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A RE-ASSESSMENT OF THE RELATIONSHIP BETWEEN REAL EXCHANGE RATES AND REAL INTEREST RATES: 1974 - 1990

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Abstract

The general view of the economics profession is that we can not explain exchange rate movements. However, some researchers still contend that the relationship between real interest rates and the real exchange rate is a useful framework for thinking about exchange rate movements. This paper asks whether there is such a systematic relationship and whether it is revealed by the data. In our attempt to find such a relationship we investigate whether the empirical results are conditional on: (1) the time period selected, (2) the choice of interest rate, (3) the measure of expected inflation, and (4) the choice of exchange rate. The results show that exchange rates and interest rates, both nominal and real are nonstationary; however, they are not cointegrated with each other. On the other hand, the dynamic models indicate that there might be a long-run relationship between these variables, but cannot corroborate this. Consequently, the final conclusion is that the empirical results do not confirm the relationship and this result is robust across exchange rates, time periods, interest rates, and inflation measures.

A RE-ASSESSMENT OF THE RELATIONSHIP BETWEEN REAL EXCHANGE RATES AND REAL INTEREST RATES: 1974 - 1990

Hali J. Edison and B. Dianne Pauls[1]

I. Introduction

The wide swings in the value of the U.S. dollar during the past two years have rekindled interest in the search for understanding exchange rate movements. However, the general view of the economics profession as represented in Meese (1990) is that past research has been unsuccessful in explaining exchange rate movements. Nevertheless, some researchers still contend that if there is a relationship that is robust in explaining exchange rate movements it is the relationship between real exchange rates and real interest rate differentials. Furthermore, these researchers contend that this relationship is a useful framework to think about exchange rate movements. Figure 1 plots the CPI-adjusted value of the dollar against a measure of the real long-term interest rate differential. Casually inspecting this chart, many argue that these two time series appear to move together. However, this appearance may be an apparition and may not reflect a true long-run stable relationship. This paper investigates these issues. The fundamental question it asks has two parts: (1) Is there a systematic relationship between real exchange rates and real interest rate

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differentials and (2) if so, what empirical representation of it does the data support.

Of the extensive literature on this topic, two of the more recent well-known papers are those of Campbell and Clarida (1987) and Meese and Rogoff (1988).[2] Campbell and Clarida examine whether real exchange rate movements can be explained by shifts in real interest rate differentials and find, in contrast to earlier research, that expected real interest rate differentials have simply not been persistent enough, and their innovation variance not large enough to account for much of the fluctuation in the dollar's real exchange rate. Meese and Rogoff, on the other hand, investigate whether real exchange rates and real interest rate differentials are cointegrated and find that they cannot reject the null hypothesis of non-cointegration between long-term real interest rates and real exchange rates. They suggest that this finding may indicate that a variable omitted from the relationship, possibly the expected value of some future real exchange rate, may have a large variance which, if included, would lead to finding cointegration. This conjecture of an important missing variable is also consistent with the Campbell-Clarida results.

Two recent papers by Coughlin and Koedijk (1990) and Blundell-Wignall and Browne (1991) also report results using cointegration techniques; however, both papers find that real exchange rates and real interest rates may be cointegrated. The ability of Blundell-Wignall and Browne to find cointegration is due to the inclusion of the difference in

2. There are a number of papers including Frankel (1979), Hooper and Morton (1982), Meese and Rogoff (1983), Shafer and Loopesko (1983), and Boughton (1987) that model exchange rate movements focusing on the real interest rate differential and incorporating other economic fundamentals. Most of these studies find that the coefficient on the interest rate differential is statistically significant. This result is not specifically the question we address. We, like the papers discussed in the text, are more interested in establishing the existence of a long-run relationship between real exchange rates and real interest rates.

the share of the cumulated current account relative to GNP in the relevant countries; the finding of cointegration by Coughlin and Koedijk is only for the mark/dollar exchange rate and results from extending the sample period by using more recent data.

This paper also focuses on the long-run relationship between real exchange rates and real interest rate differentials. We begin by examining the statistical properties of the data. Using a variety of tests for unit roots, we show that generally, exchange rates and interest rates, both nominal and real, as well as some of our measures of expected inflation, are nonstationary. The exceptions to these findings are the various measures associated with the cumulated current accounts, U.K. and Japanese prices, and our myopic measure of expected inflation: the quarterly inflation variables. We then test the long-run implications of the model for the cointegration of real exchange rates and real interest rates. Similar to the Meese-Rogoff result, we have not been able to detect any long-run relationship between exchange rates and interest rates using Engle-Granger cointegration tests over the entire sample period. We have expanded these tests to allow for other variables, such as the cumulated current account balance, that may affect the long-run expected real exchange rate, but we still fail to find any evidence of cointegration.

In addition to these tests, general dynamic specifications for the real trade-weighted dollar are examined in an attempt to find an error correction model. Error correction models provide information not only about the long-run relationship but also about short-run dynamics. The final models derived show that most of the short-run movements in real exchange rates are accounted for by their own past; over the longer run, however, changes in interest rates are important in explaining movements in exchange rates. However, we can not impose a specific error correction term as indicated by each of the level variables entering with a statistically different coefficient. This result suggests the lack of a long-run relationship. Therefore, the findings from the dynamic models must be interpreted quite carefully -- they do not corroborate the hypothesis that there is a long-run relationship between real exchange rates and real interest rate differentials.

The rest of the paper is organized as follows. Section II examines the data and section III gives the model framework. Section IV presents the the time series properties of the data. Section V discusses the econometric results. Section VI concludes the paper.

II. The Data

The issues in this paper are fundamentally empirical. Before presenting a formal model, we consider the data by visually inspecting it. In particular, we want to know whether the results as depicted in Figure 1 are conditional on: (1) the time period selected, (2) the choice of interest rate, (3) the inflation measure used to construct the real interest rate, and (4) the choice of exchange rate. Some of the differences in the results in the existing literature appear to stem from aspects of the data selected. It is possible for graphs misleadingly to portray the data, nevertheless we think this method is useful to highlight the above issues.[3]

The data are quarterly observations for 1974 - 1990. Exchange rates are the Federal Reserve Board staff's trade-weighted value of the U.S. dollar against the other G-10 currencies, and the Japanese yen, German mark, British pound sterling, and Canadian dollar against the U.S. dollar. Nominal interest rates are the 10-year constant maturity rate on Treasury bonds for the United States (i) and yields on bellwether government bonds for the

3. Danker and Hooper (1990) also present several graphs in their examination of this relationship.

foreign G-10 countries (i^*).[4] Prices are measured by CPIs. The weighted average value of the dollar in real terms is calculated by adjusting the nominal value by the ratio of the U.S. to the foreign CPI. For the analysis of the trade-weighted dollar, the foreign variables are similarly trade weighted. The cumulated current account balances are created assuming the cumulated current accounts of the various countries were in balance as of 1972 Q4; the current accounts were then accumulated as of 1973 Q1.[5]

Three alternative measures of expected inflation are considered. The first alternative is a 12-quarter centered moving average of CPI inflation rates, where forecasts are used when published data are not available. The other two measures are based on quarterly and 4-quarter changes in the CPI index, respectively. Appendix I gives details of the data and sources.

Figure 1 presents the weighted average value of the dollar in real terms and a measure of the real long-term interest differential calculated using the 12-quarter centered moving average measure of expected inflation.[6] The figure indicates that movements in the two series have been at least roughly correlated over most of the floating rate period. The

4. In most of the foreign G-10 countries, the liberalization of financial markets is a fairly recent phenomena. Previously, 10-year bonds did not exist in many of these countries. For the early part of our sample, we used the best available proxy -- often an average yield on a set of bonds of intermediate maturity.

5. The assumption that the cumulated current accounts were in balance does not, of course, accord with the data. However, this assumption only affects our initial condition and does not alter the dynamic results.

6. The history of the dollar since the collapse of the Bretton Woods system breaks up fairly neatly into six phases: 1973-75, when the dollar depreciated after the breakdown of Bretton Woods; 1975-76, when the dollar appreciated; 1977-80, when the dollar depreciated as market participants were concerned that U.S. authorities were not adequately fighting inflation; 1981-84, when the dollar appreciated sharply as monetary policy in the United States was firm and prospects for continued large U.S. fiscal deficits exerted upward pressure on real interest rates; 1985-86, when the dollar peaked and reversed its trend after U.S. monetary conditions had begun to ease; and 1987-90, when the dollar fluctuated within a range.

decline in the dollar during the 1970s is consistent with a general downtrend in the interest differential. The relationship also holds up reasonably well during the dollar's appreciation in 1979-83, and again during its depreciation in 1985-86. The relationship breaks down, however, during 1984 to early 1985, when the dollar continued to rise strongly after the interest differential turned down. The same thing occurred to a lesser extent in the first part of 1989. The chart shows a tendency for movements of real interest rate differentials to precede movements in real exchange rates, but the strength of this relationship may vary over time.

A very different story about the relationship between real interest rate differentials and real exchange rates emerges when using short-term real interest rates. Figure 2 illustrates that the relationship between real exchange rates and real short-term interest rate differentials does not resemble its long-term counterpart over most of the floating rate period.[7]

Figure 3 displays the nominal and real trade-weighted values of the dollar. As is well known, there is a close correspondence between the two series, and, as has been shown elsewhere in the literature, most of the movement in the real exchange rate reflects movements in the nominal exchange rate. Figure 4 shows that there is little apparent relationship between the nominal trade-weighted dollar and the nominal long-term interest rate differential. One explanation for this seeming lack of correlation is that the expected future nominal value of the dollar, unlike its real counterpart, does not even approximate a stable anchor; it varies with

7. The relationship does not hold up well, in general, because the expected value of the dollar over a short horizon tends to vary more than does its expected long-run real value. However, since 1985, the CPI-adjusted value of the dollar and the real short-term interest differential -- like its long-term counterpart -- have tended to move together as relative yield curves have changed little.

changes in inflation expectations. On the other hand, this picture does raise the question of whether the relationship in real terms is dependent on the inflation measure we use. Figure 5 presents three alternative real interest rate differentials based on three different expected inflation measures. As this figure illustrates, the generated real interest rate differentials do vary considerably with the different measures of inflation.

Figures 6 - 9 plot for the four bilateral rates -- German mark, Japanese yen, British pound sterling, and Canadian dollar against the U.S. dollar -- the relationship between real exchange rates and real interest rate differentials using a 12-quarter centered moving average measure of expected inflation. A strong relationship between real long-term interest differentials and real exchange rates is seen for the mark/dollar over most of the period. In contrast to the mark/dollar, there appears to be little relationship between the other three bilateral real exchange rates and their real interest differentials. One reason why this relationship may not be evident for the United Kingdom during much of the 1970s is that capital controls were in place there until late 1979; however, the relationship does not work well since that date either. Although Japan also had capital controls until late 1980, much of the apparent breakdown in the relationship for the yen/dollar occurred since then.[8]

All in all, these graphs seem to suggest that the strong relationship between real exchange rates and real interest rate differentials that was apparent in Figure 1 may be tenuous. The next few sections of this paper examine this issue statistically.

