



American Finance Association

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Source: *The Journal of Finance*, Vol. 39, No. 5 (Dec., 1984), pp. 1345-1357

Published by: Blackwell Publishing for the American Finance Association

Stable URL: <http://www.jstor.org/stable/2327731>

Accessed: 27/11/2009 07:50

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Are Real Interest Rates Equal Across Countries? An Empirical Investigation of International Parity Conditions

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ABSTRACT

This paper conducts empirical tests of the equality of real interest rates across countries. The empirical evidence strongly rejects the hypothesis of real rate equality and the joint hypotheses of uncovered interest parity and ex ante relative PPP, or the unbiasedness of forward rate forecasts and ex ante relative PPP. The evidence suggests that it is worth studying open economy macroeconomic models which allow: 1) domestic real rates to differ from world rates, 2) time varying risk premiums in the forward market, or 3) deviations from ex ante relative PPP.

THE RELATIONSHIP OF REAL interest rates across countries is of central importance to our understanding of open economy macroeconomics. In some models where there is costless international arbitrage in goods and financial assets, real interest rates for comparable securities should be equal across countries. This has been a feature of much of the early research in the monetary approach to exchange rates, e.g., Frenkel [11] and Bilson [2]. On the other hand, finance theory indicates that risk premia may well differ for comparable securities denominated in different currencies (Solnick [27], Roll and Solnick [26], Stulz [28], Fama and Farber [7], Hansen and Hodrick [17], and Dornbusch [6]), and more recent theoretical models in the exchange rate literature, such as Dornbusch [5], Frankel [10], and Mussa [24], depend on real rates differing between countries in the short run.

The proposition that real rates are equal across countries is worth studying because it sheds light on these theoretical models and because it is also an important issue to policy makers. If it is true, then domestic monetary authorities have no control over their real rate relative to the world rate, limiting the impact of their stabilization policies. In addition, as Feldstein [8] has pointed out, unless real rates can differ across countries, policies directed at increasing domestic savings cannot increase the rate of capital formation and hence productivity. We shall also see that the equality of real rates is also worth investigating because it

* Graduate School of Business, Columbia University and NBER. I thank the following for their helpful comments: Robert Cumby, Thomas Doan, Robert Gordon, Fumio Hayashi, Craig Hakkio, Marjorie McElroy, Michael Mussa, Michael Parkin, and the participants in workshops at the University of Liverpool Seminar in Open Economy Macroeconomics, The Board of Governors of the Federal Reserve, the University of Illinois, Champaign-Urbana, Northwestern University, University of Western Ontario, Columbia University, Tulane University, and the University of Florida. This research is part of the National Bureau of Economic Research's Program in Economic Fluctuations. The National Science Foundation and the Sloan Foundation have provided research support. The usual disclaimer applies.

is intimately linked to and provides information on the basic parity conditions featured so prominently in open economy macro models.

This paper conducts empirical tests of the equality of real rates across countries, an *ex ante* version of purchasing power parity, uncovered interest parity, and the unbiasedness of forward rate forecasts of exchange rates over the 1967-II to 1979-II sample period. The next section develops the methodology of the tests. It is then followed by a discussion of the data and the empirical results. The final section summarizes the empirical evidence and provides some concluding remarks.

I. The Methodology of the Tests

Each country's real rate of interest for one-period bonds is defined from the Fisher [9] equation as

$$rr_t^j = i_t^j - \pi_t^{ej} \quad (1)$$

where

i_t^j = the nominal interest rate earned on a one-period bond denominated in country j 's currency that matures at time t , i.e., it is the nominal return from holding the one-period bond from $t - 1$ to t ,

π_t^{ej} = the country's rate of inflation from $t - 1$ to t expected at time $t - 1$,

rr_t^j = the one-period real rate of interest.¹

The real rate defined above, which is more precisely referred to as the *ex ante* real rate, is unobservable in contrast to the *ex post* real rate, which is defined as

$$eprr_t^j = i_t^j - \pi_t^j = rr_t^j - (\pi_t^j - \pi_t^{ej}) = rr_t^j - \epsilon_t^j \quad (2)$$

where

$eprr_t^j$ = the one-period *ex post* real rate for the bond maturing at time t ,

π_t^j = the actual inflation rate from $t - 1$ to t ,

$\epsilon_t^j = \pi_t - \pi_t^{ej}$ = the forecast error of inflation.

