the major currency countries than is the small-country approach, under which only domestic residents are assumed to hold assets denominated in the domestic currency. A major implication of the preferred-habitat approach is that sterilized exchange-market intervention, by altering the cumulated balance on private capital, may alter the equilibrium exchange rate. 1/ Another implication is that the supply of foreign-currency assets is endogenous to the model, since a change in the stock of claims outstanding against a country's residents might or might not be reflected in a change in the stock of assets denominated in foreign currencies.

The expected rate of change in the nominal exchange rate is expressed in equation (5) as equivalent to the expected inflation differential (plus an implied random term with expected value of zero). As a long-run proposition, this purchasing power parity (PPP) condition is practically without controversy, and it describes the rational-expectations steady state of the present model. 2/ The interesting empirical question is whether it is an adequate representation of the short run.

The rationale for equation (5) may be better seen by contrasting it with the PPP-based regressive expectations functions employed in a number of asset-based exchange rate models. For example, Frankel (1979) has a function of the form:

$$e = (\pi - \pi^f) - \Theta(E - \overline{E}) \qquad (5')$$

where $\overline{E}$ is the long-run equilibrium value to which the market expects E to return. That value is not observable, but in the monetary model it is replaced by the value that satisfies the PPP condition given by the

1/ This effect depends on the intervention being large enough to alter the cumulated private capital balance by a sufficient amount, and on it not producing offsetting effects on expectations.

2/ See, however, Bomhoff and Korteweg (1983) for a model that dispenses with long-run PPP on the grounds that currencies are subject to differing degrees of risk in predictions of their purchasing power.

relative demands for and supplies of money. Equation (5') requires both that market participants have firm views about the equilibrium exchange rate level on which they are prepared to speculate and that goods prices are not sufficiently flexible to maintain equilibrium in the short run. In view of the very lengthy and sizeable swings that have characterized the movement of major exchange rates during the first decade of generalized floating, one may be led to doubt the empirical significance of this relationship. If market participants face substantial uncertainty as to the equilibrium level, they may instead act as if the current level is the best estimate of the equilibrium level. Alternatively, if $\bar{E}$ is different from E but there is substantial uncertainty as to the timing of the pressures that are necessary to restore the exchange rate to that level, then the adjustment parameter θ may be very small or unstable. In either case, markets will treat the real exchange rate as a random walk; hence equation (5) will be preferable to (5') as a description of market participants' expectations in the short run as well as the long run.

Equation (6) determines the private capital balance as a function of the lagged value of the real exchange rate. This simplified function implicitly assumes that the Marshall-Lerner condition is fulfilled and that the full effect takes place with a one-period lag. Since the cumulated capital balance is an argument in the supply function for assets denominated in foreign currencies, this equation serves to introduce the exchange rate indirectly into that market.

The model is closed by the adjustment functions (7) and (8). Equation (7) states that the rate of change in the real exchange rate is proportional to the excess demand for foreign-currency assets. That is, in the steady state the nominal exchange rate will change at the same rate as the inflation differential, consistent with expectations as expressed in equation (5). If a shock, such as an increase in the private capital balance, increases the excess demand for foreign-currency assets, then the real exchange rate will depreciate until the capital account weakens enough to restore equilibrium.

This specification of the adjustment to excess demand, which is consistent with the way markets for domestic financial assets are usually specified, may be characterized as a weak form of market efficiency. That is, the market is efficient in that the net demand for the asset is always equal to the existing stock. It is inefficient in that market participants may not fully adjust the currency composition of existing claims so as to maintain full equilibrium at all times.

This adjustment process yields a reduced form that differs from those of most other asset-market exchange rate models published in recent years. The two adjustment processes that dominate the modern literature on exchange rate determination are valuation effects of exchange rate changes on foreign-currency assets and regressive expectations. The former, which is found in the models of Branson et al. (1977), and Dooley

and Isard (1982), among others, implies that the level of the exchange rate must be such as to equate the demand for foreign-currency assets with the exogenously given stock. Once one allows for the endogeneity of the stock of these assets, this form of the valuation effect drops out. *Unless the current level of the exchange rate appears (directly* or indirectly) as an argument in the demand or the supply function, the market for foreign-currency assets can be equilibrated at any exchange rate, as may be seen by equating equations (3) and (4) in the present model. With the second standard mechanism, regressive expectations, the exchange rate adjusts over time toward its expected steady-state value ($\overline{E}$). With regressive expectations, even if the level of the exchange rate does not appear directly in the demand or supply functions, it determines the expected rate of change and thus appears as an indirect argument.