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8. Another reason why this relationship might not be evident for these two countries is that the consumer price index might not be the most appropriate index to use. The weight of raw commodities, especially oil prices, in the CPI for both Japan and the U.K. might bias the calculation.

III. The Model

As in Isard (1982), we begin with a set of useful definitions. The uncovered interest parity condition, assuming a risk premium, is defined as follows:

(1) $$s_t = E(s_T) + i_{t,T} - i^*_{t,T} - \rho_t,$$

where:

- s = log of spot exchange rate (foreign currency per dollar)
- $E(x)$ = the expected value of any future variable x based on information at time t
- i, i^* = nominal own rates of interest on assets denominated in home and foreign currencies, as compounded over horizon T-t
- ρ = exchange risk premium

Next the real exchange rate is defined as:

(2) $$q = s + p - p^*,$$

where:

- q = log of the real exchange rate
- p, p^* = log of domestic, foreign price levels

Combining (1) with an expression for $E(s_T)$ derived from (2):

(3) $$s_t = E(q_T) + E(p^*_T) - E(p_T) + i_{t,T} - i^*_{t,T} - \rho_t$$

It is convenient to rewrite the expected future logarithmic price levels in terms of expected inflation, using the approximation:

(4) $$E(p_T) = p_t + E(\pi)$$

$$E(p_T^*) = p_t^* + E(\pi^*)$$

Applying the Fisher equation to obtain an expression for expected real rates of interest:

(5) $$E(r_{t,T}) = i_{t,T} - E(\pi)$$

$$E(r_{t,T}^*) = i_{t,T}^* - E(\pi^*)$$

Substituting (4) and (5) into (3), and using the definition in (2):

(6) $$q_t = E(r_{t,T}) - E(r_{t,T}^*) + E(q_T) - \rho_t$$

In order to obtain a relationship between the real exchange rate and the expected real interest rate differential, it is necessary to model the expected future real exchange rate and the risk premium. Traditional econometric work in this area has used a single-equation semi-reduced form often with no dynamics. The equation is derived by assuming that the risk premium is white noise and the expected long-run real exchange rate is equal to a constant plus possibly a function of some "fundamental" factors; a typical example of a "fundamental" factor is the cumulated current account.

That is,

(7) $$q_t = E(r_{t,T}) - E(r^*_{t,T}) + k + \bar{q}(ccbal_t) - \rho_t$$

where

k = a constant

ccbal = relative cumulated current accounts (domestic to foreign)

We introduce dynamics into equation (7) by modelling the risk premium as an autoregressive process[9] i.e., $A(L)\rho = -\epsilon_t$. This allows us to obtain a general dynamic specification, having dropped the constant, of the following form:

(8) $$A(L)q_t = A(L)\, r^+_{t,T} + A(L)\, \bar{q}(ccbal)_t + \epsilon_t$$

where:

$$r^+_{t,T} = E(r_{t,T}) - E(r^*_{t,T})$$

Equation (8) represents a very general relationship and is empirically motivated. In section V, we refer to this equation as the autoregressive distributed lag model. In implementing this equation we attempt to fit empirically a specific form, namely an error correction model. A simplified version of the general dynamic specification,

9. We choose to model the risk premium with an autoregressive process because of the poor empirical performance of variables that have been used to explain the risk premium, such as relative asset supplies or the conditional covariance of the asset return with the intertemporal marginal rate of substitution.

truncating the lags at one, is:

(9) $$\Delta q_t = \lambda_1 \Delta r^{+}_{t,T} + \lambda_2 \Delta \bar{q}(ccbal_t) + \beta_1 q_{t-1} - \beta_2 r^{+}_{t-1,T} - \beta_3 \bar{q}(ccbal_{t-1}) + \epsilon_t$$

If we have an error correction model, then we can restrict the coefficients to be $\beta_1 = \beta_2 = \beta_3$, which is the restriction implied by equation (6). This is a testable hypothesis that is considered in the empirical section.

IV. Time Series Properties of the Data

Before modelling the relationship between exchange rates and interest rates, the statistical properties of the data are analyzed. In particular, each time series is examined to assess whether it contains a unit root. We need to establish the order of integration of the time series before we can proceed to our next step of testing for cointegration.

For an arbitrary time series (x_t), consider the model

(10) $$x_t = \beta_0 + \beta_1 t + \beta_2 x_{t-1} + u_t.$$

Using this equation, two hypotheses are tested. First we test the null hypothesis H_0: $\beta_2 = 1$ against the general alternative. This is a simple unit root test based on a 't' statistic. Second we test the null hypothesis H_0: $(\beta_0, \beta_1, \beta_2) = (\beta_0, 0, 1)$ against the general alternative based on an 'F' statistic. This hypothesis tests whether there is a unit root and whether the trend term is important. To test both of these hypotheses three test statistics are reported in Tables 1 and 2: the standard Dickey-Fuller (columns 1 and 3), the augmented Dickey-Fuller (columns 2 and 4)[10], and the Phillips test (columns 5 and 6). The standard Dickey-Fuller test assumes that the u_t in (10) is white noise and the augmented Dickey-Fuller test includes additional lagged changes in the x's to ensure u_t is white noise. Alternatively, following Phillips (1987) and Phillips and Perron (1988) the error process is assumed to be heterogenous and modelled appropriately.[11]

Table 1 reports the results for testing for unit roots for the trade-weighted time series and table 1a reports the results for the bilateral time series. In both tables the inflation series relate to the 12-quarter centered moving average measure of expected inflation, which is also used to construct the real interest rates shown. In table 1, for most of the variables tested, the null hypothesis that these series have a unit root can not be rejected. The results for the inflation variables and inflation differentials are sensitive to the lags selected in the augmented tests.[12] Because the overwhelming majority of the tests indicate that these variables are I(1) series we treat them as such in the study.[13]

The results reported for the cumulated current account variables, at the bottom of table 1, indicate that these time series are either I(1)

10. For each variable we compute the augmented Dickey-Fuller test for lags 1 - 5. We report results using 1 lag for the augmented tests, based on the criteria that the errors are white noise using an LM test. For a great majority of the variables examined we were able to achieve white noise with 1 lag. For those variables that needed more lags the inference for the test reported are almost always unchanged. (We will, however, note in the text where the results are sensitive to the length of lag selected.)

11. For other applications of these tests to exchange rate data see for example Edison and Fisher (1991).

12. Note that the differences in the results across the different test statistics suggest that caution should be taken when interpreting the results as the power of the tests may be low.

13. We repeated our unit root tests on the first differences of each time series and found in general that we rejected the null that the first difference of these series had a unit root. In other words, we confirmed that most levels of our original time series are I(1) -- the exceptions being the cumulated current accounts variables.

with a trend or I(2). Testing the first differences of these two series tests, which we do not report, suggest that they are I(2). This result implies that it would be inappropriate to include cumulated current account variables in an Engle-Granger cointegrating regression, because in this regression it is assumed that all variables are integrated of the same order, usually I(1). Note that using the level of the current account itself does not make sense theoretically. We include these variables in some of our cointegration tests but are aware that they may be integrated of a higher order.

The results reported in Table 1a for the U.S. - German and the U.S. - Canadian data mirror the trade-weighted results; however the results for U.S. - Japan and the U.S. - U.K. data are somewhat different from those in Table 1. In particular, the price level for Japan and the U.K. appear to be trend stationary rather than I(1).[14] Even though the results for prices are not clear cut, we treat them as though they are I(1) and note that they are only used to create real exchange rates and are not used independently in this study. Similar to the results reported in table 1, the behavior of the various time series involving the cumulated current account appear to be either I(1) with trend or I(2). Further testing, which we do not report, seems to indicate that the variables may be I(2). Intuitively, this implies that the level of the current account or the GNP share of the current account contains a unit root.

Table 2 and 2a report similar test statistics for the other measures of expected inflation for the trade-weighted dollar and the bilateral exchange rates, respectively. It is not surprising that if the price level has a unit root, that we reject the null of a unit root for the

14. The results for the augmented tests are highly sensitive to the choice of lag length. For Japan, for example, with longer lags the augmented tests indicate the series may be I(2).

first difference of the price level, which is our first alternative measure of expected inflation -- the quarterly change in prices (at an annual rate). In addition, the difference in expected inflation and the real interest rate differential using this inflation measure also appear trend stationary. In contrast, the tests where expected inflation is measured by 4-quarter changes in the price level consistently cannot reject the null hypothesis of a unit root. The results in table 2a are similar to those in table 2 with the exception of those for inflation in Japan.

We conclude that the time series relevant for our basic cointegration tests are all integrated of the same order -- I(1), which is a necessary condition for these time series to be cointegrated. The cointegration tests provide a means of evaluating the relationship between real exchange rates and real interest rate differentials (and the components of the differential) as described in equation (7).

a. Cointegration Tests

Tables 3 and 3a contain the results of cointegration tests. We specify the right-hand-side variables with and without coefficient restrictions imposed.[15] These cointegration tests are based upon the residuals from a simple OLS regression of the following sort:

$$(11) \qquad q = \beta_0 + \beta_1 i + \beta_2 i^* + \beta_3 \pi + \beta_4 \pi^* + \beta_5 \mathbf{X} + u$$

where **X** is a vector of unspecified additional variables.

A two-step procedure as outlined in Engle-Granger (1987) and Engle-Yoo (1987) is followed. First we run the OLS regression implied by equation

15. In an earlier version of this paper we also reported results from decomposing the real exchange rate into the nominal exchange rate and the respective price levels. The results from these test were similar to those reported in Tables 3 and 3a and are not reported here because our focus in this paper is on the relationship between real exchange rates and real interest rates.

(11). Second, we test the regression residuals for stationarity using the same Dickey-Fuller tests that we used to test for unit roots. If the residuals from the cointegration regressions are indeed I(0), then we can reject the null hypothesis of non-cointegration.

Before discussing the general results from these cointegration tests we present equation (12), which reports the first stage of an Engle-Granger cointegration test using the simple bivariate case for the trade-weighted value of the dollar and the real interest rate differential.

$$q = \underset{(394.7)}{4.56} + \underset{(10.18)}{.062}\ (r-r^*) \tag{12}$$

$R^2 = .622$ DW = .35 RSS = .5110

LM F[5, 58] = 27.47 ARCH F[4, 55] = 23.99 Normality $\chi^2(2) = 3.98$

Cointegration test: -2.47

The results of this equation appear to show that there is a relationship between these variables as indicated by the strongly significant coefficient -- the numbers in parenthesis are t-statistics -- on the real interest rate differential. Note, however, when testing for cointegration we find that we can not reject the null hypothesis of a unit root. This result implies that q and (r-r*) are not cointegrated and that the results of equation (12) could be spurious. Furthermore, if we make the real interest rate differential the dependent variable our conclusions are unchanged.[16]

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16. The results for this regression are as follows:

$$(r - r^*) = \underset{(10.06)}{-45.303} + \underset{(10.17)}{9.972}\ q$$

$R^2 = .621$ DW = .392 RSS = 81.725

LM F[5, 58] = 24.73 ARCH F[4, 55] = 12.01 Normality $\chi^2(2) = 3.09$

Cointegration test: -2.63

The specifications examined to test for cointegration are shown at the bottom of the table 3. The tests were run first examining whether nominal interest rates, actual inflation, and real exchange rates can be cointegrated. These tests are valid under the assumption that in the long-run actual and expected inflation move together. We then tested whether the real interest rate differential and real exchange rates can be cointegrated. The final set of specifications include the cumulated current account. The inclusion of this variable might be inappropriate if these variables are indeed I(2).

