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Asset Market and Balance of Payments Characteristics: An Eclectic Exchange Rate Model for the Dollar, Mark, and Yen

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Abstract

In this paper we use an exchange rate model that combines asset market characteristics with balance of payments interactions to examine the nominal effective exchange rates of the German mark, Japanese yen, and U.S. dollar for the recent experience with floating exchange rates. Our approach may be interpreted as one which attempts to flesh out the missing links that arise in conditioning an exchange rate solely on relative prices, as occurs in a standard PPP analysis. In contrast to much other empirical exchange rate modeling, our approach explicitly involves the use of a current account sustainability term. Amongst the findings reported in this paper are: significant, and sensible, long-run relationships for all of the currencies studied; appealing short-run dynamics for two of the currencies; and a finding that the Japanese effective exchange rate closely tracks the long-run exchange rate defined in this paper.

JEL Classification Numbers:

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1/ University of Strathclyde. This paper was begun when I was a visiting scholar in the Economic Modeling and External Adjustment Division of the Research Department. I am indebted to Peter B. Clark and Ian Marsh for very valuable comments on an earlier version of this paper. I am also grateful to Ian Marsh for efficient research assistance and Susanna Mursula for assistance in compiling the data base. The usual disclaimer applies.

Contents

Summary

Recently there has been a resurgence of interest in modeling "long-run" real and nominal exchange rates. In large part, such interest has arisen because the stylized fact that freely floating exchange rates are rarely, if ever, at their equilibrium levels has generated a desire to understand just how far away from equilibrium a current exchange rate might be. For bilateral exchange rates, a growing body of evidence suggests that some form of stable 'long-run' relationship exists between exchange rates and fundamentals, particularly relative prices. This latter relationship, however, does not conform exactly to what would conventionally be regarded as purchasing power parity (PPP), in that often, particularly for U.S. dollar bilateral rates, standard symmetry and degree one homogeneity restrictions (implied by absolute PPP) are strongly rejected and the implied mean reversion of the real exchange rate is very slow. There would therefore appear to be more to exchange rates than simply relative prices.

In this paper, the recent work on long-run exchange rate relationships is taken as the point of departure and combined with a theoretical model of exchange rate determination--a "hybrid asset market" or "balance of payments" model--to examine the determinants of nominal exchange rates. From an empirical perspective, the model has two appealing features. It incorporates a key element of the asset approach to exchange rate modeling, namely, that an asset price is related to the present value of expected future fundamentals, along with elements of a more traditional balance of payments or portfolio balance approach, in which real factors can have an important bearing on the nominal exchange rate, even in equilibrium. A key aspect of this latter feature is the issue of sustainability.

The hybrid asset market or balance of payments model considered in this paper, labeled an "eclectic exchange rate model" (EERM), is implemented for the effective exchange rates of the deutsche mark, Japanese yen, and U.S. dollar over the period 1973 Q3 to 1993 Q4. It is demonstrated that the EERM produces sensible estimates of the long-run values of these exchange rates, whereas simple PPP does not. Interestingly, the actual value of the Japanese yen stays very close to its equilibrium value throughout the period, whereas both the deutsche mark and dollar are often quite far away; this is especially so for the U.S. dollar in the period coinciding with its dramatic appreciation in the early 1980s. The short-run dynamic equations implied by the long-run exchange rate systems are deemed reasonably successful on the basis of standard criteria. The paper concludes by arguing that the approach adopted warrants further attention, particularly in terms of the data requirements necessary to implement it for bilateral exchange rates.

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I. Introduction

Recently there has been considerable interest in modeling "long-run" real and nominal exchange rates (see the surveys of Froot and Rogoff (1995) and MacDonald (1995)). In part, this literature has been stimulated by the existence and development of time series methods in econometrics. More fundamentally, perhaps, the perception that freely floating exchange rates are rarely, if ever, at their equilibrium levels has generated a desire to understand just how far away from equilibrium a current exchange rate might be. The recent applied work in this area has suggested that researchers who have completely abandoned purchasing power parity (PPP) may have thrown the baby out with the bathwater, since for most bilateral currencies there does appear to be a stable "long-run" relationship between exchange rates and relative prices. This relationship, however, does not conform exactly to what would conventionally be regarded as PPP since often, particularly for U.S. dollar bilateral rates, standard symmetry and degree one homogeneity restrictions implied by absolute PPP are strongly rejected and the implied mean reversion of the real exchange rate is very slow: there would therefore appear to be more to exchange rates than simply relative prices.

In this paper we take the recent work on modeling long-run PPP and related monetary models as our point of departure. In particular, we present an eclectic model of the exchange rate which is consistent with recent theorizing in the exchange rate literature and focuses attention on the key real and nominal determinants of exchange rates. In contrast to purely monetary based models, a central feature of the present model is that it allows for real exchange rate changes consistent with optimizing; that is, it allows for sustainable real exchange rate changes. 1/

In summary, this paper makes the following contributions to the empirical exchange rate literature. First, we operationalize, in an empirical sense, what we label an eclectic exchange rate model (EERM); this model has hitherto been overlooked by empirical researchers. 2/ Second, and as a corollary to the first point, we seek to flesh out the missing link(s) in the exchange rate/ relative price relationship recently noted by a number of researchers (see Froot and Rogoff (1995) and MacDonald (1995)). We do this by modeling factors which cause temporary and permanent changes of the real exchange rate. Third, we attempt to introduce the sustainability of current account imbalances into an estimated exchange rate reduced form relationship. Until now, discussion of this concept has been the almost exclusive preserve of the fundamental equilibrium exchange rate (FEER) literature. 3/ Our model hopefully partly bridges the gap between

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1/ This point is stressed in the FEERS, or internal-external balance, view of the exchange rate; see Bayoumi et al. (1994).

2/ An exception is Faruqee (1994), who uses a version of this model to analyze the long-run effective real exchange rates of the U.S. dollar, and Japanese yen for the period of 1990.

3/ See the papers contained in Williamson (1994).

this literature and the more mainstream academic literature. Fourth, to our knowledge all of the recent applied work on long-run exchange rate modeling has focussed on bilateral exchange rates (real and nominal). Here, because one of our interests concerns the sustainability of current account imbalances, we use effective exchange rates in our empirical work. As we shall demonstrate, in the context of long-run exchange rate modeling, effective rates have very different properties to bilateral rates.

The outline of the remainder of this paper is as follows. In the next section we present the theoretical model used in our empirical investigation of the effective exchange rates of the German mark, Japanese yen and U.S. dollar. In Section III we outline the econometric methods used to implement the EERM. The data set used to implement our tests is discussed in Section IV. One particularly attractive feature of our econometric method is that it allows for two forms of disequilibrium adjustment toward the equilibrium specified in the theoretical model. Two sets of results are presented in Section V. First, we examine the validity of long-run PPP using effective exchange rates. Second, we present estimates of the short- and long-run exchange rate models for each of the currencies noted above. The paper closes with a concluding section.

II. An Eclectic Exchange Rate Model

In this section we discuss a model of the exchange rate which combines asset market attributes with traditional balance of payments characteristics. The model may be viewed as a truly general equilibrium model of the exchange rate and we accordingly label it the eclectic exchange rate model (EERM). Its attractions are at once obvious. First, by incorporating an asset market approach we capture key features of exchange rate behavior; for example, there is a close link between the spot price and the expected price (as reflected in the close link between spot and forward exchange rates). These are features common to prices determined in organized asset markets, such as stock and bond markets (see Mussa (1984), MacDonald (1988), and Frenkel and Mussa (1988)). Second, by incorporating concepts from the balance of payments equilibrium condition, flow elements, such as those suggested in the portfolio balance approach to the exchange rate, are introduced into the process of exchange rate determination. In particular, the model recognizes that changes in net foreign asset holdings and real shocks generate changes in the balance of payments which may require real exchange rate adjustment, even in equilibrium. This seems a particularly attractive feature of the model given the recent empirical work on long-run exchange rate relationships.

Thus a number of researchers, 1/ using data for the recent floating experience, have estimated unique and statistically significant cointegrating relationships between exchange rates and relative prices, thereby suggesting some form of long-run PPP. However, the form of the long-run does not accord exactly with a traditional interpretation of PPP in that degree one homogeneity and symmetry restrictions are usually rejected and, furthermore, the adjustment to the long-run relationship is often very slow. Slow adjustment, per se, does not necessarily conflict with a traditional interpretation of PPP, but it nevertheless suggests that other factors have important explanatory power in the short term. MacDonald and Marsh (1994) summarize the upshot of recent empirical work on long-run PPP as suggesting that 'there would seem to be something in the entrails of the exchange-rate relative-price relationship.' 2/ We believe that the synthesis of the balance of payments and monetary sectors proposed in this paper should help to capture the missing elements in the PPP relationship noted by many other researchers. A further advantage of the explicit modeling of a balance of payments sector, in combination with a monetary sector, is that it introduces issues of sustainability in a natural way (a characteristic emphasized in the FEERs approach to exchange rate modeling).

A useful starting point for our discussion is the definition of the real exchange rate as:

$$q = p - (s + p^*), \tag{1}$$

where p denotes the log of the domestic price of domestic goods, p^* denotes the logarithm of the foreign price of foreign goods and s the log of the domestic price of one unit of foreign exchange. When a variable is not explicitly dated it is assumed to be contemporaneous; i.e., period t. The logarithm of the general price level, P, in the home country is assumed to be a weighted average of p and $s + p^*$:

$$P = \sigma p + (1-\sigma).(s + p^*) = s + p^* + \sigma.q, \tag{2}$$

where σ denotes the weight of domestic goods in the domestic price index. Expression (2) may be used to define the expected nominal exchange rate in period n, as:

$$E_t s_n = E_t P_n - E_t p_n^* - \sigma.E_t q_n. \tag{3}$$

This decomposition of the expected nominal exchange rate illustrates three key channels of exchange rate determination; two of these, P and p^*, are consistent with the exchange rate continually tracking PPP, whilst the

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1/ See, for example, Cheung and Lai (1993a), Kugler and Lenz (1993) and MacDonald (1993). These papers, and other related work, are surveyed in Froot and Rogoff (1995) and MacDonald (1995).