Both of these alternative approaches imply that the level of the exchange rate is a function of, *inter alia*, the level of the differential between domestic and foreign interest rates. In contrast, replacing the two assumptions--exogeneity of the stock of foreign-currency assets and speculative behavior predicated on an expected steady-state exchange rate--with the dynamic adjustment process described in equation (7) implies instead that in the short run the rate of change of the exchange rate is related to the level of the interest rate differential. 1/ Given the state of expectations, there exists an interest rate differential that will equilibrate the demand for foreign-currency assets with the supply. As long as the differential differs from that level, a gap will remain that will induce changes in the exchange rate. Over time, those changes will affect the stock of foreign-currency assets, closing the gap and restoring equilibrium.

The restoration of equilibrium is also fostered by the adjustment of trade and capital flows to changes in the real value of the exchange rate. The model as set out here takes goods prices as given exogenously, but it does allow for the endogenous response of the private capital balance--and hence the supply of foreign-currency assets--to the exchange rate. If this adjustment process is dynamically stable, then there exists an equilibrium level of the exchange rate that is consistent with the underlying equilibrium of the balance of payments.

The last equation in the model takes one of two forms, depending on the way monetary policy is conducted. The money supply function determines a relationship between the stock of money and the level of interest

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1/ A different approach by which this same result is obtained is to assume that the expected level of the exchange rate is a function of the level of the interest rate differential and that the rate of change in the exchange rate is related to the difference between this expected level and the actual lagged level. See von Furstenberg (1983).

rates, but it does not reveal the nature of the causality. In practice, central banks may compromise between interest rate and monetary growth objectives, controlling one or the other more closely at different times in response to changing conditions. A particularly relevant issue in this context is the extent to which interest rates are determined independently of the exchange rate. If they are largely independent, then it is appropriate to introduce interest rates into exchange rate equations as exogenous variables. However, if the authorities respond endogenously to exchange rate movements or to changes in foreign interest rates in determining their own monetary policies, then that endogeneity should be taken into account in the estimation of exchange rate equations.

There is no fully satisfactory way to model the process of monetary control in major industrial countries, since all central banks follow eclectic policies to some extent. The procedure adopted here is to assume that monetary policy in the United States is formulated primarily on the basis of domestic objectives, while policies in other countries take external conditions into account more explicitly. To be specific, it is assumed that the Federal Reserve authorities determine a level of interest rates that is estimated to be consistent with their monetary objectives, the latter generally being set so as to apply gradual downward pressure on the growth rate of the money stock. Open market operations are then conducted so as to achieve the desired interest rate level, and actual monetary growth is determined by the relationship between the demand for money at that interest rate and the initial money stock.

In terms of model specification, these assumptions imply, for the United States, that equation (2) is eliminated on the grounds that interest rates are largely exogenous with respect to current data, and that the dynamic adjustment of the money stock is represented by equation (8b). For all other countries, interest rates are assumed to be determined endogenously via equation (8a). This formulation implies that U.S. monetary policy plays a major role in determining the world level of real interest rates, while the authorities in other countries retain some autonomous control by permitting their own real interest rates to differ from world levels in order to pursue domestic objectives.

III. Estimation

The structural model set out above cannot be estimated directly, because the stock of foreign-currency assets is not observable. However, a semi-reduced form may be derived in order to solve for exchange rates. Solution of equations (3) through (7) is straightforward, yielding the following exchange rate equation to be estimated. 1/

1/ The relationship between the parameters of equation (9) and the structural parameters is as follows:

$$\alpha_0 = \lambda_1(f_0 - g_0), \quad \alpha_1 = \lambda_1(f_1 + g_1), \; \alpha_2 = \lambda_1 g_2, \text{ and } \alpha_3 = \alpha_2 \kappa.$$

With goods prices exogenous, stability of this function requires $0 < \alpha_3 < 1$.

$$\Delta \ln E_t = \alpha_o - \alpha_1(r-r^f)_t + (1+\alpha_1)(\pi-\pi^f)_t + \alpha_2 k_{t-1} - \alpha_3 \ln(E \cdot P^f/P)_{t-1} \quad (9)$$

