IMF WORKING PAPER

WP/87/63

INTERNATIONAL MONETARY FUND

Research Department

Exchange Rates and the Term Structure of Interest Rates *

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September 24, 1987

Abstract

This paper argues that our understanding of the determination of major-currency exchange rates can be enhanced by reference to information about the term structure of interest rates. Although the standard monetary models have not helped to explain movements in these exchange rates, some portfolio-balance models have shown more promise. The paper extends one such model by incorporating term-structure information, in order to determine whether exchange rate movements have been linked more closely to short- or long-term interest rates and to see whether the performance of the model can be improved by the inclusion of this more detailed information. Empirical estimates of the model suggest that both short and long differentials do matter and that the model accounts for a substantial portion of the broad swings in key exchange rates.

* I am grateful to Joshua Aizenman, Michael Dooley, Paul Masson, and Assaf Razin for comments on earlier drafts. The views and any errors in the paper are my own.

I. Introduction

Empirical tests of exchange-rate models in recent years have established that the exchange rates of major currencies follow a pattern that approximates a random walk but that may contain a small portion amenable to explanation in terms of financial-market theories. Although the standard monetary models have not worked, a number of other formulations have shown more promise. The purpose of this paper is to extend one such model by incorporating information about the term structure of interest rates, in order to determine whether exchange rate movements have been linked more closely to short- or long-term interest rates and to see whether the performance of the model can be improved by the inclusion of this more detailed information.

The issue of whether it is principally short- or long-term rates that matter for exchange-rate determination is important, because differentials among interest rates in the large industrial countries have behaved quite differently across the maturity spectrum. Chart 1 shows differentials between U.S. interest rates and a weighted average of rates in the next four largest countries, along with an index of the effective exchange rate between the United States and those countries. The first, rather obvious, point that is illustrated by this figure is that there is no simple causal relationship between exchange rates and interest rate differentials, whether short- or long-run. Whatever relationships exist can be uncovered only by allowing for the joint endogeneity of these variables. But it is also clear that the surface impression of the interactions must depend on the maturity. 1/

Broadly speaking, the U.S. dollar appreciated slightly from 1973 to 1976, then depreciated through 1980, appreciated through 1984, and then turned down once again. Meanwhile, nominal short-term interest differentials generally moved favorably for dollar-denominated assets through 1981 before trending downward, while the favorable trend on long-term differentials persisted through 1984. Chart 2, which shows the same data in real rather than nominal terms, also shows marked differences in patterns between short and long differentials. Note especially that there was no discernible trend in short-term real differentials from 1979 to 1984, while long-term differentials moved sharply in favor of dollar-denominated assets.

1/ The interest rate data used in this paper are yields to maturity in domestic markets; real interest rates are calculated with reference to inflation in domestic goods-price indexes. The conditions for constant yield-curve differences with these data are presumably stronger than would be the case for Euro-currency markets or for holding-period yields. The analysis could usefully be extended in that direction, but empirical estimation would be problematic for long-term assets.

These differences are difficult to interpret. The fact that long-term differentials appear to be more closely related to exchange rate swings, at least during the early 1980s, lends itself to a number of interpretations. It could imply that long-term real differentials are what principally mattered in contributing to the dollar's strength in that period; or that the negative effect on U.S. economic activity from the currency appreciation had a relatively stronger negative pull on short-term U.S. interest rates than on long-term rates; or that relatively greater arbitrage (i.e., smaller risk premia) in short-term markets tended to pull those differentials toward zero; and so forth. All that can be inferred from the charts is that the choice of maturity is not trivial.

The question of whether short- or long-term interest rates should be more important in explaining exchange rate movements is theoretically ambiguous except under fairly strict assumptions. At one extreme, assume that all interest-bearing assets are perfect substitutes and that purchasing power parity (PPP) holds continuously. 1/ In this case, nominal interest rate differentials between countries will purely reflect differentials in expected inflation rates, or--equivalently--expected movements in the nominal exchange rate. In the absence of anticipated shifts in the inflation rate, nominal interest differentials should be identical at all maturities, and one could equally well choose any one. It is easily established that these conditions have not held in practice, even to a weak approximation. The observation that nominal differentials have varied widely across the maturity spectrum implies that market participants have a complex expectation about the time path of the future inflation rate, that assets at different maturities have differing degrees of substitutability, that PPP does not hold in the short run, or some combination of the above.

One popular way of relaxing this strict combination of assumptions is to assume that the real exchange rate may depart from its PPP level for a substantial period of time but that it is always expected to return home at a fixed speed. 2/ With this assumption plus the others listed above, the real exchange rate will appreciate in response to a positive real interest differential. In this case, the choice of maturity is still immaterial, because the real interest differential is expected to decline geometrically as the maturity lengthens. To illustrate, let

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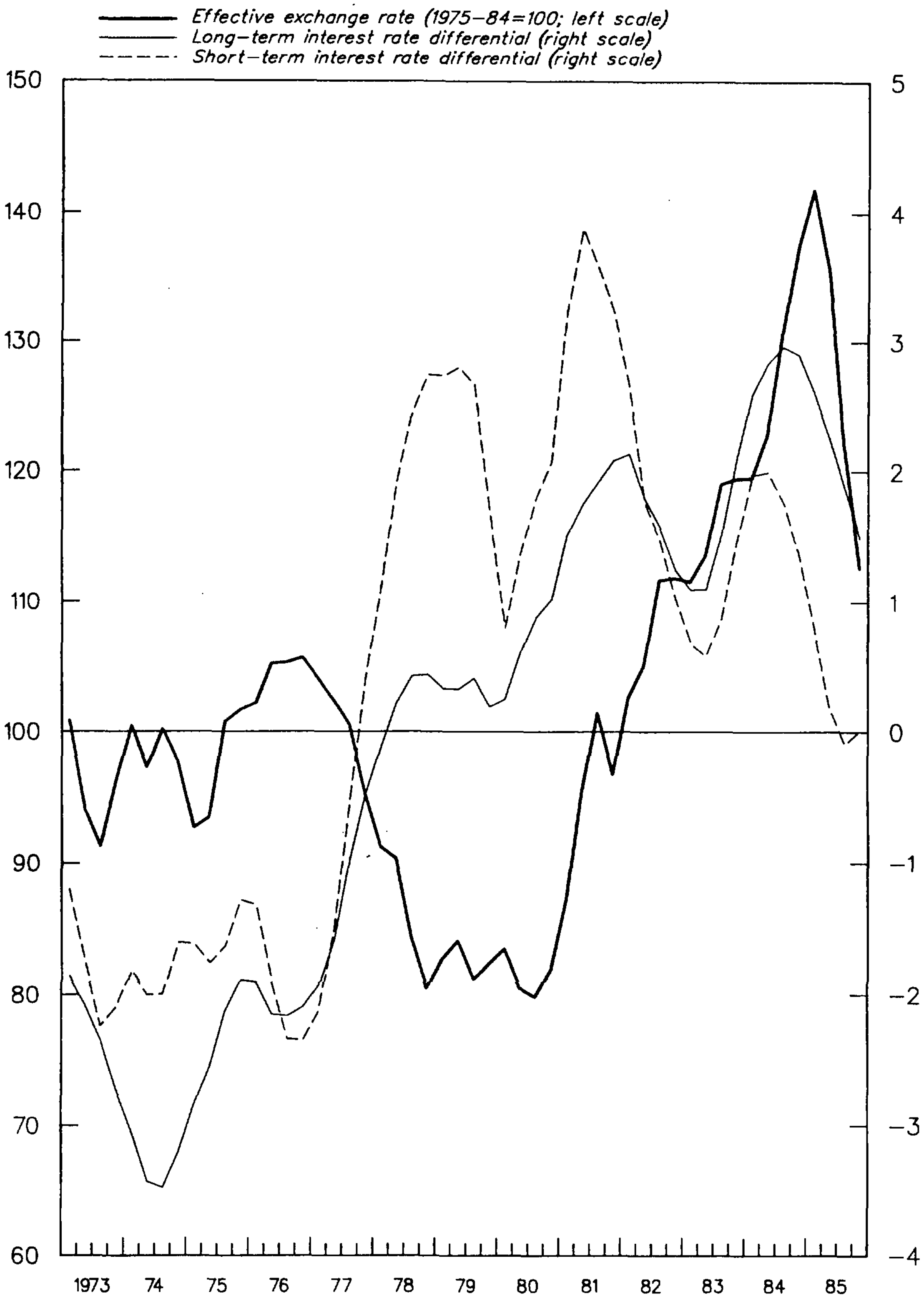
1/ These assumptions underlie the models developed by Frenkel (1976), Mussa (1976), Bilson (1978), and others. It should be noted that the hypothesis of perfect substitutability requires uncovered interest parity as well as covered parity.