2/ MacDonald and Marsh (1994) model the missing factor(s) using relative (home-foreign) long-bond yields.

third is clearly not. Let us consider each of these channels in a little detail.

1. The general price level channel and the demand and supply for money

As in standard monetary models of the balance of payments and exchange rate, we assume that the general price level is determined by the interaction of the demand and supply of money. In contrast to the standard money demand function that has often been utilized in exchange rate studies, we follow Mussa (1984) in our use of a richer specification for this function. In particular, this specification includes, in addition to conventional domestic variables, currency substitution and portfolio balance (i.e., open economy) effects. In particular, the logarithm of the home demand for money is assumed to be given by:

$$m^d = K + \alpha_1 P + \alpha_2 A + \alpha_3 s + \alpha_4 q - \alpha_5 i - \alpha_6 E_t \Delta s, \tag{4}$$

$$\alpha_1, \alpha_2, \alpha_3, \alpha_5, \alpha_6 > 0 \text{ and } \alpha_4 \lesseqgtr 0,$$

where K captures all of the exogenous influences on the demand for money, such as real income effects, and A denotes the stock of net foreign assets [defined in terms of foreign currency - the foreign good] which is assumed to have a positive effect on the demand for money because it represents a wealth effect. The nominal exchange rate has a positive effect on the demand for money because a currency depreciation, by revaluing net foreign assets in domestic currency terms, increases domestic wealth. The relative price of domestic goods in terms of imported goods can affect the demand for money through a variety of channels (one being because of the effect on the value of domestic product). Both the domestic interest rate and the expected exchange rate change are negatively associated with the demand for money through the standard opportunity cost channel; in the case of $E_t \Delta s$, an expected depreciation of the domestic currency will, through a currency substitution argument, result in a switch out of domestic assets into foreign assets.

It is further assumed that the domestic interest rate is given by the familiar risk-adjusted uncovered interest rate parity condition:

$$i = i^* + E_t \Delta s + \lambda, \tag{5}$$

where λ denotes an exogenous risk premium. On using equations (1) through (5) we may express the condition of money market equilibrium, in which the demand for money is equal to the supply, as:

$$m = l + \gamma s - \phi E_t \Delta s, \tag{6}$$

where m denotes the supply of money, $\gamma = \alpha_1 + \alpha_3 > 0$ and $\phi = \alpha_5 + \alpha_6 > 0$. and 1/

$$l = K - \alpha_3 p^* - \alpha_5(i^* + \lambda) + (\alpha_4 - \sigma\alpha_3)q + \phi.E\Delta p^* + \phi\sigma.E_t\Delta q + \alpha_2 A.$$

If it is assumed that p^*, i^*, q and A are determined independently of the money supply 2/ we may obtain the following expression for the expected price level in period n.

$$E_t P_n = (1/(\gamma + \eta)) \cdot \sum_{j=0}^{\infty} (\eta/(\gamma + \eta))^j \cdot E_t[m_{n+j} - l_{n+j}] \tag{7}$$

In words, (7) simply says that the expected price level in any period is the present discounted value of the present and expected stream of the excess demand for money. Changes in either the expected or unexpected component of this general price level will result in exchange rate changes which are consistent with PPP. Equation (7) also illustrates under what circumstances the nominal exchange rate may be more volatile than current fundamentals. Thus, if a current change in fundamentals signals to agents a revision in expected future fundamentals, this may generate excess volatility in the nominal exchange rate--the so-called magnification effect (Bilson, 1978). Such effects are a key feature of asset market prices. As (3) illustrates, however, there is likely to be more to exchange rates than PPP. The issue of how real factors affect the nominal exchange rate, independently of their effects through the demand for money, may be introduced by discussing the evolution of A and q.

2. The balance of payments and the real exchange rate

In this section, we discuss how the term $\sigma.E_t q_n$ may impinge on the nominal exchange rate using a balance of payments model of the determination of the exchange rate. 3/ The current account surplus of the balance of payments, ca, is defined as:

$$ca = \beta\ (z - q) + r^* A, \ \beta > 0 \tag{8}$$

1/ It is worth contrasting the money market relationship used here with the standard money market relationship used in many theoretical and empirical applications of the monetary model, that is: $m - p = \alpha_0 y - \alpha_1 i$.

2/ It is probably more likely that it is the equilibrium values of q and A which are independent of the money supply; in a world of sticky prices the actual values of q and A will in all likelihood be simultaneously determined with s. Although the theoretical model presented here does not pick up these effects (for an extension which does, see Mussa (1984)), our empirical implementation of the model does not assume continuous market clearing and may therefore be deemed consistent with, for example, sticky price behavior and other forms of inertia.

3/ The discussion here is based on Mussa (1984).

where, of variables not previously defined, z summarizes the exogenous real factors that affect domestic excess demand and foreign excess demands for domestic goods and β is a reduced form parameter containing the relevant relative price elasticities. 1/ Because the foreign country (or the rest of the world) is assumed to willingly absorb changes in assets in exchange for foreign goods, at the fixed foreign real interest rate r^*, the capital account deficit, cap, denotes the desired rate of accumulation of net foreign assets by domestic residents. The capital account deficit is assumed to be a function of the discrepancy between private agents' target level of net foreign assets, $\hat{A}$, and their current actual level, A, and the expected change in the real exchange rate:

$$cap = \mu(\hat{A}-A) - \alpha E_t \Delta q, \ \mu, \ \alpha > 0. \tag{9}$$

There are two ways of interpreting the $E_t \Delta q$ term in (9). The first is to say it captures the influence of expected changes in the value of foreign goods, measured in terms of the domestic good, on the desired accumulation of foreign assets, or simply the influence of domestic real interest rates on desired savings (that is, there is a condition of real interest parity between $E_t \Delta q$ and relative real interest rates). 2/ The condition of balance of payments equilibrium requires that the current account surplus be matched by the capital account deficit:

$$\beta (z - q) + r^* A = \mu (\hat{A} - A) - \alpha E_t \Delta q. \tag{10}$$

Since the capital account position is driven by the desired accumulation of net foreign assets, we may interpret any current account imbalance given by (10) as sustainable. The issue of sustainability is a central feature of the internal-external balance view of the determination of the exchange rate (see Bayoumi et al., 1994). If we additionally assume that the evolution of net private holdings of foreign assets is determined by the current account surplus (in the absence of official holdings of foreign assets):

$$\Delta A = \beta (z - q) + r^* A, \tag{11}$$

1/ Additionally, the β term contains income, or expenditure, elasticities. It is relatively straightforward to unravel β in terms of the underlying income, or expenditure, and price elasticities. This is not done here because it would not affect our analysis in any significant way. See Mussa (1984) for a further discussion.

2/ Note that (9) is perfectly consistent with the condition of risk-adjusted uncovered interest parity given in (5). Thus, it is straightforward to rewrite (5) in real terms, where we have a relation between the expected change in the real rate, real interest rates and a risk premium. The risk premium in (5) exists because foreign assets are imperfect substitutes for domestic (nonmoney) assets. This is captured in (9) by the term $\mu(\hat{A}-A)$.

then the two forward-looking difference equations (10) and (11) provide a solution for the two endogenous variables, A and q. The solution for the current (equilibrium) real exchange rate in (3) is given by:

$$q_t = \bar{q}_t + \tau(A_t - \bar{A}_t), \tag{12}$$

where a bar denotes an equilibrium, or desired, value. More specifically:

$$\bar{q} = \bar{z}_t + (r^*/\beta)\ \bar{A}_t, \tag{13}$$

$$\bar{z}_t = (1 - \phi) . \sum_{j=0}^{\infty} \phi^j . \ E_t z_{t+j},$$

$$\bar{A}_t = (1 - \phi) . \sum_{j=0}^{\infty} \phi^j . \ E_t \hat{A}_{t+j},$$

$$\phi = (1/(1+\eta)) \quad \text{and} \quad \tau = (\eta/\beta) - (1/\alpha) > 0,$$

and where η has the interpretation of a "discount rate." In the current context this may be shown to reflect the sensitivity of the current account surplus to the level of q and the sensitivity of the capital account deficit both to the expected change of q and to the divergence of net foreign assets from their target level. 1/

This framework usefully illustrates the dependence of the current value of the real exchange rate on two key factors. The first is the current estimate of the long-run equilibrium real exchange rate, $\bar{q}_t$. This is the rate that is expected to be consistent with current account balance, on average (in present and future periods). The second factor is the divergence between the current value of net foreign asset holdings and investors' current estimate of the long-run desired level of these holdings, $\bar{A}_t$. As Mussa (1984) has emphasized, it is important to note that this model goes far beyond the traditional flow balance of payments view of the determination of the exchange rate. This is because $\bar{q}_t$ depends on the discounted sum of present and expected future z's where it is assumed that such expectations are consistent with the economic forces that will actually determine the future real exchange rate, and also $\bar{A}_t$ depends on a discounted sum of present and expected future A's. What then are the factors determining the desired net foreign asset position, and by implication the long-run equilibrium net foreign asset position?

Usefully, Masson, Kremers, and Horne (1993) have presented a succinct summary of the long-run determinants of a country's net foreign asset position. In particular, they cite demographic factors, which reflect the age-structure of the population and have a bearing on cross country variations in savings rates and hence net foreign asset positions. Second,

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1/ More specifically, $\eta = (1/2).\{r^*+(\beta/\alpha)+[(r^*+(\beta/\alpha))^2+4.(\mu\beta/\alpha)]^{-1/2}\} > (r^*+(\beta/\alpha))$.

in a world in which Ricardian equivalence is broken, a higher level of government debt, ceterus paribus, is associated with a lower net foreign asset position. 1/

We therefore have two channels through which real factors can affect the nominal exchange rate, defined by (3). If the real factors have their affect solely through the demand for money, l, they will induce movements in the nominal exchange rate consistent with PPP. If, however, the real changes have their influence through q_t this will necessitate a change in the exchange rate and relative price configuration that implies a deviation from PPP. Nominal exchange rate movements associated with expected or unexpected changes in the discounted present value contained in P will be those consistent with PPP. The third, and final, determinant of $E_t s_n$ is $E_t p_n^*$, and movements in the latter variable will also generate expected nominal exchange rate movements which are consistent with PPP.

