International Finance Discussion Papers

Number 136

April 1979

THE REAL RATE OF INTEREST ON INTERNATIONAL FINANCIAL MARKETS

by

David H. Howard

The Real Rate of Interest on International Financial Markets

by

David H. Howard*

Recent experience with high nominal interest rates and inflation rates has raised the question of the behavior of expected real rates of interest -- defined as the nominal interest rate less the expected rate of inflation and called simply the real rate of interest in this paper -- during this period. This paper examines real domestic interest rates in four major industrialized countries (Canada, Germany, the United Kingdom, and the United States) during the period 1971:Q1 - 1977:Q3. The approach taken is to construct time-series models for consumer-price inflation in each of the countries. These models yield predicted inflation rates which are then used to calculate a short real rate of interest for each country. Questions regarding the behavior of the real rate of interest over time and across countries are addressed. In particular, the questions of the existence of a constant real rate and a world real rate of interest are investigated.

The empirical evidence presented in this paper indicates that the real rate of interest varies over time and differs across countries. Only when market forward rates are used to express the real rates in terms of U.S. dollars is it found that real rates across countries are equal or differ only by some capital control and risk terms.

---

*/ International Finance Division, Federal Reserve Board. This paper represents the views of the author and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or other members of its staff. I would like to thank Betty Daniel, Richard Freeman, Peter Garber, Dale Henderson, George Henry, Peter Isard, Val Koromzay, Frank McCormick, Larry Promisel, Kenneth Singleton, and Ted Truman for their comments on earlier versions of this paper.

I. The Real Rate of Interest

The expected real rate of interest (r) is defined here to be:

(1) $r = R - p^*$,

where R is the nominal rate of interest, and p* is the expected inflation rate, during the relevant time interval, in consumer prices. The problem with equation (1) is that it involves two variables that are not readily observed. There are two commonly used methods of solving this problem: one is to assume that the expected real rate is constant, or at least essentially constant; the other is to specify a particular way by which inflation expectations are formed. Eugene Fama (1975, 1977) reports evidence consistent with the assumption of a short-term real rate of interest that is constant (or practically so). Other analysts, commenting on Fama's work, report evidence of a variable real interest rate. For example, in the papers by John Carlson and by Charles Nelson and William Schwert the second method mentioned above is employed in that particular measures of p* are used to calculate (at least implicitly) r series, which then serve as evidence to contradict Fama's results. Using complete macroeconomic models for the determination of r, J.W. Elliott also reports evidence that indicates that the real rate of interest is not constant over time.

The approach taken in this paper is to construct forecast models for consumer-price inflation (p_t) in each of the four countries studied here. These models yield predicted inflation rates which are then taken to be p* in equation (1) and are used to calculate a short real rate of interest series for each country.

The procedure for deriving the inflation-forecasting model is first to estimate an autoregressive integrated moving average (ARIMA) model for inflation using the past history of the inflation series itself. Next, ARIMA models of various possible leading indicator series are estimated. Then the residuals, i.e., the whitened series, from all of these models are cross-correlated. Significant cross-correlations can be interpreted as evidence of causality as defined by C.W.J. Granger and are used here as the criterion for deciding whether or not the consumer will use a particular leading indicator to forecast inflation.1/ It is suggested by Edgar Feige and Douglas Pearce that such inflation expectations may very well represent economically rational inflation expectations in that at least some attention is given to the costs and benefits of obtaining and utilizing information. In any case, the approach taken here is a useful way of approximating an essentially unobservable variable. Table 1 presents the ARIMA models for price inflation.2/

Denote the forecasts from the Table 1 equations as $\hat{p}_t$. Examination of the cross-correlations between the whitened inflation series and the whitened series for wage (w_t) and M1 ($m1_t$) growth in all four countries and exchange-rate growth (e_t) in all but the United States indicates that $\hat{p}_t$ cannot be improved on in Germany and the United States, but that in the United Kingdom past wage data significantly improve the inflation forecast while in Canada past M1 data improve the forecast. (The ARIMA models for variables other than p_t and the cross-correlations are not reported here.) Thus, for Germany and the United States the inflation-forecasting equation is: $p_t^* = \hat{p}_t$; for Canada and the United Kingdom it is $p_t^* = \tilde{p}_t$, where for Canada:

TABLE 1

ARIMA Models for Price Inflation

Canada: 1960:Q2 - 1977:Q4

$$(1 - B^4)(1 - \underset{(.11)}{.415}B + \underset{(.11)}{.312}B^4)p_t = .00408 + u_t;$$

Q(30) = 23.9

Germany: 1960:Q2 - 1977:Q4

$$(1 - B^4)p_t = .00124 + (1 + \underset{(.11)}{.418}B^3)u_t;$$

Q(30) = 23.8

United Kingdom: 1948:Q2 - 1977:Q4 (see footnote 2)

$$(1 - B^4)(1 - B)p_t = - .00066 + (1 - \underset{(.05)}{.903}B^4)u_t;$$

Q(30) = 22.1

United States: 1960:Q2 - 1977:Q4

$$(1 - B)p_t = .00025 + (1 + \underset{(.12)}{.336}B^3)u_t;$$

Q(30) = 25.2

Notes: B is the backshift operator; figure in parentheses is the standard error of the estimated parameter directly above it; Q(K) is the Box-Pierce Q-statistic calculated for K lags; u_t is the difference between actual and predicted p_t; p_t is the inflation rate between quarters t-1 and t, expressed at an annual rate.

(2) $\tilde{p}_t = \Psi(p_{t-1},\ldots,p_{t-m},ml_{t-1},\ldots,ml_{t-m})$;

and for the United Kingdom:

(3) $\tilde{p}_t = \Omega(p_{t-1},\ldots,p_{t-m},w_{t-1},\ldots,w_{t-m})$;

where Ψ and Ω are unconstrained distributed lag functions. Table 2 presents the estimates of the coefficients in equations (2) and (3).[3/]

The predictions of the models in Tables 1 and 2 are taken to be p* in equation (1) and must be subtracted from a nominal three-month interest rate in order to obtain the real interest rate. It is important that the nominal rates of interest be reasonably comparable across countries and that the dating of the interest rate correspond to the period for which the inflation rate is predicted. The interest rates used in this study are quarterly averages of three-month rates selected for their comparability for publication in the Federal Reserve Bulletin. Appendix Tables 1-5 contain the data on nominal interest rates, expected and actual inflation, and the calculated series for expected and actual, i.e., ex post, real rates of interest.

Table 2

Cochrane-Orcutt Estimates of Equations (2) and (3)

Equation (2):

		Lag on p_t									
	Constant	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10
Coefficient	-.010	1.061	-.715	.390	-.150	.324	-.363	-.095	.258	-.105	.043
(S.E.)	(.005)	(.160)	(.231)	(.257)	(.261)	(.251)	(.255)	(.250)	(.233)	(.224)	(.156)

	Lag on ml_t									
	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10
Coefficient	.017	.013	.085	-.087	.100	-.004	.078	.059	-.001	.066
(S.E.)	(.030)	(.036)	(.036)	(.035)	(.037)	(.040)	(.040)	(.042)	(.038)	(.034)

R^2 = .837 DW = 2.182 ρ = -.734 Q(36) = 21.41 sample size = 60

Equation (3):

		Lag on p_t									
	Constant	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10
Coefficient	-.023	1.344	-1.143	.717	-.252	-.131	.167	-.654	.501	-.781	.366
(S.E.)	(.011)	(.172)	(.283)	(.300)	(.283)	(.293)	(.271)	(.225)	(.251)	(.218)	(.156)

	Lag on w_t									
	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10
Coefficient	-.083	.430	-.183	.250	-.376	.495	-.155	.111	.315	.096
(S.E.)	(.084)	(.102)	(.125)	(.126)	(.131)	(.142)	(.161)	(.144)	(.137)	(.153)

R^2 = .924 DW = 2.045 ρ = -.705 Q(36) = 22.42 sample size = 48

Notes: Durbin's h-statistic is not computable; ρ is the autoregressive parameter calculated in the Cochrane-Orcutt procedure.

II. Testable Hypotheses

Two types of hypotheses will be tested in this study. One has to do with the real interest rate in each individual country, and the other has to do with the relationship across countries of the real interest rate.