The critical assumption behind the methodology developed here is the rationality of expectations in the bond market, which yields the condition that the forecast error of inflation, ϵ_t^j , is unforecastable and hence

$$rr_t^j = E(eprr_t^j | \phi_{t-1}) \quad (3)$$

¹ All returns, inflation, and interest rates in the empirical work here are continuously compounded so that the usual second-order term is not necessary in the Fisher equation (1). Note that if holding period returns are used in the empirical work here rather than continuously compounded returns, there is almost no change in the results. Note also that this definition of a country's real rate matches up the euro security denominated in its currency with its inflation rate. Clearly, a domestic resident might be interested in the real rate obtained by purchasing a euro security denominated in a foreign currency. However, given that uncovered interest parity holds, in this case he will earn the same real return. As will become obvious shortly, uncovered interest parity is intimately related to the equality of real rates across countries and thus it is only necessary to test the equality of real rates using the definition above.

The equality of the real rates across countries then implies

$$rr_t^j - rr_t^i = E(epr_{rr_t^j} - epr_{rr_t^i} | \phi_{t-1}) = 0 \quad (4)$$

for all countries i and j . This equation indicates that the ex post real rate differential between all countries is unforecastable given *any* information that is available at time $t - 1$.

With m countries, there are $m(m - 1)/2$ equations of the type above, but only $m - 1$ of them are independent. Thus, the test of the null hypothesis of real rate equality for all countries is obtained by jointly testing $\alpha^j = 0$ in the $m - 1$ ordinary least squares (OLS) regressions

$$epr_{rr_t^j} - epr_{rr_t^1} = X_{t-1}\alpha^j + u_t^j, \quad j = 2, \dots, m \quad (5)$$

where

X_{t-1} = any variables in the available information set ϕ_{t-1} ,
 $u_t^j = \epsilon_t^j - \epsilon_t^1$ under the null hypothesis, so that $E(u_t^j | \phi_{t-1}) = 0$ under rational expectations, and hence u_t^j will be serially uncorrelated under the null.²

There are two important points to make about this test. As the condition in Equation (4) makes clear, the test procedure is valid for *any set of variables in X_{t-1} as long as they are contained in the information set ϕ_{t-1}* .³ Even if information relevant to the determination of real rates in different countries is excluded from X_{t-1} , the test procedure described here is valid; that is, a rejection of the null hypothesis is indeed a rejection of the equality of real rates across countries. That the test procedure is valid even when relevant information is ignored is a common feature of rational expectations tests (see Abel and Mishkin [1]).

One pitfall to beware is that these joint tests cannot be conducted by estimating each country's OLS constrained and unconstrained regressions separately, adding up their sum of squares, and then carrying out the usual comparison to construct the F -test. This yields incorrect test statistics because the covariance of the OLS parameter estimates in different equations is assumed to be zero. Instead the covariance of the parameter estimates must be allowed for by using generalized least squares (GLS) when constructing the test statistics.⁴

As we have seen, the test procedure is valid regardless of the variables included in X_{t-1} as long as they are available information at time $t - 1$. However, as the condition in Equation (4) makes clear, the information set X_{t-1} must be chosen

² The parameters and their variance-covariance matrix will be estimated consistently with OLS under the null, so that test statistics will have the appropriate asymptotic distributions. However, if the null is false, the u_t^j could be serially correlated and then the power of the test might not be high. Therefore, if there is a failure to reject the null, we would want to be sure that this is not the result of serial correlation in the u_t^j . There are three countries that display significant first-order serial correlation in the Equation (5) regression using WPI data (Durbin-Watson statistics of 1.03 to 1.36), but first-order serial correlation is not present when CPI data are used. In any case, strong rejections of the null hypothesis arise for both CPI and WPI regressions. In the regression tests of uncovered interest parity, the unbiasedness of the forward rate, and ex ante purchasing power parity, no evidence of first-order serial correlation is found.

³ This statement is proved more formally in a working paper version of this article, Mishkin [22].