The above model is, we believe, an extremely useful conceptual framework for thinking about the determination of a country's exchange rate. It captures the effect of current and expected relative excess demand for money on the exchange rate in the way suggested by the asset approach to the exchange rate. Additionally, it allows for real exchange rate changes and, in particular, captures issues concerning the sustainability of current account imbalances and their implications for real and nominal exchange rates. One potential disadvantage of the model structure as portrayed above is that it is very much an equilibrium model; monetary disturbances, for example, do not have real effects (in the short run) as they would, say, in the Dornbusch (1976) model. However, in our empirical implementation of the model such disequilibria are in fact explicitly modelled. 2/ We now turn to a discussion of our econometric methods.

III. The Specification of the Determinants of the Long- and Short-Run Exchange Rate: Econometric Methods

How then may the EERM model be estimated? For estimation purposes it is useful to rearrange (3) into an expression which is analytically equivalent, namely 3/

$$s_t = (1/(\gamma + \eta)) \cdot \sum_{j=0}^{\infty} (\eta/(\gamma + \eta))^j \cdot E_t[m_{t+j} - k_{t+j}], \qquad (14)$$

where we have set t=n and

1/ This association between fiscal policy and the equilibrium rate is spelled out in some detail in Krugman (1989).
2/ For a theoretical extension of the model incorporating such effects, see Mussa (1984).
3/ See Frenkel and Mussa (1988).

$$k = K + \alpha_1 p^* - \alpha_5(i^* + \lambda) + (\alpha_4 + \sigma\alpha_1)q + \alpha_2 A.$$

Expression (14) is useful from an estimation perspective for two key reasons. First, in the context of a present value model such as (14) if the dependent variable and the right hand side variables are integrated of order 1, I(1), then it follows (see, for example, Campbell and Shiller (1988) and MacDonald and Taylor (1993)) that for the model to be valid s_t must be cointegrated with the right hand side variables. Secondly, the existence of cointegration facilitates the construction of a dynamic error correction model of the short-run exchange rate and its dynamic adjustment to the long-run equilibrium. Let us consider these two time frames in more detail.

1. The long-run relationship

The long-run equilibrium relationship, or cointegrating vector, implied by (14) is given by:

$$\bar{s} = \beta_0\bar{m} + \beta_1\bar{y} + \beta_2\bar{p}^* + \beta_3(\bar{i}^* + \bar{\lambda}) + \beta_4\bar{q} + \beta_5\bar{A}. \tag{15}$$

where

$$\beta_0, \beta_3 > 0, \ \beta_1, \beta_2, \beta_4, \beta_5 < 0$$

and, for expository purposes, we have used a bar to denote a long-run equilibrium value, y, real income, has been substituted for K and the β's are reduced form coefficients.

In testing for the existence of a relationship like (15) it has become conventional to simply use actual outcomes of the variables in a multivariate cointegration framework. In the context of the Johansen method, for example (discussed below), this simply means that the vector of variables entering (15) is equally appropriate for explaining the long-run behavior of each of the other variables entering the vector. This would imply that equation (15) could be renormalized in terms of, say, net foreign assets; however, none of the fundamental determinants of net foreign assets discussed earlier appear in (15). The specification of the long-run exchange rate relationship could, therefore, be improved by exploiting the appropriate equilibrium relationship for $\bar{A}$. In particular, we see that $\bar{A}$ is essentially the present value of expected future desired net asset accumulation, where the latter is determined by demographic factors and government budgetary imbalance. Thus, we may think of a separate cointegrating relationship determining $\bar{A}$ and this, in turn, feeds back into (15). Essentially, then, we may think of additional cointegrating, or equilibrium, relationships which may be substituted into (15) to obtain the 'true' reduced form. Distinguishing between A and $\bar{A}$ is important from the perspective of our objectives in this paper since it allows us to

incorporate a sustainability term into the short-run exchange rate equation (this is discussed in more detail below). 1/

We note from (13) that the equilibrium real exchange rate has two determinants, consisting of trade and finance components. For the trade component we follow Faruqee (1994) in utilizing two explanatory variables, namely a terms of trade (tot) index (constructed as the ratio of export unit value to import unit value) and an index of the relative price of traded to nontraded goods (tnt) 2/; these variables are designed to capture any productivity bias (i.e., the so-called Balassa-Samuelson effect). The direct effect of A on q will already be captured in the reduced form coefficient β_5 and we do not discuss it further here.

A final point regarding the specification of (15) is that we do not incorporate the risk premium term, λ_t, directly into the long-run cointegrating set. This is because theoretical models of the risk premium, such as the open economy version of Lucas' (1978) representative agent model, suggest that the risk premium is an I(0) process and therefore not a suitable candidate for a cointegrating relationship (see Hodrick, 1987) and Hallwood and MacDonald (1994) for an overview of this model). A further, more practical reason, for the non-inclusion of the risk premium is that it has proven notoriously difficult to measure and model. This last story explains why the risk premium does not appear in our short-run exchange rate modeling exercises either. 3/

2. Estimating the short- and long-run exchange rate equations: a dynamic vector error correction model

As we have noted, equation (15) describes the long-run equilibrium of the model. The EERM model discussed in the previous section suggests that the actual exchange rate will always track this level. It is clear, however, from traditional demand for money studies (see, for example, Laidler (1986)) and from the Masson et al. (1993) study of net foreign assets, that adjustment to (15) would not expect to be achieved instantly; indeed, in all likelihood adjustment will be relatively slow. How then does the exchange rate reach this equilibrium? In this paper we propose modeling the dynamics using a dynamic vector error correction model (VECM). The VECM

1/ It is worth noting that by incorporating a separate cointegration term for equilibrium real income into (15), where such equilibrium is determined by natural rate factors, we would end up with a version of the FEERs approach (that is, one which incorporates internal and external balance elements into an exchange rate equation) embedded within a more traditional model of the exchange rate.

2/ It is worth noting that for a 'dependent economy' this is the usual measure of the real exchange rate.

3/ We do not believe that this materially affects our empirical implementation.

is especially useful in the current context since it may also be used to recover the long-run relationship. The VECM is defined as:

$$\Delta x_t = \mu + \sum_{i=1}^{p-1} \Phi_i \Delta x_{t-i} - \Pi x_{t-1} + \epsilon_t, \tag{16}$$

where Δ denotes the first difference operator, x is the (nxl) vector of variables entering (15), μ is a (nxl) vector of deterministic variables, Φ is a (nxn) coefficient matrix, Π is a (nxn) matrix whose rank determines the number of cointegrating vectors, and ϵ_t is a (nxl) vector of white noise disturbances. 1/ If Π is of either full rank, n, or zero rank, $\Pi=0$, there will be no cointegration amongst the elements in the long-run relationship (in these instances it will be appropriate to estimate the model in, respectively, levels or first differences). If, however, Π is of reduced rank, r (where r<n), then there will exist (nxr) matrices α and β such that $\Pi=\alpha\beta'$ where β is the matrix whose columns are the linearly independent cointegrating vectors and the α matrix is interpreted as the adjustment matrix, indicating the speed with which the system responds to last period's deviation from the equilibrium level of s. Hence the existence of the VECM model, relative to say a VAR in first differences, depends upon the existence of cointegration. 2/ As we have noted, for our model to be valid cointegration must exist amongst the variables in (15).

As Granger, and many others have noted, if there exists cointegration amongst the variables entering x_t, and therefore Π in (16) is of reduced rank, the implication is that there must be Granger causality running from the error correction term (ECM), Πx_{t-1}, to Δx_t. There are essentially two interpretations that one can place on this relationship. First, the model may be interpreted as possessing a long-run equilibrium, although random shocks push the system away from equilibrium in the short run. The ECM term picks up such disequilibria and guides the variables of the system back to equilibrium: the ECM term therefore causes changes in the variables of the model.

An alternative interpretation is that the ECM term results from agent's forecasts of changes in the variables of interest. In circumstances where the loading of the error correction term in the exchange rate equation is significant it implies that it contains information over-and-above that contained in lagged Δs_t for forecasting Δs_{t+j}: Πx_{t-1} Granger-causes Δs_t because agents have superior information to that contained in lagged Δs_t. This latter interpretation of the present value model may be estimated along the lines suggested by Hansen and Sargent (1982) and Campbell and Shiller

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1/ It is straightforward to demonstrate that equation (16) is simply a reparameterization of a VAR in levels.

2/ The so-called Granger representation theorem (see Engle and Granger, 1987) implies that if there exists cointegration amongst a group of variables there must also exist and error correction representation.

(1987), where all of the relevant restrictions implied by forward-looking expectations have been imposed across the equations. In this paper, however, we favor the former interpretation of the ECM representation and accordingly propose estimating a parsimonious dynamic VECM model of the exchange rate. Such a representation, we believe, explicitly highlights the dynamic interactions between the menu of real and nominal variables.

We propose estimating the long-run exchange rate equation from the VECM using the methods of Johansen (1988, 1991). Since his methods are now well known we do not discuss them in detail here. Rather we note two of the tests Johansen proposes to test for the number of cointegrating vectors in a system like (15). The likelihood ratio, or Trace, test statistic for the hypothesis that there are at most r distinct cointegrating vectors is

$$LR1 = T \sum_{i=r+1}^{N} \ln(1 - \hat{\lambda}_1), \tag{17}$$

where $\hat{\lambda}_{r+1}$, ..., $\hat{\lambda}_N$ are the N-r smallest squared canonical correlations between x_{t-k} and Δx_t series (where all of the variables entering x are assumed I(1)), corrected for the effect of the lagged differences of the x process (for details of how to extract the λ_i's see Johansen 1988, and Johansen and Juselius, 1990). Additionally, the likelihood ratio statistic for testing at most r cointegrating vectors against the alternative of r+1 cointegrating vectors - the maximum eigenvalue statistic - is given by (18)

$$LR2 = T\ln(1 - \lambda_{r+1}) \tag{18}$$

Johansen (1988) shows that (17) and (18) have a non-standard distribution under the null hypothesis. He does, however, provide approximate critical values for the statistic, generated by Monte Carlo methods.