In this equation, expected inflation is treated as exogenous with respect to current changes in the exchange rate. 1/ Interest rates, however, with the exception of U.S. rates (which are treated as exogenous), are endogenously determined by the solution of the money market equation (8a). 2/

$$\Delta r_t = \beta_0 + \beta_1 \pi_t + \beta_2(r^f-\pi^f)_t + \beta_3 y_t - \beta_4 \mu_t + \beta_5 r_{t-1} \quad (10)$$

Equation (9), which is a semi-reduced form containing one endogenous variable $(r-r^f)$, and equation (10), which is a reduced form for the interest rates r and r^f to be used as instruments in the estimation of equation (9), are to be estimated using quarterly data from 1973 Q2 to 1983 Q3. 3/ The beginning date is dictated by the advent of generalized floating; the ending date is determined by the availability of data. This model is applicable primarily to the large industrial countries, because only their currencies are held internationally to any significant extent. Furthermore, in light of the predominance of the large countries in international finance, changes in interest rates or other variables outside this group are not likely to exert a significant impact on portfolio allocation within the group. It is proposed, therefore, to treat the five largest industrial countries--the United States, Japan, the Federal Republic of Germany, the United Kingdom, and France--as if they formed a closed financial system.

The construction of a two-country model for each currency implies that investors perceive foreign-currency assets as a single composite good serving as a substitute for assets denominated in the domestic currency. That assumption is consistent either with a world in which one currency dominates all others for this purpose, or with one in which

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1/ Expected inflation is measured in this study as a moving average of the rate of change in the deflator for private domestic demand. In practice there is likely to be some feedback from the exchange rate to expected inflation. The estimate of α_1 is thus expected to be biased, to an unknown extent; nonetheless, for major industrial countries the extent of this bias should be relatively small.

2/ These parameters are derived as follows:

$$\beta_0 = \gamma(\ell_0 - m_0),\ \beta_1 = \gamma m_2,\ \beta_2 = \gamma m_3,\ \beta_3 = \gamma \ell_2,$$
$$\beta_4 = \gamma m_1, \text{ and } \beta_5 = \gamma/\lambda_2, \text{ where } \gamma = \lambda_2/[1+\lambda_2(\ell_1+m_2)].$$

3/ Data on money, income, prices, and financial wealth are seasonally adjusted.

investors in effect form a portfolio composite of assets denominated in several currencies, that composite then serving as a substitute for domestic-currency assets. In the latter case, an ideal weighting scheme would require data on the currency exposure of investors in each country, which are not available. Trade weights--such as those derived from the IMF's Multilateral Exchange Rate Model (MERM)--are not appropriate for this purpose, since there is no reason to expect portfolio composition to reflect trading patterns alone. Conceptually, at least, SDR weights--which are intended to reflect the importance of major currencies in world finance as well as trade--are more appropriate, especially as the SDR is restricted to the five most widely traded currencies.

There is evidence that foreign-currency portfolios outside the United States are predominantly denominated in U.S. dollars. For example, at the end of 1982, approximately 80 percent of the foreign-currency assets and liabilities of banks located outside the United States and reporting to the BIS were dollar-denominated. 1/ It seems clear that all of the standard weighting schemes for computing effective exchange rates would greatly understate the importance of the U.S. dollar in international financial portfolios. 2/ In the absence of a good alternative, therefore, it is proposed to treat the bilateral rates for each currency against the U.S. dollar as equivalent to the effective "portfolio-weighted" rate for that currency. For the U.S. dollar, the effective exchange rate is measured as an SDR-weighted average of its exchange rates against the other four major currencies. 3/

The SDR-weighted effective rate for the U.S. dollar is fully determined by the bilateral rates for the other four currencies, so the unrestricted system estimated below is overdetermined. 4/ It is not

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1/ Bank for International Settlements (1983), p. 112.

2/ For example, in the MERM the U.S. dollar has a weight of 50 percent in the computation of the effective exchange rate for the Japanese yen and less than 25 percent for the other three major currencies. The weight for the dollar in computing the value of the SDR was set in 1981 at 42 percent.

3/ An SDR-weighted effective exchange rate is not the same as the SDR value of a currency. The latter is a variable-weight value based on a fixed basket of currencies. The index developed here is a fixed-weight value based on the SDR weights established at the time that the SDR was reconstituted as a five-currency basket in 1981.

