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THE FORWARD EXCHANGE RATE BIAS: A NEW EXPLANATION

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ABSTRACT

Although the literature has devoted prodigious resources to investigating the risk premium explanation of the systematic time-varying discrepancies between forward and corresponding future spot exchange rates, empirical verification of the risk premium hypothesis has proven elusive. This paper tests an alternative explanation of the forward bias: the anticipated real exchange rate hypothesis. This hypothesis states that except for a constant risk premium, the predictable, time-varying wedge between forward and expected future spot exchange rates is fully explained by the anticipated rate of change in the real exchange rate. The data do not reject this hypothesis. This suggests that the literature's almost singular concern with the risk premium explanation of the forward bias should be amended to include the effects of anticipated real exchange rate movements.

The Forward Exchange Rate Bias: A New Explanation

Ross Levine[1]

I. Introduction

It is widely recognized that there exists a systematic time-varying discrepancy between forward and corresponding future spot exchange rates.[2] In searching for the source of this forward bias, the literature has focused almost exclusively on the risk premium explanation and ignored the potential role of anticipated real exchange rate movements in determining the forward bias. In fact, the vast majority of theoretical asset pricing paradigms assume that real exchange rate changes are unpredictable and thus equate the forecastable component of the forward bias with the risk premium reflected in expected real interest rate differentials. As a result, the literature frequently refers to the forward bias as "the forward exchange risk premium."[3] Nonetheless, empirical support for the risk premium hypothesis has proven elusive [Frankel (1982), Frankel and Engel (1984), Hodrick and Srivastava

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1. The author is an economist in the International Finance Division. This paper represents the views of the author and should not be interpreted as reflecting those of the Board of Governors of the Federal Reserve System or other members of its staff. I would like to thank Heidi Lyss for outstanding research assistance. Very beneficial comments were received from M. Carkovic, J. Coleman, H. Edison, J. Gagnon, D. Howard, D. Hsieh, J. Marquez, D. Pauls, G. Schinasi, and especially D. Gordon.

2. See, for example, Hansen and Hodrick (1980, 1983), Hodrick and Srivastava (1984), Cumby and Obstfeld (1984), Fama (1984), Korajczyk (1985), Geweke and Feige (1979), and Stockman (1978).

3. See: the asset pricing models by Kouri (1977), Hodrick (1981), Stulz (1981, 1987), Lucas (1982), and Levine (1989a); the reviews of the literature by Levich (1985) and Meese (1989); and the papers by Domowitz and Hakkio (1985), Mark (1985b), Giovannini and Jorion (1987), Campbell and Clarida (1987), Sweeney (1986), and Cosset (1984).

(1984), Cumby (1988), Meese (1989)], while Levine (1989b) rejects the risk premium hypothesis as a complete explanation of the forward bias.[4]

This paper empirically evaluates the importance of anticipated real exchange rate movements in determining the time-varying wedge between forward and expected future spot exchange rates. As we will show formally below, a few basic conditions common to almost all international finance model suggest that if agents anticipate real exchange rate movements, these anticipations will create a wedge between forward exchange rates and expected future spot prices. Intuitively, this discrepancy arises because in writing a forward contract to exchange two currencies at a future date, the forward exchange rate must incorporate the expected change in the real exchange rate in order to compensate the investor receiving the asset expected to be less valuable. If expected real exchange rate changes were not fully reflected in a wedge between forward and expected future spot exchange rates, a riskless arbitrage opportunity would arise that could be exploited in existing asset markets. If the expected rate of change in the real exchange rate varies over time, then the expected difference between forward and future spot exchange rates will also vary.

4. Although alternative explanations have been advanced, empirical support for these theories is similarly limited. For example, Frankel and Froot (1987) argue that agents make systematic mistakes, and reject rational expectations. But, as the authors discuss, there are important problems with using survey data, and it is unclear whether the data accurately reflect the margin at which financing decisions are made. Krasker (1980), Flood and Garber (1983), Obstfeld (1986), Borensztein (1987), Tabellini (1988), Kaminsky (1988), Levine (1988), and Lewis (1988) suggest that even if expectations are rational ex ante, they may appear biased in the ex post sample if there is the possibility of a large policy switch. This "peso problem" or "process switching" phenomenon, however, has also not been convincingly identified.

In examining the empirical relevance of anticipated real exchange rate changes causing the observed forward bias, this paper goes to the opposite extreme from the literature's almost singular concern with the risk premium hypothesis: we test the hypothesis that anticipated real exchange rate changes <u>fully</u> account for the observed systematic, time-varying discrepancies between forward and future spot exchange rates. This "anticipated real exchange rate hypothesis" leads to testable restrictions on the parameters of a multivariate regression model. An inability to reject these restrictions may not lead us to accept the null hypothesis that only expected real exchange rates drive a time-varying wedge between forward and expected future spot prices. But, an inability to reject the restrictions would strongly suggest that expected real exchange rate movements are an important factor keeping forward exchange rates from equalling expected future spot prices.

Perhaps one reason the profession has ignored the anticipated real exchange rate explanation of the forward bias is that considerable empirical work suggests that real exchange rate changes are unpredictable [Roll (1979), Frenkel (1981), and Adler and Lehman (1983)]. Therefore, in order to test the anticipated real exchange rate hypothesis, we must first demonstrate that real exchange rate changes are indeed forecastable. Consequently, this paper tests two sequential null hypotheses: (1) real exchange rate changes are unpredictable, i.e., ex ante purchasing power parity holds; and (2) the intertemporal deviations between forward and expected future spot exchange rates equal the expected rates of change in real exchange rates. In contrast to past work, we reject the first hypothesis and conclude that information available at time t is useful in predicting the rate of change in the real exchange rate between periods t and t+1.[5] In addition, we cannot reject the second hypothesis that anticipated real exchange rate movements fully account for the time-varying wedge between forward and corresponding expected future spot exchange rates. This leads us to conclude that anticipated real exchange rate movements are an important component of the forward bias. Given the literature's almost exclusive focus on the risk premium hypothesis, these results are surprising and suggest that considerably more attention needs to be placed on incorporating anticipated real exchange rate movements into our asset pricing models and our explanations of the forward bias.[6]

Section II derives the testable restrictions, and describes the estimation methodology. Section III presents the empirical work. The data strongly reject the ex ante purchasing power parity hypothesis, but do not reject the anticipated real exchange rate explanation of the forward bias. Thus, although a constant risk premium may be a component of the forward bias, the empirical results strongly imply that anticipated real exchange rate movements are an important factor determining the observed time-varying discrepancies between forward and future spot exchange rates. The tests conducted in this paper are not tests of a particular model. Rather, they test whether the data are consistent with a few conditions common to a broad class of models. Section IV summarizes the results.

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5. Also see Krugman (1978), Darby (1983), Mishkin (1984), Cumby and Obstfeld (1984), Huang (1987), Edison and Klovland (1987), and Huizinga (1987).

6. See, for example, Stulz (1987) and Levine (1989a).

II. The Forward Bias and Expected Real Exchange Rate Changes

The unbiased forward rate hypothesis (UBFR) states that the forward exchange rate equals the market prediction of the corresponding future spot price. In logarithmic form this implies that

$$(1) \qquad E[s_{t+1} - f_t | \phi_t] = 0,$$

where

s_{t+1} is the logarithm of the spot exchange rate at time t+1 expressed, for example, in dollars per foreign currency;

f_t is the logarithm of the forward exchange rate set at time t, payable at t+1, and also expressed in dollars per foreign currency;

ϕ_t is the information set available at time t; and

E(.) is the expected value operator.

A substantial empirical literature convincingly rejects the UBFR hypothesis by demonstrating that information available at the signing of the forward contract is useful in predicting ex post discrepancies between forward and future spot exchange rates. This literature also shows that the forward bias varies substantially through time. The source of these time-varying systematic discrepancies between forward and future spot exchange rates, however, is still unclear. Following Korajczyk (1985), this section develops a theoretical framework and testing procedure designed to determine the relative importance of anticipated real exchange rate changes and risk premia in explaining the intertemporal variation of the forward bias.

The Covered Interest Rate Parity (CIRP) condition states that in an unrestricted market, two nominally riskless investments must have the same nominal rate of return or else profitable and riskless arbitrage opportunities would exist. Frenkel and Levich (1975), McCormick (1979), Frankel and MacArthur (1988) present empirical support for the CIRP condition. In logarithmic form the CIRP condition may be written as

(2) $${}_t i_{t+1} = {}_t i^*_{t+1} + f_t - s_t,$$

where

${}_t i_{t+1}$ = the continuously compounded yield on a 1-period nominally riskless bond denominated in (for example) dollars (from t to t+1); and

${}_t i^*_{t+1}$ = the continuously compounded yield on a foreign denominated 1-period nominally riskless bond (from t to t+1).

The logarithm of the nominal exchange rate at time t+1 may be specified as

(3) $$s_{t+1} = p_{t+1} - p^*_{t+1} + d_{t+1},$$

where p_{t+1} is the logarithm of the U.S. price level, p^*_{t+1} is the logarithm of the foreign price level, and d_{t+1} is the logarithm of the relative price of a bundle of U.S. goods for a bundle of foreign goods. The term d_{t+1} is often called the logarithm of the real exchange rate (or the logarithm of the deviation from purchasing power parity) at time t+1.