Aside from the estimation strategy, a key element in the theoretical model is the concept of current account sustainability. We propose capturing this in our dynamic modeling by incorporating a sustainability term, defined as $(\bar{A}-A)_{t-1}$. It is expected that an increase in the desired equilibrium value of net foreign assets, $\bar{A}$, relative to the actual value, A, should generate an exchange rate depreciation (that is, an improvement in competitiveness to generate the requisite current account surplus). In terms of our dynamic exchange rate modeling, the sustainability term may be interpretated as an error correction term and, by definition, is expected to be stationary; it should not therefore be incorporated directly into the x_t vector. In fact the appropriate way to deal with an I(0) variable in the context of cointegrated systems is to treat it as a deterministic variable and include it in the deterministic set, μ, thus facilitating conditioning of the exchange rate (and the other variables entering x_t). This is the procedure we follow here.

We decided to enter the sustainability term in our dynamic exchange rate equations as a separate variable in an attempt to discern if it has a

separate effect on the evolution of the exchange rate. Since $\bar{A}$ is incorporated into our long-run equation, the introduction of $(\bar{A}-A)_{t-1}$ into the dynamic equation will imply a restriction across its coefficient and the coefficient on the error correction term of the long-run exchange rate relationship. Since, however, the coefficient on the sustainability term enters all of the equations insignificantly, we do not test this restriction. 1/

IV. Data Sources

The data set used in this paper has been constructed for the effective exchange rates of the German mark, Japanese yen and U.S. dollar. The data frequency is quarterly, for the period 1973 quarter through to 1993 fourth quarter. Foreign magnitudes have been constructed on an effective basis with the same trade weights used to define the effective exchange rates. All data are taken from the IMF's IFS data base. The $\bar{A}$ series is that estimated by Masson et al. (1993) for the same three currencies studied in this paper. Unfortunately, the Masson et al. data are annual and we interpolated it to a quarterly basis. 2/ Additionally, the Masson et al. data ends in 1990 and we have updated it for our complete sample using a simple forecasting equation. 3/ Neither of these processes are ideal, but in the absence of any alternative higher frequency data we believe this represents an acceptable compromise. 4/ A useful topic for future research would involve producing a consistent quarterly time series for equilibrium net foreign assets (this is something we return to in our concluding section).

V. Empirical Results

One of the features of the modeling exercises in this paper is that the EERM model should encompass, and indeed dominate, a simple PPP relationship. The reason for this is that, as we noted earlier, although there is now a large body of evidence supporting the proposition that nominal exchange rates and relative prices are cointegrated, the relationship described does not conform exactly to a traditional interpretation of PPP (in the sense

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1/ Our empirical results are in fact qualitatively unchanged if we drop the sustainability term from our system. We have, however, retained this variable in our empirical estimates to illustrate how sustainability effects may be captured.

2/ In particular, we used a RATS program, called interpol.src, to implement the interpolation.

3/ In particular, we use an AR1 forecasting equation to generate the extra observations.

4/ We also implemented our approach using actual net foreign asset data. However, this did not prove to be as successful as using $\bar{A}$. We therefore only report our estimates with $\bar{A}$.

that symmetry and homogeneity restrictions are not supported by the data). There are therefore other factors, such as net asset accumulation and productivity shocks, which may affect the relationship between exchange rates and relative prices. We believe, therefore, that the EERM model should be well-suited to explaining this twist. Before examining the EERM model, however, we consider the usefulness of PPP as a long-run relationship for effective exchange rates and a weighted average of foreign prices); to our knowledge all of the extant research on long-run PPP has used bilateral exchange rates.

1. Tests of PPP with effective rates

One reason why effective rates may be of interest in a test of PPP is that if absolute PPP does, indeed, relate to the current account of the balance of payments and, in particular, goods arbitrage on this account, it may be more appropriate to test the relationship using "effective" prices and effective exchange rates (since the latter are constructed using trade weights). Also, of course, if bilateral PPP holds (and there is, as we have noted, compelling evidence to suggest that some form of bilateral PPP does indeed hold) it should hold by construction for aggregations using trade weights. In order to test bilateral PPP with effective exchange rates and prices we propose estimating the following relationship using the multivariate cointegration methods of Johansen; therefore, we assume the x_t vector in (16) is given by $[s_t, p_t, p_t^*]'$: 1/

$$s_t = \beta + \alpha_0 p_t - \alpha_1 p_t^* + \varphi_t. \tag{19}$$

If the variables entering x_t are integrated of order 1, I(1), then the existence of a long-run PPP relationship will be detected by a stationary, I(0), residual series, φ_t (MacDonald (1993) refers to this as 'weak-form' PPP). Additionally, the restriction of degree one homogeneity should hold with respect to the influence of prices on the exchange rate; that is, $\alpha_0 = \alpha_1 = 1$ (MacDonald (1993) classifies the existence of weak-form PPP plus degree one homogeneity as representative of 'strong-form' PPP). A less restrictive hypothesis concerning the α coefficients in (19) is that of symmetry, defined as $\alpha_0 = \alpha_1$.

In Table 1 we report λMax and Trace tests for the number of cointegrating vectors for our six exchange rate relative price combinations. 2/ In terms of these test statistics, we note that there is no evidence of cointegration, for the German mark rate, regardless of the price series used, nor is there evidence of cointegration for the U.S. dollar using the

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1/ All of the variables entering the x_t vector are I(1). The unit root properties of our complete data set are discussed below.

2/ The lag length used in the underlying VECM systems was three and was estimated on the basis of a likelihood ratio test. All of the estimated significance levels have been corrected using the small sample correction of Cheung and Lai (1993b).

Table 1. Effective Purchasing Power Parity Cointegration Tests

	Trace			λMax			β		α	LR3	LR4
Germany											
CPI	0.73	9.89	27.45	0.73	9.83	17.54	4.28	-1.87	-0.046	-	-
WPI	4.59	14.51	29.69	4.59	9.92	15.18	2.84	-2.05	0.110	-	-
Japan											
CPI	4.36	15.14	36.34*	4.36	10.77	21.20	10.69	-5.53	0.012	0.00*	0.00*
WPI	2.56	7.12	35.01*	2.56	4.56	27.89*	1.82	-1.56	-0.126	0.00*	0.00*
United States											
CPI	2.34	12.91	29.56	2.34	10.56	16.65	-58.11	69.69	-0.008	-	-
WPI	2.27	10.28	39.00*	2.27	8.02	28.72*	78.75	-90.78	0.007	0.00*	0.00*

Notes: The first column indicates the country and relevant price series used in the Johansen test. Entries in the columns directly below Trace and λMax are the estimates of the Trace (21) and λMax (22) statistics discussed in the text. The estimates of the normalized (on the exchange rate) cointegration statistics are contained in the two columns headed by β, and the entries in the α column are the estimated α coefficients from the exchange rate equation. LR3 and LR4 are, respectively, likelihood ratio tests for symmetry and proportionality. An * denotes significance at the 5 percent level.

CPI. Of the combinations that do produce cointegration, namely the Japanese yen (both WPI and CPI) and the U.S. dollar (WPI), in two instances the α term, which represents the adjustment coefficient of the nominal rate with respect to the error correction term is wrongly signed, indicating that the exchange rate moves in the opposite direction to that required for PPP to be valid. Thus, there is only one currency-price combination which produces both a significant cointegrating vector and a sensible value for α. Our findings for effective rates contrast markedly with the findings reported by a number of researchers for U.S. dollar bilateral and German mark bilateral rates. Thus, for example, MacDonald (1993) 1/ in his examination of a number of U.S. dollar bilateral exchange rates, reported strong evidence of cointegration and a correctly signed α term. In common, though, with the bilateral rate studies we note that all of the coefficients are far from their PPP-predicted values (indeed these values are much larger, in absolute terms, than the bilateral counterparts) and the formal restrictions tests are strongly rejected for currency combinations which produce a significant cointegrating vector (the statistics LR3 and LR4 are, respectively, tests of symmetry and degree one homogeneity). Purchasing power parity cannot, therefore, be regarded as a good description of the three effective exchange rates considered in this paper. Does the EERM offer a better long-run relationship for these currencies?

2. Tests of the EERM: long- and short-run relationships

As we have noted, in testing the long-run EERM relationship we use cointegration methods. In addition to the existence of cointegration, we are also interested in whether the coefficients in any long-run relationship are correctly signed and are of roughly the correct order of magnitude. Although the *a priori* signs of the coefficients entering (15) are clear enough, we do not have explicit priors on the absolute magnitudes for all of them. Thus, although the β_1 coefficient may be interpreted as the income elasticity of the demand for money, and should therefore have a value which closely corresponds to that suggested by money demand theory, the magnitude of β_5 is not tied down by theory. However, in order to test whether a coefficient is correctly signed we have to have explicit values of at least some of the variables and we therefore propose using the following coefficient grid to facilitate such testing:

$$\beta_0 = 1,\ \beta_1 = -1,\ \beta_2 = -1,\ \beta_5 = -1.$$

1/ See also Cheung and Lai (1993a) and Kugler and Lenz (1993).

Table 2. Unit Root Tests

Variable	No Trend		With Trend	
	L	Δ	L	Δ
<u>U.S. dollar</u>				
s	-1.128	-6.519	-1.560	-6.537
y	-0.230	-5.974	-2.610	-5.937
p^*	-2.376	-3.622	-1.730	-4.028
i^*	-2.182	-5.111	-2.295	-5.104
tnt	-2.875	-7.357	-3.338	-7.465
tot	-2.663	-6.380	-2.539	-6.519
A	-1.194	-4.833	-1.994	-4.768
m	-3.321	-3.690	+1.311	-5.363
<u>German mark</u>				
s	-1.544	-7.263	-2.530	-7.288
y	+0.084	-8.897	-1.846	-8.867
p^*	-2.757	-3.266	-1.686	-4.015
i^*	-2.279	-5.564	-2.377	-5.663
tnt	-2.216	-6.153	-1.226	-6.517
tot	-1.763	-6.493	-1.951	-6.487
A	-2.950	-3.982	-1.707	-5.861
m	-2.366	-18.34	+0.207	-18.91
<u>Japanese yen</u>				
s	-0.315	-5.324	-3.205	-5.343
y	-0.213	-8.549	-2.417	-8.485
p^*	-3.584	-3.571	-2.140	-4.742
i^*	-1.779	-5.974	-1.869	-5.979
tnt	-2.102	-5.866	-4.062	-5.985
tot	-2.031	-5.225	-2.995	-5.489
A	-1.808	-2.265	-2.099	-3.963
m	-2.421	-1.916	-0.499	-3.029

Notes: The numbers denote augmented Dickey Fuller (ADF) t-ratios, where the lag length used in the underlying autoregression was chosen using the Schwarz selection criterion. The column headings 'no trend' and 'with trend' indicate, respectively, that only a constant is included in the underlying autoregression and both a constant and a time trend are included. The L and Δ denote, respectively, that the unit root test relates to the level and first difference of the appropriate variable. The variables listed in the first column are as defined in the text. The 5 percent critical values for the ADF statistics are approximately -2.89, without a time trend, and -3.43 with a time trend.