2/ These assumptions characterize the Dornbusch-Frankel extension of Frenkel's model. For an exposition, see Frankel (1983) and Boughton (1987a). The implied term-structure relationship is also discussed briefly in Frankel (1979).

CHART 1
UNITED STATES
NOMINAL INTEREST RATE DIFFERENTIALS AND EFFECTIVE EXCHANGE RATE, 1973–85[1]

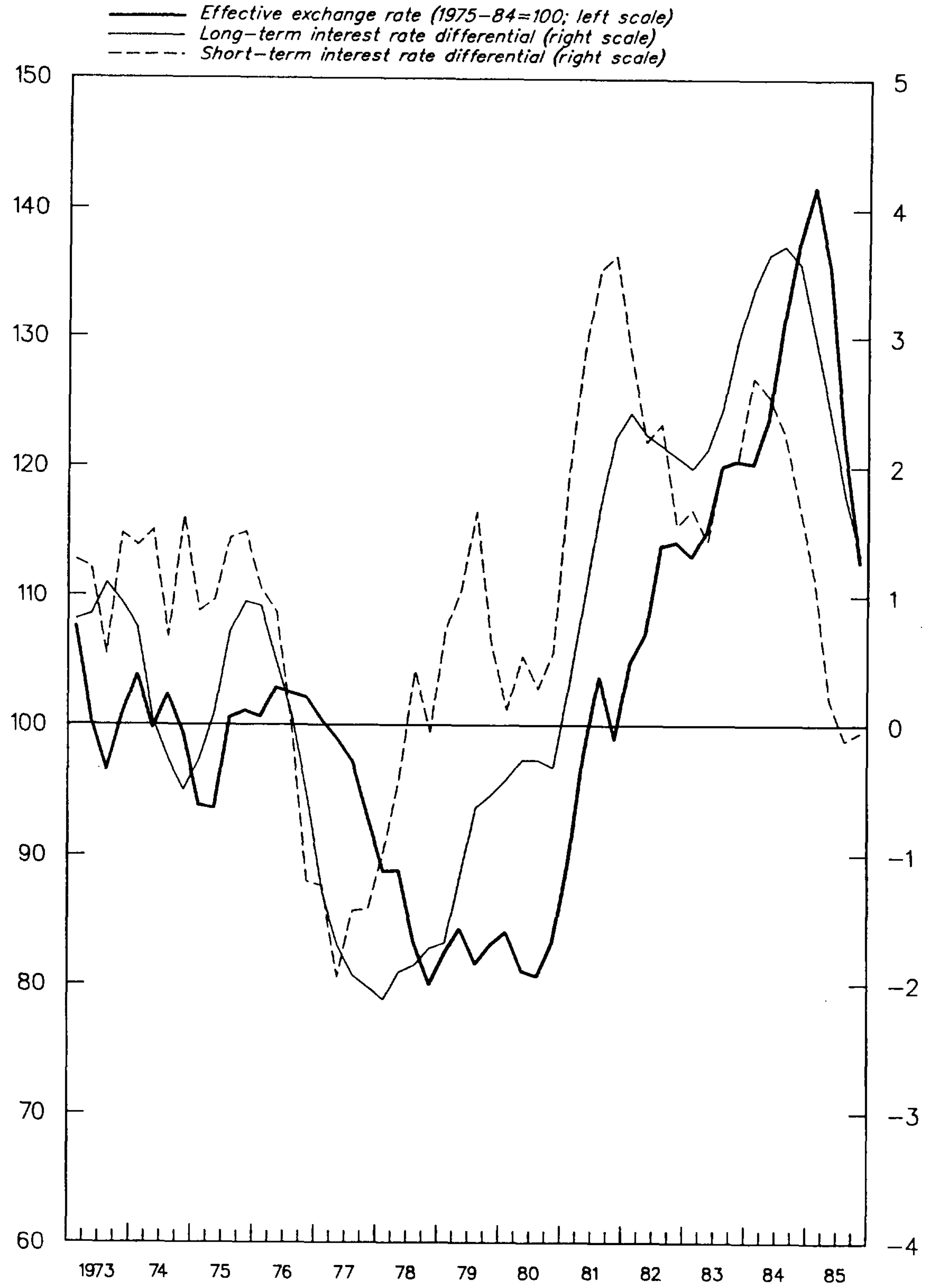


[1] Interest differentials are the U.S. rate minus an average of rates in four other major industrial countries, weighted by each country's weight in the SDR and plotted as a five–quarter centered moving average. The effective exchange rate is calculated using these same weights. The calculations are described further in the Appendix.

CHART 2

UNITED STATES

REAL INTEREST RATE DIFFERENTIALS AND REAL EFFECTIVE EXCHANGE RATE, 1973–85[1]



[1] Interest differentials are the U.S. rate minus an average of rates in four other major industrial countries, weighted by each country's weight in the SDR and plotted as a five–quarter centered moving average. The effective exchange rate is calculated using these same weights. Expected inflation is measured as a centered moving average of actual inflation. The calculations are described further in the Appendix.