4/ If the equations for the four bilateral rates are combined to solve for the effective rate for the U.S. dollar, one obtains an equation similar to equation (9) except that the U.S. private capital balance is replaced by a weighted average of the capital balances for the other four countries, and the weights on the foreign interest rates depend on the parameters of the bilateral equations as well as the exchange rate weights.

clear a priori whether more efficient estimates would be obtained by excluding the effective rate or one of the bilateral rates, so all five equations are included in the tables.

The major measurement problems that arise in estimating the money market equations are the selection of monetary aggregates and the development of proxies for inflationary expectations and targeted money stocks. This last variable is more complex than it might appear, given that monetary targets are routinely announced by all of the central banks concerned. The problems are that targets were not announced during the first part of the sample period, in some cases the targeted aggregates have changed definition during the sample period, and the authorities have not always aimed at the midpoint of the announced ranges. For this study, it has been assumed for simplicity that the implicit target for the growth rate of the money stock in each quarter has been proportional to the actual growth rate lagged one period; that is, the targeted growth rate is assumed to change each period so as to maintain, ceteris paribus, a steady downward pressure on monetary growth. More sophisticated proxies could, of course, be derived, but it seems unlikely that they would be accurate enough to produce improved results. Broadly defined money stocks have been used for all five countries, partly because they served as target variables in each country for at least part of the sample period and partly because they tend to have demand functions that are more stable than those for narrower aggregates and thereby should produce better estimates of equilibrium interest rates. Inflationary expectations are measured as a centered three-quarter moving average of the deflator for private domestic demand.

The semi-reduced form of the model has been estimated in stages, as follows. First, the interest rate equations have been estimated for each country except the United States using Hatanaka's (1976) residual-adjusted Aitken estimator. This procedure provides consistent parameter estimates in the presence of serial correlation and lagged dependent variables. 1/ Foreign interest rates, domestic money stocks, and expected inflation are assumed to be exogenous. Second, the predicted values of interest rates from those equations have been used as instruments for r and r^f in the exchange rate equations, with actual U.S. interest rates representing

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1/ The Hatanaka estimator uses two-stage least squares, with the lagged dependent variable treated as endogenous because of the presence of serially correlated residuals, to obtain an initial estimate of the autocorrelation coefficient. An ordinary least squares regression is then run on quasidifferences of the data, plus the residuals from the first regression. The coefficient on the residuals is added to the initial estimate to give the final estimate of the autocorrelation coefficient.

r^f in the equations for the bilateral rates. The exchange rate equations have been estimated subject to the restriction on the interest rate and inflation coefficients specified in equation (9).

The estimated reduced-form money market equations are shown in Table 1. The statistical properties are generally satisfactory, with no evidence of significant serial correlation remaining after the transformation of the data. All of these equations provide a fairly close overall fit, although the source of the explanatory power varies from one to another. Broadly speaking, income and money stocks have a less uniformly significant influence on interest rates than the other included variables. These results may suggest that interest rates in these four countries are influenced somewhat more by the authorities' policy decisions (i.e., by their reaction functions) and by autoregressive movements (represented by the lagged interest rates) than by changes in the demand for money.

Table 2 displays the results for the exchange rate equations. Again the statistical results are rather good for most currencies, the exception being the equation for the pound sterling. 1/ There is no evidence of significant serial correlation in these equations, and no correction has been made for it. Interest rate differentials are an important determinant in all cases except that of the pound. For the bilateral rates, a one-point shift in the real interest rate differential in favor of the home currency is associated with about a 1 percent appreciation. 2/ The equation for the effective rate for the dollar has a significantly higher coefficient on the interest differential than the weighted average of the coefficients in the bilateral rate equations, but the difference may have more to do with the difficulties of estimating an equation for the pound than with an inconsistency in the specification of the functions. The other two variables--the cumulated private capital balance and the lagged real exchange rate--are in the appropriate range and for the most part are significantly different from zero. This evidence suggests--albeit in a very preliminary way--that sterilized intervention may play a role in affecting major exchange rates.

1/ The problems with the equation for the pound sterling most likely reflect the instability of demands for financial assets in the United Kingdom, as has long been evident in studies of the demand for money. For a discussion of that issue, see Boughton (1981).