These constraints are imposed not because we believe they are necessarily exactly true 1/, but because in relatively large cointegration systems such as that implied by our EERM model the imposition of a priori restrictions can result in "substantial power gains (Horvarth and Watson, 1994; see also Lee and Pesaran, 1994). The above grid of constraints is tested using a likelihood ratio test statistic and the estimated values for the three currencies are contained in the column labeled LR5 in Table 3.

In Table 2 we present a set of unit root results for the orders of integration of each of the series contained in the EERM model. The reported statistics are augmented Dickey Fuller statistics, where the lag length in the underlying VAR is calculated using a likelihood ratio test. The basic import of these tests is that, with the exception of three variables, all of the variables are I(1) at the 5 percent significance level. Of the three variables which appear stationary in levels (namely, U.S. money, m, German net foreign assets, A, and Japanese foreign prices, p^*) all of them have t-ratios which are sufficiently closed to the 5 percent critical value that we may assume they are I(1).

In Table 3 we present our results for the cointegrating analysis for the three currencies. In estimating VECM models of the form given by (16) a lag length must be chosen (i.e., the order of p). Given the relatively large number of variables entering our cointegrating set we have imposed a lag structure of two (i.e., p=2). 2/

3. The U.S. dollar

For the U.S. dollar effective rate our estimates of (17) and (18) indicate clear evidence of cointegration, although the two statistics give conflicting messages regarding the number of significant cointegrating vectors. Thus, the Trace statistic suggests three significant vectors whereas the λMax statistic is supportive of a single significant vector. We therefore err on the side of caution, interpreting these results as indicating one significant vector for the dollar.

1/ Mussa (1984), for example, makes the point that it is not vital to the validity of asset market models that degree one homogeneity should pertain in the exchange rate money supply relationship. We experimented with other numerical values for the β coefficients (for example, $0<\beta_0<1$), with the same signs as noted above, and this did not affect the results in a qualitative sense.

2/ Ideally, we would want to test down from, say, a general four lag system to the optimal lag length using some form of lag length selection criterion, such as the likelihood ratio test used in our PPP estimation. However, the relatively small number of degrees of freedom associated with the most general lag structure makes this an impractical option. As we shall demonstrate, setting p=2 produces a satisfactory set of diagnostics for all systems.

Table 3. Mulitivariate Cointegration Results for the EERM

Null Hypothesis	Dollar		Mark		Yen	
	Trace	λMax	Trace	λMax	Trace	λMax
1. Tests for the number of significant cointegrating vectors						
r=0	281.21*	80.72*	288.75*	108.18*	265.41*	89.21*
r≤1	200.44*	60.47	180.58*	72.56*	176.20*	47.73
r≤2	139.96*	53.67	108.02	44.81	128.47*	42.73
r≤3	86.28	33.05	63.21	26.97	85.75	35.93
r≤4	53.24	30.53	36.91	22.67	49.81	22.14
r≤5	22.71	10.19	14.24	9.32	27.67	16.55
r≤6	12.53	7.65	4.93	4.88	11.12	11.11
r≤7	4.88	4.88	0.05	0.05	0.01	0.01

2. Adjustment speeds and coefficient restrictions

	α	LR5
Dollar	-0.043	4.53 (0.21)
Mark	-0.114	2.56 (0.46)
Yen	-0.167	0.59 (0.44)

Notes: In part (i) of the table, the entries in the columns directly below Trace and λMax are the estimates of the Trace (21) and λMax (22) statistics discussed in the text. The r terms in the first column denote the number of cointegrating vectors and an asterisk denotes significance at the 5 percent level, using the 5 percent critical value adjusted using the small sample correction of Cheung and Lai (1993b). The numbers entering the α column, in part (ii), are the estimated adjustment coefficients from the exchange rate equation. LR5 is the likelihood ratio test for the grid restrictions noted on page of the text.

The long-run dollar exchange rate equation implied by the significant cointegrating vector is:

$$s_t = 0.80m_t - 1.76y_t - 1.48p_t^* - 0.05i_t^* - 3.49tnt_t - 2.81tot_t - 6.42\bar{A}_t. \quad (20)$$

All of the coefficients in this equation are correctly signed, apart from the foreign interest rate term. The latter effect may simply be picking up the well-known correlation between domestic U.S. interest rates and other international interest rates. Given that domestic U.S. rates do not appear in the model, the negative sign is perhaps simply picking up this correlation and could therefore be interpreted as a form of domestic interest rate effect. Indeed, imposing the coefficient grid noted above, we cannot reject the hypothesis that the coefficients are all, apart from the interest rate, correctly signed; the likelihood ratio test statistic for this hypothesis, reported in Table 3, has a chi-squared distribution with three degrees of freedom and is statistically insignificant at the 5 percent level. Notice that the α coefficient, also reported in Table 3 is correctly signed (i.e., negative) and this contrasts with the PPP result for the U.S.

The parsimonious dynamic exchange rate equation, derived from the VECM system is reported here as equation (21):

$$\underset{}{\Delta s_t} = \underset{(2.07)}{0.029} - \underset{(2.59)}{0.043ECM_{t-1}} + \underset{(0.54)}{0.058(\bar{A} - A)_{t-1}} + \underset{(2.06)}{1.053\Delta p_{t-1}^*} - \underset{(2.62)}{0.326\Delta s_{t-1}}. \quad (21)$$

R^2 =0.16 SER=0.033 DW=1.94 LB(28) = 29.88(0.19)
ARCH(2)=0.82 SKEW=0.25 EKURT=0.50 NORM=1.66

where: heteroscedastictic t-ratios are in parenthesis under estimated coefficients; R^2 denotes the coefficient of determination; SER is the standard error of the regression; DW is the Durbin Watson statistic; LB(28) is the Ljung-Box portmanteau autocorrelation statistic (with chi-squared distribution and 28 degrees of freedom); ARCH(2) is a chi-squared test (with two degrees of freedom) for second-order autoregressive conditional heteroscedasdcity in the residuals of (21); SKEW, EKURT and NORM are, respectively, tests for the skewness, excess kurtosis and normality (in the form of a Jacque Beru statistic) of the residuals in (21). The equation easily passes this set of diagnostic tests and the R^2 is reasonably good for a differenced equation. Indeed, on the basis of Mussa's (1979) criterion for a successful exchange rate model (i.e., being able to explain 10 percent of the quarter-to-quarter exchange rate change), the model may be deemed successful. The dynamic exchange rate equation is relatively simple with the only significant dynamic terms being the lagged exchange rate change and the lagged change in the foreign price level. Crucially, the error correction adjustment term, α, enters significantly and with a negative sign, thus indicating the importance of the EERM term in forcing the U.S. dollar toward its long-run value. Unfortunately, the sustainability term enters insignificantly, although correctly signed (we return to this point in our concluding section).

In Figure 1a we present plots of our long-run equilibrium relationship against the actual exchange rate for the U.S. dollar, over the full sample period. 1/ Although for some periods the two rates are quite close (a good example being late 1975-80), for much of the time the two rates appear to be divergent. The most dramatic instance of this occurs during the dramatic appreciation of the dollar in the early 1980s, where the trend in the equilibrium rate indicates a depreciation. This would seem to confirm the view of those who have suggested that the appreciation was reflecting a speculative bubble, fad or some other kind of non-fundamental behavior. The relatively low correlation between the long-run equilibrium rate and the actual outcome is confirmed by the estimated correlation coefficient for these two series, which is 0.474 (see Table 4). The comparable dynamic exchange rate relationship for the dollar is portrayed in Figure 2a. The model (that is (21)) seems to make a reasonable job of picking up the volatility of the exchange rate, and also captures a number of the turning points. Consistent with the apparent importance of non-fundamentals for the dollar, the model fails to pick out the turning point for the currency in early 1985. The correlation coefficient between the actual change and that predicted by the dynamic model is 0.396.

It is worth noting the contrast between our findings for the dollar using the EERM and those obtained for PPP. Thus, in terms of PPP we did not get cointegration on the basis of the CPI and although there is evidence of cointegration using the WPI, the coefficient of adjustment is wrongly signed. For the dollar, then, the EERM model, seems to work well in a long-run sense, particularly, in relation to the simple PPP relationship.

4. The German mark

For Germany, our success in modelling the long-run exchange rate is repeated. Thus the German data produce two significant cointegrating vectors; this result contrasting very sharply with our PPP results. Both of the significant vectors have correctly signed α terms and the vector corresponding to the largest eigenvalue (vector 1) has a reasonably rapid adjustment speed of -0.114. 2/ With two significant vectors the sign pattern is difficult to interpret, since some of the coefficients enter with an incorrect sign. We therefore formally tested the grid restrictions across the two cointegrating vectors and these were rejected at the 5 percent level. We then tried restricting the two vectors separately and

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1/ In this figure, and all other figures discussed below, the exchange rates are defined as the foreign currency price of a unit of domestic currency and therefore a rise of an exchange rate represents an appreciation. We have used this definition here to be consistent with Fund practice.

2/ The term reasonableness here relates to the speed of adjustment reported in long-run bilateral PPP relationships. For example, MacDonald (1993) reports a value for α of -0.03 for the German mark-U.S. dollar in a study of a number of bilateral long-run PPP exchange rate equations.