In the empirical work, equation (3) defines the logarithm of the real exchange rate.

Differencing equation (3), substituting for s_t from equation (2), and rearranging, we obtain an expression for the ex post difference between s_{t+1} and f_t:

$$(4) \qquad s_{t+1} - f_t = d_{t+1} - d_t - {}_ti_{t+1} + {}_ti^*_{t+1} + \pi_{t+1} - \pi^*_{t+1} ,$$

where π_{t+1} equals $p_{t+1} - p_t$, the domestic inflation rate from period t to t+1, and π^*_{t+1} is the corresponding foreign inflation rate.

Abstracting from tax issues raised by Darby (1975), we can simplify equation (4) by using the Fisher equation which decomposes the nominal return on a nominally riskless asset in to the expected real return and the expected inflation rate. Formally,

$$(5a) \qquad {}_ti_{t+1} = E(r_{t+1}|\phi_t) + E(\pi_{t+1}|\phi_t),$$

$$(5b) \qquad {}_ti^*_{t+1} = E(r^*_{t+1}|\phi_t) + E(\pi^*_{t+1}|\phi_t),$$

where r_{t+1} [r^*_{t+1}] is the real return on a nominally riskless U.S. [foreign] bond maturing at time t+1, and where the real return is evaluated using the U.S. [foreign] inflation rate. In what follows, equations (5a) and (5b) may also be viewed as definitions of the expected real return on nominally riskless bonds. Note that the expected real return on a foreign bond held by a foreign resident may differ from the expected real return on a foreign bond held by a U.S. resident because of anticipated real exchange rate changes. For example, if $E(r^*_{t+1}) = E(r_{t+1})$, then a U.S. resident would expect a higher real return from holding foreign bonds than from holding U.S. bonds if he anticipates a real depreciation of the dollar.[7] Thus, if agents anticipate real exchange rate movements, the expected real return on the same asset will differ internationally.

Substituting (5a) and (5b) into (4) and taking expectations as of time t, we obtain an expression for the forecastable differences between forward exchange rates and expected future spot prices:

$$(6) \qquad E[(s_{t+1} - f_t)|\phi_t] = E[(d_{t+1} - d_t)|\phi_t] + E[(r^*_{t+1} - r_{t+1})|\phi_t] .$$ [8]

Equation (6) implies that the UBFR hypothesis will not hold unless (1) the expected rate of change in the real exchange rate is zero ($[(d_{t+1})|\phi_t] = d_t$); and (2) expected real returns on nominally riskless bonds are equal internationally ($E[(r^*_{t+1}|\phi_t] = E[(r_{t+1})|\phi_t]$).[9]

Condition (1), $[(d_{t+1})|\phi_t] = d_t$, is the ex ante purchasing power parity condition, often referred to as Roll's (1979) "efficient market

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7. Implicit in this discussion is a definition of residency: a U.S. resident is someone who purchases his goods in the U.S. and deflates nominal returns by the U.S. price level.

8. This expression has been used by Hooper and Morton (1982), Shafer and Loopesko (1983), Hooper (1985), and Hooper and Mann (1987) to study economic issues dealing with exchange rate and current account determination.

9. The anticipated discrepancy between forward and future spot prices would equal zero if the expected real return differential and the expected rate of change in the real exchange rate were perfectly negatively correlated. But, Campbell and Clarida (1987) and Meese and Rogoff (1988) present evidence contrary to this proposition.

version of PPP" (EPPP). The EPPP hypothesis states that real exchange rate changes are unpredictable, and implies that expected real asset returns are independent of investor nationality. If the EPPP hypothesis is violated, then the expected real return on an asset is a function of the country in which real returns are evaluated, and the forward exchange rate will not equal the market's expected future spot exchange rate as evinced in equation (6).

Empirically, condition (1), $E[(d_{t+1} - d_t)|\phi_t] = 0$, has been tested by analyzing whether or not $\boldsymbol{\beta} = \mathbf{0}$ in the regression equation:

$$d_{t+1} - d_t = X_t\boldsymbol{\beta} + e_{t+1}, \tag{7}$$

where X_t is a subset of the information set ϕ_t and $E[e_{t+1}|X_t] = 0$. Studies by Roll (1979), Frenkel (1981), Adler and Lehman (1983), and Mishkin (1984), cannot reject the EPPP hypothesis and conclude that real exchange rate changes are unpredictable. Using the two-step two-stage least-squares procedure developed by Cumby, Huizinga, and Obstfeld (1983) and adding a correction for conditional heteroskedasticity, Cumby and Obstfeld (1984) and Huang (1987) present evidence that is inconsistent with the EPPP hypothesis. This paper uses variables suggested by theory to reject <u>directly</u> the hypothesis that $\boldsymbol{\beta} = \mathbf{0}$ in equation (7), and goes on to explore the role of anticipated real exchange changes in the pricing of forward exchange rates.

Condition (2), $E[(r^*_{t+1} |\phi_t] = E[(r_{t+1})|\phi_t]$, lies at the heart of the risk premium explanation of the forward bias. If agents are risk averse and national currencies have different purchasing power risks, a variety of asset pricing models predict the rejection of condition (2):

assets considered to be more risky must compensate investors with a risk premium in the form of higher expected real returns. Indeed, a diverse set of paradigms equate the forecastable deviations between forward and future spot exchange rates with the risk premium reflected in expected real interest rate differentials on nominally riskless bonds [see, for example, Kouri (1977), Hodrick (1981), Stulz (1981), and Hodrick and Srivastava (1984)]. Although these models characterize the term, $E[(r^*_{t+1} - r_{t+1})|\phi_t]$, differently, they all refer to the expected real rate differential as the forward foreign exchange market risk premium. To the extent that the relative purchasing power risk of national currencies varies over time, the resultant time-varying forward exchange risk premium will be reflected in systematic, time-varying differences between forward and future spot prices. If the relative purchasing power risk of currencies is constant, however, risk premia will not be able to track the observed intertemporal movements between forward and future spot exchange rates. Mishkin (1984) and Cumby and Obstfeld (1984) reject the equality of expected real interest rates, and we should therefore not expect the UBFR hypothesis to hold. Just as importantly, however, Cumby and Obstfeld (1984) and Campbell and Clarida (1987) present empirical evidence consistent with the hypothesis that these expected real rate differentials are constant for major industrialized countries.[10]

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10. Also see: Mark (1985a), Merrick and Saunders (1986), and Cumby and Mishkin (1986).

Thus, as past empirical work suggests, we assume that

$$E[(r^*_{t+1} \,|\phi_t] = E[(r_{t+1})|\phi_t] + c,$$

where c is some constant. Equation (6) then becomes

$$(8) \qquad E[(s_{t+1} - f_t)|\phi_t] = E[(d_{t+1} - d_t)|\phi_t] + c.$$

Equation (8) formally expresses the anticipated real exchange rate hypothesis of the forward bias: except for a constant risk premium, the predictable difference between the forward exchange rate and the expected future spot rate equals the expected rate of change in the real exchange rate.

Intuitively, this anticipated real exchange rate hypothesis is straightforward and similar to the risk premium explanation of the forward bias. If two investors are writing a forward contract to exchange two currencies at a future date, the forward exchange rate must incorporate the expected change in the real exchange rate in order to compensate the agent receiving the asset expected to be less valuable. Unlike the risk premium hypothesis, even risk neutral agents will demand this compensation for anticipated real exchange rate movements. If expected real exchange rate changes are not fully reflected in a discrepancy between forward and expected future spot exchange rates, a riskless arbitrage opportunity will exist. In other words, covered interest rate parity, expected real exchange rate changes, and the forward exchange rate equalling the market's expected future spot value are inconsistent. To show this, consider a situation in which nominal and real interest rates are equal internationally and where there is no inflation, i.e., ${}_t i_{t+1} = {}_t i^*_{t+1}$, $E[\pi_{t+1}|\phi_t] = E[\pi^*_{t+1}|\phi_t] = 0$, and $E[(r^*_{t+1})|\phi_t] = E[(r_{t+1})|\phi_t]$ and c = 0 for all t. Also, suppose that in period t, the expected rate of change in the real exchange rate is positive and equal to k, i.e., $E[(d_{t+1} - d_t)|\phi_t] = k$. Given the other assumptions, this implies that the expected rate of change in the nominal exchange rate also equals k, i.e., $E[(s_{t+1} - s_t)|\phi_t] = k$. Under these conditions, if the forward exchange rate were to equal the expected future spot exchange rate ($f_t = E[s_{t+1}|\phi_t]$), then the following riskless arbitrage opportunity would exist: borrow one dollar domestically at the domestic interest rate ${}_t i_{t+1}$, convert the dollar into foreign currency at the period t nominal exchange rate, invest in a foreign bond at ${}_t i^*_{t+1}$ (= ${}_t i_{t+1}$), cover the investment in the forward exchange market by purchasing dollars forward at f_t, and finally, settle the initial loan by paying ${}_t i_{t+1}$ in period t+1. Under the specified conditions, this investment strategy <u>guarantees</u> a positive riskless rate of return of k without committing any initial resources! This riskless arbitrage opportunity is negated because the forward exchange rate does not equal the expected future spot exchange rate. Under the conditions of the example, **<u>the forward exchange rate equals the the expected future spot exchange rate minus the anticipated rate of change in the real exchange rate</u>**, i.e., $E[(s_{t+1} - f_t)|\phi_t] = k$. With the forward exchange rate priced in this fashion, the riskless arbitrage opportunity is removed, and the expected real return of investing in a nominally riskless domestic asset or investing in a nominally riskless foreign asset and covering in the forward market (both of which have the same state contingent pattern of real returns) will be equated.