The first hypothesis, which is associated with Fama in the above discussion, is:

H1: the real rate of interest in each country is constant.

The second set of hypotheses has to do with the international interdependence of interest rates. One hypothesis is:

H2: the real rate of interest is equal across countries.[4/]

A less extreme hypothesis is:

H3: there is a stable relationship among individual countries' real rates of interest.

Hypotheses H2 and H3 have to do with relationships between the real rates of interest that might enter into the countries' respective investment expenditure demand functions. The final hypothesis to be investigated in this paper has to do with the relationship between the real rates of interest relevant to international portfolio investment. When making his portfolio investment decision, the investor residing in country i compares the expected return available in all countries. That is, he compares $R_i - p_i^*$ with $R_j + e_{ji}^* + e_{ji}^* R_j - p_i^*$, where the subscript denotes the country and e_{ji}^* denotes the expected appreciation of the value of country j's currency in terms of the currency of country i. Note that the comparison is in terms of a country i consumption bundle. In a well-developed international market, the two rates of return would be forced to equality or to differ only by some risk terms. Thus, ignoring risk,

(4) $R_i - p_i^* = R_j + e_{ji}^* + e_{ji}^* R_j - p_i^*$.

From equation (4) it is readily seen that

(5) $e_{ji}^* = (R_i - R_j)/(1 + R_j)$.

The properties of $[(R_i - R_j)/(1 + R_j)]$ as a predictor of e_{ji}^* allow one to test the following hypothesis:

> H4: international financial markets force real rates of return in terms of any one currency to be equal, i.e., uncovered interest parity holds.[5/]

Nearly all of the above hypotheses pertain to the question of the ability of a government to influence the level of the real rate of interest in its own country. Hypothesis H4 involves the substitutability of financial assets and the interdependence of international financial markets and has implications for the effects of monetary and exchange-rate policies. The policy implications of the results obtained from testing the above hypotheses will be discussed below.

III. Empirical Results

A. Constancy of the Real Rate

A constant real rate of interest will be defined as one where the expected value of r is equal to a constant, k, regardless of other information available. In other words the differences between r and k are white noise. There are several ways in which this proposition can be tested. The first method used here is to estimate

(6) $r = k,$

that is, simply regress r on a constant, and examine the residuals. Table 3 presents these results.

A second method is first to estimate

(7) $R = k + \beta p*$

using ordinary least squares. The residuals are examined and the estimate of β is compared to unity. A constant real rate of interest implies that k will be the mean of r, that the estimate of β will not be significantly different from unity, and that the residuals from the regressions will be white noise. These results are presented in Table 4.

The final method used here for testing the constancy of the real interest rate is one used by Fama (1975). Fama presents several tests, but the one used here involves:

(8) $p = \mu + \delta R.$

TABLE 3

OLS Estimates of: (6) r = k

	Canada	Germany	United Kingdom	United States	Eurodollar
k	-.005 (.004)	.014 (.006)	-.048 (.013)	-.005 (.003)	.005 (.004)
Q(12)	18.17	21.46	10.30	20.18	23.43
DW	.82	.99	1.38	.81	.66
ρ_1	.59*	.50*	.31	.55*	.62*
ρ_2	.11	-.02	.08	.39*	.46*
ρ_3	-.05	.11	-.17	.39*	.40*
ρ_4	-.02	.27	.13	.11	.19

Notes: Sample size = 27; figure in parentheses is the standard error of the estimated parameter directly above it; ρ_i is the i^{th}-order sample autocorrelation; */ indicates a sample autocorrelation that exceeds twice its standard error.

TABLE 4

OLS Estimates of: (7) $R = k + \beta p^*$

	Canada	Germany	United Kingdom	United States	Eurodollar
k	.036 (.011)	.040 (.012)	.066 (.011)	.022 (.004)	.034 (.006)
β	.483 (.128)	.528 (.192)	.215 (.067)	.599 (.058)	.576 (.077)
Q(12)	22.62	44.35	33.31	7.95	13.62
DW	.58	.41	.55	1.27	.90
ρ_1	.70*	.79*	.71*	.35	.53*
ρ_2	.26	.51*	.50*	.03	.20
ρ_3	.11	.34	.14	.24	.25
ρ_4	.07	.16	.03	.09	.20
R^2	.362	.232	.290	.810	.689

Notes: Sample size = 27.