Table 4. Correlation Coefficients Between Actual and Fitted Values

	Long-Run Equation	Short-Run Equation
Dollar	0.474	0.396
Mark	0.675	0.324
Yen	0.963	0.540

Notes: The numbers are correlation coefficients between the actual exchange rate level and long-run exchange rate (under column labeled Long-Run Equation) and the actual change in the exchange rate and the change predicted by the dynamic error correction model (under column labeled Short-Run Equation). The currencies are indicated in column one.

with vector two we were unable to reject the grid restrictions. The restricted version of vector 2 is reported here as equation (23).

$$s_t = 1.00m_t - 1.00y_t - 1.00p_t^* - 0.28i_t^* - 12.91tnt_t - 9.79tot_t - 1.00\bar{A}_t. \quad (23)$$

As in the case of the long-run U.S. dollar equation, all of the coefficients are correctly signed apart from the foreign interest rate term. Unfortunately, the single equation exchange rate model implied by the VECM had no significant dynamic terms. Dynamic terms were, however, significant in the other equations of the system and we interpret these as feeding through into the significant error correction term in the exchange rate equation forcing it back to the equilibrium value.

In Figure 1b we report the plots of the equilibrium rate implied by (23) and the associated actual rate for the mark. The association is close, particularly for the 1970s, with the actual rate cycling around the equilibrium value. The association from the mid-1980s onwards is less good; this presumably is in large measure a reflection of the impact of German reunification. The correlation coefficient between the actual and equilibrium values, reported in Table 4, is 0.675, which is higher than the corresponding value for the U.S. dollar. Consistent with our discussion of the dynamic relationship noted above, the plot of the actual change in the mark against the model predicted change, reported in Figure 2b, is not that impressive in that the fitted change is relatively flat compared to the actual change.

5. <u>The Japanese yen</u>

The EERM relationship for the Japanese yen also exhibits strong evidence of cointegration. In particular, there is evidence of one significant vector on the basis of the λMax test and three on the basis of the Trace test. We therefore again err on the side of caution and interpret these results as suggesting two significant cointegrating vectors. A formal test of our grid restrictions did not result in rejection and the restricted vector is reported here as equation (24).

$$s_t = 1.00m_t - 1.00y_t - 1.84p_t^* + 0.01i_t^* - 0.99tnt_t - 0.61tot_t - 1.00\bar{A}_t. \quad (24)$$

Interestingly, all of the coefficients are correctly signed in this equation (including the foreign interest rate term, which was wrongly signed for the other two currencies). Further support for the model may be adduced from the fact that the speed of adjustment term, α, is negative and, indeed, is the largest in, absolute terms, for the three currencies. Furthermore, the α term implied by the EERM is larger than that for the only successful PPP relationship, that for the yen using WPI's.

The parsimonious dynamic equation derived from the VECM is reproduced here as equation (25) 1/

$$\underset{}{\Delta s_t} = \underset{(2.62)}{-1.467} - \underset{(2.49)}{0.149ECM_{t-1}} - \underset{(0.26)}{0.035(\bar{A}-A)_{t-1}} - \underset{(1.47)}{0.171\Delta tot_{t-1}} - \underset{(2.06)}{0.343\Delta s_{t-1}}, \quad (25)$$

R^2 =0.30 SER=0.039 DW=1.98 LB(20) = 23.35(0.27)

ARCH(2)=6.74 SKEW=0.10 EKURT=-0.62 NORM=1.43,

where terms have the same interpretation as in the definitions given immediately under equation (21). Again the dynamic equation is relatively simple, but passes a standard set of diagnostic tests. Interestingly, the change in the terms of trade is significantly negative, suggesting that productivity changes (which is what tot is proxying in our model) are an important determinant of the short-run appreciation of the yen. The sustainability term is wrongly signed and statistically insignificant. As in the case of the U.S. dollar the lagged change in the exchange rate and the error correction terms are statistically significant determinants of the short-run exchange rate change. The R^2 is about double that for the U.S. dollar and, on the basis of the Mussa criteria for gauging the success of an exchange rate model, this would be deemed a very successful model.

The plots of both the equilibrium yen against the actual yen and the model predicted change in the yen against the actual change are reported in Figures 1c and 2c, respectively. Interestingly, the actual value of the yen tracks the equilibrium value very closely throughout the period, the correlation coefficient being 0.963. Also, the volatility of the model-predicted change in the yen is very close to the actual change, and the fitted change makes a reasonable job of tracking the actual change (the correlation coefficient here is 0.540). The close correspondence, particularly for the equilibrium rate, is much better than for the other currencies and suggests, therefore, that either the EERM model is better suited to explaining the external value of the yen than for the other two currencies, or that the yen was the only one of the three currencies which was close to its equilibrium value for our sample period.

VI. Summary and Concluding Comments

In this paper we have taken the recent research on long-run exchange rate modeling as our point of departure. In particular, we have taken the finding that the long-run relationship between bilateral currencies and relative prices does not conform exactly to that described by purchasing

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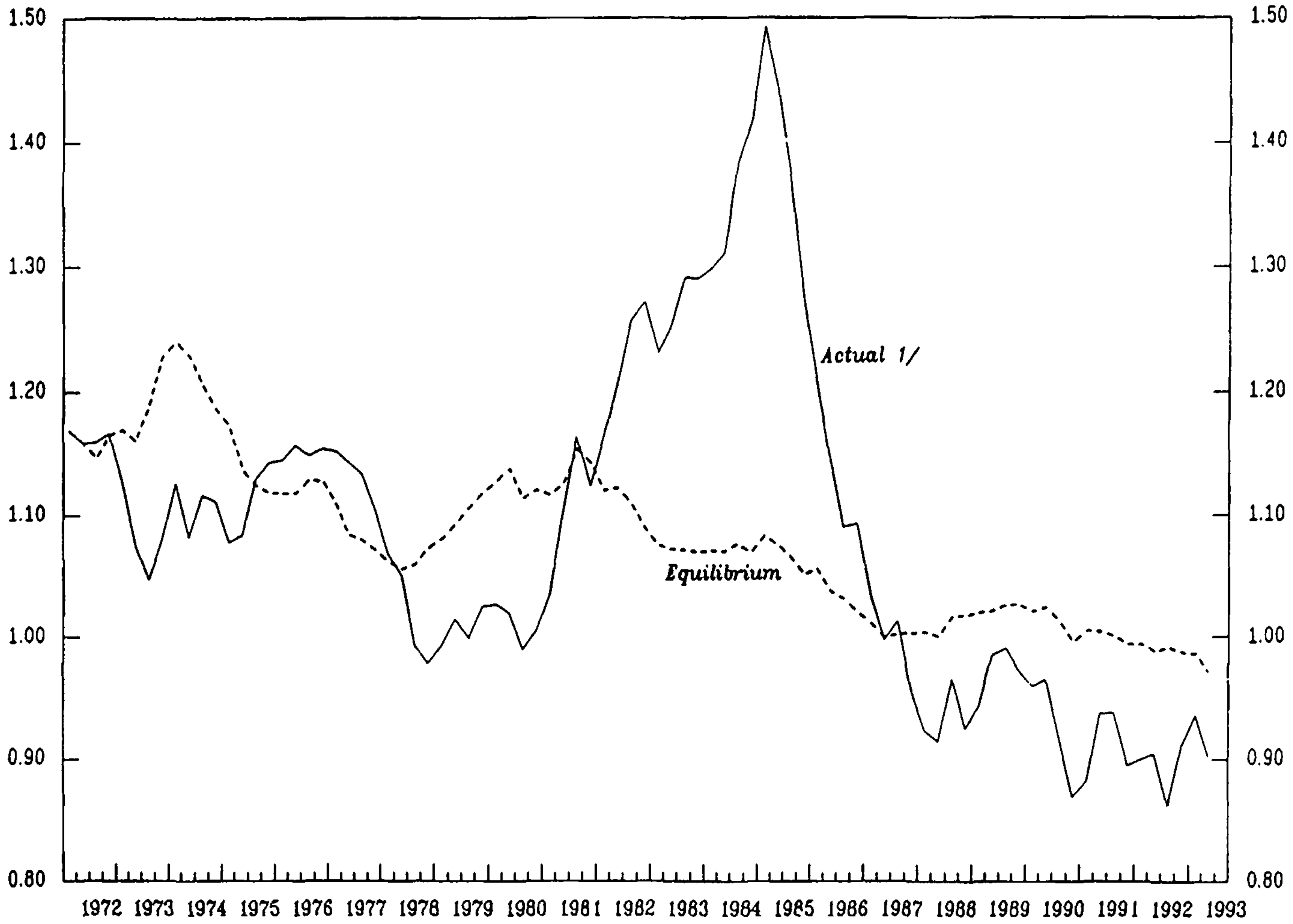
1/ Although we could not, as we noted above, reject the grid restrictions on the long-run vector, the restricted long-run vector entered the dynamic equation insignificantly; we therefore used the unrestricted ECM in the dynamic equation, which is that reported in equation (25).