Assuming that $E[(d_{t+1} - d_t)|\phi_t]$ is observable, equation (8) may be transformed into an estimable regression equation for the anticipated real exchange rate hypothesis:

$$(9) \qquad s_{t+1} - f_t = \alpha_0 + \alpha_1 E[(d_{t+1} - d_t)|\phi_t] + \alpha_2 Y_t + u_{t+1},$$

where Y_t is a subset of the information set ϕ_t. The variable Y_t is a "nuisance" variable, and its role in the testing of the anticipated real exchange rate hypothesis will be described shortly. Given the assumptions regarding expected real interest rate differentials, the anticipated real exchange rate hypothesis predicts that (i) $\alpha_0 = c$, which may be greater or less than zero, i.e., the anticipated real exchange rate hypothesis allows for a constant risk premium, but predicts that the observed time-varying discrepancies between forward and future spot prices are not due to risk premia, (ii) α_1 equals one as anticipated real exchange rate changes are reflected directly in discrepancies between forward and future spot prices, and (iii) α_2 equals zero because information available at the signing of the forward contract, Y_t, should be useless in forecasting the differences between forward and future spot exchange rates beyond the information's ability to predict real exchange rate movements. Formally, the testable null hypothesis is: H_0: $\alpha_1 = 1$ and $\alpha_2 = 0$. Assuming rational expectations, rejection of this null hypothesis suggests that anticipated real exchange rate movements are not the only systematic component of the forward bias and implies that time-varying risk premia are an important force in the intertemporal evolution of the forward bias.

Since the expected rate of change in the real exchange rate, $E[(d_{t+1} - d_t)|\phi_t]$, is unobservable, we use an econometric procedure developed by Wickens (1982) for estimating rational expectations models. Wickens shows that in equations such as (9), consistent and asymptotically efficient parameter estimates may be obtained using the three stage least squares (3SLS) instrumental variables procedure. A set of predetermined variables are used to form predictions of the rate of change in the real exchange rate, and the model is estimated jointly treating the auxiliary equations describing expectations formation as part of the system. Thus, the 3SLS system used to retrieve consistent and asymptotically efficient estimates of α_0, α_1, and α_2 is:

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2 Y_t + u_{t+1}, \tag{10}$$

$$d_{t+1} - d_t = \delta I_t + \epsilon_{t+1},$$

where I_t is a set of instrumental variables used to predict real exchange rate changes, and ϵ_{t+1} is a white noise error term. It is worth noting that even if the instrument set employed by the econometrician in predicting real exchange movements is incomplete, the 3SLS estimator will remain consistent though not asymptotically efficient. The instruments are described below.

III. Evidence

This section examines the empirical validity of the anticipated real exchange rate explanation of the forward bias by testing whether (a) real exchange rate movements are predictable; (b) these anticipated real exchange rate changes are fully reflected in the forward bias; and (c) information available at the setting of the forward exchange rate is useless in forecasting the forward bias beyond its ability to predict real exchange rate changes. If the data do not reject (a)-(c), then we cannot reject the anticipated real exchange rate hypothesis. And, although we might not want to conclude that anticipated real exchange rate movements are the only systematic component determining the evolution of the forward bias, we could certainly conclude that they are an important component.

III.A. Data

Spot exchange rates, 1-month forward exchange rates, and 1-month Eurocurrency interest rates come from Data Resources Incorporated (DRI). End-of-month forward exchange rates are matched with corresponding future spot exchange rates appropriately accounting for holidays and weekends as described in Riehl and Rodriguez (1983) and Levine (1989b). Other data are taken from the International Financial Statistics and will be described below.

Except where otherwise indicated, the data cover the period July 1974 through January 1988. Data were obtained for the United States (US), the Netherlands (NE), the United Kingdom (UK), West Germany (WG), Switzerland (SW), Belgium (BE), Canada (CA), Japan (JA), Italy (IT), and France (FR). Because of capital controls, CIRP did not hold for France or Italy for parts of the estimation period, and they are, therefore, excluded from the sample.[11] In addition, the DRI data set does not contain Eurocurrency interest rates for Canada, Japan, and Belgium until 1981 so that it is impossible to check CIRP for the earlier period. Consequently, the analysis is conducted and the results presented both excluding and including these three countries for the entire sample period and various sub-periods. The seven country test results are in Appendix A.

III.B. The Predictability of Real Exchange Rate Movements

Since the anticipated real exchange rate hypothesis postulates that the time-varying wedge between forward and expected future spot exchange rates is fully explained by expected real exchange rate changes, and since a number of empirical studies argue that real exchange rate changes are unpredictable, this subsection demonstrates that real exchange rate changes between period t and t+1 are forecastable given information at time t. Roll's (1979) EPPP hypothesis states that the conditional expectation of $(d_{t+1} - d_t)$, given all information available at time t, is zero. This implies that in the regression:

$$(11) \qquad d_{t+1} - d_t = X_t\boldsymbol{\beta} + e_{t+1},$$

the estimated parameters, $\boldsymbol{\beta}$, should be insignificantly different from zero.

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11. When France and Italy are included and the tests are conducted over the periods in which CIRP does hold for France and Italy, the results presented below do not change.

Since we want to test whether real exchange rate movements are forecastable (and not to build and estimate a general equilibrium model of the real exchange rate), we simply choose a variable suggested by the theoretical framework outlined in Section II as a proxy for X_t in equation (11).

Thus, Table 1 presents ordinary least squares (OLS) regression results of the following equation:

$$(12) \qquad d_{t+1} - d_t = \beta_0 + \beta_1(f_t - s_t) + e_{t+1}.$$

The data strongly reject the hypothesis that $\beta_0 = \beta_1 = 0$ for each of the four currencies paired with the dollar. Thus, in contrast to work by Roll (1979), Frenkel (1981), and Adler and Lehman (1983), we find that information available at time t systematically predicts the rate of change in the real exchange rate between periods t and t+1.[12]

A number of diagnostic tests were conducted on the results presented in Table 1. The Durbin-Watson statistic does not indicate significant first-order autocorrelation, and the Lagrange-Multiplier test for q-th order residual autocorrelation fails to detect any problems for q=12 [see: Harvey (1981), p.173]. Similarly, Engle's (1982) test for autoregressive conditional heteroskedasticity (ARCH) does not detect significant ARCH in the residuals at the q=12 order. White's (1980) test, however, indicates statistically significant heteroskedasticity in the Switzerland equation. But, when the ("Jack-Knife") heteroskedastic

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12. It is worth noting that other variables such as lagged values of stock market indices, lagged values of the terms of trade, and lagged values of the trade balance also significantly predict real exchange rate changes for some of the countries.

consistent standard errors suggested by MacKinnon and White (1985) are used, the data still reject the hypothesis that $\beta_0 = \beta_1 = 0$.[13] The Kolmogorov-Smirnov test does not signal significant departures from normality in any of the regression residuals. But, the Jarque-Bera (1980) statistic finds evidence of non-normally distributed regression residuals in the United Kingdom and Switzerland equations. Upon further inspection, we found that these departures result from a few "outlier" observations in early 1985 when the dollar sharply depreciated against all major currencies. Moreover, when using the Box-Watson (1962) degrees of freedom correction for hypothesis testing when regression residuals are not normally distributed, the results are unaltered.

The empirical results strongly reject the EPPP hypothesis and suggest that the profession's common assumption that real exchange rates follow a martingale should be reconsidered. It is important to note, however, that we make no claim that equation (12) is an "optimal" or even a "good" empirical model of the rate of change in the real exchange rate. We simply demonstrate that information readily available at time t is useful in predicting the evolution of $d_{t+1} - d_t$. For our immediate purposes, the rejection of the EPPP hypothesis indicates that real exchange changes are predictable and allows us to move on to the second question of our empirical evaluation: are anticipated real exchange rate changes fully reflected in the forward bias?

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13. These results were obtained using PC-GIVE Version 5.0; see Hendry (1987).