Fama's hypothesis -- involving both a constant real interest rate and efficient markets -- is that $-\mu$ equals the mean of r, δ equals unity, and the residuals are white noise. That is, Fama's hypothesis has to do with the properties of nominal interest rates as predictors of actual inflation (p). In Table 5, the results from estimating equation (8) are presented.

In Table 3, one or more of the sample autocorrelations in the Canadian, German, U.S. and Eurodollar regressions are inconsistent with the hypothesis that (r-k) is white noise,[6] and the U.K. ρ_1 has a fairly large t-ratio (1.63). These autocorrelations are inconsistent with the hypothesis that the real rate of interest as defined in this paper was constant during the sample period. Turning to Table 4, in all five cases the estimate of β is significantly different from unity, but, of course, the presence of positive autocorrelation biases the standard errors downward. In Canada, Germany, the United Kingdom, and the Eurodollar case, the sample autocorrelations suggest that the residuals are not white noise. In the U.S. regression the residuals appear to be white, although ρ_1 is fairly large with a t-ratio of 1.84. Thus the results reported in Tables 3 and 4 indicate that in the five cases investigated here during the period 1971-1977, the real interest rate probably was not constant.

The estimates presented in Table 5 are more favorable to the hypothesis of a constant expected real rate of interest. Only in the German regression is the estimate of δ significantly different from unity. In addition, in the German and Eurodollar equations the autocorrelations suggest that the residuals are not white noise. Nevertheless, in the three other regressions -- i.e., in Canada, the United Kingdom, and the United States -- Fama's joint hypothesis seems to be confirmed.

TABLE 5

OLS Estimates of: (8) $p = \mu + \delta R$

	Canada	Germany	United Kingdom	United States	Eurodollar
μ	.034	.026	-.033	-.006	-.005
	(.019)	(.012)	(.044)	(.011)	(.014)
δ	.634	.407	1.812	1.170	.997
	(.247)	(.151)	(.427)	(.167)	(.190)
Q (12)	10.93	40.05	10.47	10.60	12.81
DW	1.28	1.67	1.36	1.38	1.03
ρ_1	.36	.12	.31	.29	.48*
ρ_2	.04	-.59*	.02	-.36	-.06
ρ_3	-.03	-.03	-.24	-.03	.07
ρ_4	.14	.51*	.06	.18	.16
R^2	.209	.224	.418	.663	.524

Notes: Sample size = 27.

However, following Nelson and Schwert, the hypothesis can be subjected to an additional test by estimating the following equation :

(9) $p = \mu + \delta R + \lambda p^*$.

If p* significantly improves the predictive power of the equation compared to that of equation (8), then Fama's hypothesis is falsified and the real rate is variable and/or markets are inefficient. Table 6 presents the results obtained from estimating equation (9).

In Table 6 the inclusion of p* results in a significant λ and -- except for the U.K. regression -- an insignificant δ as well. In addition, in each case the R^2 values increase substantially when p* is included.[7/] If it is assumed that markets are efficient, the results in Tables 5 and 6 taken together lead to the conclusion that the expected real rate of interest is not constant, thus corroborating the conclusion reached on the basis of Tables 3 and 4.[8/]

B. Relationships Among Interest Rates

For the purpose of investigating the relationships among the various countries' interest rates it is useful to begin by examining the simple correlations between rates. Table 7 presents these correlations. Except for the correlation between the real U.S. rate and the real Euro-dollar rate the correlations are quite small.[9/] Thus the Table 7 results seem to indicate little or no relationship among the real interest rates on assets denominated in different currencies.