⁴ Note that the parameter estimates from the GLS procedure will be identical to the OLS parameter estimates because in the tests here the explanatory variables in each country's regression are identical.

so that it has significant explanatory power in the ex post real rate regressions for these countries if the statistical test is to have any power. The tests here specify the right-hand side of Equation (5) as a fourth-order polynomial in time; that is, the X_{t-1} variables are a constant term and the four variables TIME, TIME², TIME³, and TIME⁴. These time variables are used in the statistical tests here because in previous research (Mishkin [23]), they have been found to have significant explanatory power, while using up few degrees of freedom.⁵

Clearly, the time variables used in the tests here do not contain all the information relevant to predicting real rates in the countries we examine. However, it is important to remember that the validity of the test proposed here does not require that all relevant information be included in the regressions. Indeed, we can think of the time variables as a proxy for the smoothly moving (low frequency) component of economic variables that are related to real rates.⁶ Using them in the tests here has the advantage that the tests will only pick up deviations in real rates across countries that move smoothly over time. Since these low frequency deviations from real rate equality are potentially most important to investment and consumption decisions, they are probably of greatest interest to economists.

The second set of tests conducted in this paper involve the basic parity conditions discussed in the international economics literature. Roll [25] has noted that 1) interest parity, 2) an ex ante version of purchasing power parity (PPP), and 3) the unbiasedness of the forward rates as a predictor of the spot exchange rate are linked to the proposition that real rates are equal across countries. We can see this as follows. Denoting the log of the spot exchange rate and one-period ahead forward rate for country j relative to country i given at time $t - 1$ as s_{t-1}^j and ${}_{t-1}f_t^j$, respectively, the interest parity condition (IP) is

$$i_t^j - i_t^i = {}_{t-1}f_t^j - s_{t-1}^j \quad (6)$$

The ex ante version of relative PPP is⁷

$$E(\pi_t^j - \pi_t^i - (s_t^j - s_{t-1}^j) | \phi_{t-1}) = 0 \quad (7)$$

and the unbiasedness of forward rate forecasts is

$${}_{t-1}f_t^j = E(s_t^j | \phi_{t-1}) \quad (8)$$

⁵ In Mishkin [23], four lags of inflation, the lagged money growth rate, and the nominal euro rate for each country have been found to be significant explanatory variables in the ex post real rate regressions for each country. If we included them in the X_{t-1} information set when the number of countries, m , is 7, then there would be 42 variables in each regression. The total number of constraints to be tested would then be a very large number, 252, and we would expect this test to have very little statistical power. The test with the time trend variables, on the other hand, only involves 5 variables per regression, for a total of 30 constraints to be tested. Because these time variables have been found to have significant explanatory power in regressions for all these countries, we would expect this test to have much greater power because fewer restrictions are tested.

⁶ This issue is discussed more extensively in Mishkin [22].

⁷ This is a weaker condition than the usual relative PPP condition because it will be satisfied even if the log of the real exchange rate follows a random walk. Thus, findings such as Frenkel's [12] rejecting PPP but finding that the deviations follow a random walk would be consistent with Equation (7). However, evidence discussed later suggests that even ex ante relative PPP is violated.

Combining (6) and (8), we obtain the uncovered interest parity condition (UIP), which is also known as the Fisher-open hypothesis, i.e.,

$$E(i_t^j - i_t^i - (s_t^j - s_{t-1}^j) | \phi_{t-1}) = 0 \quad (9)$$

Subtracting (7) from (9) we have

$$E(eprrr_t^j - eprrr_t^i | \phi_{t-1}) = 0 = rr_t^j - rr_t^i \quad (10)$$

which is the condition for the equality of real rates.

As the above derivation shows, a breakdown in any of the conditions in (6)–(9) can lead to a rejection of the equality of real rates.⁸ Frenkel and Levich [13, 14] and McCormick [20] have shown that deviations from the interest parity condition are quite small in the euro currency market. Indeed, since interest rate parity is a pure arbitrage condition for euro rates, there is some suspicion that many of the deviations may be the result of data problems.⁹ Thus, the tests that follow focus on the other conditions.