For the various specifications using the 12-quarter centered moving average measure of expected inflation and the 4-quarter change measure of expected inflation, it is not possible to reject the null hypothesis of no cointegration, which is similar to the results in Meese-Rogoff.[17] This result suggests that there does not exist a linear combination of real exchange rates and real interest rate differentials that is itself stationary, implying that there is no simple long-run relationship between the two variables (and/or its components broken out).

As Meese-Rogoff suggest, it is most likely one or more highly variable factors have been omitted from the real exchange rate - real interest rate relationship. We investigate this possibility by including various measures of the cumulated current account recognizing that these variables might be I(2) and therefore inappropriate. Even after including these data we consistently can not reject the null hypothesis of non-cointegration. Our findings conflict with those of Blundell-Wignall and Browne as they report that real exchange rates are cointegrated with the real interest rate differentials and the differential between cumulated

17. We do not examine the series that involve the 1-quarter inflation measures because we found these series to be I(0).

current account balances as shares of GNP, which is one of the measures we investigate.

We do find, however, very weak evidence in support of Coughlin and Koedijk results that the cointegration tests are time period sensitive.[18] In running recursive, or expanding, cointegration tests for the trade-weighted dollar including the cumulated current account we find we can reject the null of non-cointegration for sample periods ending from 1980 Q1 to 1982 Q3. We examine this possibility for several other cointegration regressions for different bilateral exchange rates and found that the Dickey-Fuller test statistic varied over time, but the conclusion drawn for the statistics remained unchanged: we could not reject the null of non-cointegration.

In summary, the cointegration test do not find any conclusive evidence linking the real exchange rate to the components of the real interest rate differential. As we said earlier, this may be due to the omission of an important factor or alternatively it may be due to our test procedures.

V. Empirical Results[19]

Note that Engle-Granger show that if a set of variables are cointegrated then there always exists an error correction formulation of the dynamic model and vice versa. This result suggests that the two approaches are isomorphic. In addition, error correction models give information about short-run dynamics; it is this information that distinguishes the two approaches. Also, not only does the error correction approach offer an alternative test of the existence of the equilibrium imposed by theory, but

18. In contrast to Coughlin and Koedijk, we do not find evidence of cointegration for the mark/dollar rate, even over the longer time period.
19. In this section we limit our investigation to the trade-weighted value of the dollar.

these tests often tend to be more powerful than the simple cointegration tests presented above.[20] The rest of this section attempts to obtain an an error correction model to test the hypothesis that there exists a relationship between real exchange rates and real interest rate differentials.[21] The main body of this section will discuss models using the 12-quarter centered moving average measure of expected inflation. The following subsection will discuss the two other measures of expected inflation.

The starting point for the dynamic modelling is a single equation using an autoregressive distributed lag model similar to equation (8) in section III.[22] The goal of the specification search is to derive an error correction model such as equation (9). In estimating these equations we introduce an impulse dummy variable around the dramatic increase in the dollar from 1984 Q1 to 1985 Q1. The dummy represents the unexplained run-up in the dollar -- the so-called "bubble". The dummy takes on values starting at 1 in 1984 Q1 and going to 5 in 1985 Q1.

Table 4 lists the coefficient estimates for equation (8), the associated conventional and heteroscedasticity-consistent standard errors, and the relevant model diagnostic statistics. The residual standard error is slightly above 2.3 percent. We reparameterize the changes in nominal

20. Banerjee et al (1986) show that testing for cointegration using an error correction model under the null that cointegration is valid, has more power than a typical test suggested by Engle and Granger .
21. In an earlier version of this paper we considered including the cumulated current account in the general model. The results of specifications that included this variable indicated significant autocorrelation and parameter instability. One explanation for this misspecification may be that the cumulated current account is an I(2) variable. Therefore in this version of the paper we exclude this variable from our investigation.
22. It is well known that an autoregressive distributed lag model can be reparameterized with variables in levels and differences. See for example Harvey (1990, chapter 8.5) and/or Hendry, Pagan, and Sargan (1984).

interest rates and expected inflation to become changes in the real rates. Several exclusion restrictions are also applied, including the lagged change in the real exchange rate.

Table 5 gives the final specification. The estimated equation standard error is roughly that of the general model and the joint F statistics that all the restrictions on the model are valid are below any reasonable significance level. The results in Table 5 show that in the short-run most of the movement in the real exchange rate is accounted for by the level of its own past and changes in foreign real interest rates. The stationary state shown at the bottom of the table indicates that in the long-run real interest differentials are the important determinant of the real exchange rate. The estimates of the long-run elasticity of the real exchange rate with respect to the real interest differential is approximately 7 percent.

The implied stationary state of this dynamic equation, however, is at odds with the results of the cointegration tests, which suggested that there was no simple long-run relationship between real exchange rates and real interest rate differentials. We know from Banerjee et al that the results from the error correction model are more powerful if the null of cointegration is valid, but what we do not know is if the null is correct. Our final specification of the dynamic model shows that the level of the real interest rate differential is statistically significant based on the null hypothesis. However, we can not impose a specific error correction term as indicated by the level variables entering with statistically different coefficients.[23] This result suggests the lack of a long-run relationship. Therefore, the finding from the dynamic model must be

23. We tested an error correction term, which scaled the real interest rate term by the appropriate constant, but we still rejected the implied restriction.

interpreted quite carefully -- they do not corroborate the hypothesis that there is a long-run relationship between real exchange rates and real interest rate differentials.

a. Alternative Inflation Measures

Two alternative expected inflation measures are used to evaluate the real exchange rate-real interest rate relationship. A similar modelling methodology was employed for each expected inflation measure. That is, we start with a general autoregressive distributed lag model in each instance and impose exclusion and parameter restrictions to derive the final model. Table 6 reports the final model for inflation modelled as quarterly changes in the price index (at an annual rate). Table 7 gives the final model for expected inflation modelled as 4-quarter changes in the price index. The standard errors for each equation are about 0.2 percent lower than the final model reported in table 5.

The final models derived for the two measures share a number of common features. In both instances, short-run changes in the real exchange rate are explained not only by changes in the real interest rate and the past level of the exchange rate, but also by changes in foreign interest rates. The long-run stationary states of the models are also very similar. The implied long-run shows that the components of the real interest rate differential have different effects on the real exchange rate, this is in contrast to results in table 5, which uses the 12-quartered centered moving average measure of inflation. The results in table 6 and 7 are similar to those in table 5 insofar as we can not impose the error correction term -- $(q - \lambda r^{+})$. Consequently, even though these results appear at first blush to support the hypothesis that there exists a relationship between real exchange rates and real interest rates, they are not, in fact, consistent with the hypothesis.

VI. Conclusion

The fundamental question this paper asks has two parts: (1) Is there a systematic relationship between real exchange rates and real interest rate differentials and (2) if so, what empirical representation of it does the data support. The model we present, as one would expect, suggests that there is good reason to believe that there should be a systematic relationship between the two variables. However, similar to other researchers, we can not find a good empirical representation that is supported by the data. In our attempt to find such a relationship we have investigated whether the empirical results are conditional on: (1) the time period selected, (2) the choice of interest rate, (3) the inflation measure used to construct the real interest rate, and (4) the choice of exchange rate.

The results presented here for the trade-weighted value of the U.S. dollar, and of the value of the U.S. dollar against the Japanese yen, German mark, British pound sterling and the Canadian dollar suggest that the respective real exchange rates and real interest rates, and most of their constituent series are nonstationary. Yet, similar to other researchers, we cannot find a series or a set of series that are cointegrated with real exchange rates. In particular, the real interest differentials using a 12-quarter centered moving average measure for expected inflation are not cointegrated with real exchange rates, nor are nominal interest differentials and inflation differentials cointegrated with real exchange rates. These results are duplicated for various alternative measures of expected inflation and are robust to the sample period selected. Furthermore, the inclusion of cumulated current account balances does not reverse these results. We could not find evidence corroborating the finding of a systematic relationship between real interest rate differentials and real exchange rates as reported in the recent studies of Coughlin and Koedijk and Blundell-Wignall and Browne.

In the final section of this paper we investigate a general dynamic specification for the trade-weighted value of the dollar in an attempt to derive an error correction model. Our final specifications of the dynamic models show that the level of the real interest rate differential (or its components) are statistically significant under the null hypothesis of cointegration. However, the cointegration test results suggest a lack of cointegration, and we can not impose a specific error correction term as indicated by the level variables entering separately. This result suggests the lack of a bivariate long-run relationship between real exchange rates and real interest rate differentials, in contrast to what the dynamic models might seem to suggest.

The final interpretation of the empirical work is that the apparent relationship as depicted by figure 1 is not confirmed using standard statistical methods. One or more highly variable factors most likely have been omitted from the relationship as the charts for some of the bilateral exchange rates seem to suggest. One extension for future research might be to employ more powerful tests of cointegration, which allow for more than one cointegrating vector.

References

Banerjee, A., J. J. Dolado, D. F. Hendry and G. W. Smith (1986), "Exploring Equilibrium Relationships in Econometrics Through Static Models: Some Monte Carlo Evidence," Oxford Bulletin of Economics and Statistics, August, 48, 3: 253-277.

Boughton, J. M. (1987), "Tests of the Performance of Reduced-Form Exchange Rate Models," Journal of International Economics 23, .

Blundell-Wignall, A. and F. Browne (1991), "Increasing Financial Market Integration. Real exchange rates and Macroeconomic Adjustment," OECD Working Paper.

Campbell, J. Y. and R. H. Clarida (1987), "The Dollar and Real Interest Rates," Carnegie-Rochester Conference Series on Public Policy, 24: (eds.) A. Meltzer and K. Brunner, North Holland: Amsterdam.

Coughlin, C. C. and K. Koedijk (1990), "What Do We Know About the Long-Run Real Exchange Rate?," St Louis Federal Reserve Bank Review, Volume 72, No 1 January/February, 36 - 48.

Danker, D. and P. Hooper (1990), "International Financial Markets and the U.S. External Imbalance," International Finance Discussion Paper #372, Board of Governors of the Federal Reserve, January.