(1) $\varepsilon = \hat{\pi} - \lambda(\rho - \bar{\rho})$

and (2) $\hat{i} - \varepsilon = 0$

where ε = the expected rate of depreciation

π = the expected inflation rate

ρ = the logarithm of the real exchange rate

and i = the instantaneous rate of return.

Carats indicate differentials between the home country and abroad, and the bar indicates a long-run equilibrium value.

Because λ in this type of model is assumed to be a constant, $(\varepsilon - \hat{\pi})$--and therefore the real interest differential--must be expected to decline over time as ρ approaches $\bar{\rho}$. That is, next period's short-term real interest rate differential must be smaller than this period's, because the real exchange rate for that period must be expected to be closer to its equilibrium value than it is today. Assuming that long-term interest rates reflect the expected path of short-term rates and that the expected inflation rate is the same in the short and long run, the term structure of the interest rate differential will be fully determined by equations (1) and (2). Furthermore, the interest rate differential will approach the expected inflation differential as the maturity approaches infinity. Again, it appears that this stylized scenario is far from descriptive of the data for major countries: real long-term differentials, at least ex post, are frequently larger than those for short-term assets.

Another way of viewing the term-structure relationship is to jettison the assumption that the exchange rate is expected to return to equilibrium at a fixed rate, and to assume instead that it will return to equilibrium by a certain date. As long as no restrictions are imposed on the adjustment path, there is no necessary relationship between long- and short-term interest differentials. Furthermore, short-term differentials will be irrelevant, because they will bear no necessary relationship with the size of the current disequilibrium in the exchange rate. A very simple version of this type of model (see Shafer and Loopesko (1983)) may be written as follows:

(3) $\rho = e - \hat{p}$

(4) $\rho - \bar{\rho} = (e - \bar{e}) - (\hat{p} - \hat{\bar{p}})$

(5) $e - \bar{e} = N \cdot \hat{i}_n$

(6) $\hat{p} - \hat{\bar{p}} = N \cdot \hat{\pi}$

where e = the logarithm of the nominal exchange rate

p = the logarithm of the price level and

i_n = the interest rate for an asset of maturity of N years.

Equation (3) defines the real exchange rate, and equation (4) describes the departure of the real exchange rate from its long-run equilibrium value. Equation (5) is the integral version of equation (2); it states that--assuming uncovered interest parity--the gap between the current exchange rate and its equilibrium value must be equal to the cumulative difference in returns on assets denominated in the two currencies. The value of N must be at least as great as the length of time that the exchange rate is expected to take to return to equilibrium. 1/ Finally, equation (6) notes that the total expected change in relative price levels is equal to the cumulated differential in expected inflation rates.

The solution to this model is

(7) $\rho = \bar{\rho} + N \cdot \hat{r}_n$

where $\hat{r}_n$ is the real interest rate differential for a maturity of N years. Clearly, this model implies that one should look at long-term rather than short-term interest rates, unless one wishes to argue that PPP is generally expected to be restored over short periods. In addition, it leads to another very strong conclusion: the slope coefficient in a regression linking interest differentials and exchange rates should rise proportionally with the length to maturity. An equation such as (7) estimated using 10-year bonds should yield a coefficient of 10, and one with 20-year bonds should yield a coefficient of 20. Empirical tests of this model by Shafer and Loopesko (1983) and by Boughton (1987b) rejected this strong version. 2/

Further relaxation of restrictions--for example, to allow for shifts in the long-run equilibrium real exchange rate, more flexible expectations processes for either exchange rates or interest rates, or limited substitutability among securities denominated in different currencies--would in general imply that both short- and long-term interest rates would matter in the determination of the exchange rate. From the poor performance of the more restricted models, such generalizations would appear to be warranted. The difficulty is to know just how to specify a less restricted model while retaining tractability.

1/ Once $\rho = \bar{\rho}$, real returns on short-term assets will be equalized. Hence it should not matter whether N is equal to or greater than that maturity. Note that in cases where $\hat{\pi} \neq 0$, $\bar{e}$ and $\hat{p}$ will be time-dependent, but the conclusions will be unaffected.

2/ See footnote 51 in Shafer and Loopesko for a list of reasons that the strict version might not hold.

Section II sets out a portfolio-balance model in which short- and long-term interest rate differentials both affect exchange rate movements. Section III presents empirical estimates of the model; Section IV discusses some simulation exercises; and a summary and conclusions are given in Section V.

II. Theoretical Considerations

Development of a model that incorporates both short- and long-term interest rate differentials must begin by considering the nature of the rigidities or imperfections that are hypothesized to break down the simpler relationship. As noted above, the simplest models are invalidated by the direct observation of nominal differentials that vary across the term structure. In general, two types of hypothesis may be advanced to generate a less restricted model. First, the degree of substitutability--i.e., the magnitude of the "risk premium"--may not be uniform across the maturity spectrum. Second, the expected rate of depreciation might not be uniform. 1/

A number of papers in recent years have tested the first of these null hypotheses--invariance of the risk premium across the maturity spectrum--jointly with a specific expectations hypothesis, usually that of perfect foresight. That is, market participants are assumed to have had unbiased expectations of the time path of the exchange rate that actually occurred. The nonlinearity of observed exchange rate paths implies that considerable variance could have occurred in the term structure of nominal interest rate differentials without violating the joint null hypothesis.

Evidence on models of this type (maturity-independent risk premium and perfect foresight) has been mixed. A few studies--notably Clarida and Campbell (1985) and Park (1985)-- have found that short- and longer-term "expected" differentials tend to move together, but several others--including Hakkio and Leiderman (1986), Longworth (1985), and Giovannini (1980)--have presented tests that lead to rejection of the null hypothesis. Without going into the details of these various tests, it seems safe to assert that there is a sufficient empirical basis for concluding that it is worth looking at models that allow for a maturity-dependent elasticity of substitution (risk premium) and/or a maturity-dependent (and non-perfect foresight) expected rate of depreciation.

Another recent line of research has focused on the possibility that investors view the determination of the exchange rate differently in the short and long run, on the grounds that "fundamental" factors have less

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1/ A third possibility is that market participants might have maturity-dependent expectations of the inflation rate, while simultaneously having a single expected path for the exchange rate. This possibility does not seem as realistic as the two mentioned here and so is ignored in the following discussion.

of an effect on short-run movements. The rationale for such an assumption might be that groups of investors have preferred maturity habitats and have expectations that are not necessarily consistent with those of other groups. To take the simplest case, one group (say, arbitraging firms) might invest only in assets with maturities of no more than thirty days and act on the basis of static expectations with respect to the nominal exchange rate; portfolio decisions in this market would be made on the basis of nominal short-term interest differentials. Another group (say, pension funds) might invest only in securities with maturities of ten years or more and have expectations based on the return of the real exchange rate to a perceived PPP level; portfolio decisions in this market would be based on expected real long-term interest differentials.