2/ Recall that the predicted values of interest rates from the equations shown in Table 1 have been used as instruments in these equations, so that these coefficients should be relatively free of reverse causation bias.

Table 1. Interest Rate Equations

Country	Coefficients (with t-ratios)						Equation Statistics		
	$r^f-\pi^f$	π	y	μ	r_{-1}	ρ	$\bar{R}^2$ (levels)	$\bar{R}^2$ (changes)	D.W. (h)
United Kingdom	0.266 (2.08)	0.185 (1.90)	6.546 (0.78)	−4.569 (1.05)	0.463 (3.18)	0.658	.74	.27	1.97 (0.19)
Japan	0.016 (0.26)	0.232 (6.13)	12.999 (1.98)	−4.298 (2.19)	0.786 (9.54)	0.235	.92	.54	2.18 (0.76)
France	0.249 (2.87)	0.292 (2.29)	5.844 (1.23)	−2.171 (1.01)	0.556 (4.15)	0.218	.87	.49	1.89 (0.60)
Fed. Rep. of Germany	0.244 (3.59)	0.366 (1.92)	2.089 (0.69)	−1.631 (0.75)	0.600 (4.25)	0.573	.95	.56	2.03 (0.43)

Table 2. Exchange Rate Equations

Currency	Coefficients (with t-ratios) 1/ $r-r^f$	k_{-1}	$(E \cdot P^f/P)_{-1}$	Equation Statistics $\bar{R}^2$ (levels)	$\bar{R}^2$ (changes)	F (changes)	D.W. (h)
U.S. dollar	-1.629 (4.76)	0.653 (1.37)	0.941 (17.34)	.89	.35	8.29**	2.31 (1.18)
Pound sterling	-0.294 (1.50)	-0.237 (2.61)	0.967 (17.74)	.90	.19	4.18**	1.68 (1.01)
Japanese yen	-0.952 (3.70)	0.701 (2.83)	0.745 (9.93)	.88	.24	5.21**	1.69 (1.06)
French franc	-1.011 (3.33)	0.177 (1.85)	0.910 (10.16)	.94	.28	6.07**	2.14 (0.63)
Deutsche mark	-1.055 (2.89)	0.197 (2.59)	0.775 (9.61)	.85	.22	4.74**	2.13 (0.58)

1/ The coefficients on $\pi-\pi^f$ are not shown, as they are constrained in estimation to be equal to one plus the coefficients on $r-r^f$ [see equation (9)].

** Significant at the .01 level.

It may be argued that the appropriate criterion for judging the within-sample properties of exchange rate equations is not so much whether they are able to explain some arbitrarily high portion of the total variance, but whether they are able to explain a significant portion of the variance of the changes. 1/ Therefore, for each equation in the tables in this paper, two adjusted R^2s are shown: one for levels, computed as $1 - \varepsilon^2/\sigma^2(E)$, where ε^2 is the residual variance and $\sigma^2(E)$ is the total variance of the dependent variable; and one for first differences, computed as $1 - \varepsilon^2/\sigma^2(\Delta E)$. The F statistics test the significance of this second R^2. The second will always be smaller than the first, but for exchange rates the ratios are somewhat smaller than for other variables. 2/

Focusing on the R^2 in terms of first differences, and the F statistic associated with it, may help to explain the difficulties that have become apparent as exchange rate equations have been used for predictive purposes. As is evident from the recent literature in this field, a variety of models can be employed to provide an apparently good fit to the historical data on exchange rate levels, but the predictive power of those models has proved to be quite weak. The reasons for this out-of-sample failure are not entirely clear, since a number of explanations may be offered. 3/ Inspection of the statistics in terms of first differences in exchange rate equations suggests that at least part of the problem may be simply that the explanatory power of the models is smaller within the sample than the published results have appeared to indicate. The seriousness of this problem for at least one type of model is shown in the next section.

IV. Tests of the Model

The model described in this paper provides a statistically significant explanation for quarterly movements in the exchange rates of four of the five major currencies. This section provides two additional tests of the usefulness of the model. First, the estimates are compared with an alternative model that has previously been subjected to extensive tests. Second, the model is re-estimated for a shorter period and then used to generate post-sample predictions that are then compared both with

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1/ Mussa (1979) has asserted that a model should be judged "successful" if it explains "10 percent of the actual quarter-to-quarter changes in exchange rates" (p. 50). The criterion applied here, using a .05 significance level, is roughly equivalent to Mussa's for the present sample.