The tests of the parity conditions are conducted in a similar fashion to the tests of the equality of real rates. For example, uncovered interest parity implies that $\delta^j = 0$ in the following regressions:

$$i_t^j - i_t^i - (s_t^j - s_{t-1}^j) = X_{t-1} \delta^j + \eta_t^j, \quad j = 2, \dots, m \quad (11)$$

where

η_t^j = error term with the property $E(\eta_t^j | \phi_{t-1}) = 0$ under the null.¹⁰

Ex ante relative PPP implies that $\partial^j = 0$ in

$$\pi_t^j - \pi_t^i - (s_t^j - s_{t-1}^j) = X_{t-1} \partial^j + \omega_t^j, \quad j = 2, \dots, m \quad (12)$$

where

ω_t^j = error term with the property $E(\omega_t^j | \phi_{t-1}) = 0$ under the null.

The tests involve estimating these regression equations and testing for $\delta^j = 0$ in the $m - 1$ regressions of (11) or $\partial^j = 0$ in the $m - 1$ regressions of (12).

II. The Empirical Results

A. The Data

Obviously, there is no unique real interest rate. The magnitude of a real rate depends not only on the risk characteristics of the security being studied, but also on the price index used to calculate real returns. What the appropriate price

⁸ Note that if the deviation from one of these conditions is exactly offset by a deviation from one of the others, real rates could still be equal. But since this is extremely unlikely, it is reasonable to view a breakdown in one of these conditions as leading to a violation of real rate equality.

⁹ For example, conversations with Harris Bank personnel indicate that the timing of the euro rate data on the Harris tape used in the tests here can differ by up to an hour from that of the forward premium. This would lead to spurious deviations from interest parity.

¹⁰ Under the null, the η_t^j and ω_t^j error terms are as defined in Equations (13) and (14). Rationality of expectations then clearly implies that $E(\eta_t^j | \phi_{t-1}) = E(\omega_t^j | \phi_{t-1}) = 0$.

index is depends on what economic decision is being analyzed. For example, if we are interested in the savings-consumption decision, a price index based on a commodity bundle of consumption goods, such as the CPI, is appropriate. If, on the other hand, we are interested in decisions to trade among countries, then a price index with tradeable goods as a larger proportion of its commodity bundle, such as the WPI, is more appropriate.

This study analyzes real interest rates in the euro deposit market in the 1967-II to 1979-II period for the following countries: the United States, Canada, the United Kingdom, France, West Germany, the Netherlands, and Switzerland. Euro deposits denominated in different countries' currencies are offshore securities issued by the same bank and therefore have similar default risk. Hence, a comparison of real euro rates across countries will not have to be adjusted for differing default risk or non-comparability because of capital controls. Quarterly data has the advantage that the data are non-overlapping and timing problems that would arise with monthly data are avoided.¹¹ The dating convention is as follows. The ex post real rate for a quarter is the actual real return on a three-month euro deposit held from the beginning of the quarter to the end of that quarter, continuously compounded. Both the CPI and WPI are used in the empirical analysis to calculate inflation rates for the reasons discussed above. Quarterly data on three-month euro rates, spot exchange rates, and forward exchange rates are used in this study, and were obtained from the Harris Bank tape. Both the seasonally unadjusted CPI and WPI were obtained from the International Financial Statistics (IFS) tape maintained by the International Monetary Fund.¹²

B. The Results

Line 1.1 of Table I conducts a test for the equality of the mean real rates in the seven countries by only including the constant term in the information set X_{t-1} . The equality of the mean real rates is rejected at the 1 percent level when the CPI is used to calculate the ex post real rate, but not when the WPI is used. However, when the time variables are added to the information set in the tests of line 1.2, we now see very strong rejections of the equality of real rates in both the WPI and CPI results.

Even though real rates are not equalized across countries, it is possible that they have a different mean, but move similarly over time. This proposition is tested in line 1.3, where the information set has the same variables as in line 1.2. Here only the coefficients of the time variables are tested for equality, while the mean real rates across countries are allowed to differ by not constraining the

¹¹ See Mishkin [21].