TABLE 6

OLS Estimates of: (9) $p = \mu + \delta R + \lambda p^*$

	Canada	Germany	United Kingdom	United States	Eurodollar
μ	.011	.008	-.047	.003	.009
	(.012)	(.009)	(.012)	(.011)	(.012)
δ	-.108	.105	.492	.467	.131
	(.189)	(.122)	(.134)	(.357)	(.276)
λ	.992	.686	.978	.520	.724
	(.152)	(.133)	(.054)	(.238)	(.191)
Q (12)	5.16	5.16	8.06	10.40	9.79
DW	2.26	1.46	2.37	1.56	1.55
ρ_1	-.13	.22	-.28	.18	.18
ρ_2	.01	-.17	-.28	-.45*	-.39*
ρ_3	-.12	-.23	.03	.01	.07
ρ_4	-.07	-.04	-.14	.17	.14
R^2	.715	.631	.961	.719	.702

Notes: Sample size = 27.

TABLE 7

Correlations Between Real Interest Rates

	Canada	Germany	United Kingdom	United States	Eurodollar
Canada	1	-.38	-.08	.26	.26
Germany		1	.37	-.18	-.14
United Kingdom			1	.16	.10
United States				1	.96
Eurodollar					1

Hypotheses H2 and H3 can be tested by estimating an equation of the form:

(10) $r_j = \alpha + \pi r_i.$

If expected real rates are equal across countries, i.e., H2 is true, then $\alpha = 0$ and $\pi = 1$. If there is a relationship between the two rates, i.e., H3 is true, then $\pi \neq 0$. If the residuals from the regression are not white noise, then there may be omitted variables in equation (10) and the relationship postulated is only an approximation of the true relationship. Table 8 presents the results of estimating equation (10) using in turn the interest rates on the two U.S.-dollar-denominated assets as the right-hand-side variable.

The method for testing the hypothesis that real rates of return in terms of any one currency are equal, i.e., H4, utilizes equations (4) and (5). However, in order to allow for the possibility of a capital control and risk premium, equation (4) must be changed to

(4') $R_i - \overset{*}{p}_i = R_j + \overset{*}{e}_{ji} + \overset{*}{e}_{ji} R_j - \overset{*}{p}_i - c,$

where c -- the capital control and risk premium -- is composed of a constant component as well as one that varies with the nominal interest rate.[10] That is, $c = b + a(1+R_j)$ and equation (5) becomes

(5') $\overset{*}{e}_{ji} = (R_i - R_j)/(1+R_j) + b/(1+R_j) + a.$

TABLE 8

OLS Estimates of: (10) $r_j = \alpha + \pi r_i$

	U.S. Real Rate on RHS				Eurodollar Real Rate on RHS			
	Canada	Germany	United Kingdom	Eurodollar	Canada	Germany	United Kingdom	United States
α	-.003 (.004)	.012 (.006)	-.045 (.013)	.010 (.001)	-.007 (.004)	.015 (.006)	-.050 (.013)	-.009 (.001)
π	.364 (.273)	-.340 (.377)	.666 (.816)	1.119 (.061)	.316 (.235)	-.233 (.327)	.353 (.709)	.833 (.045)
Q(12)	15.60	17.24	11.26	18.42	16.33	17.80	11.35	19.43
DW	.86	1.01	1.41	.68	.83	1.00	1.38	.83
ρ_1	.57*	.48*	.29	.64*	.58*	.49*	.30	.57*
ρ_2	.12	-.03	.05	.28	.14	-.01	.07	-.17
ρ_3	.00	.11	-.20	.05	.01	.12	-.19	-.02
ρ_4	.02	.33	.10	-.09	.02	.31	.11	-.22
R^2	.066	.032	.026	.931	.067	.020	.010	.931

Notes: Sample size = 27.

Table 9 presents the results of regressing actual exchange rate changes on $[(R_i-R_j)/(1+R_j)]$, $[1/(1+R_j)]$, and a constant. If the resulting regression residuals are white noise and if the coefficient of $[(R_i-R_j)/(1+R_j)]$ is significantly different from zero and not significantly different from unity, hypothesis H4 cannot be rejected. An alternative -- and less exacting -- test of H4 uses the actual market forward premium (f_{ji}) as a measure of e^*_{ji} and proceeds as described above. These results are reported in Table 10.