III.C. The Forward Bias and Anticipated Real Exchange Rate Changes

This section examines the empirical validity of the anticipated real exchange rate hypothesis by testing whether or not the observed time-varying, systematic differences between forward and future spot exchange rates are fully explained by expected rates of change in real exchange rates. As discussed in Section II, we test this hypothesis by performing 3SLS on equation (10), which is repeated here for convenience:

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2 Y_t + u_{t+1}, \tag{13}$$

$$d_{t+1} - d_t = \delta I_t + \epsilon_{t+1},$$

The instruments for the expected rate of change in the real exchange rate, I_t, were chosen on the basis of their theoretically and empirically documented correlation with real exchange rate movements. The instrumental variables are: (1) a constant; (2) the one month lagged rate of change in the real exchange rate; (3) the difference between the average rate of change in the two stock market indices over the past six months (line 62 in the IFS); (4) the one month lagged growth rate in the U.S. terms of trade; (5) the one month lagged growth rate in the foreign country's terms of trade (lines 74 and 75); (6) the one month lagged growth rate in the U.S. trade balance; (7) the one month lagged growth rate in the foreign country's trade balance (lines 70 and 71); and (8) the forward premium. Instrumental variables one and two are chosen based simply on the time-series properties of the sample real exchange rates. Since the productivity differential approach to real exchange rate determination is an important paradigm of structural real exchange rate movements [see: Harrod (1957), Balassa (1964), Samuelson (1964), Hsieh (1982), Edison and Klovland (1987), and Huizinga (1987)] instrumental variable three is chosen in order to capture market expectations concerning productivity trends. Variables four through seven are included based on a number of papers that study real exchange rate determination [Helpman and Razin (1983), Barro (1983), Stockman (1983), Hooper (1985), Stockman and Dellas (1986), and Evans (1986)], while variable eight is chosen because of the discussion in Section II, and the empirical results given above. The unadjusted R^2 statistics for the first stage regressions used to form the predicted rate of change in the real exchange rate range between 0.20 and 0.26.

We first test the hypothesis that anticipated real exchange rate movements are fully reflected in the ex post forward bias by estimating equation (13) without the "nuisance" variable Y_t. The anticipated real exchange rate hypothesis predicts that α_1 should equal one, i.e., the ex post forward bias should completely incorporate the market's expected rate of change in the real exchange rate. Table 2 presents the results. For each of the four countries paired with the dollar, the data strongly reject the hypothesis that the slope coefficient equals zero, but the data do not reject the hypothesis that $\alpha_1 = 1$ for any individual country. In the system tests given in the bottom part of table 2, the data do not reject the null hypotheses that (1) the slope coefficients are equal across currencies; or (2) all of the slope coefficients equal one. It is also worth noting that only in the case of Switzerland do the data reject the hypothesis that the constant term is zero, which highlights the empirical unimportance of the risk premium.

In order to evaluate the reliability of the test results presented in Table 2, we perform a number of diagnostic tests. Since the model includes the lagged values of the rate of change in the real exchange rate (one of the dependent variables), Godfrey's (1978) Lagrange-Multiplier statistic is used to test for serial correlation at orders 1, 6, and 12. The residuals in the forward bias equations and in the equations used to form predicted real exchange rate changes do not exhibit significant serial correlation in any of the four currencies. Similarly, Engle's (1982) test does not detect ARCH in the residuals at orders 1, 6, and 12. And, the Jarque-Bera (1980) and Kolmogorov-Smirnov tests fail to detect statistically significant departures from normality in the forward bias and real exchange rate regression residuals at the 0.05 significance level.[14]

Since the data do not reject the hypothesis that the α_1's are equal across equations, equation (13) (without Y_t) is estimated restricting the slope coefficients to be equal, and the 3SLS results are given in Table 3. Imposition of this constraint permits a more powerful test of the anticipated real exchange rate hypothesis. The constrained parameter estimate of α_1 is 1.00, and the data do not reject the

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14. Although the regression residuals in the equations used to predict real exchange rate movements (and in the forward bias equations) do not exhibit significant departures from normality, the United Kingdom and Switzerland real exchange rate variables themselves deviate from the normal distribution because of "outlier" observations related to the sharp turn-around in the dollar against all major currencies in early 1985. This caused some concern since the system of four currencies and eight equations were estimated jointly and mis-specification in any one equation would be spread throughout the entire system (See: Hausman 1978). Thus, in order to check the robustness of the results, each two-equation currency system is estimated separately using 3SLS. These results are presented in Appendix B, and show that the conclusions are unaltered.

anticipated real exchange rate hypothesis. Furthermore, the battery of diagnostic tests discussed above do not raise any concerns about the Table 3 estimates.

Thus, both the unrestricted and restricted tests do not reject the hypothesis that anticipated real exchange rate changes are fully reflected in the forward bias. This along with the finding above that real exchange rate movements are predictable implies that anticipated real exchange rate changes are an important component of the observed systematic discrepancies between forward and future spot exchange rates.

The estimation results presented above in Table 2 and Table 3 do not include Y_t. We now use a variety of variables contained in agents' information sets to examine whether or not information available at the setting of the forward exchange rate is useful in forecasting the ex post differences between forward and future spot exchange rates beyond the information's ability to predict real exchange rate changes. Thus, we test whether the data are consistent with a world in which <u>only</u> anticipated real exchange rate movements explain the time-varying wedge between forward and expected future spot exchange rates. Formally, the null hypothesis is: H_0: $(\alpha_1, \alpha_2) = (1, 0)$. In all of the tests reported below, α_1 is constrained to be equal across equations. Appendix C, however, provides the unrestricted test results, which do not differ in any important way from the restricted estimates.

Geweke and Feige (1979) and Hansen and Hodrick (1980, 1983) find that the forward bias is significantly autocorrelated, i.e., lagged values of the forward bias are statistically significant explanatory variables of the current forward bias. Consequently, Table 4 presents 3SLS results of equation (13) with Y_t set equal to $s_t - f_{t-1}$. For no individual country do the data reject the hypothesis that $\alpha_1 = 1$ and $\alpha_2 = 0$. Furthermore, the systems tests do not reject the hypothesis that $\alpha_1 = 1$ and $\alpha_2 = 0$ for all countries. Thus, lagged values of the forward bias do not significantly explain current values of the forward bias beyond their ability to predict real exchange rate movements. These results are consistent with the anticipated real exchange rate explanation of the forward bias. The regression residuals were checked for autocorrelation and ARCH at various orders, and for deviations from normality: no important departures from the standard null hypotheses were detected at the 0.05 significance level.

Table 5 presents the system tests results for three Y_t variables. In Table 5a, Y_t is set equal to the corresponding forward premium. Although Hodrick and Srivastava (1984), Fama (1984), Levine (1989b), and others find that $f_t - s_t$ systematically predicts the forward bias, $s_{t+1} - f_t$, if the anticipated real exchange rate hypothesis holds, we should expect the forward premium to enter insignificantly once we account for the forward premium's ability to forecast real exchange rate changes. In Table 5b, Y_t is set equal to the average real interest rate differential over the preceding twelve months ($ARRD_t$) because Fama and Gibbons (1984) demonstrate that it did a reasonable job of tracking some nations' real interest rate differentials with the United States. If anticipated real interest rate differentials vary importantly through time, then they will induce important intertemporal variation in the forward bias, and the anticipated real exchange rate hypothesis will not hold. Finally, Table 5c presents the system tests setting Y_t equal to the variables in the auxiliary equation used to form real exchange rate predictions $(\sum_{i=1}^{7} I_t^i)$.

As the results indicate, the data do not reject the anticipated real exchange rate hypothesis. Information, even information shown by past investigators to be predictors of the forward bias, enters insignificantly once appropriate account is taken of the information's ability to forecast real exchange rate movements. Moreover, the proxy variable for anticipated real interest rate differentials ($ARRD_t$) fails to overturn the anticipated real exchange rate hypothesis. Thus, although we might not accept the null hypothesis that only anticipated real exchange rate changes induce systematic discrepancies between forward exchange rates and corresponding expected future spot prices, we may certainly conclude that anticipated real exchange rate movements are an important component of the forward bias.[15, 16]

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15. In order to examine the robustness of the conclusions, equation (13) is estimated over various sub-samples. The tests for the sub-periods July 1974-December 1980 and for January 1981-January 1988 are presented in Appendix D. The results are the same: we cannot reject the anticipated real exchange rate hypothesis, and the diagnostic statistics discussed above do not indicate important departures from the standard assumptions regarding 3SLS estimation or hypothesis testing.

16. One may suggest incorporating ex ante real interest rate differentials into equation (13), and testing whether or not this variable also enters with a coefficient of one. As Robert Korajczyk proved to me, however, there is an econometric problem with doing this because the parameters are biased toward the null. This proof is available on request.

IV. Conclusions

Although the literature has devoted prodigious resources to investigating the risk premium explanation of the systematic time-varying discrepancies between forward and corresponding future spot exchange rates, empirical verification of the risk premium hypothesis has proven elusive. This paper tests an alternative explanation of the forward bias: the anticipated real exchange rate hypothesis. This hypothesis states that except for a constant risk premium, the predictable difference between the forward exchange rate and the expected future spot rate equals the anticipated rate of change in the real exchange rate.

The empirical results are two-fold: (1) we reject the ex ante purchasing power parity hypothesis by demonstrating that real exchange rate changes are predictable; and (2) we cannot reject the hypothesis that the time-varying wedge between forward and expected future spot exchange rates is fully explained by anticipated real exchange rate movements. The systematic, intertemporal variation between forward and future spot exchange rates seems to be primarily due to expected real exchange rate movements.

Although the inability to reject the null hypothesis that the time-varying wedge between forward and expected future spot exchange rates equals the anticipated rate of change in the real exchange rate may not lead us to accept the null hypothesis, the empirical results strongly suggest that the literature's almost exclusive focus on the risk premium explanation of the forward bias should be amended to include the effects of anticipated real exchange rate movements.