Figure 1a

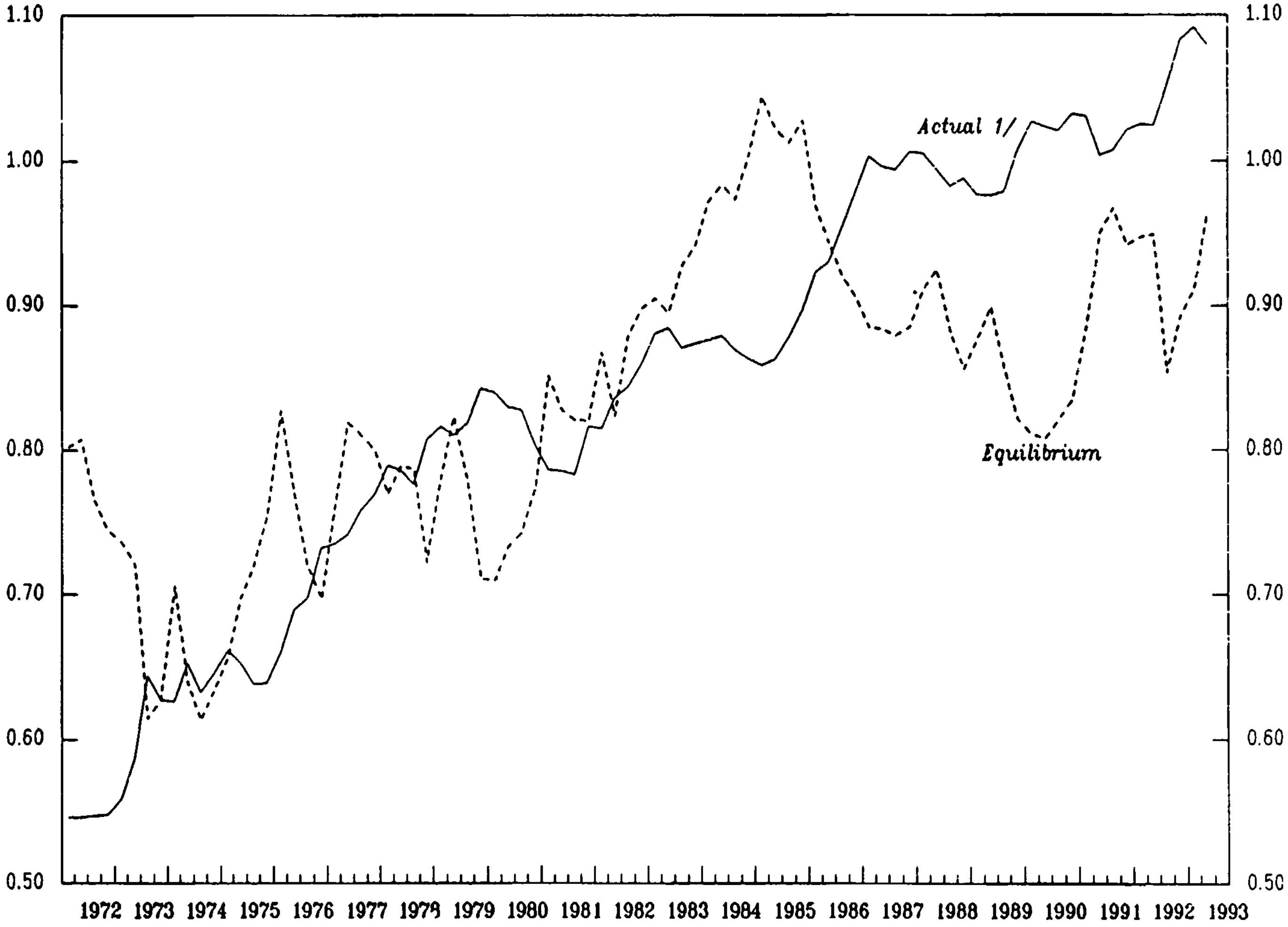
U.S. Dollar Long-Run Equilibrium



1/ Nominal effective exchange rate using trade weights of 21 industrial countries; 1987 = 1.

Figure 1b

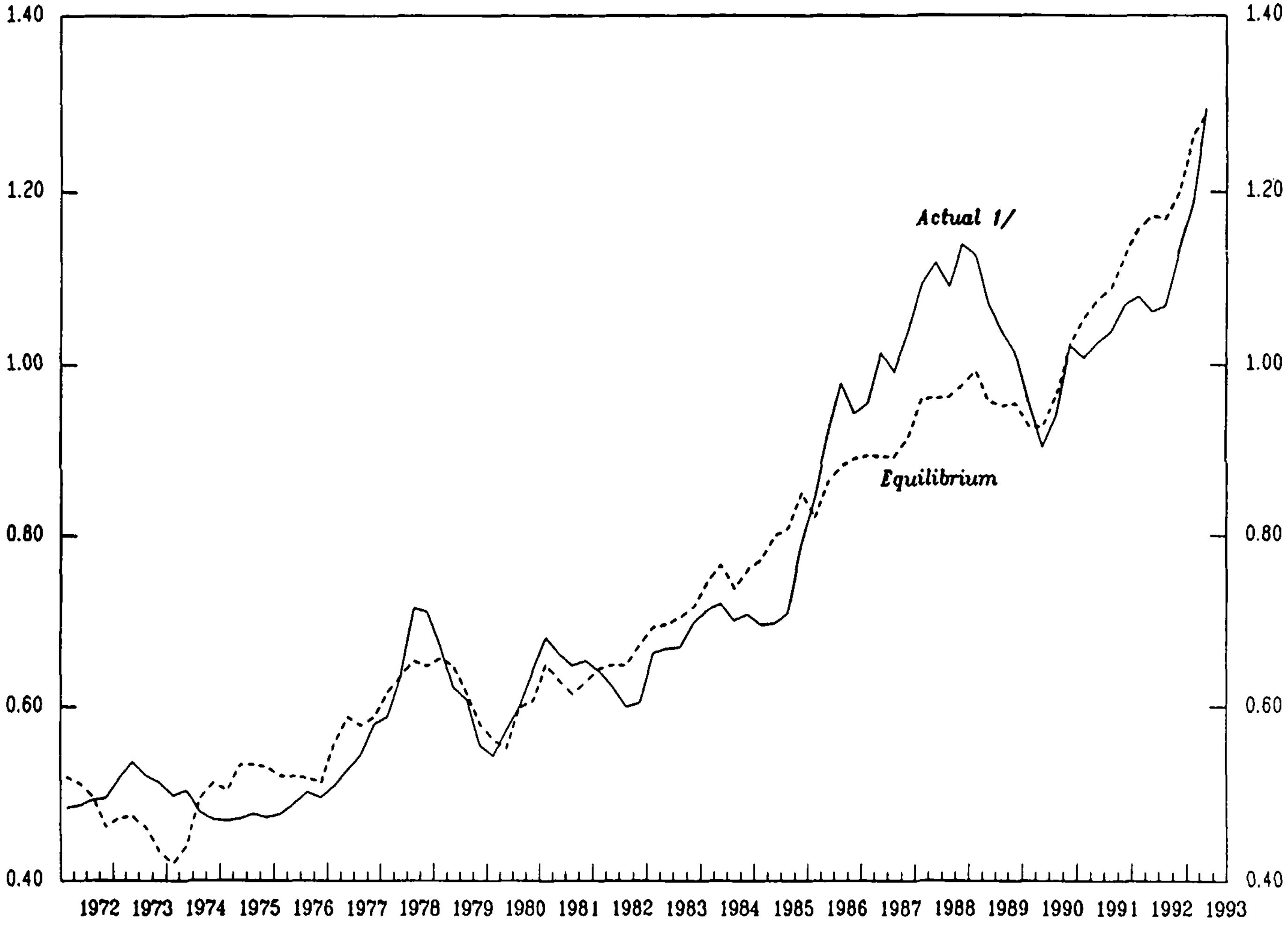
Deutsche Mark Long-Run Equilibrium



1/ Nominal effective exchange rate using trade weights of 21 industrial countries; 1987 = 1.

Figure 1c

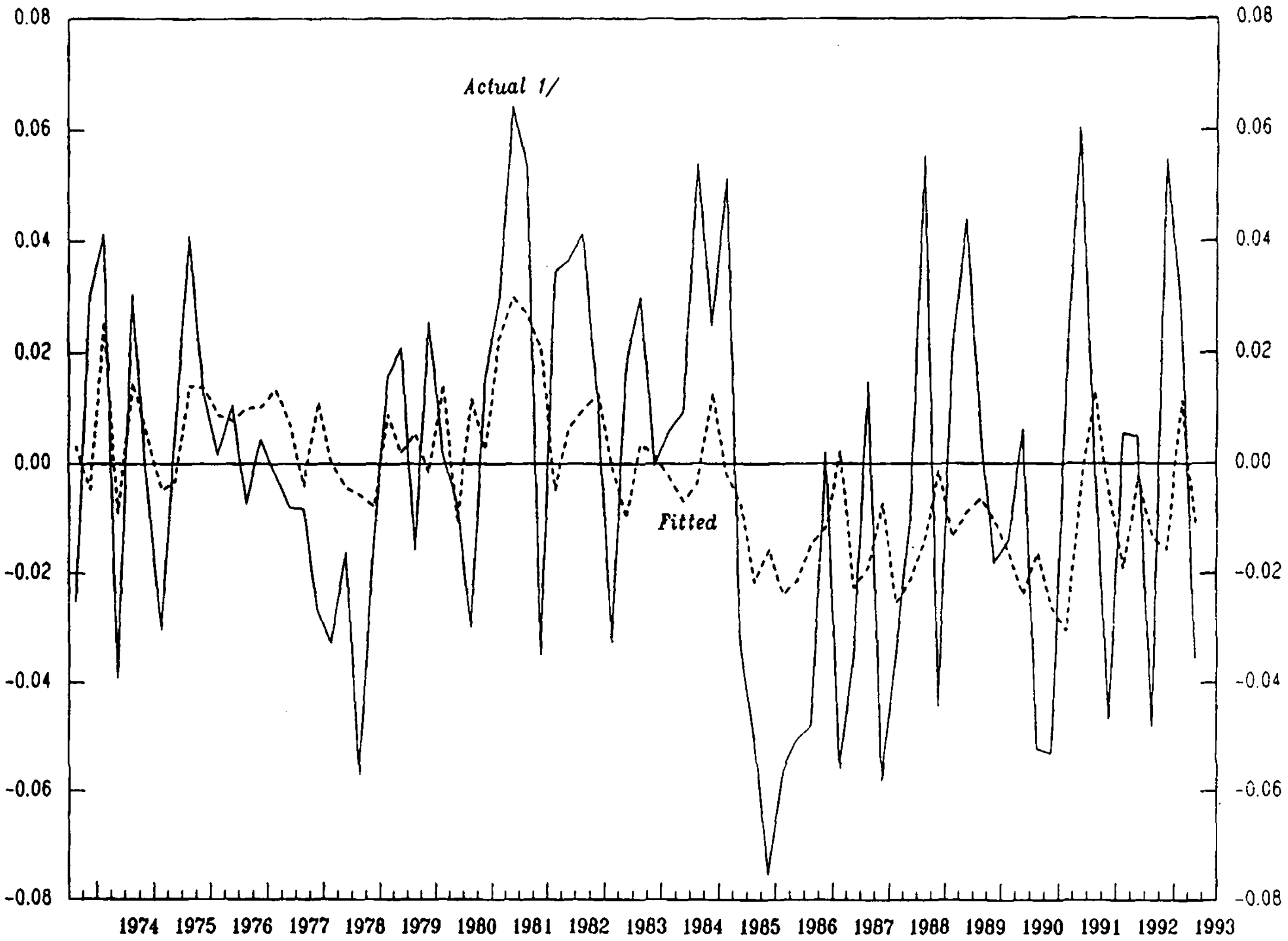
Japanese Yen Long-Run Equilibrium



1/ Nominal effective exchange rate using trade weights of 21 industrial countries; 1987 = 1.