2/ Compare Table 2 with the interest rate equations in Table 1. In both cases the average R^2 for levels is about 0.88. However, the average for first differences of interest rates is 0.47, while for exchange rates it is 0.26. The F statistics are omitted from Table 1; all of the equations in that table are significant at the .01 level.

3/ See Meese and Rogoff (1983).

the alternative model and with two random-walk series. As an alternative model for this exercise, the Hooper-Morton (H-M) model (1982) is quite useful. It is a portfolio-balance model that uses the same data as the present model, although in a different functional form and with additional data as well; it contains the monetary models (but not the present model) as special cases; and it has been examined both by Hooper and Morton (for its within-sample properties using trade-weighted effective exchange rate data for the U.S. dollar from 1973 through 1978) and by Meese and Rogoff (for its post-sample properties through 1981).

The essence of the H-M model (and of the monetary models) is that the equilibrium exchange rate is determined by the relative money stocks in the home country and the rest of the world. Ceteris paribus, the exchange rate should move proportionally to the ratio of these money stocks in order to maintain purchasing power parity. In addition, the exchange rate depends on the variables that determine the relative demands for money (inflation and interest differentials, and relative income flows) and--in the general H-M model but not the monetary models that it contains as special cases--on the relative supplies of bonds, represented by the outstanding balance on the private capital account.

In the notation of this paper, the H-M reduced form may be written as follows:

$$\ell n E_t = a_0 - a_1(r-r^f)_t + a_2(\pi-\pi^f)_t + a_3 M^*_t - a_4 Y^*_t + a_5 k_t \qquad (11)$$

where M^* is the logarithm of the ratio of domestic to foreign money stocks and Y^* is the logarithm of the ratio of domestic to foreign real income. 1/ The primary differences between equation (11) and equation (9) are that equation (11) determines the level of the exchange rate rather than its rate of change, it treats the cumulated capital balance as exogenous, and it includes M^* and Y^* as additional arguments.

The results for the H-M model are shown in Table 3. In contrast to the equations for Table 2, which were free of serial correlation and were therefore estimated by ordinary least squares, these equations were estimated with a Cochrane-Orcutt transformation. For both models, the predicted interest rates from Table 1 served as instrumental variables. The overall closeness of fit for this model appears to be almost as good as for the first model when measured against the variance of the level of

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1/ This version of the model is simplified somewhat from the functions estimated in Hooper and Morton (1982); for example, their version included the current account as well as the capital account, with both deflated by trend GNP rather than by wealth. Also, income here is measured by private domestic demand, rather than GNP.

Table 3. Estimates of Alternative Exchange Rate Equations (H-M Model)

Currency	Coefficients (with t-ratios)						Equation Statistics			
	$r-r^f$	$\pi-\pi^f$	M*	y*	k	ρ	$\bar{R}^2$ (levels)	$\bar{R}^2$ (changes)	F (changes)	D.W.
U.S. dollar	-0.738	2.268	-0.276	-0.631	-1.809	0.917	.88	.29	4.15**	1.63
	(1.64)	(2.58)	(0.45)	(1.22)	(2.83)					
Pound sterling	-0.677	0.075	-0.573	-0.196	-0.594	0.942	.89	.09	1.76	1.17
	(1.99)	(0.20)	(1.19)	(1.07)	(1.47)					
Japanese yen	-0.823	1.796	-1.756	0.197	0.704	0.702	.84	-.01	0.94	1.80
	(1.60)	(2.84)	(1.82)	(0.34)	(1.57)					
French franc	-0.857	1.431	0.141	0.137	0.248	0.987	.91	-.05	0.63	1.84
	(1.31)	(1.51)	(0.16)	(0.15)	(1.13)					
Deutsche mark	-1.590	3.253	-0.239	-0.290	-0.152	0.907	.83	.13	2.19	2.01
	(2.36)	(2.65)	(0.46)	(0.37)	(0.60)					

** Significant at the .01 level.

the exchange rate (on average, the adjusted R^2 is about 3 points lower); however, it is markedly lower when measured against the variance of the first differences. For four of the five currencies, these equations fail to explain any significant portion of the variance of the first differences.