Estimates of the importance of different expectations processes have been generated by Frankel and Froot (1986). Their tests were based on surveys of market expectations over horizons ranging from one week to one year with respect to the exchange rate between the U.S. dollar and the Japanese yen. Frankel and Froot concluded that short-term expectations were characterized largely by bandwagon effects, while longer-term expectations took account of the possibility of a return toward an equilibrium rate. They also argued that such behavior may be irrational, because it seems to imply that investors on average expect to be able to ride a short-run bandwagon but get off ahead of the market. However, if the markets for widely spaced maturities are effectively segregated, each investor could be behaving rationally within the confines of a particular habitat.

These general considerations can be developed into a portfolio-balance model of exchange-rate determination characterized by preferred habitats in terms of both currency denomination and maturity. The basic structure for the following is adapted from Boughton (1983, 1984).

The first structural relationship in this two-country model is a demand function for securities denominated in the foreign currency ($\underline{f}$, expressed as a percentage of total net financial assets); this demand is hypothesized to be determined by expected returns relative to returns available on similar securities denominated in the home currency. For simplicity, it is assumed that there are two available maturities (short, s; and long, ℓ). Aggregating the demands for the two maturities gives equation (8):

$$(8)\quad f^d = f_0 - f_1(\hat{i}_\ell - \varepsilon_\ell) - f_2(\hat{i}_s - \varepsilon_s)$$

Next, it is hypothesized that short- and long-term exchange rate expectations are formed by independent processes. Long-term expectations are founded on PPP: the nominal exchange rate is expected to depreciate at the rate of the expected inflation differential between the two countries. That is, investors do not attempt to take account of any difference between the current level of the real exchange rate and its unknown PPP (or fundamental equilibrium) level, and they therefore expect the real exchange rate to follow a random walk. 1/ This hypothesis is expressed by equation (9):

$$(9) \quad \varepsilon_{\ell} = \hat{\pi}$$

In contrast, short-term expectations are hypothesized to be founded on one of two concepts: either that the nominal exchange rate will follow a random walk ($\varepsilon_s = 0$) or that it will depreciate at a rate equal to the nominal interest differential ($\varepsilon_s = \hat{i}_s$). The latter condition will hold if short-term securities are perfect substitutes, because arbitrage will then ensure that the nominal interest rate differential equals the expected rate of depreciation. A more general hypothesis, incorporating these two notions as special cases, is that the short-run expected rate of depreciation is a weighted average of the rate determined by arbitragers and by speculators with static expectations:

$$(10) \quad \varepsilon_s = \theta \cdot \hat{i}_s,$$

Where $\theta = 1$ under perfect arbitrage and $\theta = 0$ under static expectations.

The supply of foreign-currency assets is assumed to be determined in the long run by the cumulated balance on private capital flows between the two countries ($-k$). In the short run, however, because capital flows can be financed in either currency, this equality will not necessarily hold. The real exchange rate is hypothesized to equate continuously the demand for foreign-currency assets with the existing stock; however, that stock may adjust gradually over time. Hence there will be an adjustment process in response to gaps between f_d and $-k$:

$$(11) \quad \Delta\rho = \lambda_1(f^d + k)$$

Equation (11) does not fully capture the adjustment process in the model, because the current account (and hence the capital account) balance will itself respond gradually to changes in the real exchange rate. Equation (12) is a highly simplified version of this real-sector adjustment, which assumes that the Marshall-Lerner condition is satisfied with a one-period lag:

$$(12) \quad \Delta k = k_0 - \kappa\rho_{-1}$$

This equation obviously does not adequately capture the dynamics of the adjustment process, but it should at least reflect the medium-term role

1/ This hypothesis is consistent with the long-run equilibrium of the model, as long as the equilibrium real exchange rate is constant over time.

of the real exchange rate as an influence on the current account balance. 1/ A more complete representation would include a lengthy distributed lag on the real exchange rate.

Equations (8) through (12) constitute a partial-equilibrium block explaining changes in the exchange rate. Assuming for simplicity that domestic prices are determined exogenously, the block solution may be written conveniently in terms of the real exchange rate:

$$(13)\quad \rho = \lambda_1(f_0 + k_0) - \lambda_1 f_1 \hat{r}_\ell - (\lambda_1 f_2(1 - \theta))\hat{i}_s + (1 - \lambda_1 \kappa)\rho_{-1} + \lambda_1 k_{-1}$$

By estimating equation (13), most of the structural parameters of the block may be identified, the major exception being that θ and f_2 cannot be disentangled. 2/

An interesting feature of equation (13) is that the exchange rate is affected by nominal short-term interest differentials and by real long-term differentials. This property is a consequence of the different natures of the two hypothesized expectations functions, because inflation matters only in the longer run. Given this hypothesis, there is an econometric advantage to the formulation, since these two differentials are less collinear than would be the case for two nominal or two real differentials at different maturities. 3/

The model may be closed by the specification of an interest rate block comprising a money market (determining the short-term rate) and either a term-structure equation or some other representation of the determination of the long-term rate. Equation (14) is a straightforward money-demand equation, in which the demand for real money balances (m) is related to real income and the nominal short-term interest rate.

1/ In the steady state, when $\Delta k = 0$ and ρ is at its long-run equilibrium value $\bar{\rho}$, then equation (12) reduces to $k_0 = \kappa\bar{\rho}$. That is, if κ represents the adjustment process, then k_0 expresses the effects of the fundamental determinants of the real exchange rate.

2/ In versions of this model discussed in earlier papers, the supply function for foreign-currency assets was explicitly introduced as a function of relative returns as well as the cumulated capital balance. In that more general formulation, the structural parameters are less well identified, but the form of the block solution is unchanged.

3/ The simple correlation coefficients between short- and long-term nominal interest differentials are 0.69, 0.70, and 0.78 for the United States, Germany, and Japan, respectively. The correlations between nominal short-term differentials and real long-term differentials are -0.06, 0.46, and -0.09.

(14) $m^d = \ell_0 + \ell_1 y - \ell_2 i_s$

As a general proposition, the demand function for money could also include long-term interest rates and other rates of return, such as the inflation rate and Tobin's q. Long-term rates, however, may be eliminated on the assumption that the selection among interest-bearing securities is separable from the money-bonds choice in asset-holders' utility functions. 1/ Rates of return on physical assets are ignored for simplicity.

The supply of money is expressed as a reaction function in which the arguments are the targeted money stock (μ) and the short-term real interest rates both at home and abroad. For a given monetary target, monetary growth will be allowed to rise in response to a rise in the domestic real interest rate, although some effort is also assumed to be made to keep domestic real rates in line with those prevailing abroad.