In Table 8 only two of the estimates of α -- both for Canada -- are not significantly different from zero and the estimates of π are not significant except for those between the U.S. and Eurodollar rates. Therefore hypothesis H2 can be rejected in all cases and H3 can be rejected for all but the U.S.-Eurodollar relationship. When the U.S. real rate is taken to be the right-hand-side variable in the U.S.-Eurodollar relationship, Table 8 indicates that π is not significantly different from unity and the relationship is one where the Eurodollar rate is different from the U.S. rate by a (positive) constant term only. There is evidence of positive first-order autocorrelation in the Canadian, German, and Eurodollar-U.S. regressions, which would bias the results in favor of rejecting the null hypotheses, $\alpha = 0$, $\pi = 0$. This may present a problem with regard to the above conclusions about α but not those concerning π except for the estimate of π in the Eurodollar-U.S. regressions. As a check, a Cochrane-Orcutt procedure was used to re-estimate those equations exhibiting autocorrelation in Table 8. These results -- not presented here -- indicate insignificant α's in the two German equations, and a π that is not significantly different from unity in either U.S.-Eurodollar equation.

TABLE 9

OLS Estimates of: (11) $e_{ji} = a + b\,[1/(1 + R_j)] + \gamma\,[(R_i - R_j)/(1 + R_j)]$

	U.S. Rate as R_i			Eurodollar Rate as R_i		
	Canada	Germany	United Kingdom	Canada	Germany	United Kingdom
a	.019 (.662)	.574 (2.070)	.199 (1.554)	-.083 (.677)	.372 (2.037)	-.109 (1.556)
b	-.022 (.620)	-.468 (1.947)	-0.198 (1.459)	.068 (.630)	-.248 (1.898)	.091 (1.444)
γ	.622 (.812)	-3.612 (3.133)	.274 (2.204)	.677 (.689)	-3.344 (3.175)	.768 (1.866)
Q(12)	32.50	16.04	5.30	33.43	17.82	5.02
DW	.83	1.83	1.57	.84	1.83	1.60
ρ_1	.53*	.07	.17	.53*	.08	.16
ρ_2	.09	-.40*	-.06	.08	-.42	-.08
ρ_3	-.21	-.15	-.03	-.23	-.17	-.02
ρ_4	-.51*	-.23	.06	-.53*	-.24	.07
R^2	.031	.079	.005	.045	.071	.011

Notes: Sample size = 27.

TABLE 10

OLS Estimates of: (12) $f_{ji} = a + b\,[1/(1 + R_j)] + \gamma\,[(R_i - R_j)/(1 + R_j)]$

	U.S. Rate as R_i			Eurodollar Rate as R_i		
	Canada	Germany	United Kingdom	Canada	Germany	United Kingdom
a	-.065 (.044)	-.099 (.156)	.297 (.745)	-.121 (.039)	-.131 (.150)	.288 (.067)
b	.066 (.041)	.114 (.147)	-.275 (.070)	.108 (.037)	.142 (.140)	-.280 (.062)
γ	1.105 (.052)	.168 (.245)	1.082 (.105)	.948 (.039)	.247 (.239)	.931 (.079)
Q(12)	36.93	11.95	5.36	40.24	14.76	8.78
DW	.72	1.22	1.80	.52	1.12	1.53
ρ_1	.64*	.38	.08	.65*	.43*	.21
ρ_2	.35	.02	-.09	.25	.08	.02
ρ_3	-.11	-.21	-.00	-.21	-.17	-.13
ρ_4	-.29	-.17	.16	-.44*	-.20	-.37
R^2	.958	.026	.941	.968	.051	.953

Notes: Sample size = 26.

In Table 9 there are no statistically significant coefficients, the R^2's are very small, and four of the six regressions exhibit some evidence of autocorrelation. These results are inconsistent with hypothesis H4.

Table 10 presents some positive results. In each Canadian equation, the estimate of γ is significantly positive and in the Canadian-Eurodollar case γ is not significantly different from unity. (In the Canadian-U.S. case γ is just slightly greater than unity.) Both capital control and risk terms are significant in the Canadian-Eurodollar regression, while neither is significant in the other Canadian regression. The R^2's are quite large in the Canadian equations and there is evidence of first-order autocorrelation. In each of the U.K. regressions reported in Table 10, at least one capital control and risk term enters significantly and the estimates of γ are significantly positive and not significantly different from unity. Furthermore, the R^2's are large and there is no evidence of autocorrelation. In contrast to the rest of the results in the table, the German regressions indicate that there is no relationship between U.S. dollar and German real rates of interest even when forward rates are used as the measure of exchange-rate expectations. As in the Canadian equations, there is some evidence of first-order autocorrelation in the German regressions. Cochrane-Orcutt estimates of the Canadian and German equations in Table 10 are reported in Table 11.