REFERENCES

Adler, M. and B. Lehman, "Deviations from Purchasing Power Parity in the Long Run", Journal of Finance, December 1983, **38:** 1471-87

Barro, R.J., "Real Determinants of Real Exchange Rates", Unpublished manuscript, University of Chicago, 1983.

Balassa, B., "The Purchasing Power Parity Doctrine: A Reappraisal", The Journal of Political Economy, December 1964, **72:** 584-96.

Borensztein, E., "Alternative Hypothesis about the Excess Return of Dollar Assets", International Monetary Fund Staff Papers, March 1987, **34:** 29-59.

Box, G.E.P. and G.S. Watson, "Robustness to Non-Normality of Regression Tests", Biometrika, March 1962, **49:** 93-106.

Campbell, J.Y., and R.H. Clarida, "The Dollar and Real Interest Rates", in K. Brunner and A. Meltzer, eds, Carnegie-Rochester Conference Series on Public Policy, 27, Amsterdam: North Holland, 1987, 103-40.

Cosset, J.C., "On the Presence of Risk Premiums in Foreign Exchange Markets", Journal of International Economics, February 1984, **16:** 139-54.

Cumby, R.E., "Is It Risk? Explaining Deviations From Uncovered Interest Parity", Journal of Monetary Economics, September 1988, **22:** 279-300.

Cumby, R.E. and J. Huizinga, and M. Obstfeld, "Two-Step Two-Stage Least Squares Estimation in Models with Rational Expectations", Journal of Econometrics, April 1983, **21:** 333-55.

Cumby, R.E., and F. Mishkin, "The International Linkages of Real Interest Rates: The European-U.S Connection", Journal of International Money and Finance, March 1986, **5:** 5-24.

Cumby, R.E. and M. Obstfeld, "International Interest-Rate Linkages Under Flexible Exchange Rates: A Review of Recent Evidence", in J.F.O. Bilson and R.C. Marston, eds, Exchange Rates Theory and Practice, Chicago: University of Chicago Press for the National Bureau of Economic Research, 1984.

Darby, M.R., "Movements in Purchasing Power Parity: The Short and Long Runs", in M.R. Darby et al., The International Transmission of Inflation, Chicago: University of Chicago Press for the National Bureau of Economic Research, 1983.

Darby, M.R., "The Financial and Tax Effects of Inflation." Economic Inquiry, June 1975, **8:** 266-76.

Domowitz, I., and C.S. Hakkio, "Conditional Variance and the Risk Premium in the Foreign Exchange Market", Journal of International Economics, August 1985, **19:** 47-66.

Edison, H., and J.T. Klovland, "A Quantitative Reassessment of the Purchasing Power Parity Hypothesis: Evidence from Norway and the United Kingdom", Journal of Applied Econometrics, October 1987, **2.4:** 309-334.

Engle, R., "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation", Econometrica, July 1982, **50:** 987-1007.

Evans, P., "Is the Dollar High Because of Large Budget Deficits?", Journal of Monetary Economics, November 1986, **18:** 227-50.

Fama, E.F., "Forward and Spot Exchange Rates", Journal of Monetary Economics, November 1984, **14:** 319-38.

Fama, E.F., and M.R. Gibbons, "A Comparison of Inflation Forecasts", Journal of Monetary Economics, May 1984, **13:** 327-48.

Flood, R.P., and P.M. Garber, "A Model of Stochastic Process Switching", Econometrica, May 1983, **51:** 537-52.

Frankel, J., "In Search of the Exchange Risk Premium: A Six-Currency Test Assuming Mean Variance Optimization", Journal of International Money and Finance, December 1982, **1:** 255-74.

Frankel, J., and C. Engel, "Do Asset Demand Functions Optimize over the Mean and Variance of Real Returns? A Six Currency Test", Journal of International Economics, November 1984, **17:** 309-23.

Frankel, J., and K.A. Froot, "Using Survey Data to Test Standard Propositions Regarding Exchange Rate Expectations", American Economic Review, March 1987, **77:** 133-53.

Frankel, J, and A. MacArthur, "Political vs. Currency Premia in International Real Interest Differentials: A Study of Forward Rates for 24 Countries", European Economic Review, June 1988, **32:** 1083-1114.

Frenkel, J.A., "Flexible Exchange Rates, Prices and the Role of 'News': Lessons from the 1970s", Journal of Political Economy, August 1981, **89:** 665-705.

Frenkel, J.A., and R. Levich, "Covered Interest Arbitrage: Unexpected Profits?" Journal of Political Economy, April 1975, **83:** 325-338.

Geweke, J.F., and E.L. Feige, "Some Joint Tests of the Efficiency of Markets for Forward Foreign Exchange", Review of Economics and Statistics, August 1979, **61:** 334-41.

Giovannini, A., and P. Jorion, "Interest Rates and Risk Premia in the Stock Market and in the Foreign Exchange Market", Journal of International Money and Finance, March 1987, **6:** 107-123.

Godfrey, L.G., "Testing Against General Autoregressive and Moving Average Error Models when the Regressors Include Lagged Dependent Variables", Econometrica, November 1978, **46:** 1293-1303.

Hansen, L.P., and R.J. Hodrick, "Forward Exchange Rates and Optimal Predictors of Future Spot Rates: An Econometric Analysis", Journal of Political Economy, October 1980, **88:** 829-53.

Hansen, L.P., and R.J. Hodrick, "Risk Averse Speculation in the Forward Exchange market: An Econometric Analysis of Linear Models", in J.A. Frenkel, ed., Exchange Rates and International Macroeconomics, Chicago: University of Chicago Press, 1983.

Harrod, R., International Economics, Chicago: University of Chicago Press, 1957.

Harvey, A.C., The Econometric Analysis of Time Series, Oxford: Philip Allan, 1981.

Hausman, J.A., "Specification Tests in Econometrics", Econometrica, November 1978, **46:** 1251-71.

Helpman, E., and A. Razin, "The Roles of Savings and Investment in Exchange Rate Determination under Alternative Monetary Mechanisms", Journal of Monetary Economics, May 1983, **13:** 307-26.

Hendry, D.F., PC-GIVE: An Interactive Menu-Driven Econometric Modelling Program for IBM-Compatible PC's, Version 5.0, Oxford, University of Oxford, Institute of Economics and Statistics and Nuffield College, 1987.

Hodrick, R.J., "International Asset Pricing with Time-Varying Risk Premia", Journal of International Economics, November 1981, **11:** 573-87.

Hodrick, R.J., and S. Srivastava, "An Investigation of Risk and Return in Forward Foreign Exchange", Journal of International Monetary and Finance, April 1984, **3:** 5-29.

Hooper, P., "International Repercussions of the U.S. Budget Deficit", Brookings Discussion Papers in International Economics, 27, Washington: Brookings Institution, February 1985.

Hooper, P., and C. L. Mann, "The U.S. External Deficit: Its Causes and Persistence", International Finance Discussion Paper, No. 316, Federal Reserve Board, Washington, 1987.

Hooper, P., and J. E. Morton, "Fluctuations in the Dollar: A Model of Nominal and Real Exchange Rate Determination", Journal of International Money and Finance, April 1982, **1:** 39-56.

Hsieh, D.A., "The Determination of the Real Exchange Rate: The Productivity Approach", Journal of International Economics, May 1982, **12:** 355-62.

Huang, R.D., "Expectations of Exchange Rates and Different Inflation Rates: Further Evidence on Purchasing Power Parity in Efficient Markets", Journal of Finance, March 1987, **42:** 69-80.

Huizinga, J., "An Empirical Investigation of the Long Run Behavior of Real Exchange Rates", in K. Brunner and A. Meltzer, eds, Carnegie-Rochester Series on Public Policy 27, Amsterdam: North Holland, 1987, 149-214.

Jarque, C.M., and A.K. Bera, "Efficient Tests for Normality, Homoscedasticity and Serial Independence of Regression Residuals", Economic Letters, 1980, **6.2:** 255-9.

Kaminsky, G., and R. Peruga, "Credibility Crises: The Dollar in the Early Eighties", Unpublished manuscript, UCSD, September 1988.

Korajczyk, R.A., "The Pricing of Forward Contracts for Foreign Exchange", Journal of Political Economy, April 1985, **93:** 346-68.

Kouri, P., "International Investment and Interest Rate Linkages under Flexible Exchange Rates", in R. Aliber, ed., The Political Economy of Monetary Reform, London: Macmillan & Co., 1977.

Krasker, W.S., "The 'Peso' Problem in Testing the Efficiency of Forward Exchange Markets", Journal of Monetary Economics, April 1980, **6:** 269-276.

Krugman, P., "Purchasing Power Parity and Exchange Rates: Another Look at the Evidence", Journal of International Economics, August 1978, **8:** 397-407.

Levich, R.M., "Empirical Studies of Exchange Rates: Price Behavior, Rate Determination and Market Efficiency", in R.W. Jones and P.B Kenen, eds., Handbook of International Economics, Vol. 2, New York: Elsevier Science Publishers B.V., 1985.