These considerations lead to equation (15):

(15) $m^s = m_0 + m_1\mu + m_2 r_s - m_3 r_s{}^*$

Changes in the nominal short-term interest rate are assumed to be determined by the state of excess demand in the money market: 2/

(16) $\Delta i_s = \lambda_2(m^d - m^s)$

This dynamic condition, together with the two market-equilibrium functions, determines the level of the short-term rate. The reduced-form solution to this sub-block is equation (17): 3/

1/ The conditions for and implications of this assumption are discussed in Tobin (1969). Without this assumption, the reduced-form equation for i_s (equation (17)) would include a term in i_ℓ with an expected negative coefficient.

2/ This formulation assumes slow adjustment of a financial-market price; alternative hypotheses would be (a) that goods prices adjust gradually in response to excess money demand or (b) that the money stock adjusts gradually. The former would require a more general equilibrium framework than has been developed here, while the second would seem to be inconsistent with the view expressed in equation (15) that the monetary authorities control the money stock via a reaction function. Tests of these alternatives would constitute a useful extension of the estimates presented below.

3/ The structural parameters of equations (14) to (16) may be recovered from the reduced-form estimates of (17) as long as one parameter is determined independently. A convenient choice is ℓ_1, which may be estimated from other studies of the income elasticity of the demand for money.

(17) $i_s = \beta_0 + \beta_1 y - \beta_2 \mu + \beta_3 \pi + \beta_4 r_s^* + \beta_5 i_{s,-1}$

The final requirement for the model is an equation determining the long-term interest rate. There are at least two approaches to consider: a term-structure equation, or a reduced form summarizing the "fundamental" macroeconomic factors related to long-term rates. Unfortunately, neither approach has been applied very successfully in the empirical literature.

Many attempts have been made to estimate term-structure equations based on expectations theory, and they generally have not supported the theory. Mankiw (1986), for example, summarized the evidence on the term structure in four major countries and concluded that "fluctuations in the slope of the yield curve...largely reflect changes in the term premium"; however, "Neither (of the leading theories of the term premium) seems able to explain observed interest rate fluctuations" (page 63). Mankiw therefore explains the data through a simple conditional forecasting equation that is not founded on a specific theory of market behavior:

$$(18)\ i_\ell - i_s = s_0 - s_1(i_s - i_{s,-1}) - s_2(i_{s,-1} - i_{s,-2}) + s_3(i_{\ell,-1} - i_{s,-1})$$

It may be noted that the role of equation (18) in the model is not to "explain" the term structure but to take into account the observed empirical regularities between short- and long-term interest rates.

An alternative approach would be to derive a reduced-form equation summarizing the relationships between long-term interest rates and other macroeconomic variables. This approach has been used in many studies, going back notably to the portfolio-balance analysis of Feldstein and Eckstein (1970). Feldstein and Eckstein estimated an equation in which the yield on U.S. corporate bonds was related to private GNP, the stock of government debt, the monetary base (all in real per capita terms), and the expected inflation rate. More recent studies have re-estimated this type of equation over a longer data base and have found results quite different from, and generally with a poorer fit than, the original. See, for example, Barth et al. (1984), which finds that several variations on this theme that had appeared to be successful are actually rather unstable. An apparent exception, however, was the study by DeLeeuw and Holloway (1985), in which the yield on 3-year U.S. government bonds was related to the monetary base, the cyclically adjusted federal debt, and the expected inflation rate.

The "structural" approach would, in principle, be more consistent with the specification of the above model: unlike the term-structure approach, it does not require the assumption of effective arbitrage between short-and long-term asset markets. However, in view of the limited empirical success for both approaches, the best way to describe the determination of long-term interest rates remains an open question. For the present study, tests have been made both with equation (18) and with structural equations similar to those just described; the results reported below use equation (18). Similar results were obtained with the alternative structures, because in all cases the behavior of long-term rates is primarily autoregressive; neither short-term rates nor the various structural variables contribute very much explanatory power.

III. Empirical Estimates

The semi-reduced form model represented by equations (13), (17), and (18) has been estimated for the three largest industrial countries--the United States, Japan, and the Federal Republic of Germany--using monthly data for the period from May 1973 through December 1985. For the United States, the "rest of the world"--i.e., the region that is relevant for measuring foreign variables and the exchange rate--has been taken to be a weighted average of the next four largest industrial countries: Japan, Germany, France, and the United Kingdom, with the weights being approximately those used in measuring the SDR. For the other countries, the rest of the world is the United States. 1/ A detailed description of the data is given in the Appendix.

Estimation of the three-equation model has been based on the assumption that real private domestic demand (y) and national price levels (measured by the deflator for y) are exogenous; while not strictly credible, this assumption certainly should be much more applicable to these large countries than it would be for others, and more applicable to the domestic demand deflator than to consumer prices. In addition, the short-term interest rate in the United States has been taken as a control variable, eliminating equation (17) for that country. Estimation of equation (17) was not helpful for the United States, perhaps because monetary targeting may have been applied less consistently there than in Japan or Germany.

Even with these variables given, there remain a number of simultaneities and cross-equation restrictions in the model. Notably, the foreign interest rates in the U.S. equations are weighted averages of variables that are determined endogenously elsewhere. Consequently, the model has been estimated as a simultaneous system of eight behavioral relations (equations 13, 17, and 18 for Japan and Germany, and equations 13 and 18 for the United States) and three identities defining the endogenous

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1/ The rationale for this weighting pattern is discussed in Boughton (1984).

foreign interest rates. 1/ This system has been estimated by a FIML routine with linear cross-equation constraints. 2/

The results of estimation of this system are summarized in Table 1. It is difficult to assess adequately the goodness of fit for a system of interdependent equations such as this. The R^2 statistic for the system is .9667; however, this high value reflects in part the presence of lagged endogenous variables in several equations. Also of interest is the evaluation of serial correlation in the error processes of the individual equations, which could signal a misspecification or the omission of important influences.

For the model shown in Table 1, some first-order serial correlation--measured by Durbin's h statistic--appears to be present in the term-structure equations for the United States and Germany, and for the interest-rate equations for Germany and Japan. In addition, the Japanese term-structure equation appears to have some higher-order serial correlation, as measured by the Box-Pierce chi-square statistic. Software limitations make it quite cumbersome to try to correct for serial correlation in this model, so the affected equations are presented as is. Nonetheless, the equations that are of key interest--the exchange rate equations--seem to have well-behaved and uncorrelated error processes.

The exchange-rate equations for the United States and Germany are broadly satisfactory in terms of sign and significance levels of the coefficients. Both short-term and long-term interest differentials are significantly related to exchange rate movements (except for Japan, where the long-term differential is insignificant). The portfolio effect is significant for both the United States and Germany but is essentially zero for Japan. As for the interest-rate and term-structure equations, the signs are all as hypothesized, and most appear to be significant. Again, the equations for Japan are less satisfactory than those for the other two countries.