TABLE 11

Cochrane-Orcutt Estimates of: (12) $f_{ji} = a + b\,[1/(1 + R_j)] + \gamma\,[(R_i - R_j)/(1 + R_j)]$

	U.S. Rate as R_i		Eurodollar Rate as R_i	
	Canada	Germany	Canada	Germany
a	-.050 (.066)	-.434 (.253)	.036 (.036)	-.375 (.212)
b	.053 (.061)	.430 (.237)	-.035 (.034)	.367 (.197)
γ	1.169 (.080)	1.141 (.300)	1.004 (.038)	1.099 (.231)
Q(12)	8.04	6.77	9.66	9.23
DW	1.80	1.61	1.84	1.45
ρ_1	.09	.18	.02	.27
ρ_2	.21	.21	.08	.25
ρ_3	-.21	-.23	-.19	-.10
ρ_4	-.03	-.33	-.19	-.32
ρ	.678 (.147)	.795 (.121)	.797 (.121)	.809 (.118)
R^2	.975	.352	.993	.464

Notes: Sample size = 25; ρ is the autoregressive parameter calculated in the Cochrane-Orcutt procedure.

In Table 11 the only estimate of γ that is significantly different from unity is in the Canadian-U.S. regression and even that one is fairly close to unity. However, even though the point estimates of the German γ's are not statistically different from unity, their standard errors are substantially larger than are those of the Canadian and U.K. point estimates reported in Tables 10 and 11. In addition, the R^2's for the German equations are considerably lower than those for the other equations. Thus it seems that in the German case the true relationship may be somewhat more complicated than the one represented by equation (12) in Table 10. Similarly the presence of autocorrelation in the Canadian regressions in Table 10 -- and corrected for in Table 11 -- indicates the possibility of omitted variables in equation (12). Nevertheless, the results are broadly consistent with hypothesis H4, i.e., that real interest rates in terms of any one currency -- in this case U.S. dollars -- are equal or at least differ only by some capital control and risk terms when market forward premia are taken to be the relevant measure of expected exchange rate changes.[11/]

As mentioned in the preceding paragraph, there is evidence that equation (12) may be missing some significant explanatory variables for Canada and Germany. Jacob Frenkel and Richard Levich (1975, 1977) have attributed deviations from covered-interest parity to transactions costs. Their work suggests that these costs may be an omitted variable. (Frank McCormick has called into question the size -- but not the relevance -- of the transactions costs involved.) Changes in capital controls are another potentially important factor omitted in this study.[12/]

Finally, it should be pointed out that the real rates of return used in this study do not take taxes into account. Cross-country differences in taxation as well as changes in tax rates over time could very well be important factors in determining the international investor's decisions and thus represent another set of potentially important factors omitted in this study.

IV. Conclusion

A. Summary of Empirical Findings

The results reported above indicate that at least during recent years the (expected) real rates of interest studied here were not constant. Furthermore these rates were not equal across countries. In fact in only the U.S.-Eurodollar case is there found evidence of a significant relationship between real interest rates. In this case the U.S. and Eurodollar rates differ by a constant term only. When the real rates of interest are put in terms of one currency -- in this study U.S. dollars -- there appears to be no significant relationship across countries except when forward rates are used as the measure of exchange-rate expectations.

This paper's empirical findings depict international financial markets that are sufficiently integrated and interdependent that covered-interest parity holds (at least approximately) between comparable assets issued in different countries. However, the results do not support the stronger hypothesis of uncovered-interest parity. Thus unless the assumption is made that forward premia represent the market's forecast of exchange-rate changes, this paper's empirical results indicate that international financial markets are not so integrated and interdependent that expected real rates of return expressed in one currency are forced either to equality or to differ only by some capital control and risk terms.