Dickey, D. A. and W. A. Fuller (1981), "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," Econometrica, 49, 1057-1072.

Edison, H. J. and E. Fisher (1991), "A Long-Run View of the European Monetary System," Journal of International Money and Finance, 10, 53 -70.

Frankel, J. (1979), "On the Mark: A Theory of Floating Exchange Rates Based on Real Interest Differential," American Economic Review, volume 69, September, 610 - 622.

Engle, R. and C. Granger (1987), "Co-Integration and Error Correction: Representation, Estimation, and Testing," Econometrica, 55, 251-276.

Engle, R. and B. S. Yoo (1987), "Forecasting and Testing in Co-integrated systems," Journal of Econometrics, 35, No. 1, 143-160.

Fuller, W. A. (1976), Introduction to Statistical Time Series, New York: John Wiley and Sons, 373.

Harvey, A. C. (1990), The Econometric Analysis of Time Series, 2nd. ed., Cambridge, Mass: MIT Press.

Hendry, D. F., A. R. Pagan and J. D. Sargan (1984), "Dynamic Specification," in Handbook of Econometrics, edited by Griliches, Z. and M. Intriligator, Amsterdam: North Holland, 1023-1100.

Hooper, P. and J. Morton (1982), "Fluctuations in the dollar: a model of nominal and real exchange rate determination," Journal of International Money and Finance, Volume 1, 1: April, 39 - 56.

Isard, P. (1982), " An Accounting Framework and Some Issues for Modelling How Exchange Rates Respond to the News," International Finance Discussion Paper #200, Board of Governors of the Federal Reserve, January.

Meese, R. (1990), "Currency Fluctuations in the Post-Bretton Woods Era," Journal of Economic Perspective, Volume 4, 1: Winter, 117 - 134.

Meese, R. and K. Rogoff (1983), "Empirical Exchange Rate Models of the 1970's: Do they Fit out of Sample?," Journal of International Economics 14, 3-24.

Meese, R. A. and K. Rogoff (1988), "Was it Real? The Exchange Rate Interest Rate Relation, 1973-1984," Journal of Finance, September,43: 933 - 948.

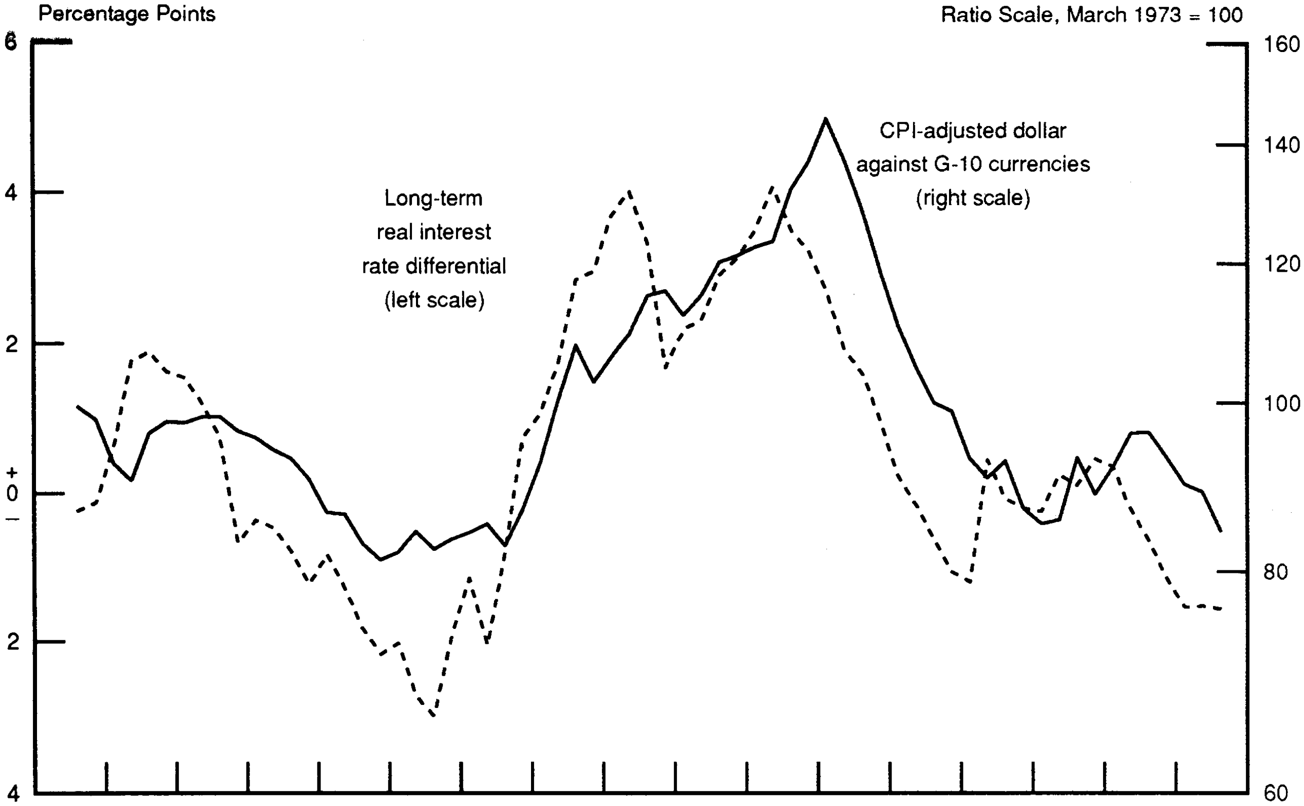
Phillips, P. (1987), "Time Series Regression with a Unit Root," Econometrica 55, 277-302.

Phillips, P. and P. Perron (1988), "Testing for a Unit Root in Times Series Regression," Biometrika 75, 335-46.

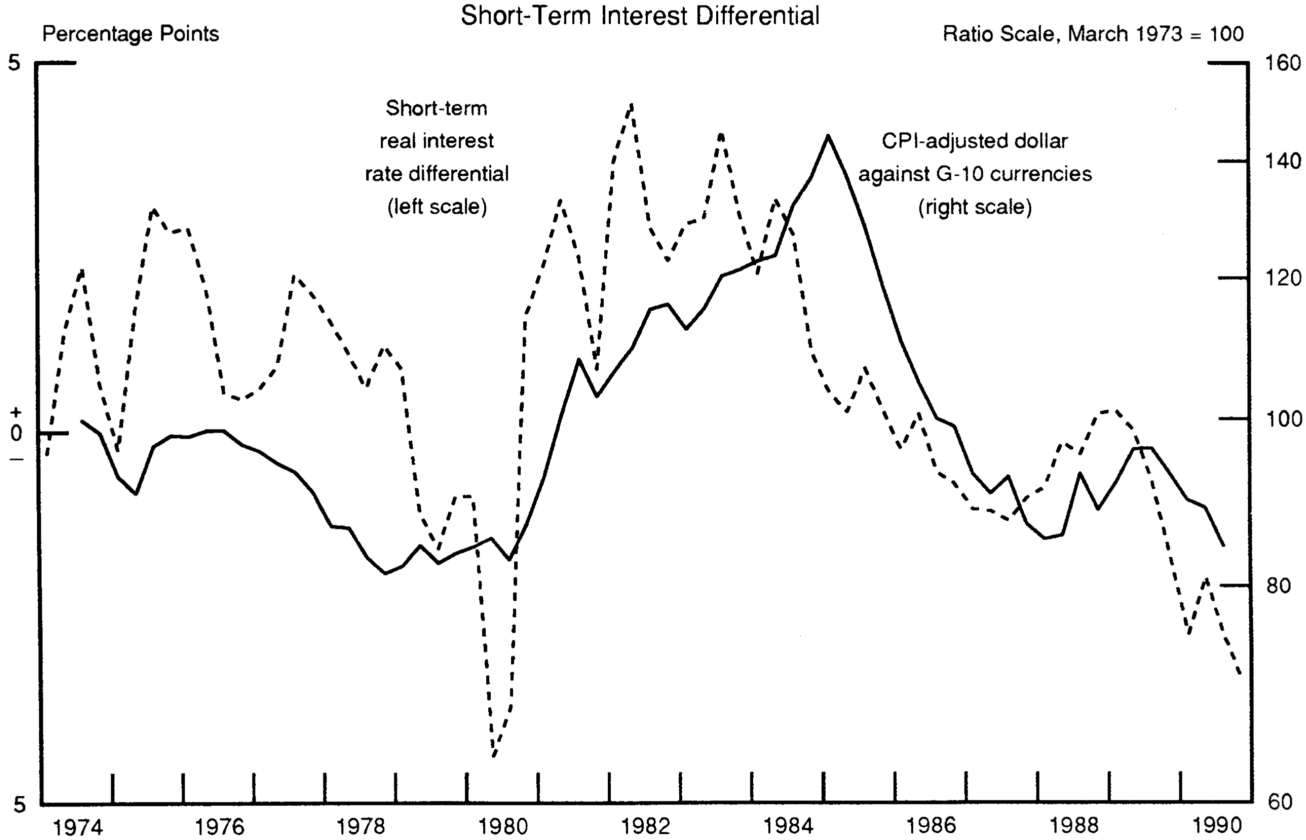
Shafer, J., and B. Loopesko (1983), "Floating Exchange Rates after Ten Years," Brookings Papers on Economic Activity 1, 1-70.