Figure 2a

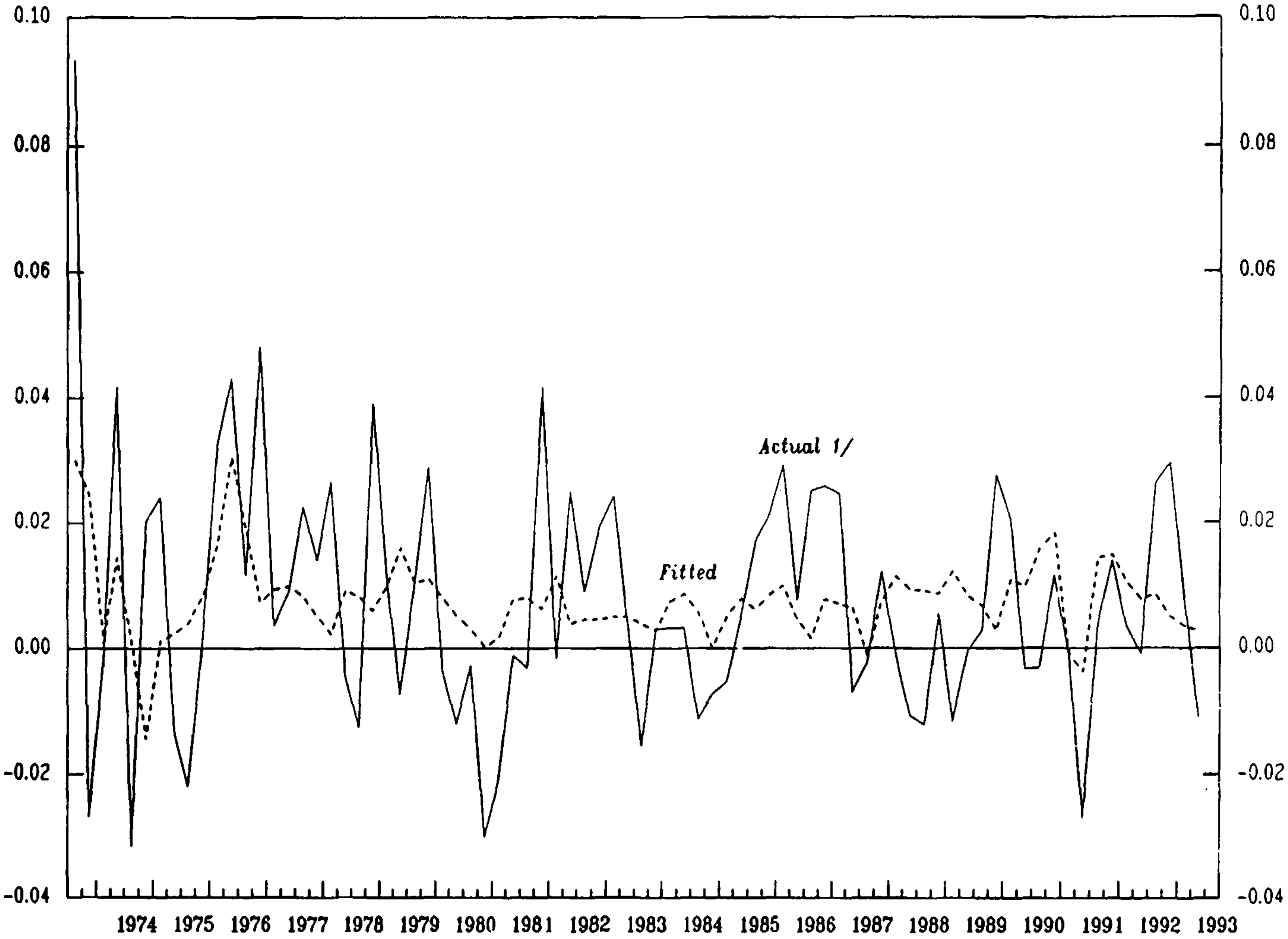
Log Change in U.S. Dollar



1/ Nominal effective exchange rate using trade weights of 21 industrial

Figure 2b

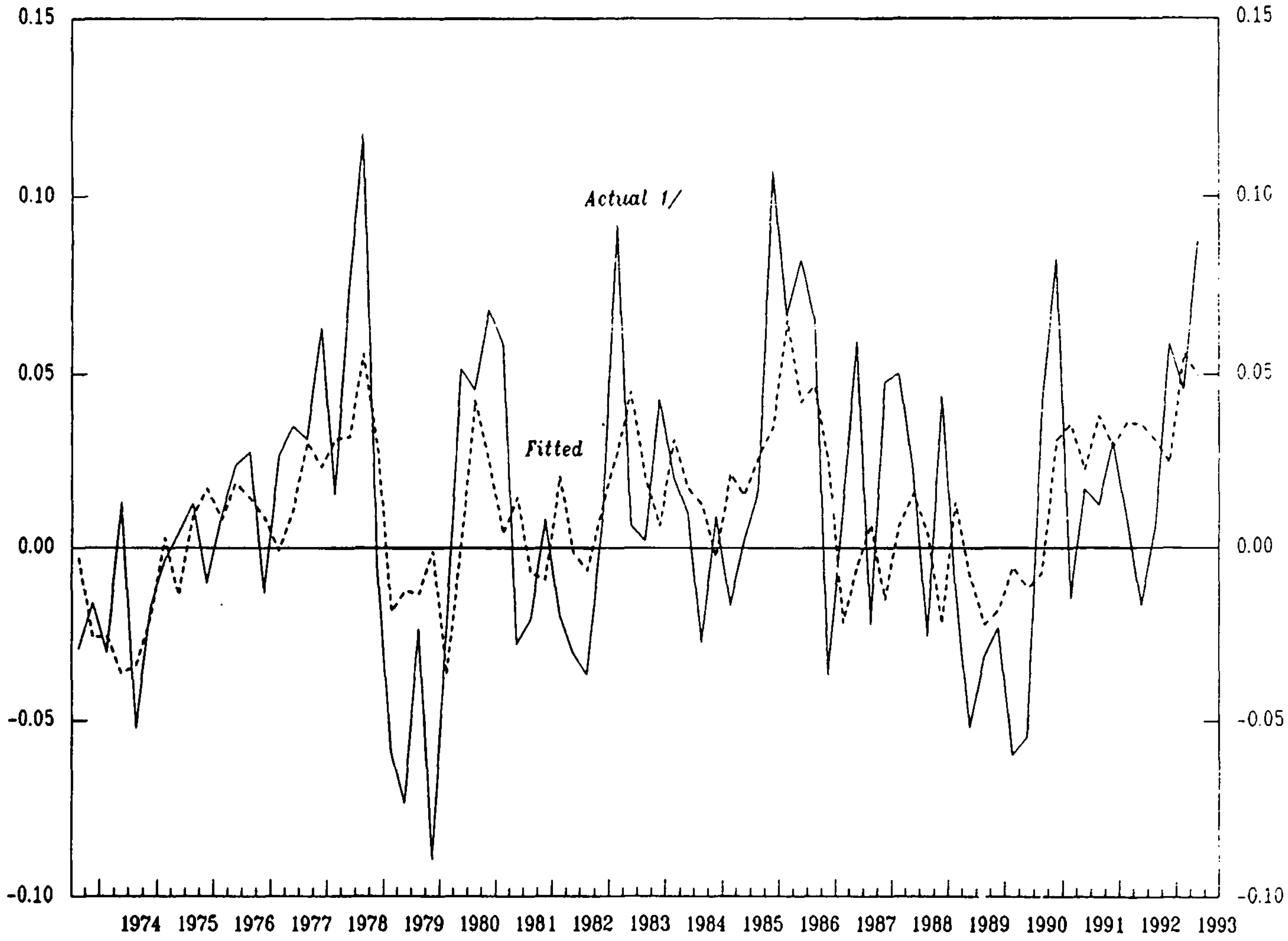
Log Change in Deutsche Mark



1/ Nominal effective exchange rate using trade weights of 21 industrial

Figure 2c

Log Change in Japanese Yen



1/ Nominal effective exchange rate using trade weights of 21 industrial

power parity as a discrepancy worth explaining. We sought to explain this discrepancy using a model labeled the eclectic exchange rate model (EERM); that is, a model which combines both real and nominal determinants of the exchange rate. Since the model features net asset accumulation, and in particular the sustainability of such, we have used effective exchange rates in our modeling strategy. A number of findings emanate from our work.

First, we demonstrated that for effective exchange rates purchasing power parity relationships work very badly compared to their bilateral counterparts. Thus, for the six currency-price combinations studied in this paper, only three produce evidence of a long-run relationship and of these three only one was sensible from an economic perspective. Thus, there would appear to be more to explain in the effective exchange rate-relative price configuration than for comparable bilateral relationships. We believe our empirical implementation of the EERM did relatively well in this regard. Thus, for each of the three currencies we found strong evidence of cointegration for the EERM model and each of the models had correctly signed and significant adjustment coefficients. Two of the models produce successful short-run dynamic exchange rate equations (those for the U.S. dollar and Japanese yen). The absence of significant dynamics for the German mark perhaps reflected the effect of the reunification process on the German data.

We consider our modeling strategy to have been reasonably successful, particularly when compared to PPP and, therefore, propose that our approach warrants further research. Such research could proceed in a number of directions. First, our modeling exercises could be conducted for real exchange rates, rather than nominal rates, and this should result in a more parsimonious exchange rate model which could be estimated as a system. Such a modeling strategy would help to bring out the simultaneities between the variables in a natural and illuminating way. Second, since it is really bilateral rates that are the market determined rates, effective rates being, at best, a mongrelization of bilateral rates, it would be of some interest to apply our methods to bilateral rates (particularly since PPP seems to work much better for such rates, and therefore one would be building on a better foundation). One stumbling block in this regard is the lack of bilateral time series data on net foreign asset accumulation. There are, however, time series methods available which could allow a researcher to extract the bilateral information from the effective series. As a related theme, producing quarterly data on equilibrium net foreign assets is we believe extremely worthwhile, particularly if it resulted in the construction of sensible sustainability measures.

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