What is most striking about the equations in Table 3 is that they provide no support at all for the monetary models: all of the relative money stocks have perverse signs and are statistically insignificant. 1/ The interest rate differentials have the expected signs, but the significance levels are relatively low. These results thus reinforce the view expressed above that interest rate differentials have a more stable relationship to exchange rate changes than to exchange rate levels.

The next step in testing the model developed in this paper is to evaluate its ability to forecast exchange rates beyond the end of the sample period. The scope for this test is limited by the paucity of quarterly observations of floating exchange rates, so it is necessary first to re-estimate the model for a somewhat shorter sample. The procedure adopted here is to estimate the interest rate equations and the exchange rate equations for a sub-sample ending in the fourth quarter of 1981 and then forecast the exchange rates through the third quarter of 1983. These forecasts are generated dynamically, using predicted values of exchange rates in place of actual lagged values. Actual values are used for the other data.

The root mean squared errors (RMSEs) for these seven-quarter forecasts are shown in Table 4, along with three other sets for comparison. The second column shows the RMSEs for forecasts from the Hooper-Morton model, with the equations re-estimated in the same way as the first model. These estimates also are dynamic in the sense that predicted values are used in computing the autocorrelation correction during the forecast period. The other two columns relate to random-walk forecasts. In the first of these, the real exchange rate is assumed to follow a random walk; the nominal exchange rate is thus forecast to appreciate or depreciate at a constant rate determined by the inflation differential expected at the beginning of the forecast period. These are the forecasts that would be generated by the expectations mechanism described above, in equation (5). The final set of forecasts is based on the "naive" assumption that the nominal exchange rate will follow a random walk.

The difficulty of forecasting exchange rates during 1982 and 1983 is illustrated by the fact that the nominal-rate random walk actually outperforms the real-rate random walk for two of the five currencies:

1/ The failure of relative money stocks to explain exchange rates has been observed in a number of recent papers; see Frankel (1983).

Table 4. Root Mean Squared Errors From Dynamic Forecasts, First Quarter 1982 to Third Quarter 1983

Currency	New Model (Eq. (9))	H-M Model (Eq. (11))	Random Walk (Real)	Random Walk (Nominal)
U.S. dollar	8.4	12.6	8.9	13.0
Pound sterling	12.3	22.1	10.5	21.1
Japanese yen	8.5	7.8	20.8	11.2
French franc	12.0	21.1	14.2	30.2
Deutsche mark	8.2	10.1	13.2	10.8

the Japanese yen and the deutsche mark. For the other three currencies, the real-rate random walk outperforms both the nominal form and the Hooper-Morton model. On the other hand, the Hooper-Morton model does not fare so badly in this test as it did in the tests performed by Meese and Rogoff; its average errors are lower than those for either of the random walks for both the yen and the mark.

The model developed in this paper outperforms both versions of the random walk for four of the five currencies examined. The exception again is the pound sterling, for which--as noted above--the within-sample properties were also unsatisfactory. It also outperforms the Hooper-Morton model for four of the five currencies, the exception here being the Japanese yen. These comparisons might, of course, turn out differently over other time periods. Nonetheless, the results in Table 4 are consistent with the conclusions drawn from the within-sample properties of the two models described above.

V. Conclusions

This paper has highlighted a number of aspects of exchange rate determination that are relevant primarily to the major industrial countries. First, the major swings that have taken place in real exchange

rates among these countries have contributed to uncertainty about the equilibrium levels of exchange rates. Consequently, the effect of purchasing power parity considerations on the level of current exchange rates via expectations has tended to be quite weak. Although relative inflation rates certainly have played an important role in determining actual exchange rate changes, disparities among relative price levels have been corrected slowly, if at all. Therefore, even if money demand functions are stable and have normal homogeneity properties, relative money stocks and relative income flows may well have no discernible sway over the exchange rate, except insofar as they alter expected inflation differentials. This paper has confirmed the empirical failings of the monetary approach that had become increasingly evident in the recent literature and has suggested a rationale for the problem and an alternative approach. This approach retains the assumptions of stable money demands and of exchange rate expectations based on relative inflation rates, dropping only the assumption that expectations are also based on the gap between the current exchange rate and its PPP level.