Figures 1 - 2
The Dollar and Real Interest Rate Differentials

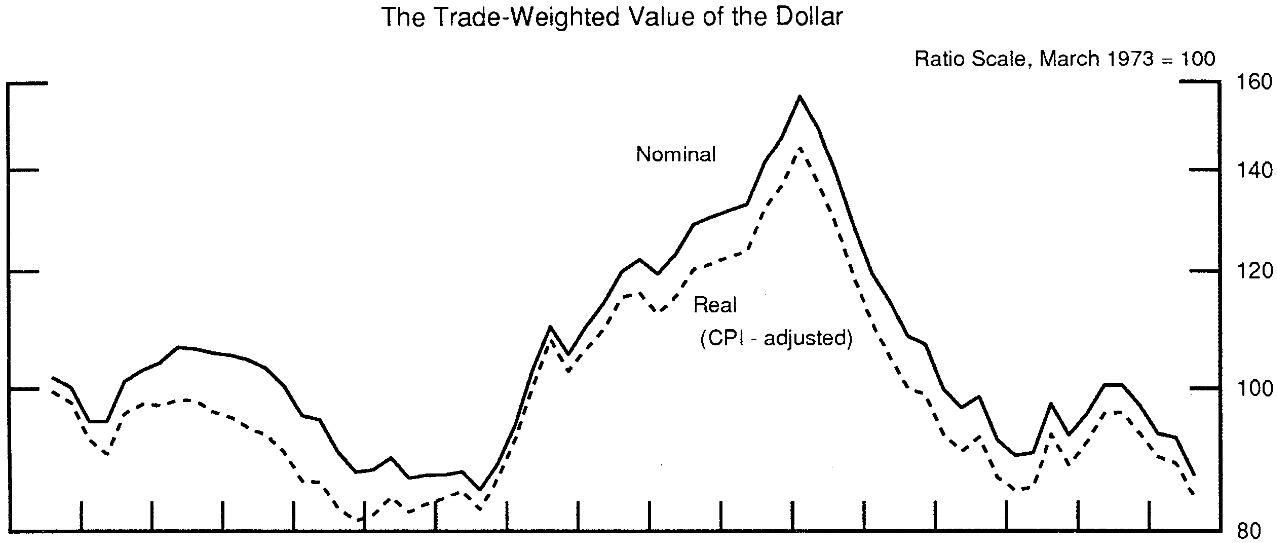
Long-Term Interest Differential

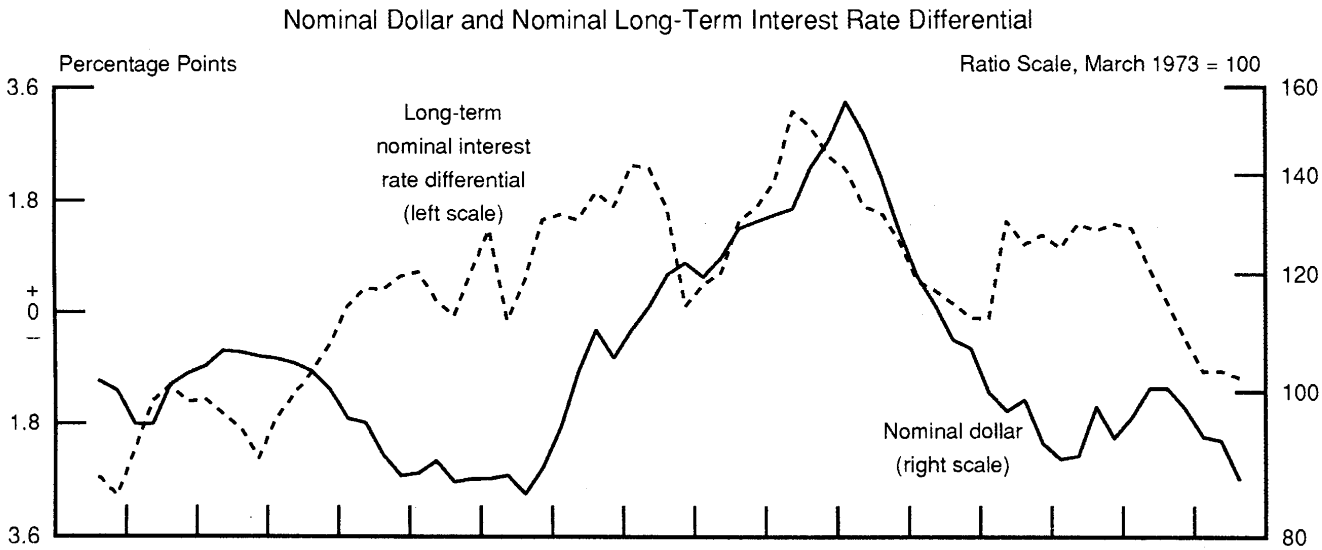


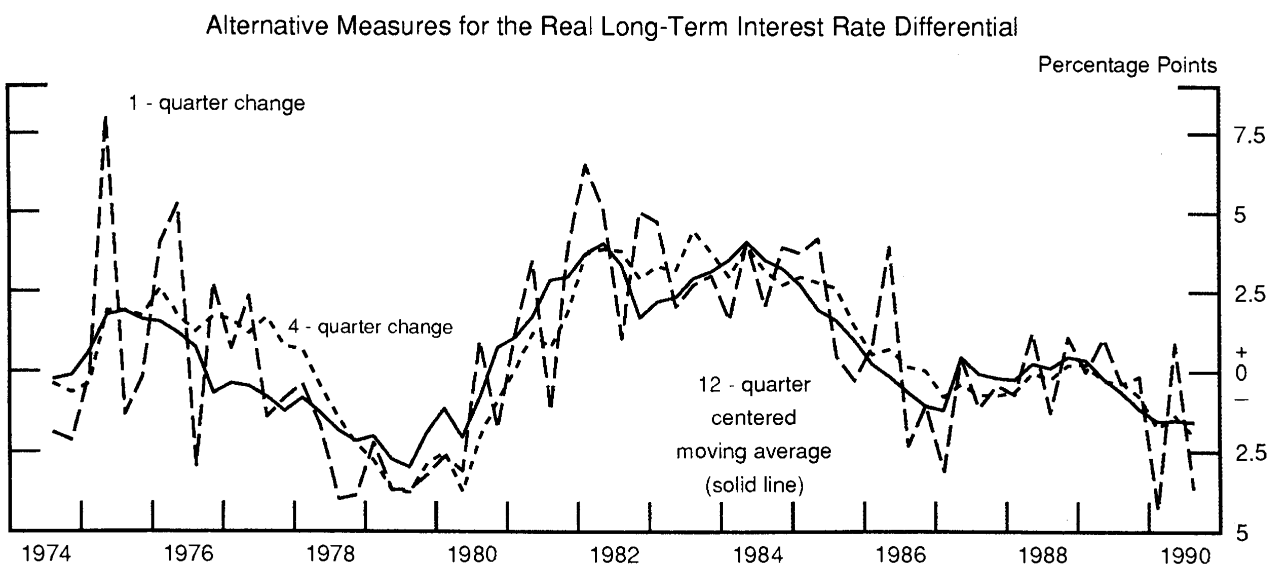
Short-Term Interest Differential



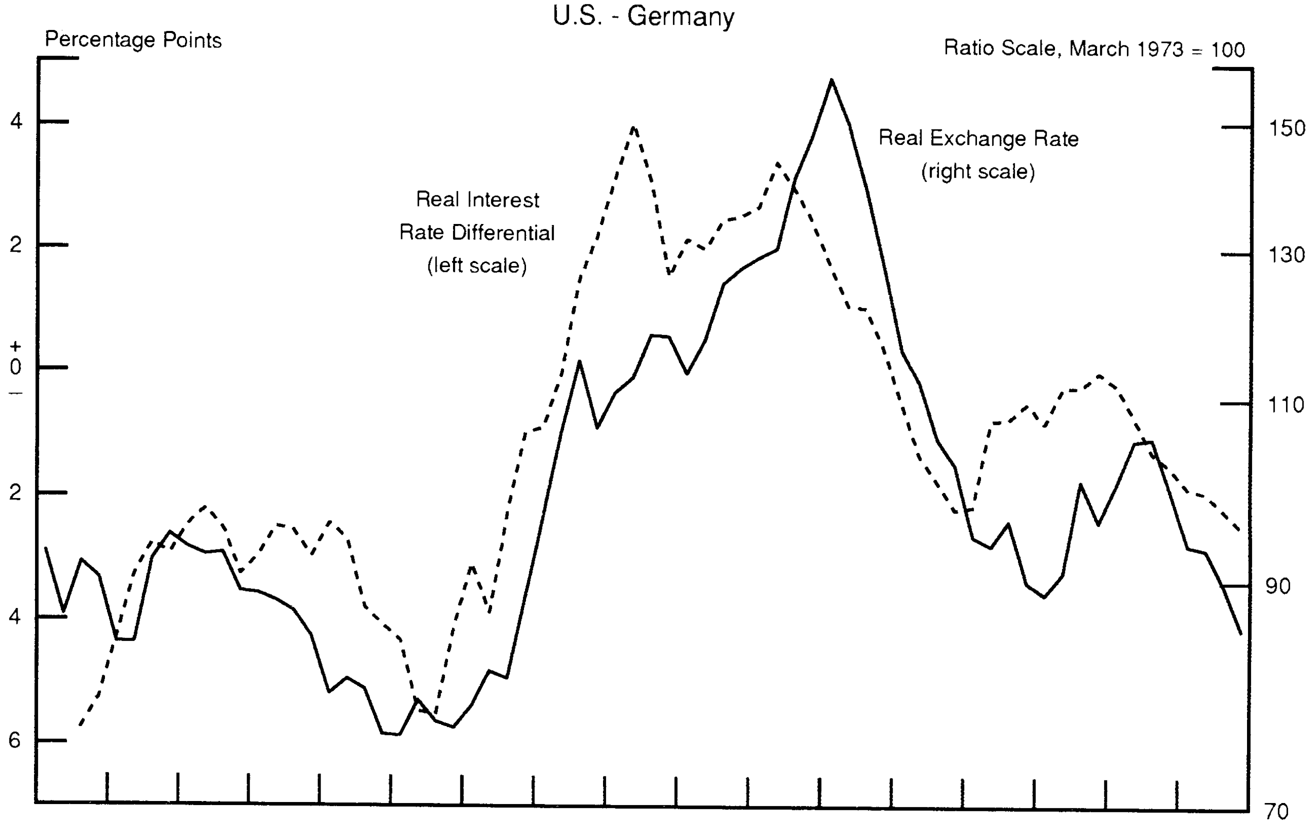
Figures 3 - 5

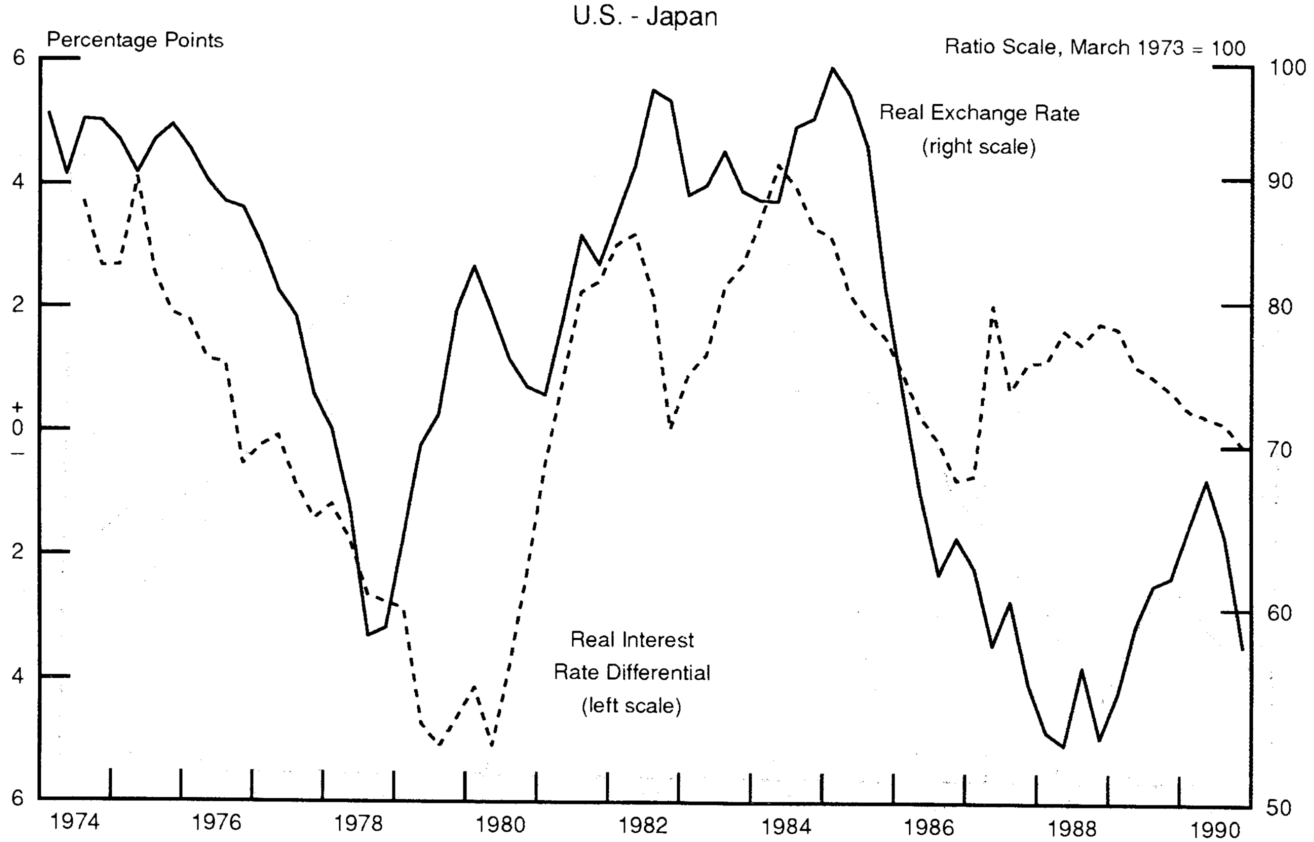

The Trade-Weighted Value of the Dollar
Ratio Scale, March 1973 = 100
160
140
120
100
80
Nominal
Real
(CPI - adjusted)


Nominal Dollar and Nominal Long-Term Interest Rate Differential
Percentage Points
Ratio Scale, March 1973 = 100
3.6
1.8
+
0
–
1.8
3.6
160
140
120
100
80
Long-term
nominal interest
rate differential
(left scale)
Nominal dollar
(right scale)

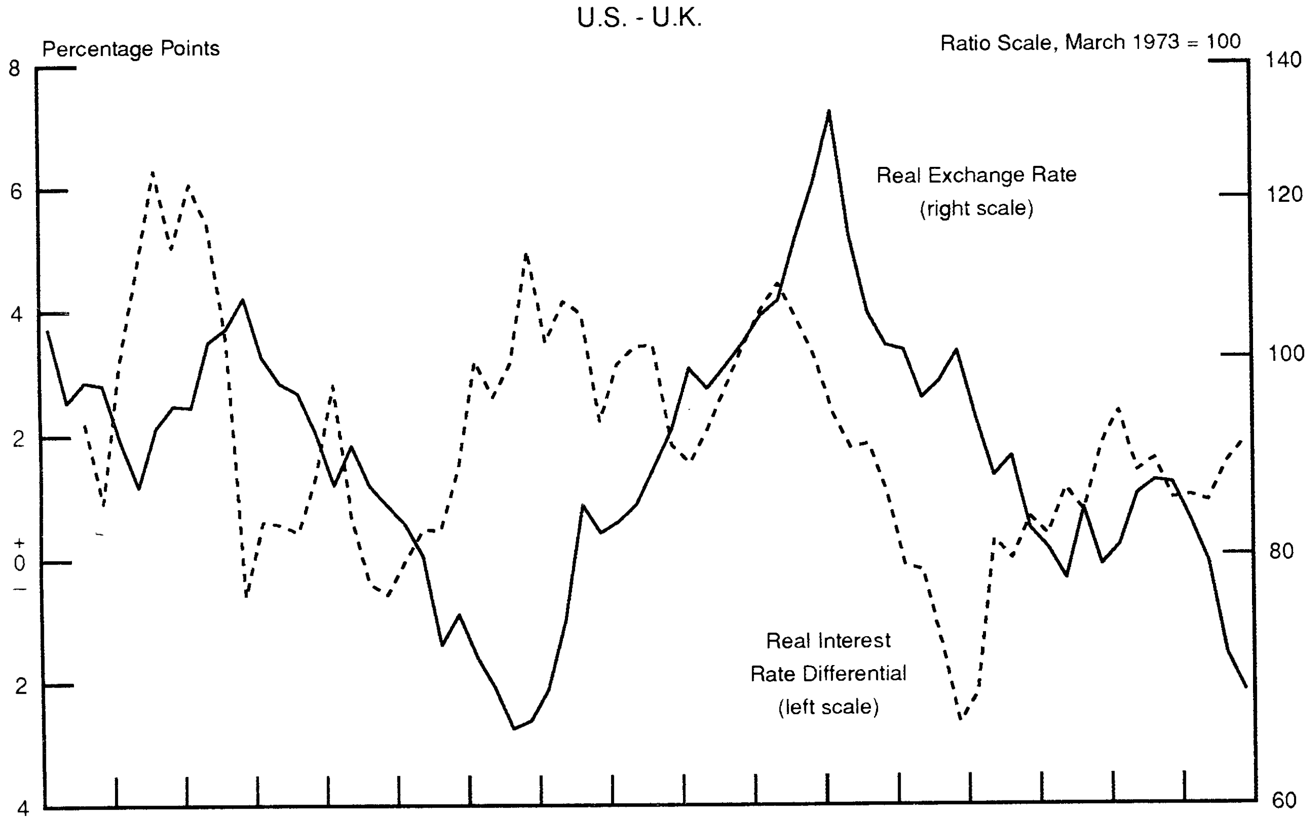

Alternative Measures for the Real Long-Term Interest Rate Differential
Percentage Points
7.5
5
2.5
+
0
–
2.5
5
1 - quarter change
4 - quarter change
12 - quarter
centered
moving average
(solid line)
1974
1976
1978
1980
1982
1984
1986
1988
1990

Figures 6 - 7
Bilateral Exchange Rates and Real Long-Term Interest Rate Differentials





Figures 8 - 9
Bilateral Exchange Rates and Real Long-Term Interest Rate Differentials



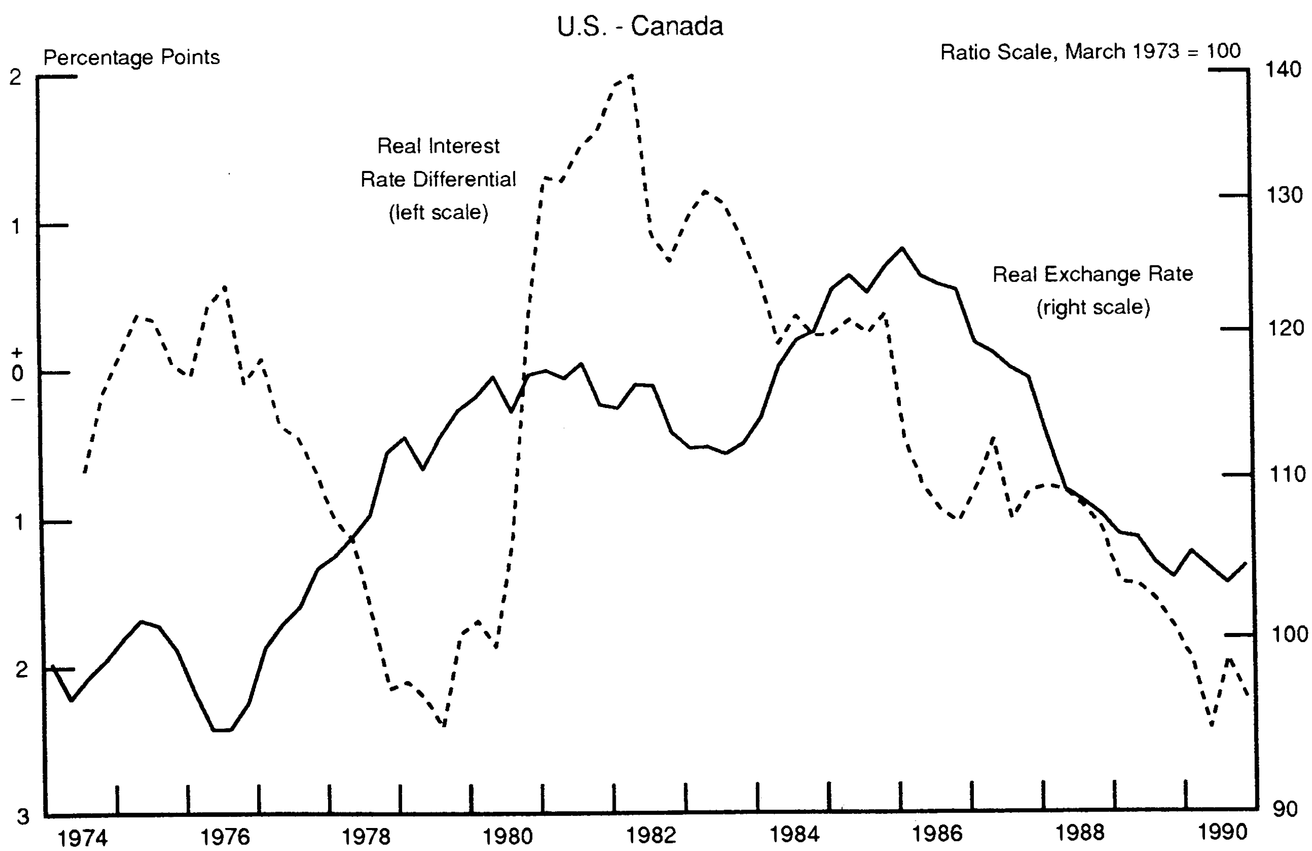


Table 1
Statistical Properties of Variables
12-quarter centered moving average inflation measure
Trade-Weighted Dollar
1974:3 - 1990:3

Variable	DFT	ADFT	DFF	ADFF	PPT	PPF
s	-0.5694	-1.2257	0.7830	1.2312	-1.2330	1.7527
p_*	-0.7169	-1.6085	0.2786	1.3690	-1.3234	1.6955
p	-0.1550	-0.9617	3.3910	1.0686	-0.7987	1.7179
q	-0.7087	-1.2575	0.5591	1.0918	-1.3050	1.7510
i_*	-1.2994	-1.7336	1.1967	1.8577	-1.6164	2.3249