Levine, R., "An International Arbitrage Pricing Model with PPP Deviations", forthcoming in Economic Inquiry, 1989a.

Levine, R., "The Pricing of Forward Exchange Rates," forthcoming in the Journal of International Money and Finance, 1989b.

Levine, R., "The Peso Problem: An Empirical Investigation", unpublished manuscript, The Board of Governors of the Federal Reserve System, 1988.

Lewis, K.K., "The Persistence of the 'Peso Problem' when Policy is Noisy", Journal of International Money and Finance, March 1988, **7:** 5-21.

Lucas, R.E., "Interest Rates and Currency Prices in a Two-Country World", Journal of Monetary Economics, November 1982, **10:** 335-60.

Mark, N., "Some Evidence on the International Inequality of Real Interest Rates", Journal of International Money and Finance, June 1985a, **4:** 189-208.

Mark, N., "On Time-Varying Risk Premia in the Foreign Exchange Market: An Econometric Analysis", Journal of Monetary Economics, July 1985b, **16:** 3-18.

MacKinnon, J.G., and H. White, "Some Heteroscedastic Covariance Matrix Estimators with Improved Finite Sample Properties", Journal of Econometrics, September 1985, **29:** 305-25.

McCormick, F., "Covered Interest Arbitrage: Unexploited Profits? Comment", Journal of Political Economy, April 1979, **87:** 411-17.

Merrick, J.J., and A. Saunders, "International Expected Real Interest Rates: New Tests of the Parity Hypothesis and U.S. Fiscal Policy", Journal of Monetary Economics, November 1986, **18:** 313-322.

Meese, R., "Empirical Assessment of Currency Risk Premiums", in Courtenay Stone, ed., Financial Risk: Theory, Evidence and Implications, Boston: Kluwor Academic Publishers, 1989.

Meese, R., and K. Rogoff, "Was It Real? The Exchange Rate-Interest Differential Relation over the Modern Floating-Rate Period", Journal of Finance, September 1988, **43:** 933-48.

Mishkin, F.S., "Are Real Interest Rates Equal Across Countries: An Empirical Investigation of International Parity Conditions", Journal of Finance, December 1984, **39:** 1345-57.

Obstfeld, M., "Peso Problems, Bubbles, and Risk in the Empirical Assessment if Exchange-Rate Behavior", unpublished manuscript, University of Pennsylvania, 1986.

Powell, F.C., Statistical Tables for the Social, Biological, and Physical Sciences, Cambridge: Cambridge University Press, 1982.

Riehl, H., and R.M. Rodriguez, Foreign Exchange and Money Markets, New York: McGraw-Hill Book Co., 1983.

Roll, R., "Violations of Purchasing Power Parity and Their Implications for Efficient International Commodity Markets", in M. Sarnat and G.P. Szego, eds, International Finance and Trade, Vol. 1, Cambridge, Mass.: Ballinger Publishing Co., 1979.

Samuelson, P., "Theoretical Notes on Trade Problems", Review of Economics and Statistics, May 1964, **46:** 145-154.

Shafer, J.R., and B.E. Loopesko, "Floating Exchange Rates After Ten Years", Brookings Papers on Economic Activity,**1:** 1983.

Stockman, A., "Risk, Information, and Forward Exchange Rates", in J.A. Frenkel and H.G. Johnson, eds, The Economics of Exchange Rates: Selected Studies, Reading MA: Addison-Wesley, 1978, 159-178.

Stockman, A., "Real Exchange Rates under Alternative Nominal Exchange Rate Systems", Journal of International Money and Finance, August 1983, **2:** 147-66.

Stockman, A., and H. Dellas, "International Portfolio Nondiversification and Exchange Rate Variability", Unpublished manuscript, University of Rochester, 1986.

Stulz, R.M., "A Model of International Asset Pricing", Journal of Financial Economics, December 1981, **9:** 383-406.

Stulz, R.M., "An Equilibrium Model of Exchange Rate Determination and Asset Pricing with Nontraded Goods and Imperfect Information", Journal of Political Economy, October 1987, **95:** 1024-40.

Sweeney, R., "Beating the Foreign Exchange Market", Journal of Finance, March 1986, **41:** 163-82.

Tabellini, G., "Learning and the Volatility of Exchange Rates", Journal of International Money and Finance, June 1988, **7:** 243-250.

White, N., "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity", Econometrica, May 1980, **48:** 817-38.

Wickens, M.R., "The Efficient Estimation of Econometric Models with Rational Expectations", Review of Economic Studies, August 1982, **49:** 55-67.

Table 1

OLS

$$d_{t+1} - d_t = \beta_0 + \beta_1(f_t - s_t) + e_{t+1}$$

Country	β_0	β_1	D.W.[a]	LM(12)[b]	ARCH(12)[c]	JB[d]
NE	.007* (.003)	-3.15* (0.98)	2.19	0.80	1.77	3.29
UK	-.005 (.003)	-3.29* (0.88)	1.91	0.82	0.84	14.8*
WG	.009 (.005)	-3.04* (1.51)	2.11	0.66	1.08	4.36
SW	.018* (.006)	-3.69* (1.17)	2.03	0.20	1.47	6.87*

April 1974-January 1988

NOTE: Standard errors in parentheses.

* Significantly different from the null hypothesis at the .05 level.

a The Durbin-Watson Statistic for first order serial correlation.

b The F-test version of the LM-test for autocorrelation of order 12.

c Engle's (1982) F-test for ARCH of order 12.

d The Jarque-Bera (1980) normality test, distributed χ^2.

TABLE 2

UNRESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + u_{t+1}$$

Country	α_0	α_1	$F(\alpha_1=1)$
NE	-.001 (.001)	.94* (.03)	0.60
UK	-.001 (.001)	1.00* (.03)	0.01
WG	-.001 (.001)	.99* (.02)	0.02
SW	-.002* (.001)	1.04* (.02)	0.28

SYSTEM TESTS

TEST	F	P-Value
α_1: equal across equations	0.49	0.70
$\alpha_1=1$: all equations	0.37	0.83

Weighted R^2 = .23 July 1974-January 1988

NOTE: Standard errors in parentheses. $F(\alpha_1=1)$ represents the F-statistic for the null hypothesis that $\alpha_1=1$.

* Significantly different from the null hypothesis at the .05 level.

TABLE 3

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + u_{t+1}$$

Country	α_0	α_1	$F(\alpha_1=1)$
NE	-.001 (.001)	1.00* (.02)	0.01
UK	-.001 (.001)	1.00* (.02)	0.01
WG	-.001 (.001)	1.00* (.02)	0.01
SW	-.002* (.001)	1.00* (.02)	0.01

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.01	0.99

Weighted R^2 = .23

July 1974-January 1988

See note in Table 2.

TABLE 4

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(s_t - f_{t-1}) + u_{t+1}$$

Country	α_0	α_1	α_2	$F(\alpha_1=1)$	$F(\alpha_1=1,\alpha_2=0)$
NE	-.001 (.001)	.99* (.02)	.03 (.01)	0.03	0.22
UK	-.001 (.001)	.99* (.02)	-.02 (.02)	0.03	0.09
WG	-.001 (.001)	.99* (.02)	-.01 (.01)	0.03	0.01
SW	-.002* (.001)	.99* (.02)	.02 (.01)	0.03	0.13

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.01	0.99
$\alpha_2=0$: all equations	0.30	0.88
$\alpha_1=1, \alpha_2=0$: all equations	0.16	0.99

Weighted R^2 = .24

July 1974-January 1988

See note in Table 2.

TABLE 5a

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + (f_t - s_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.15	0.96
$\alpha_2=0$: all equations	0.64	0.63
$\alpha_1=1, \alpha_2=0$: all equations	0.32	0.96

Weighted R^2 = .23 July 1974-January 1988

TABLE 5b

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(ARRD_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.03	0.99
$\alpha_2=0$: all equations	0.74	0.56
$\alpha_1=1, \alpha_2=0$: all equations	0.40	0.92

Weighted R^2 = .25 July 1974-January 1988

TABLE 5c

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \sum_{i=1}^{7} \alpha_2^i I_t^i + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.01	0.99
$\alpha_2^1=\ldots=\alpha_2^7=0$: all equations	0.28	0.99
$\alpha_1=1, \alpha_2^1=\ldots=\alpha_2^7=0$: all equations	0.25	0.99

APPENDIX A

This appendix presents the unrestricted and restricted 3SLS tests given in the text for seven countries against the dollar over the entire sample period July 1974-January 1988 and over the sub-samples July 1974-December 1980 and January 1981-January 1988 in Tables A1-A24. All of the unrestricted tests are given first and the restricted 3SLS results begin in Table A13.

The results presented here are supportive of those given in the text: the data do not reject the anticipated real exchange rate for the seven countries over the entire period or various sub-periods. It should be noted that the errors in the Canada and Japan equations exhibit significant departures from the normal distribution. Although this does not violate the anticipated real exchange rate hypothesis, it may cause us to have less confidence in the test results: mis-specification in one equation may affect the results in all equations. But, as is shown in Appendix B, when each individual country system is estimated alone using 3SLS, the results are unaltered.