Second, nonresidents of the major industrial countries may hold significant amounts of the domestic currency of these countries. The cumulated balance on the private capital account therefore is not equal to the supply of foreign exchange, although it is an important determinant of it. The supply of foreign-currency assets faced by residents of a major industrial country therefore should be treated as endogenous. This formulation implies that exchange rate changes may be determined by the excess demand in the foreign exchange market. Consequently, the rate of change in the exchange rate, rather than its level as in a number of other models, is determined in the short run by, inter alia, the level of the interest rate differential. The level of the real exchange rate is ultimately determined in this model by the balance of payments via the cumulated net stock of external claims.

Third, monetary policy in these countries is not adequately represented by an assumption that monetary growth is exogenous. Monetary policy is formulated by a process in which various objectives are reconciled, including both control of monetary growth and keeping interest rates in line with domestic and external goals. The specific approach taken in this paper is to treat U.S. monetary policy as playing the key role in determining the average level of world interest rates, as the U.S. authorities conduct policy more nearly independently of external conditions than do those of other countries. Under this approach, the rate of monetary growth is endogenous (though constrained by targets) in all countries, and interest rates are endogenous in all countries except the United States.

A model based on these assumptions appears to provide a good statistical explanation for exchange rate changes for four of the five currencies examined. Interest rate differentials, inflation differentials, and cumulated external balances all play a role in generating exchange rate

changes. The significance of the coefficients on the cumulated balance on the private capital account indicates for some currencies that sterilized intervention might have stronger effects on exchange rates than other studies have suggested; this effect, however, is only a necessary, not a sufficient, condition for sterilized intervention to be effective. 1/ An alternative model, incorporating elements of the sticky-price monetary model and the portfolio balance approach, has weaker statistical properties. A comparison of the two models makes clear that the role of monetary policy in affecting exchange rates is only indirect. It does not operate directly by imposing a long-run equilibrium (PPP) value toward which the exchange rate must return, but rather by altering interest rates and inflation rates, on which exchange rates have a close and reliable dependence.

1/ See footnote 1 on page 7.

The definition and measurement of wealth in this paper may be illustrated by the following set of highly simplified balance-sheet identities:

$$W = M + S^p + F \tag{A1}$$

$$M = S^c + Z \tag{A2}$$

$$S = S^c + S^f + S^p \tag{A3}$$

$$-K = F + Z - S^f \tag{A4}$$

First, private-sector wealth (W) is defined as the sum of three assets: money (M), private holdings of government debt (S^p), and assets denominated in foreign currencies (F). Second, ignoring intermediation by the banking system, the stock of money equals the stock of bank reserves, which in turn is equal to the sum of the central bank's holdings of government debt (S^c) and its net claims on the rest of the world (Z). 1/ Third, the total stock of government debt (S) is held by nonresidents (S^f) as well as by domestic residents and the central bank. Finally, from the balance of payments constraint, the net stock of external claims--the right-hand side of equation (A4)--must be equal to the cumulated balance on the current and direct investment accounts (-K). For convenience, it is assumed that all external claims are denominated in the currency of the issuer, except that Z is denominated in the home currency regardless of the issuer; that is, all assets in the model except F are denominated in the home currency.

Consolidating equations (A1) through (A4) yields the result

$$W = S - K \tag{A5}$$

That is, rather than aggregating the uses of wealth, as in equation (A1), one can equally well aggregate the sources, with a substantial gain in data availability. In practice, of course, the aggregate balance sheets are more complex than those described here; a much more detailed model is set out in Boughton (1983). From that larger model, it may be shown that the appropriate domestic source of private financial wealth is not just S, but the stock of central government debt held outside the central bank, plus the nonborrowed domestic components of the monetary base, minus government deposits in commercial banks. That is the measure employed in this paper.

1/ In the full model, money is defined as currency plus most bank deposits; excluded bank liabilities and--as an offsetting item--bank loans to the private sector are ignored throughout this paper.

Comparing equations (A1) and (A5) demonstrates the critical distinction between the cumulated external balance (K) and the net stock of foreign-currency assets (F). When the rest of the world accumulates claims on the home country through an increase in K, there is no automatic effect on the outstanding stock of foreign-currency assets. Whether asset holders choose to retire a portion of those assets (reducing F) or increase their holdings of home-country debt (increasing S^f and reducing S^p) is an endogenous decision depending on expected relative returns.

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