¹² Only seven of the ten countries' data available in the tape are used here because three of the countries—Italy, Belgium, and Japan—either had a high proportion of the data missing or did not satisfy interest parity because of two-tiered exchange rates. In the few cases where euro rate data were missing for the seven countries, the euro rate was calculated from the interest parity condition. The data were checked by 1) verifying that there were no large deviations from interest parity, 2) checking that the forward premiums used in these calculations were consistent with the forward rate and spot rate data, and 3) plotting all the series to look for outliers. Several obvious errors in the tape were found in this manner and corrected.

equality of the constant terms. The rejections continue to be strong, indicating that real rates in different countries do have dissimilar movements.¹³

A basic finding of this paper is that the equality of real rates across countries can be significantly rejected statistically. But it is always important to ask not only whether a rejection is statistically significant, but whether it is economically significant as well. Evidence in Mishkin [23] which provides measures of *ex ante* real rates indicates that real rate differentials are economically significant; they are often very sizable, over ten percentage points or more.

Table II conducts tests corresponding to those in line 1.2 of Table I for uncovered interest parity and *ex ante* relative PPP, which together imply the equality of real rates. Line 2.1 of Table II tests $\delta^j = 0$ in the six independent regressions of Equation (11) where X_{t-1} includes the constant term and the four time variables. Line 2.2 conducts a similar test for *ex ante* relative PPP of $\partial^j = 0$ in the six independent regressions of Equation (12). Neither *ex ante* relative PPP nor uncovered interest parity (UIP) are rejected at the 5 percent level in these tests. However, when these hypotheses are tested jointly in line 2.3—that is, $\delta^j = 0$ and $\partial^j = 0$ are tested in the twelve regressions of (11) and (12)—they are rejected, and especially strongly in the CPI results.

At first glance the findings above are surprising. When the UIP and PPP conditions are implicitly tested together, as in tests of the equality of real rates in Table I, or when tested jointly as in Table II, they are rejected. Yet when these conditions are tested independently, they are not rejected. What explains this phenomenon?

The answer to this puzzle comes from investigating the error terms of the regressions in the tests above. Taking expectations conditional on the available information set ϕ_{t-1} of (11) and (12) and subtracting them from their respective equations, the error terms are seen to be:¹⁴

$$\eta_t^j = -[s_t^j - E(s_t^j | \phi_{t-1})] \quad (13)$$

$$\omega_t^j = [\pi_t^j - \pi_t^1 - E(\pi_t^j - \pi_t^1 | \phi_{t-1})] - [s_t^j - E(s_t^j | \phi_{t-1})] \quad (14)$$

¹³ As is pointed out in Mishkin [23], the French data and real rate estimates are somewhat peculiar. We might suspect then that France alone is the source of the rejections of real rate equality. To check this suspicion, the equality of real rates was tested with France excluded and the rejections were still strong. The 1.2 test using CPI data was $F(25, 264) = 2.63$ with a marginal significance level of 7.4×10^{-5} , while for the WPI, $F(25, 264) = 2.11$ with a marginal significance level of 0.0021. Bilateral tests carried out in Mishkin [22] also indicate that the hypothesis that real rates are equal in the United States, Canada, and the United Kingdom cannot be rejected. When France, Germany, the Netherlands, and Switzerland are included in the bilateral comparisons, significant rejections of the equality of real rates now occur, both with each other and with the first group of countries. One interesting coincidence found in Mishkin [23] that might help us find an explanation for this phenomenon is that the countries which lead to rejections of the equality of real rates are also the countries that display a stronger positive correlation between nominal interest rates and real rates, as well as a weaker Fisher effect.

¹⁴ The derivations of the error terms are done here under the null hypotheses. If the nulls are false, then an additional term of $P[i_t^j - i_t^1 - (s_t^j - s_{t-1}^j) - E(i_t^j - i_t^1 - (s_t^j - s_{t-1}^j) | \phi_{t-1}) | X_{t-1}]$ should be added to the right-hand side of the η_t^j -equation (13), where $P[\dots | X_{t-1}]$ is the linear projection onto X_{t-1} and an additional error term $P[\pi_t^j - \pi_t^1 - (s_t^j - s_{t-1}^j) - E(\pi_t^j - \pi_t^1 - (s_t^j - s_{t-1}^j) | \phi_{t-1}) | X_{t-1}]$ should be added to the right-hand side of the ω_t^j -equation (14). The basic point made here is not altered by these additional terms.