Table 2 presents estimates of the structural coefficients derived from the reduced-form regressions. In order to obtain these coefficients, it has been necessary to assume values for θ (the short-term expectations parameter) and ℓ_1 (the income elasticity of the demand for money). For simplicity, θ has been set to zero (so that the nominal exchange rate is expected to follow a random walk in the short run), and ℓ_1 has been set to unity; the effects of different assumptions could, of course, be readily calculated.

1/ Identities are required for the nominal and real short-term foreign interest rates and for the real long-term foreign rate.

2/ The program is SIMUL, developed by Clifford R. Wymer of the International Monetary Fund. It is an iterative program that uses a modified Newton-Raphson procedure to maximize the likelihood function.

Table 1: Estimated Reduced-Form Equations

	United States	Japan	Germany
A. Equation (13): real exchange rate			
coefficient on: 1/			
long-term real interest differential	-0.112	-0.015	-0.102
	(2.17)	(0.25)	(1.78)
short-term nominal interest differential	-0.160	-0.117	-0.214
	(2.94)	(2.01)	(2.89)
lagged real exchange rate 2/	0.978	0.975	0.950
	(1.85)	(1.26)	(3.04)
cumulated external balance	0.057	-0.009	0.032
	(2.62)	(0.15)	(2.33)
root mean-square error	0.0711	0.1020	0.1108
B. Equation (17): short-term interest rate			
coefficient on: 1/			
real income		2.428	2.322
		(1.64)	(2.20)
"targeted" money growth		-0.647	-0.891
		(1.04)	(2.31)
expected inflation rate		0.045	0.134
		(4.65)	(3.61)
real short-term foreign interest rate		0.012	0.069
		(0.89)	(3.94)
lagged interest rate 2/		0.949	0.909
		(3.19)	(4.29)
root mean-square error		0.1783	0.2173

Table 1 (Continued)

	United States	Japan	Germany
C. Equation (18): term structure			
coefficient on: 1/ change in short rate	-0.801 (34.55)	-0.649 (6.41)	-0.372 (3.23)
lagged change in short rate	-0.059 (2.50)	-0.055 (1.19)	-0.034 (1.14)
lagged term structure 2/	0.968 (2.96)	0.990 (0.84)	0.967 (3.04)
root mean-square error 3/	0.0939	0.0864	0.0543

1/ Numbers in parentheses are asymptotic t-ratios.
2/ T-ratio is for difference from unity, not zero.
3/ For long-term interest rate.

Table 2: Structural Coefficients 1/

	United States	Japan	Germany
Equation (8):			
f_1	1.951		3.231
f_2	2.788		6.779
Equation (11): λ_1	0.057	-0.009	0.032
Equation (12): κ	0.388		1.572
Equation (14): ℓ_2		0.002	-0.019
Equation (15): m_1		0.266	0.384
m_2		0.019	0.058
m_3		0.005	0.030
Equation (16):			
λ_2		2.557	2.553

1/ Derived from Table 1. These calculations assume that $\theta = 0$ and $\ell_1 = 1$.

With these assumptions, a one percentage-point rise in the short-term interest differential is shown to induce a shift in desired portfolios toward home-currency assets amounting to 2 percent of total portfolios in the United States and 3 1/4 percent of total portfolios in Germany. (The effect in Japan cannot be estimated because of the reversed sign on λ_1 in equation (13).) The effects of shifts in long-term differentials are somewhat larger: 2 3/4 percent in the United States and 6 3/4 percent in Germany.

The estimates of λ_1 suggest that a 1 percent increase in the demand for foreign-currency assets, or a 1 percent decrease in the stock of such assets outstanding, will lead to a 5 3/4 percent depreciation in the real effective rate for the U.S. dollar. For Germany, the depreciation amounts to 3 1/4 percent, while for Japan, there is a statistically insignificant perverse effect. To complete the circle, the estimated values for κ suggest that a 1 percent depreciation in the real exchange rate will generate a strengthening of the current account balance amounting to less than 1/2 of 1 percent of portfolios for the United States and just over 1 1/2 percent for Germany. A perhaps more familiar way of expressing this estimate is that a 10 percent real depreciation would strengthen the U.S. current account balance by 1 1/4 percent of GNP; for Germany, the strengthening is estimated at a very strong 3 1/2 percent of GNP.

The money-demand equations display semi-elasticities with respect to short-term interest rates (ℓ_2) that are close to zero. On the supply side, however, there is a significant influence from domestic interest rates, in real terms. Therefore, in this model, the observed negative correlation between nominal interest rates and the stock of money that is usually attributed primarily to the shape of the demand function is instead attributed to the authorities' reaction functions. A rise in the inflation rate in this system raises the nominal interest rate but (in the short run) lowers the real rate; through the reaction function, money growth is then reduced.

The reaction functions for Germany and Japan also suggest that foreign interest rates have an influence that is perhaps 1/4 to 1/2 as large as that of domestic interest rates. And the adjustment function (equation (16)) for the money markets in both countries is such that a 1 percent rise in the demand for money, or reduction in supply, will induce a rise in the level of domestic short-term interest rates of about 2 1/2 percentage points.

IV. Simulations

In order to test the performance of the model and to evaluate its implications regarding the importance of various determinants of exchange rates, several simulation experiments have been run. These include dynamic simulations over the full sample period and counterfactual simulations that control for changes in selected variables.

In contrast to the single-equation estimation errors or the results of static full-model simulations, the dynamic simulations allow the prediction errors to cumulate over time. For a highly autoregressive process such as those generating changes in exchange rates, the errors are likely to cumulate rather than to be offsetting. As Hendry has emphasized, this cumulation of errors should not be regarded as evidence against the validity of the model, but only as an evaluation of the joint influence of the variables that have been treated as exogenous in the specification of the model. 1/ In the present case, these non-modelled variables include inflation rates, lagged monetary growth, real domestic demand, and lagged external balances.

The results of this exercise are shown in Chart 3. It is readily seen that the amplitudes of exchange rate swings are greatly understated. This finding is typical of all asset-market exchange-rate models. The non-modelled variables are themselves highly autoregressive, and so the simulated time path for the exchange rate tends to be quite smooth and not to reflect the actual, more erratic, behavior of the exchange rate. What is sought is a measure of the extent to which the model picks up the direction and the timing of the broad swings.

For the effective rate of the U.S. Dollar, the model predicts a depreciation from 1973 through the end of 1977, followed by an appreciation through late 1984; the dollar is then predicted to depreciate throughout 1985. With minor differences in timing, the dynamic predictions for the bilateral rates of the dollar against the deutsche mark and the yen are consistent with these effective swings. Thus the model captures the grand lines of the observed situation reasonably well, although it does not indicate the buoyancy of the dollar in 1976, its weakness throughout 1979 and the first half of 1980, nor the surge in the currency's value in 1984 and the first two months of 1985. These omissions--which may reflect the importance of speculative pressures during these periods--are apparent as well in the predictions of the bilateral rates.