TABLE A1

UNRESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + u_{t+1}$$

Country	α_0	α_1	$F(\alpha_1=1)$
NE	-.001 (.001)	.94* (.02)	0.82
UK	-.001 (.001)	.96* (.03)	0.40
WG	-.001 (.001)	.97* (.02)	0.40
SW	-.002* (.001)	1.01* .02)	0.02
CA	.001 (.001)	.92* (.04)	0.67
JA	-.001 (.001)	.92* (.04)	0.87
BE	.003* (.001)	.97* (.02)	0.29

SYSTEM TESTS

TEST	F	P-Value
α_1: equal across equations	0.34	0.91
$\alpha_1=1$: all equations	0.48	0.85

Weighted R^2 = .29 July 1974-January 1988

NOTE: Standard errors in parentheses. $F(\alpha_1=1)$ represents the F-statistic for the null hypothesis that $\alpha_1=1$.

* Significantly different from the null hypothesis at the .05 level.

TABLE A2

UNRESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(s_t - f_{t-1}) + u_{t+1}$$

Country	α_0	α_1	α_2	$F(\alpha_1=1)$	$F(\alpha_1=1,\alpha_2=0)$
NE	-.001 (.001)	.95* (.02)	.01 (.01)	1.30	0.70
UK	-.001 (.001)	.96* (.03)	-.02 (.02)	0.41	0.37
WG	-.001 (.001)	.98* (.02)	-.01 (.01)	0.21	0.14
SW	-.002* (.001)	1.01* (.02)	.01 (.01)	0.08	0.19
CA	.001 (.001)	.94* (.04)	.03 (.03)	0.26	0.23
JA	-.001 (.001)	.97* (.03)	-.02 (.02)	0.11	0.25
BE	.002* (.001)	.97* (.02)	.01 (.01)	0.27	0.18

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.32	0.32
$\alpha_2=0$: all equations	0.27	0.96
$\alpha_1=1,\alpha_2=0$: all equations	0.32	0.99

Weighted R^2 = .28

July 1974-January 1988

See note in Table A1.

TABLE A3

UNRESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(f_t - s_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	1.32	0.24
$\alpha_2=0$: all equations	1.89	0.07
$\alpha_1=1, \alpha_2=0$: all equations	1.24	0.24

Weighted R^2 = .23 July 1974-January 1988

See note in Table A1.

TABLE A4

UNRESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \sum_{i=1}^{7} \alpha_2^i I_t^i + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	1.11	0.35
$\alpha_2^1=\ldots=\alpha_2^7=0$: all equations	0.50	0.99
$\alpha_1=1, \alpha_2^1=\ldots=\alpha_2^7=0$: all equations	0.51	0.99

Weighted R^2 = .24 July 1974-January 1988

See note in Table A1.

TABLE A5

UNRESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1: equal across countries	0.32	0.93
α_1=1: all countries	0.83	0.56

Weighted R^2 = .38 January 1981-January 1988

See note in Table A1.

TABLE A6

UNRESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(s_t - f_{t-1}) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1=1: all countries	0.70	0.67
α_2=0: all countries	0.81	0.54
α_1=1,α_2=0: all countries	0.62	0.85

Weighted R^2 = .46 January 1981-January 1988

See note in Table A1.

TABLE A7

UNRESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(f_t - s_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all countries	1.51	0.16
$\alpha_2=0$: all countries	1.34	0.23
$\alpha_1=1, \alpha_2=0$: all countries	1.17	0.30

Weighted R^2 = .38 January 1981-January 1988

See note in Table A1.

TABLE A8

UNRESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \sum_{i=1}^{7} \alpha_2^i I_t^i + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all countries	1.22	0.29
$\alpha_2^1=\ldots=\alpha_2^7=0$: all countries	0.34	0.99
$\alpha_1=1, \alpha_2^1=\ldots=\alpha_2^7=0$: all countries	0.43	0.99

Weighted R^2 = .38 January 1981-January 1988

See note in Table A1.

TABLE A9

UNRESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1: equal across countries	0.85	0.54
α_1=1: all countries	0.74	0.64

Weighted R^2= .44 July 1974-December 1980

See note in Table A1.

TABLE A10

UNRESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(s_t - f_{t-1}) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1=1: all countries	0.96	0.46
α_2=0: all countries	0.26	0.97
α_1=1,α_2=0: all countries	0.60	0.87

Weighted R^2 = .57 July 1974-December 1980

See note in Table A1.

TABLE A11

UNRESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(f_t - s_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all countries	1.30	0.24
$\alpha_2=0$: all countries	1.08	0.37
$\alpha_1=1, \alpha_2=0$: all countries	0.97	0.48

Weighted R^2 = .44 July 1974-December 1980

See note in Table A1.

TABLE A12

UNRESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \sum_{i=1}^{7} \alpha_2^i I_t^i + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all countries	1.08	0.38
$\alpha_2^1=\ldots=\alpha_2^7=0$: all countries	0.33	0.99
$\alpha_1=1, \alpha_2^1=\ldots=\alpha_2^7=0$: all countries	0.41	0.99

Weighted R^2 = .45 July 1974-December 1980

See note in Table A1.

TABLE A13

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + u_{t+1}$$

Country	α_0	α_1	$F(\alpha_1=1)$
NE	-.001 (.001)	.95* (.02)	1.28
UK	-.001 (.001)	.95* (.02)	1.28
WG	-.001 (.001)	.95* (.02)	1.28
SW	-.002* (.001)	.95* (.02)	1.28
CA	.001 (.001)	.95* (.02)	1.28
JA	-.001 (.001)	.95* (.02)	1.28
BE	.003 (.001)	.95* (.02)	1.28

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.18	0.99

Weighted R^2 = .28 July 1974-January 1988

See note in Table A1.

TABLE A14

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(s_t - f_{t-1}) + u_{t+1}$$

Country	α_0	α_1	α_2	$F(\alpha_1=1)$	$F(\alpha_1=1,\alpha_2=0)$
NE	-.001 (.001)	.97* (.02)	.01 (.01)	0.59	0.40
UK	-.001 (.001)	.97* (.02)	-.02 (.02)	0.59	0.64
WG	-.001 (.001)	.97* (.02)	-.01 (.01)	0.59	0.30
SW	-.002* (.001)	.97* (.02)	.02 (.01)	0.59	0.53
CA	.001 (.001)	.97* (.02)	.03 (.03)	0.59	0.40
JA	-.001 (.001)	.97* (.02)	-.02 (.02)	0.59	0.47
BE	.002* (.001)	.97* (.02)	.01 (.01)	0.59	0.35

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.29	0.96
$\alpha_2=0$: all equations	0.08	0.99
$\alpha_1=1,\alpha_2=0$: all equations	0.20	0.99

Weighted R^2 = .28 July 1974-January 1988

See note in Table A1.

TABLE A15

RESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(f_t - s_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	1.13	0.34
$\alpha_2=0$: all equations	1.87	0.07
$\alpha_1=1, \alpha_2=0$: all equations	1.15	0.31

Weighted $R^2 = .23$ July 1974-January 1988

See note in Table A1.

TABLE A16

RESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \sum_{i=1}^{7} \alpha_2^i I_t^i + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.49	0.99
$\alpha_2^1=\ldots=\alpha_2^7=0$: all equations	0.80	0.59
$\alpha_1=1, \alpha_2^1=\ldots=\alpha_2^7=0$: all equations	0.46	0.99

Weighted $R^2 = .24$ July 1974-January 1988

See note in Table A1.

TABLE A17

RESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1=1: all countries	0.56	0.79

Weighted R^2 = .38 January 1981-January 1988

See note in Table A1.

TABLE A18

RESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(s_t - f_{t-1}) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1=1: all countries	0.31	0.95
α_2=0: all countries	0.45	0.87
α_1=1,α_2=0: all countries	0.42	0.97

Weighted R^2 = .46 January 1981-January 1988

See note in Table A1.

TABLE A19

RESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(f_t - s_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all countries	0.97	0.45
$\alpha_2=0$: all countries	1.14	0.34
$\alpha_1=1, \alpha_2=0$: all countries	0.90	0.56

Weighted R^2 = .38 January 1981-January 1988

See note in Table A1.

TABLE A20

RESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \sum_{i=1}^{7} \alpha_2^i I_t^i + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all countries	0.74	0.64
$\alpha_2^1=\ldots=\alpha_2^7=0$: all countries	0.33	0.99
$\alpha_1=1, \alpha_2^1=\ldots=\alpha_2^7=0$: all countries	0.36	0.99

Weighted R^2 = .39 January 1981-January 1988

See note in Table A1.

TABLE A21

RESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all countries	0.02	0.99

Weighted R^2 = .44

July 1974-December 1980

See note in Table A1.

TABLE A22

RESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(s_t - f_{t-1}) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all countries	0.06	0.99
$\alpha_2=0$: all countries	0.24	0.98
$\alpha_1=1, \alpha_2=0$: all countries	0.15	0.99

Weighted R^2 = .56

July 1974-December 1980

See note in Table A1.

TABLE A23

RESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(f_t - s_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all countries	0.18	0.99
$\alpha_2=0$: all countries	0.76	0.62
$\alpha_1=1, \alpha_2=0$: all countries	0.40	0.97

Weighted R^2 = .44

July 1974-December 1980

See note in Table A1.