Table I
Tests of Equality of Real Rates Across Countries

	Using CPI		Using WPI	
	<i>F</i> -test	Marginal Significance Level	<i>F</i> -test	Marginal Significance Level
1.1 Equality of Constants (Mean Real Rate)	$F(6,288) = 3.28$	0.0039	$F(6,288) = 1.24$	0.2857
1.2 Equality of Constants, TIME, TIME ² , TIME ³ , TIME ⁴ Coefficients	$F(30,264) = 2.68$	1.48×10^{-5}	$F(30,264) = 2.07$	0.0013
1.3 Equality of TIME, TIME ² , TIME ³ , TIME ⁴ Coefficients, Allowing Mean Real Rate to Differ Across Countries	$F(24,264) = 2.44$	0.0003	$F(24,264) = 2.28$	0.0008

Table II
Tests of Uncovered Interest Parity (UIP) and Ex Ante Relative Purchasing Power Parity (PPP)

	Using CPI		Using WPI	
	<i>F</i> -test	Marginal Significance Level	<i>F</i> -test	Marginal Significance Level
2.1 Test of UIP	$F(30,264) = 0.84$	0.7046	$F(30,264) = 0.84$	0.7046
2.2 Test of Ex Ante Relative PPP	$F(30,264) = 1.10$	0.3363	$F(30,264) = 0.88$	0.6512
2.3 Joint Test of UIP and Ex Ante Relative PPP	$F(60,528) = 2.12$	6.88×10^{-6}	$F(60,528) = 1.45$	0.0198

That is, the error term in the UIP regression is minus the forecast error of the spot rate, while the error term in the PPP regression is the forecast error of the inflation differential minus the forecast error of the spot rate. Frenkel and Mussa [15] have documented that the spot exchange rate is highly volatile and is apparently quite hard to predict. On the other hand, inflation rates are substantially less volatile. The forecast error of the spot rate should then have a large variance which would be substantially greater than the variance of the forecast error of the inflation differential. This would imply that the variance of η and ω would be large and thus independent tests of (11) and (12) would have low power and would be unlikely to reject even if the null hypothesis were untrue. On the other hand, the contemporaneous correlation of η and ω for the same country should be highly positive¹⁵ and thus when (11) and (12) are tested jointly, properly

¹⁵ Denoting the variance of the unexpected inflation differential as σ_π^2 , the variance of the unexpected spot rate as σ_s^2 , their correlation coefficient as $\rho_{s\pi}$ and the ratio of their variances as k , then the correlation η and ω is

$$\frac{1 - \rho_{s\pi}k}{\sqrt{1 + k^2 - 2\rho_{s\pi}k}}$$

It is easy to show that the minimum correlation occurs when $\rho_{s\pi} = k$, equaling $\sqrt{1 - k^2}$. When k is small, this minimum correlation is necessarily highly positive.

allowing for the covariance of their error terms, the test should have greater power and be more likely to reject if the null hypothesis were untrue. The evidence is consistent with the above story; the correlation of the contemporaneous η and ω for the same country is always greater than 0.9 and the UIP and PPP conditions are jointly rejected although they are never rejected when tested independently.

The ability to reject the equality of real rates in Table I, but not uncovered interest parity and ex ante relative PPP individually, also is explained by the error terms in the regressions. Subtracting (12) from (11), we get the regressions that are used to test the equality of real rates across countries, and the error terms are $\eta_t^i - \omega_t^i$. Here the forecast error of the spot rate cancels out and we are left with only the forecast error of the inflation differential. By the reasoning above, this error term has much smaller variance than the error term in either the UIP or PPP regressions. Hence, the test of the equality of real rates will be more powerful than tests of uncovered interest parity and ex ante PPP when conducted independently.

If the interest parity condition holds closely, then replacing the UIP condition (9) by the unbiasedness of the forward rate forecast condition in (8) should have no appreciable effect on test results.¹⁶ This is the finding in Table III which conducts tests where $s_t^j - {}_{t-1}f_t^j$ replaces $i_t^j - i_t^i - (s_t^j - s_{t-1}^j)$ in (11). The test statistics in Table III are almost identical to those in Table II, never differing by more than 2 percent. This illustrates that results from uncovered interest parity tests can be used to make inferences about the unbiasedness of forward rate forecasts and the potential existence of risk premiums in the forward rate market. This is useful information because frequently data are available to test uncovered interest parity, as in Cumby and Obstfeld [3], but are not as readily available to test the unbiasedness of the forward rate forecasts.