The more specific question approached through simulations in this exercise concerns the role of each determining variable in generating the predicted movements shown in Chart 3. In order to have a convenient basis for comparison, counterfactual simulations have been performed over the period of the U.S. dollar's appreciation: from June 1980 through February 1985. That is, the model has been run dynamically with actual values for all exogenous variables through June 1980; then, in turn, each major determining variable is forced to follow an artificially smoother path in order to illustrate its importance in generating observed changes in exchange rates.

1/ Dynamic simulation "cannot discriminate between models in terms of the validity of their estimated parameters, nor their congruity with the sample evidence... In fact, what dynamic simulation tracking accuracy mainly reflects is the extent to which the explanation of the data is attributed to non-modelled variables." (Chong and Hendry (1986), page 673).

Table 3. Counterfactual Dynamic Simulations of Real Exchange Rates, June 1980 to February 1985 1/

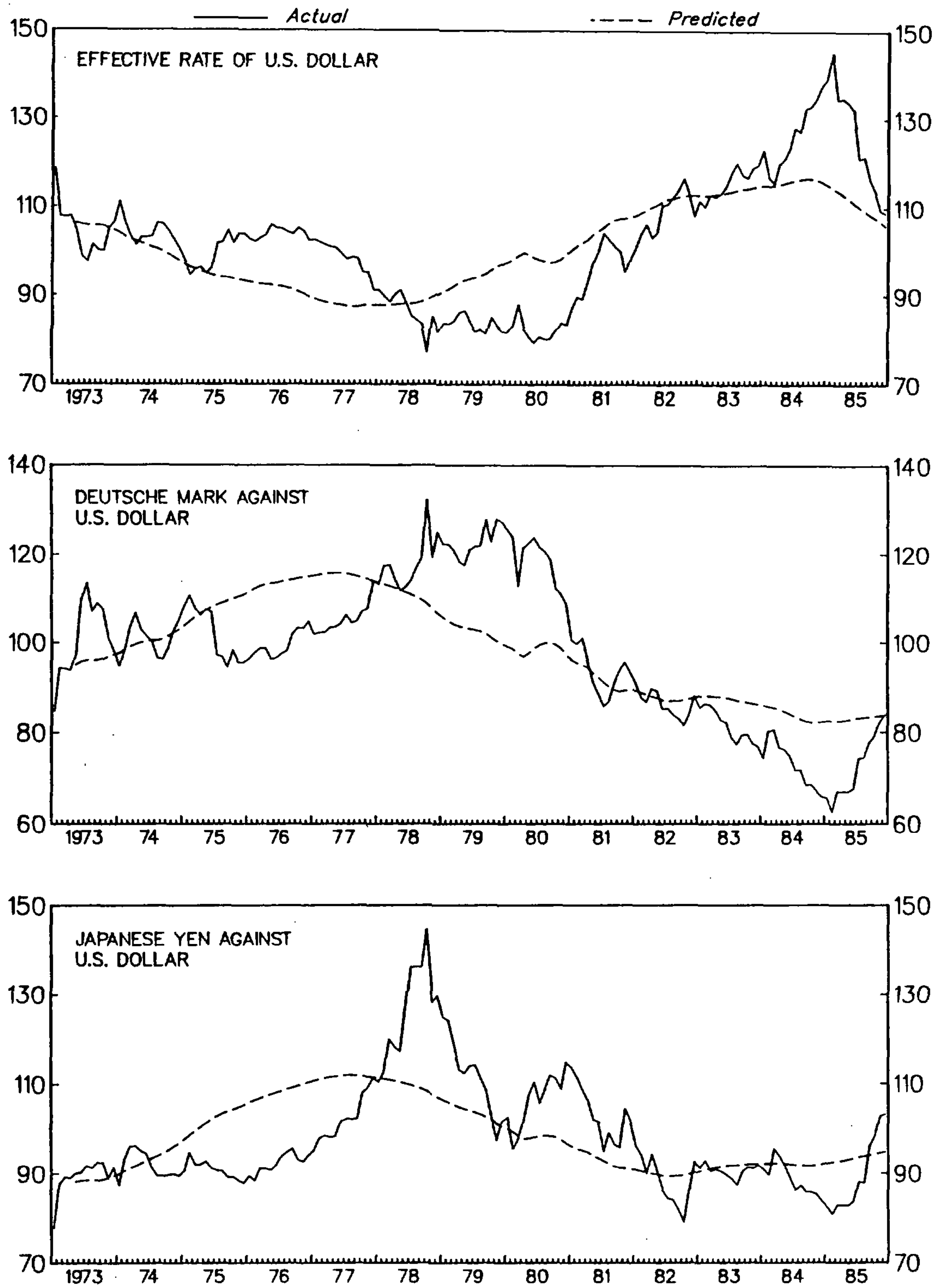
	United States	Germany	Japan
Actual change	60.5	-68.4	-31.1
Simulated change	15.1	-17.9	-5.9
Change attributed to:			
Short-term interest differentials	27.1	-27.0	-9.6
Shifts in term structure	-6.8	3.6	0.4
Differences in growth and inflation	1.2	-2.1	0.3
External balances	6.7	-7.0	-0.3

1/ Effective rate for United States; bilateral rate against United States for the other two countries. Percentage changes are first differences in logarithms; a positive change is an appreciation.

CHART 3

FULL-SAMPLE DYNAMIC SIMULATIONS OF REAL EXCHANGE RATES[1]

(Index: 1975–84=100)



[1] Rates shown are reciprocals of those appearing in the model; in this graph, an increase in the rate indicates an appreciation.

For this purpose, four counterfactual simulations have been performed. First, short-term interest rates have been exogenized; that is, it is assumed for this simulation that the monetary authorities of each country allow monetary growth to vary by enough to stabilize nominal short-term interest rate differentials vis-a-vis the United States. As in the basic model, short-term interest rates in the United States are assumed to be controlled by the Federal Reserve. For the second simulation, shifts in the term structure of interest rates have been eliminated by setting long-term rates in each country equal to observed or predicted values of short-term rates, plus the June 1980 difference between long and short rates.

In the third simulation, each country is assumed to use fiscal and other policies to keep both real domestic demand and the domestic demand deflator in line with the values in the United States. Specifically, real domestic demand in each country grows at the same rate as that in the United States, while inflation differentials are maintained at their June 1980 levels. Finally, for the fourth simulation, the cumulated external balance (k) in each country is held at its June 1980 level; the implication of this assumption is that the external balances are such as to keep net external assets or liabilities growing at the same rate as total private financial portfolios. Net deficit countries would remain in deficit, but only by enough to stabilize portfolio allocations; and conversely for surplus countries.