TABLE A24

RESTRICTED 3SLS

All Seven Countries Against the Dollar

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \sum_{i=1}^{7} \alpha_2^i I_t^i + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all countries	0.08	0.99
$\alpha_2^1=\ldots=\alpha_2^7=0$: all countries	0.31	0.99
$\alpha_1=1, \alpha_2^1=\ldots=\alpha_2^7=0$: all countries	0.27	0.99

Weighted R^2 = .45

July 1974-December 1980

See note in Table A1.

APPENDIX B

This appendix presents the individual country 3SLS test results for the period July 1974-January 1988. By an "individual country 3SLS," we refer to performing a separate 3SLS estimation on each country's two equation system: the forward bias equation and the real exchange rate equation as written in equation (13). Thus, there is no interaction permitted between the country equations.

The results of the individual 3SLS estimation are similar to the system estimation results. The data do not reject the anticipated real exchange rate hypothesis.

TABLE B1

INDIVIDUAL 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + u_{t+1}$$

Country	α_0	α_1	$F(\alpha_1=1)$
NE	-.001 (.001)	.99* (.04)	0.01
UK	-.001 (.001)	.88* (.06)	0.61
WG	-.001 (.001)	.96* (.04)	0.06
SW	-.002* (.001)	0.97* (.04)	0.04
CA	.001 (.001)	.94* (.07)	0.17
JA	-.001 (.001)	.92* (.06)	0.28
BE	.003* (.001)	1.01* (.07)	0.01

July 1974-January 1988

See note in Table 2.

TABLE B2

INDIVIDUAL 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(s_t - f_{t-1}) + u_{t+1}$$

Country	α_0	α_1	α_2	$F(\alpha_1=1)$	$F(\alpha_1=1,\alpha_2=0)$
NE	-.001 (.001)	.99* (.04)	.01 (.02)	0.01	0.01
UK	-.001 (.001)	.90* (.06)	-.03 (.02)	0.35	0.40
WG	-.001 (.001)	.95* (.04)	-.03* (.01)	0.08	0.16
SW	-.002* (.001)	0.97* (.04)	.01 (.01)	0.05	0.02
CA	.001 (.001)	.94* (.07)	.02 (.03)	0.18	0.14
JA	-.001 (.001)	.97* (.06)	-.04 (.02)	0.02	0.33
BE	.002* (.001)	1.02* (.07)	-.01 (.02)	0.01	0.01

July 1974-January 1988

See note in Table 2.

TABLE B3

INDIVIDUAL 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(f_t - s_t) + u_{t+1}$$

Country	α_0	α_1	α_2	$F(\alpha_1=1)$	$F(\alpha_1=1,\alpha_2=0)$
NE	.001 (.001)	.92* (.06)	-.49 (.26)	0.18	0.16
UK	-.002 (.001)	.72* (.15)	-.66 (.57)	0.62	0.38
WG	.001 (.001)	.94* (.05)	-.22 (.29)	0.09	0.05
SW	.001 (.002)	.90* (.58)	-.55 (.31)	0.23	0.13
CA	-.001 (.001)	.79* (.08)	-.91* (.27)	1.83	1.70
JA	.001 (.002)	.80* (.10)	-.55 (.38)	0.62	0.31
BE	.002* (.001)	.96* (.07)	-.37 (.22)	0.03	0.12

July 1974-January 1988

See note in Table 2.

APPENDIX C

This appendix presents the unrestricted 3SLS test results for the four country system considered in the text. What would logically be Table C1, the unrestricted 3SLS results without Z_t, is given in the text as Table 2. The unrestricted test results over the sub-samples July 1974-December 1980 and January 1980-January 1988 are almost exactly the same as the restricted sub-period results in Appendix D, and are thus not listed.

Again, the results are similar to the restricted results given in the text.

TABLE C1

UNRESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + (s_t - f_{t-1}) + u_{t+1}$$

Country	α_0	α_1	α_2	$F(\alpha_1=1)$	$F(\alpha_1=1,\alpha_2=0)$
NE	-.001 (.001)	.94* (.02)	.02 (.01)	0.64	0.43
UK	-.001 (.001)	1.02* (.03)	-.02 (.02)	0.04	0.11
WG	-.001 (.001)	.97* (.02)	-.09 (.01)	0.26	0.17
SW	-.002* (.001)	1.03* (.02)	.08 (.01)	0.17	0.12

SYSTEM TESTS

TEST	F	P-Value
α_1: equal across equations	0.61	0.61
$\alpha_1=1$: all equations	0.46	0.76
$\alpha_2=0$: all equations	0.29	0.88
$\alpha_1=1,\alpha_2=0$: all equations	0.38	0.93

Weighted R^2 = .24 July 1974-January 1988

See note in Table 2.

TABLE C2

UNRESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + (f_t - s_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1: equal across equations	1.01	0.39
α_1=1: all equations	0.90	0.46
α_2=0: all equations	0.84	0.50
α_1=1,α_2=0: all equations	0.70	0.69

Weighted R^2 = .23 July 1974-January 1988

See note in Table 2.

TABLE C3

UNRESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(ARRD_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1: equal across equations	0.22	0.88
α_1=1: all equations	0.19	0.94
α_2=0: all equations	0.68	0.61
α_1=1,α_2=0: all equations	0.48	0.87

Weighted R^2 = .25 July 1974-January 1988

See note in Table 2.

TABLE C4

UNRESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \sum_{i=1}^{7} \alpha_2^i I_t^i + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
a_1: equal across equations	1.59	0.19
$\alpha_1=1$: all equations	1.19	0.31
$\alpha_2^1= \ldots = \alpha_2^7=0$: all equations	0.31	0.99
$\alpha_1=1, \alpha_2^1=\ldots=\alpha_2^7=0$: all equations	0.39	0.99

Weighted R^2 = .23 July 1974-January 1988

See note in Table 2.

APPENDIX D

This appendix presents the restricted 3SLS system tests for the four country system considered in the text over the sub-period July 1974-December 1980 and January 1980-January 1988.

The sub-sample results are similar to the complete sample results: the data do not reject the anticipated real exchange rate hypothesis.

TABLE D1

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1=1: all equations	0.01	0.99

Weighted R^2 = .40 July 1974-December 1980

See note in Table 2.

TABLE D2

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(s_t - f_{t-1}) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1=1: all equations	0.01	0.99
α_2=0: all equations	0.25	0.91
α_1=1,α_2=0: all equations	0.13	0.99

Weighted R^2 = .43 July 1974-December 1980

See note in Table 2.

TABLE D3

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(f_t - s_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1=1: all equations	0.02	0.99
α_2=0: all equations	0.37	0.83
α_1=1,α_2=0: all equations	0.19	0.99

Weighted R^2 = .39 July 1974-December 1980

See note in Table 2.

TABLE D4

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(ARRD_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
α_1=1: all equations	0.01	0.99
α_2=0: all equations	0.15	0.96
α_1=1,α_2=0: all equations	0.08	0.99

Weighted R^2 = .43 July 1974-December 1980

See note in Table 2.

TABLE D5

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \sum_{i=1}^{7} \alpha_2^i I_t^i + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.02	0.99
$\alpha_2^1=\ldots=\alpha_2^7=0$: all equations	0.19	0.99
$\alpha_1=1, \alpha_2^1=\ldots=\alpha_2^7=0$: all equations	0.17	0.99

Weighted R^2 = .40 July 1974-December 1980

See note in Table 2.

TABLE D6

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.07	0.99

Weighted R^2 = .34 January 1981-January 1988

See note in Table 2.

TABLE D7

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(s_t - f_{t-1}) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.09	0.98
$\alpha_2=0$: all equations	0.24	0.92
$\alpha_1=1, \alpha_2=0$: all equations	0.17	1.00

Weighted R^2 = .36 January 1981-January 1988

See note in Table 2.

TABLE D8

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(f_t - s_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.09	0.99
$\alpha_2=0$: all equations	0.45	0.77
$\alpha_1=1, \alpha_2=0$: all equations	0.24	0.98

Weighted R^2 = .34 January 1981-January 1988

See note in Table 2.

TABLE D9

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \alpha_2(ARRD_t) + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.09	0.99
$\alpha_2=0$: all equations	0.13	0.97
$\alpha_1=1, \alpha_2=0$: all equations	0.11	1.00

Weighted R^2 = .40

January 1981-January 1988

See note in Table 2.

TABLE D10

RESTRICTED 3SLS

$$s_{t+1} - f_t = \alpha_0 + \alpha_1(d_{t+1} - d_t) + \sum_{i=1}^{7} \alpha_2^i I_2^i + u_{t+1}$$

SYSTEM TESTS

TEST	F	P-Value
$\alpha_1=1$: all equations	0.01	1.00
$\alpha_2^1=\ldots=\alpha_2^7=0$: all equations	0.22	1.00
$\alpha_1=1, \alpha_2^1=\ldots=\alpha_2^7=0$: all equations	0.20	1.00

Weighted R^2 = .35

January 1981-January 1988

See note in Table 2.

International Finance Discussion Papers

IFDP NUMBER	TITLES 1988	AUTHOR(s)
338	The Forward Exchange Rate Bias: A New Explanation	Ross Levine
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