Because of the potential non-normalities of error terms in the fixed exchange rate period—i.e., this is the *Peso problem* discussed by Krasker [19]—the tests on the equality of real rates, the unbiasedness of forward rate forecasts, and ex ante relative PPP for the flexible exchange rate period from 1973-III to 1979-II are reported in Table IV. The tests of uncovered interest parity for this sample period are not reported here because, as expected, the test statistics are very close to those for the unbiasedness of forward rate forecasts. Note that X_{t-1} again includes the constant term and the four time variables in these tests.

The general flavor of these results is similar to that found for the longer sample period. Joint tests yield much stronger rejections than independent tests of ex ante relative PPP and the unbiasedness of forward rate forecasts. However, now we do see rejections of the unbiasedness of the forward rate forecasts at the 5

¹⁶ Note that when tests of interest parity are conducted the same way the tests of uncovered interest parity are conducted in the text, a strong rejection occurs: $F(30,264) = 5.12$ with a marginal significance level of 6.47×10^{-14} . However, the deviations from interest parity, although they produce a statistically significant rejection, are quite small. In the seven countries, the mean deviations from interest parity (using quarterly rates) range from 0.02 to 0.06 percent; and the standard deviations range from 0.05 to 0.18 percent. As the comparison of Tables II and III indicates, although the rejection of interest parity is statistically significant, it is not economically significant. Of course, even the statistical rejections are probably spurious because of the data problems described in footnote 9, and the fact that Harris Bank personnel indicate that they quote euro rates as if interest parity held perfectly.

Table III
Tests of Unbiasedness of Forward Rate Forecasts and Ex Ante Relative Purchasing Power Parity

	Using CPI		Using WPI	
	<i>F</i> -test	Marginal Significance Level	<i>F</i> -test	Marginal Significance Level
3.1 Test of Unbiasedness of Forward Rate Forecasts	$F(30,264) = 0.85$	0.7016	$F(30,264) = 0.85$	0.7016
3.2 Test of Ex Ante Relative PPP	$F(30,264) = 1.10$	0.3363	$F(30,264) = 0.88$	0.6512
3.3 Joint Test of Unbiasedness of Forward Rate Forecasts and Ex Ante Relative PPP	$F(60,528) = 2.10$	8.73×10^{-6}	$F(60,528) = 1.47$	0.0152

Table IV
Flexible Exchange Rate Period: 1973-III to 1979-II Tests of Unbiasedness of Forward Rate Forecasts, Ex Ante Relative Purchasing Power Parity, and the Equality of Real Rates Across Countries

	Using CPI		Using WPI	
	<i>F</i> -test	Marginal Significance Level	<i>F</i> -test	Marginal Significance Level
4.1 Test of Unbiasedness of Forward Rate Forecasts	$F(30,114) = 1.71$	0.0229	$F(30,114) = 1.71$	0.0229
4.2 Test of Ex Ante Relative PPP	$F(30,114) = 1.61$	0.0395	$F(30,114) = 1.03$	0.4427
4.3 Joint Test of Unbiasedness of Forward Rate Forecasts and Ex Ante Relative PPP	$F(60,228) = 2.78$	2.52×10^{-8}	$F(60,228) = 5.64$	6.09×10^{-22}
4.4 Test of Equality of Real Rates Across Countries	$F(30,114) = 2.39$	0.0005	$F(30,114) = 5.32$	3.26×10^{-11}

percent level, although not at the 1 percent level, and a rejection of ex ante relative PPP for the CPI at the 5 percent level. The rejections of these hypotheses jointly is also stronger and is especially so using the WPI where the marginal significance level is below 10^{-20} . The equality of real rates, as expected from the above results, is also rejected quite strongly using both the CPI and WPI.