i	-1.0665	-1.7329	1.0309	1.8086	-1.6371	2.6589
π_*	-0.5639	-2.1831	0.4487	2.4639	-1.4257	2.0847
π	0.0792	-2.1668	3.3042	3.0901	-1.0988	2.1164
$(\pi - \pi_*)$	-1.0095	-2.1220	1.1065	2.8446	-1.6757	2.8643
$(i - i_*)$	-1.4025	-1.8851	2.6715	3.5792	-1.5627	3.0664
$(r - r^*)$	-1.1673	-1.6210	1.1255	1.6162	-1.6777	2.7139
ccbal	0.4449	-2.5942	79.0276	4.1162	-0.1495	18.2563
ccbal/gnp	-1.8647	-2.6910	29.6413	3.9013	-1.4397	8.3379

Notes to Table:

Variable definitions

s	log of nominal exchange rate
q	log of real exchange rate
i	U.S. long-term nominal interest rate
π	U.S. inflation
r	U.S. real interest rate
p	U.S. prices
ccbal	cumulated current account
ccbal/gnp	cumulated current account/gnp
dif(cbal)	difference of U.S. and foreign cumulated current account
dif(cbal/gnp)	difference of U.S. and foreign cumulated current account/gnp
*	denotes foreign country (bilateral or G-10 weighted average)

Test Statistics

Column (1)	Standard Dickey-Fuller Test t-statistic (DFT)
Column (2)	Augmented Dickey-Fuller Test (1 lag) t-statistic (ADFT)
Column (3)	Standard Dickey Fuller F-statistic (DFF)
Column (4)	Augmented Dickey-Fuller (1 lag) F-statistic (ADFF)
Column (5)	Park/Phillips t-statistic (PPT)
Column (6)	Park/Phillips F-statistic (PPF)

The critical values for columns (1), (2), and (5) are given in Fuller (1976, Table 8.5.2); they are -3.18 at the 10% significance level and -3.50 at the 5% significance level. The critical values for columns (3), (4) and (6) are given in Dickey and Fuller (1981, Table VI); they are 5.61 at the 10% significance level and 6.73 at the 5% significance level.