The results of the counterfactual simulations, which are summarized in Table 3, show the overriding importance of monetary policy in the context of this model. For all three exchange rate indexes, movements in short-term interest rate differentials have been the single most important identified factor contributing to the observed swings. The effect of this first simulation is that short-term rates in non-U.S. countries rise very sharply in tandem with U.S. rates in 1980 and 1981, and they generally remain above control levels throughout the period. Notably, to maintain a constant differential vis-a-vis the United States, German short-term interest rates would have had to reach more than 19 percent by end-1980, compared with an actual level of 10 percent; throughout the simulation period, they average about 4 percentage points above the control path. The weighted-average rate for the four non-U.S. countries was 11.2 percent in June 1980, or 2.7 percentage points above the U.S. rate. By December 1980, this rate was still 11.2 percent, whereas it would have had to go to 21.3 percent to maintain the initial differential. Overall, each of these countries would have had to tighten monetary policy substantially in order to prevent the widening of differentials that was observed in the early 1980s. Had this happened, the simulation suggests that a major portion of the observed exchange rate swings would not have occurred.

The other simulations show smaller but--in most cases--not negligible effects. In the second simulation, for which long-term interest rates are adjusted to prevent shifts in the term structure, the effects work opposite to the prevailing trends over the simulation period. Notably, the term structure shifted toward an upward tilt by less in the United States than in the other major countries during this period. 1/ Consequently, the observed shifts in the term structure generally worked to lessen the appreciation of the U.S. dollar compared with what would otherwise have occurred.

Holding differentials in income growth and inflation constant, as in the third simulation, has the general effect of raising income and lowering inflation in both Germany and Japan through most of the simulation period. The largest effect is on the growth of real private domestic demand in Germany, which was observed to average close to zero during the period concerned; in this simulation, growth averages more than 4 percent per annum. Growth in Japan is raised by about 1 1/4 percent per annum. With higher growth and lower inflation, the demand for money is higher in Europe and Japan. Consequently, interest rate differentials are squeezed, and the exchange rate swings are dampened. Nonetheless, in spite of the magnitude of the exogenous changes, the induced effects on exchange rates are quite small.

The final simulation involves holding k constant after June 1980 in each country. For the United States, this assumption prevents the cumulated private capital balance from declining from 1.1 percent of total portfolios in June 1980 to -4.8 percent in September 1982 (reflecting a strong current account position) and then rising to 14.5 percent by end-1985. Similar cycles in the opposite direction are eliminated for Germany and Japan. In essence, then, this simulation asks how exchange rates would have behaved if the U.S. current account position had not strengthened in 1981-82 and then weakened sharply, and conversely for the other two major countries. The effect is seen to be negligible for Japan; for the United States and Germany, the exchange rate swings are dampened by some 7 percentage points.

V. Summary and Conclusions

This paper has argued that our understanding of the determination of major-currency exchange rates can be enhanced by reference to information about the term structure of interest rates. In theory, the relationships among the effects of interest rates at different maturities are ambiguous except under restrictive and unrealistic assumptions. These relationships have been untangled here by specifying a portfolio-balance model in which short- and long-term securities markets are segregated into preferred habitats and in which the processes determining exchange-rate expectations

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1/ During the first two years of the simulation period, U.S. short-term interest rates were quite high; consequently, the counterfactual experiment results in correspondingly high long-term rates; during the later years, the effect is to reduce long-term rates, but by relatively smaller amounts. For the other countries, the experiment reduces long-term rates over most or all of the simulation period.

are different in each habitat. An implication of these assumptions is that exchange rates are affected by nominal short-term interest differentials and by real long-term differentials.

Empirical estimates of the model--using monthly data (1973-85) for the United States, Germany, and Japan--suggest that both short and long differentials do matter, except that long rates do not seem to have a significant effect on the yen-dollar rate. In the equation for the effective rate of the U.S. dollar, a rise of one percentage point in the short-term differential is estimated to induce a 2 percent appreciation; a commensurate rise in the real long-term differential induces an appreciation of about 2 3/4 percent.

Counterfactual dynamic simulations of the model indicate, inter alia, that the factors that caused the observed shifts in short-term differentials between June 1980 and February 1985 (the period of the dollar's major appreciation) were responsible for an appreciation of the dollar amounting to some 27 percent, compared with an observed real effective appreciation of about 60 percent. In contrast, term-structure shifts worked in the opposite direction and are estimated to have limited the dollar's appreciation by about 7 percent. Other determining factors, while significant, accounted for smaller currency movements during the early 1980s.

Data Used in the Model

i_s short-term interest rates

Rates on money-market instruments with maturities of about three months. United States - certificates of deposit; Japan - discount rate on two-month private bills; Germany and United Kingdom - interbank deposits; France - money rate against private paper.

i_ℓ long-term interest rates

Yields on government bonds with maturities of 10 to 20 years. United States - 20-year constant maturities; Japan - over-the-counter sales of interest-bearing government bonds with maturities of 10 years or more; Germany - public authority bonds; France - national equipment bonds of 1965, 1966, and 1967; United Kingdom - 20-year maturities.

i^* foreign interest rates

For the countries other than the United States, the U.S. rate serves as the foreign rate. For the United States, the foreign rate is a weighted average of the rate for the four other countries listed above. The weights are based on the relative weights used in the SDR as of end-1980: 0.3276 for Germany and 0.2241 each for Japan, France, and the United Kingdom.

k the cumulated balance on private capital, as a percentage of total private portfolios

First, each country's balance of payments is separated into 10 to 12 components (merchandise exports and imports, service transactions, transfers, direct and portfolio capital transactions, official transactions). Second, wherever monthly data are not available for one or more components, each series is benchmarked on a closely *related series or interpolated. Third, the balance on* private capital is derived as the negative of the sum of the current account and official transactions. Fourth, this balance is cumulated from the beginning of 1965; that series is the numerator of k. Fifth, the denominator is the stock of government debt held by domestic nonbank sectors, minus the numerator (i.e., plus the cumulated balance on the current account and official capital). The role of k in the model and the basis for this measure of it is explained in Boughton (1984).

μ the targeted rate of monetary growth

On the assumption that the authorities seek, ceteris paribus, to maintain steady downward pressure on the rate of monetary growth, this variable is defined as $c(2\ln(M_{t-1})-\ln(M_{t-2}))$, where c ($0< c < 1$) is an arbitrary constant that becomes embedded in the regression coefficients. The money stock (M) is broadly defined. United States - M2; Japan - M2 plus certificates of deposit; Germany - M3; France-resident M2; United Kingdom - sterling M3.

π the expected inflation rate

For calculating long-term real interest rates, a nine-month centered average of actual inflation rates. For short-term real rates, a three-month average. Prices are measured by the deflator for private domestic demand in each country.

ρ the real exchange rate

Relative price levels (domestic demand deflators) adjusted for exchange rate changes. Exchange rates are end-period. For the U.S. effective rate, weights are the same as those used for foreign interest rates.

y real income

Deflated level of private domestic demand.

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