III. Conclusions

The empirical evidence in this paper strongly rejects the hypothesis of the equality of real euro rates across countries. The joint hypothesis of uncovered interest parity and ex ante relative PPP, or the unbiasedness of forward rate forecasts and ex ante relative PPP, are also strongly rejected. Yet independent tests of uncovered interest parity, the unbiasedness of forward rate forecasts, and ex ante relative PPP yield few rejections and high marginal significance levels.

These results can be characterized in the following way. When tests are set up so that their power will be high, as in the case of the tests of real rate equality or the joint tests of the parity conditions, we find that the null hypothesis is strongly rejected. When the tests are not set up to have high power, as in the case of the independent tests of the parity conditions, significant rejections of the null hypothesis occur far less frequently. The same pattern appears in the literature. Roll [25] conducts an independent test of *ex ante* relative PPP and he rarely rejects this hypothesis. As argued here, this is likely to be the result of the low power of his tests. When more powerful statistical procedures are used to test this hypothesis, as in Cumby and Obstfeld [4], we do see significant rejections. Similarly, independent tests of the unbiasedness of forward rate forecasts or of uncovered interest parity do not frequently reject the null hypothesis when tests of low statistical power are used as in Frenkel [12]. However, more powerful statistical tests, such as Hansen and Hodrick [16, 17] and Cumby and Obstfeld [3, 4], do reject these null hypotheses. Hodrick [18] conducts independent bilateral tests of the equality of real rates in the United States versus other countries, finds the evidence mixed, and concludes that the results are reasonably supportive of the null hypothesis.¹⁷ More powerful joint tests here strongly reject the equality of real rates and this is consistent with Cumby and Obstfeld's [3, 4] tests which, using a different methodology, also strongly reject this proposition.

An important caveat about the evidence discussed here is that severe measurement error in inflation, due to mismeasurement of the price indices, could bias the results against the equality of real rates and purchasing power parity.¹⁸ This mismeasurement of inflation could arise because of the use of inadequate statistical procedures in calculating the price indices, but it also could arise because of the imposition of wage and price controls or even direct manipulation of the price indices by the government.

Overall, the evidence presented in this paper is not supportive of the equality of real rates across countries. However, this result does not imply the existence of irrationality or unexploited profit opportunities in international financial markets. In a world of risk-averse economic agents, real rates can differ across countries because risk premiums in the forward exchange market and for securities denominated in different currencies should exist, differ across countries,

¹⁷ Hodrick [18] actually uses the interest parity condition to test this hypothesis using forward and spot exchange rates rather than euro rates, but as shown above, this would have no appreciable effect on the results. One problem with just looking at one set of bilateral tests independently, as in Hodrick [18], is that which country you chose as the base country for the bilateral comparisons might lead you to very different conclusions. For example, in the 1.1 CPI and 1.2 WPI tests, when the U.S. is the base country, there are no rejections of the equality of real rates in the independent bilateral comparisons. On the other hand, with a different base country, such as France or Germany, bilateral rejections do occur. This problem does not arise with joint tests of real rate equality, and the results in Table I indicate that jointly we can reject the equality of the U.S. real rates with those from the other six countries.

¹⁸ The nature of the tests conducted here indicates that if measurement errors of inflation tend to be offsetting, then the tests will not be biased against real rate equality. For example, the inflation rate over two subsequent quarters might be measured as 5% and 10% although the actual inflation rate was the same, 7.5%, in both quarters. Because the time variables will only pick up slow moving deviations from real rate equality, this mismeasurement will not have an appreciable effect on the test results.

and undergo variation over time. (See Solnick [27], Roll and Solnick [26], Stulz [28], Fama and Farber [7], Hansen and Hodrick [17], and Dornbusch [6].) Furthermore, transactions costs and non-substitutability of different countries' goods can imply the violation of purchasing power parity even when there are no unexploited profit opportunities.¹⁹

The evidence then suggests that it is worth studying open economy macro models which allow domestic real rates to differ from world real rates. The evidence also leaves open the possibility for policy makers to exert some control over their domestic real rate, relative to those in the rest of the world. However, the evidence does not rule out that there is a tendency for real rates across countries to equalize over time, and this is an important topic for further research.

¹⁹ That marginal tax rates on euro interest payments might differ across countries might also be a factor in differing real rates.

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