Table 1a
Statistical Properties of Variables
12-quarter centered moving average inflation measure
Bilateral Exchange Rates
1974:3 - 1990:4

Variable	DFT	ADFT	DFF	ADFF	PPT	PPF
			U.S. - GERMANY			
s	-0.7311	-1.4271	0.5958	1.3505	-1.4003	2.0122
p*	-0.8177	-1.1183	8.5926	2.9063	-1.0113	4.8289
q	-0.8427	-1.5720	0.5550	1.5190	-1.5275	2.2883
i*	-1.9151	-2.3813	3.7055	3.5285	-2.3313	5.5176
π*	-0.5743	-1.8893	2.0967	2.0267	-1.3802	2.4745
(i-i*)	-1.7762	-2.0336	5.5518	4.9176	-1.8212	5.5182
(π-π*)	-1.0460	-2.5679	0.8253	3.5340	-1.7610	3.0580
(r-r*)	-1.1139	-1.5957	2.4541	2.1605	-1.5925	3.2199
ccbal*	3.3096	-1.3858	57.5137	2.7616	1.4592	16.0559
ccbal/gnp*	1.0915	-1.6594	16.5351	3.1391	0.0865	4.4262
dif(cbal)	0.6027	-3.3971	79.5754	6.1191	-0.0668	18.3667
dif(cbal/gnp)	-1.0315	-2.7681	30.1382	4.3890	-0.9995	7.9283
			U.S. - JAPAN			
s	-1.4558	-2.2349	1.1710	2.6582	-1.9967	3.5271
p*	-4.2830	-4.0578	30.176	22.357	-4.3925	31.926
q	-1.6981	-2.3902	1.7490	3.0942	-2.2213	4.3874
i*	-1.4308	-1.8171	1.8157	2.8788	-1.8020	3.1155
π*	-2.7922	-2.9901	22.038	13.356	-2.6094	17.466
(i-i*)	-1.3104	-2.0552	2.3350	3.8905	-1.5413	2.8914
(π-π*)	-2.4520	-2.6334	11.388	7.1712	-2.1605	7.0565
(r-r*)	-1.9507	-1.9623	2.0808	2.0268	-2.2526	4.0520
ccbal*	-0.6766	-2.8521	30.237	4.2061	-0.8091	7.8024
ccbal/gnp*	-1.2628	-2.8684	5.9031	4.3751	-1.3648	2.9299
dif(cbal)	-0.6714	-2.8728	30.621	4.2681	-0.8049	7.8792
dif(cbal/gnp)	-1.6109	-3.6741	14.260	7.1618	-1.4108	4.6929

Table 1a continued: Statistical Properties of Variables

Variable	DFT	ADFT	DFF	ADFF	PPT	PPF
			U.S. - U.K.			
s	-0.9641	-1.5039	1.7294	1.9832	-1.5123	2.7811
p*	-3.6507	-3.1120	23.3221	9.8759	-3.1114	15.7751
q	-1.4344	-1.9619	3.8894	3.6191	-1.8455	4.4554
i*	-2.3815	-3.0250	3.4846	6.5167	-2.3424	3.2076
π*	0.1548	-1.1596	3.4225	1.9758	-0.7386	1.9541
(i-i*)	-1.2814	-1.7130	2.3268	4.8587	-1.1798	2.1763
(π-π*)	-0.3763	-1.0819	2.8600	2.7058	-0.8788	2.3088
(r-r*)	-2.6582	-3.0620	3.5339	4.8670	-2.9473	5.9723
ccbal*	4.3488	-1.6383	25.9368	2.4495	1.7403	5.0403
ccbal/gnp*	3.1060	-0.0293	16.5812	2.8120	1.3177	4.1518
dif(cbal)	4.2030	-1.6846	23.5069	2.4762	1.6159	4.2519
dif(cbal/gnp)	-3.2443	-2.4833	16.8357	3.2411	-2.2950	6.8365
			U.S. - CANADA			
s	0.1351	-0.6995	4.6218	2.2189	-0.3876	2.8225
p*	0.1975	-0.6992	20.9953	2.1624	-0.3755	6.6684
q	0.3248	-0.8224	4.8810	2.3469	-0.3492	2.6711
i*	-1.3877	-1.8333	1.0223	1.8715	-1.7129	2.3787
π*	-0.5813	-2.2958	0.3746	2.7280	-1.4041	1.9972
(i-i*)	-2.4120	-2.8656	3.6777	4.6487	-2.5625	4.6863
(π-π*)	-1.1233	-2.6316	0.6419	3.5810	-2.0307	3.9732
(r-r*)	-1.2365	-1.8333	1.4275	1.8715	-1.6976	2.8557
ccbal*	3.8448	-0.6115	19.7891	1.3753	1.2776	2.9599
ccbal/gnp*	-1.1501	-1.6511	0.7305	1.5446	-1.6080	2.4522
dif(cbal)	-0.6239	-3.1185	65.5701	5.0973	-0.6826	15.4942
dif(cbal/gnp)	-4.3156	-2.6957	19.9231	3.7914	-2.8892	8.7701

See Notes to Table 1

Table 2
Statistical Properties of Alternative Measures of Expected Inflation
Trade-Weighted Dollar
1974:3 - 1990:3

Variable	DFT	ADFT	DFF	ADFF	PPT	PPF
1-quarter change[1]						
π	-3.3350	-2.8415	5.6527	4.4413	-3.3217	5.5027
π^*	-4.3414	-2.9944	9.4709	5.0217	-4.4589	11.3782
$(\pi - \pi^*)$	-5.3363	-3.2589	14.2515	5.4920	-5.7214	22.4725
$(r-r^*)$	-5.0522	-3.1710	12.9015	5.4266	-5.4203	19.9603
4-quarter changes[2]						
π	-1.1340	-2.0524	1.1517	2.7448	-1.8131	3.2668
π^*	-1.0986	-2.6556	2.3819	5.3303	-1.8105	3.8442
$(\pi - \pi^*)$	-1.3250	-1.6482	.09261	1.4365	-1.8700	3.1320
$(r-r^*)$	-1.2719	-1.4599	1.3241	5.4266	-1.6422	2.6199

Notes to Table:
See notes to Table 1 for an explanation of symbols and definition of tests.

[1] Defined as P/P(-1) annualized.

[2] Defined as P/P(-4).

Table 2a
Statistical Properties of Alternative Measures of Expected Inflation
Bilateral Exchange Rates
1974:3 - 1990:4

Variable	DFT	ADFT	DFF	ADFF	PPT	PPF
1-quarter change						
			U.S. - GERMANY			
π^*	-5.0676	-5.6296	12.8432	16.414	-5.1181	13.9291
$(\pi - \pi^*)$	-4.8860	-4.6867	11.9980	11.480	-5.0436	15.1366
$(r - r^*)$	-4.2736	-4.2219	9.5245	9.849	-4.3281	10.4490
			U.S. - JAPAN			
π^*	-7.8791	-4.4457	31.3523	11.4405	-8.0345	43.1906
$(\pi - \pi^*)$	-6.6952	-3.1210	22.4923	5.2245	-7.2327	39.4304
$(r - r^*)$	-7.5089	-3.3647	28.1972	5.8503	-7.9481	47.6127
			U.S. - U.K.			
π^*	-5.7108	-4.1652	16.3175	8.9723	-5.8858	21.0128
$(\pi - \pi^*)$	-6.7234	-5.0439	22.6524	13.165	-6.8389	27.9322
$(r - r^*)$	-7.6573	-6.4982	29.4815	22.019	-7.6581	26.9565
			U.S. - CANADA			
π^*	-3.4729	-2.9178	6.1306	4.4815	-3.4523	5.8818
$(\pi - \pi^*)$	-4.3316	-3.5850	9.3892	6.7945	-4.4252	10.9129
$(r - r^*)$	-4.3720	-1.8333	9.6049	1.8715	-4.4352	10.6438
4-quarter changes						
			U.S. - GERMANY			
π^*	-1.2060	-2.0120	1.7886	2.3515	-1.7935	3.4218
$(\pi - \pi^*)$	-1.3677	-2.1549	1.0017	2.7363	-1.9971	3.6141
$(r - r^*)$	-1.3133	-2.2092	2.8321	4.4385	-1.8117	3.9333
			U.S. - JAPAN			
π^*	-3.7278	-6.4966	11.2428	30.417	-3.8035	11.1941
$(\pi - \pi^*)$	-2.7986	-3.4660	5.8297	9.2638	-2.7997	6.0815
$(r - r^*)$	-2.7925	-2.7906	4.2126	4.4371	-2.9016	5.5458
			U.S. - U.K.			
π^*	-1.4249	-3.1594	1.2622	5.3469	-2.0911	3.9741
$(\pi - \pi^*)$	-1.9372	-3.2903	1.8946	5.6015	-2.4535	4.9098
$(r - r^*)$	-3.1360	-5.5503	5.0902	16.187	-3.4813	8.8730
			U.S. - CANADA			
π^*	-1.2383	-2.1286	0.8584	2.6832	-1.8848	3.2818
$(\pi - \pi^*)$	-1.7422	-2.8251	1.8679	4.2674	-2.5046	5.7905
$(r - r^*)$	-1.7944	-1.8333	2.4205	1.8715	-2.4116	5.4298

See Notes to Tables 1 and 2.

Table 3
Co-Integration Tests: Engle-Granger
Trade-Weighted Dollar
1974:3 - 1990:3

Model Inflation	(1)	(2)	(3)	(4)	(5)	(6)
<u>12-quarter center moving average</u>						
	-2.295	-2.571	-2.477	-2.716	-2.577	-2.503
[1]				-2.805	-2.578	-2.530
<u>4-quarter changes</u>						
	-3.015	-3.335	-2.68	-3.000	-3.355	-2.743
[1]				-3.014	-3.370	-2.791

Notes to Table:
[1] The test statistics reported here refer to cointegration tests using the U.S. cumulated current account as a share of GNP.

The null hypothesis is that the series are not cointegrated. The critical values are given in Engle and Yoo (1987, Table 2) and are as follows:

No of Vars	5%	10%
2	3.67	3.28
3	4.11	3.73
4	4.35	4.02
5	4.76	4.42

The models that are tested are as follows:

Model 1: $q = \alpha_0 + \alpha_1 i + \alpha_2 i^* + \alpha_3 \pi + \alpha_4 \pi^* + u$

Model 2: $q = \alpha_0 + \alpha_1 (i - i^*) + \alpha_2 (\pi - \pi^*) + u$

Model 3: $q = \alpha_0 + \alpha_1 (r - r^*) + u$

Model 4: $q = \alpha_0 + \alpha_1 i + \alpha_2 i^* + \alpha_3 \pi + \alpha_4 \pi^* + \alpha_5 ccbal + u$

Model 5: $q = \alpha_0 + \alpha_1 (i - i^*) + \alpha_2 (\pi - \pi^*) + \alpha_3 ccbal + u$

Model 6: $q = \alpha_0 + \alpha_1 (r - r^*) + \alpha_2 ccbal + u$

Table 3a
Co-Integration Tests: Engle-Granger
Bilateral Exchange Rates
1974:3 - 1990:3

Model Inflation	(1)	(2)	(3)	(4)	(5)	(6)
<u>12-quarter center moving average</u>						
U.S. - Germany	-.81	.41	-.18	-2.24	-1.56	-1.96
[1]				-2.24	-1.28	-1.88
U.S. - Japan	.04	.64	.02	-2.67	-2.70	-1.61
[1]				-2.79	-2.63	-1.82
U.S. - U.K.	-3.11	-1.78	-2.72	-2.94	-1.75	-2.33
[1]				-3.12	-2.08	-2.41
U.S. - Canada	-1.72	-1.69	-2.34	-1.82	-2.11	-1.49
[1]				-1.66	-2.38	-3.00
<u>4-quarter changes</u>						
U.S. - Germany	-1.40	.27	-.55	-2.36	-2.27	-1.96
[1]				-2.27	-1.99	-1.88
U.S. - Japan	-.23	.53	.07	-2.79	-2.95	-1.61
[1]				-2.85	-3.02	-1.82
U.S. - U.K.	-3.43	-2.19	-3.09	-3.73	-2.13	-2.33
[1]				-3.52	-2.2	-2.41
U.S. - Canada	-1.90	-1.53	-2.19	-1.85	-2.12	-1.49
[1]				-2.04	-2.21	-3.00

Notes to Table:
Models 4 - 6 differ from table 3, in this table we use dif(cbal) and dif(cbal/gnp). See table 3 for critical values.

[1] The test statistics reported here refer to cointegration tests using the differential between U.S. and foreign cumulated current account shares of GNP.

Table 4
General Specification
Trade-Weighted Value of the Dollar
12-Quarter Center Moving Average Measure of Expected Inflation

Dependent Variable: Change in the log of the real exchange rate (Δq)
Sample: 1975 Q1 to 1990 Q3

VARIABLE		COEFFICIENT	STD ERROR	H.C.S.E.	t-VALUE
Δq	1	-.0042416	.11882	.10138	-.03570
Δi		-.0034784	.00694	.00670	-.50118
Δi	1	.0053938	.00764	.00777	.70618
Δi^*		.0574286	.01629	.01966	3.52638
Δi^*	1	-.0209541	.01463	.01474	-1.43275
$\Delta \pi$		-.0103926	.01289	.01205	-.80629
$\Delta \pi$	1	.0265974	.01521	.01720	1.74825
$\Delta \pi^*$		-.0440225	.02491	.02093	-1.76725
$\Delta \pi^*$	1	.0162445	.02259	.02102	.71899
q	1	-.2414682	.05219	.05396	-4.62646
i	1	.0102686	.00726	.00590	1.41365
i*	1	.0058647	.01399	.01167	.41917
π	1	-.0139840	.00514	.00644	-2.72264
π^*	1	.0089106	.00637	.00607	1.39814
dtr84851		.0169974	.00442	.00261	3.84340
CONSTANT		.9798968	.23577	.25882	4.15616

R^2 = .779 σ = .0231056 DW = 2.2 RSS = .0213548333

Chow F[7., 40.] =	2.27	Normality Chi (2) =	1.59
AR 1- 4F[4., 36.] =	3.13	ARCH 4 F[4., 32.] =	.32
RESET F[1., 39.] =	.10		

Notes to Table:
Δ denotes first difference
dtr84851 dummy variable (1984 Q1 - 1985 Q1: 1 to 5)
Constant constant term

Table 5
Final Specification
Trade-Weighted Value of the Dollar
12-Quarter Center Moving Average Measure of Expected Inflation

Dependent Variable: Change in the log of the real exchange rate (Δq)
Sample:1975 Q1 to 1990 Q3

VARIABLE	COEFFICIENT	STD ERROR	H.C.S.E.	t-VALUE
($\Delta i^* - \Delta \pi^*$)	.0392436	.00764	.00755	5.13915
(r - r*)1	.0167970	.00289	.00271	5.81461
q 1	-.2446711	.03673	.03242	-6.66225
dtr84851	.0171952	.00377	.00277	4.55785
CONSTANT	1.1051409	.16751	.14879	6.59757

R^2 = .710 σ = .0233695 DW = 1.82 RSS = .027852

Chow F[7., 51.] =	1.81	Normality Chi (2) =	.17
AR 1- 4F[4., 47.] =	.37	ARCH 4 F[4., 43.] =	.63
Xi F[8., 42.] =	.72	RESET F[1., 50.] =	.08

Long Run Stationary State:

q = 4.51 + .0686 (r-r*)

See tables 1 and 4 for variable definitions.

Table 6
Final Specification
Trade-Weighted Value of the Dollar
Alternative Measure of Expected Inflation 1: 1-Quarter Changes

Dependent Variable: Change in the log of the real exchange rate (Δq)
Sample: 1975 Q1 to 1990 Q3

VARIABLE	COEFFICIENT	STD ERROR	H.C.S.E.	t-VALUE
Δi^*	.0386433	.00867	.00749	4.45843
$\Delta\pi$ 1	.0048643	.00144	.00138	3.37458
$(\Delta r - \Delta r^*)$	.0033028	.00140	.00118	2.36104
q 1	-.2246892	.03492	.03019	-6.43369
$(\pi - \pi^*)$1	-.0129714	.00215	.00204	-6.04338
i 1	.0176442	.00354	.00357	4.98271
i^* 1	-.0098376	.00500	.00552	-1.96776
dtr84851	.0191805	.00361	.00297	5.31519
CONSTANT	.9454743	.16365	.15208	5.77751

R^2 = .7770125 σ = .0213536 DW = 2.28 RSS = .0214308117

Chow F[7., 47.] =	1.36	Normality Chi (2) =	.38
AR 1- 4F[4., 43.] =	1.47	ARCH 4 F[4., 39.] =	.90
Xi F[16., 30.] =	.48	RESET F[1., 46.] =	.10

Long Run Stationary State:

$q = 4.21 - .058\ (\pi-\pi^*) + .0799\ i - .044\ i^*$

See tables 1 and 4 for variable definitions.

Table 7
Final Specification
Trade-Weighted Value of the Dollar
Alternative Measure of Expected Inflation 2: 4-Quarter Changes

Dependent Variable: Change in the log of the real exchange rate (Δq)
Sample:1975 Q1 to 1990 Q3

VARIABLE		COEFFICIENT	STD ERROR	H.C.S.E.	t-VALUE
Δi*		.0347305	.00840	.00839	4.13261
(Δr-Δr*)	1	.0118705	.00459	.00452	2.58878
q	1	-.2330112	.04047	.03852	-5.75817
(r-r*)	1	.0121760	.00260	.00238	4.68965
i	1	.0070445	.00161	.00179	4.36752
dtr84851		.0199061	.00356	.00257	5.58830
CONSTANT		.9881570	.17863	.16997	5.53176

R^2 = .767 σ = .0213776 DW = 2.04 RSS = .022393

Chow	F[7., 49.] =	2.11	Normality Chi (2) =	.34
AR 1- 4	F[4., 45.] =	.74	ARCH 4 F[4., 41.] =	2.00
Xi	F[12., 36.] =	.41	RESET F[1., 48.] =	1.34

Long Run Stationary State:

q = 4.24 + .0523 (r - r*) + .0302 i

See tables 1 and 4 for variable definitions.

Appendix I

Exchange Rate:
Trade-Weighted Value of the dollar (FRB Bulletin).
German mark/ U.S. dollar (FRB Bulletin).
Japanese yen/ U.S. dollar (FRB Bulletin).
British pound sterling/ U.S. dollar (FRB Bulletin).
Canadian dollar/ U.S. dollar (FRB Bulletin).

Interest Rate:[1]
10-year constant maturity rate on Treasury bonds (FRB Bulletin).
Trade-Weighted average of yields on bellwether government bonds for foreign G-10 countries (various publications)
German bellwether government bonds (Bundesbank Monthly Report).
Japanese bellwether government bonds (Toyko Stock Exchange).
British bellwether government bonds (Bank of England Quarterly Report).
Canadian bellwether government bonds (Bank of Canada Review).

Prices:
U.S. CPI price index (FRB Bulletin)
Trade-weighted average of CPIs for the foreign G-10 countries
Germany (Bundesbank Monthly Report).
Japan (Bank of Japan, Economic Statistics).
U.K. (CSO, Employment Gazette).
Canada (Bank of Canada Review).

Current Account:
U.S. (FRB Bulletin).
Germany (Bundesbank Monthly Report).
Japan (Japanese Economic Indicators, EPA).
U.K. (CSO, Economic Trends).
Canada (Bank of Canada Review).
To obtain the cumulated current account we assume for each country that the cumulated current account was zero in 1972 Q4 and accumulate the current account thereafter.

GNP:
U.S. (FRB Bulletin).
Germany (Wirtschaft Und Statistik).
Japan (Bank of Japan, Economic Statistics).
U.K. (CSO, Monthly Digest).
Canada (Canadian Economic Observer).

Expected Inflation:
(Created from CPI price indices)
12-quarter center moving average of CPI inflation rates.
1-Quarterly change in the CPI index (at an annual rate).
4-Quarterly change in the CPI index.

[1] The interest rate data are also available from FRB publication: "Selected Interest and Exchange Rates - Weekly Series of Charts".

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