B. Policy Implications

The empirical results indicate that each country's real rate of interest varies over time, and that there is no significant relationship between countries' real interest rates. These results imply that the real rate of interest is at least potentially susceptible to manipulation by policy makers.

The international interdependence of financial markets may affect the policy makers' ability to influence some economic variables. In his survey of modern theories of international finance, Dale Henderson (pp. 191-92) states that if home and foreign securities are perfect substitutes, a domestic open-market operation or an exchange-market operation will affect the exchange rate but that the nominal interest rate will change only by the amount of the change in the expected rate of depreciation. The demand for domestic-currency assets, including money, will increase in the case of an expansionary policy action if the home-country residents have net assets denominated in foreign currency. (The resulting depreciation of the home currency increases the home currency value of net foreign-currency assets.) This last effect is termed the "valuation effect" by Henderson. The evidence presented in this paper indicates that international financial assets are substitutes for each other in that their real rates of return expressed in terms of one currency tend to be equal or differ only by some capital control and risk terms only if market forward rates are taken to be the relevant measure of exchange-rate expectations.[13/] Therefore this study's results indicate that the effects of open-market and exchange-market operations may depend, inter alia, on whether or not forward premia represent the market's forecast of exchange-rate changes.

Data Appendix

(Unless otherwise specified, data are not seasonally adjusted.)

Consumer prices

For Canada, the consumer price index is from the Quarterly Canadian Forecast: Historical Supplement and the Canadian Statistical Review. The German consumer price data are taken from International Financial Statistics. The British price data are from the Central Statistical Office's Economic Trends and are the all-items retail price index. The U.S. consumer price index is the BLS all-items index.

Wages

The Canadian wage series is average weekly wages (industrial composite) from the Quarterly Canadian Forecast: Historical Supplement and the Canadian Statistical Review. For Germany the wage data are wage and salary rates (hourly basis, overall economy) from the Monthly Report of the Deutsche Bundesbank. The wage data for the United Kingdom are from Economic Trends and are average earnings (in Great Britain) in all industries and services covered. For the United States, wages are the average hourly earnings index for private nonfarm manufacturing. The U.K. and U.S. wage data are seasonally adjusted.

Money Supply (M1)

The Canadian money stock data are from the Bank of Canada Review and from data supplied by the Bank of Canada. The data for the German money supply are from the Monthly Report of the Bundesbank. The

British money data are adjusted for breaks in the series by the Bank of England and are available on request from the Bank. The U.S. money stock data are from the Federal Reserve Board.

Exchange Rates

Exchange rate data are from the Federal Reserve Bulletin and the Federal Reserve's Annual Statistical Digest. The data are expressed as U.S. cents per unit of foreign currency.

Forward Rates

All forward premia are three-month rates expressed as annual rates and are from the Federal Reserve.

Interest Rates

All interest rates are three-month rates. For Canada, the Canadian finance paper rate is used; for Germany, the Frankfurt interbank loan rate is used; for the United Kingdom the London local authority rate and the London interbank sterling bid rate were spliced to form one series; and for the United States, the CD rate is used. These data as well as the Eurodollar rate are from the Federal Reserve and are selected for their comparability.

Appendix Table 1: Canada

Period	Nominal Rate of Interest	Inflation Next Period: Expected	Inflation Next Period: Actual	Real Rate of Interest: Expected	Real Rate of Interest: Actual
1971:Q1	5.1	5.1	5.4	0.0	-0.3
Q2	3.9	3.4	6.2	0.5	-2.3
Q3	4.7	1.7	2.8	3.0	1.9
Q4	4.7	3.4	4.8	1.3	-0.1
1972:Q1	4.7	6.1	3.5	-1.4	1.2
Q2	5.7	6.5	8.3	-0.8	-2.6
Q3	5.1	4.5	3.8	0.6	1.3
Q4	5.2	7.3	7.7	-2.1	-2.5
1973:Q1	5.2	10.5	9.5	-5.3	-4.3
Q2	6.3	11.1	11.6	-4.8	-5.3
Q3	8.0	9.4	7.5	-1.4	0.5
Q4	9.1	10.5	10.0	-1.4	-0.9
1974:Q1	8.8	10.7	14.1	-1.9	-5.3
Q2	10.9	12.9	12.6	-2.0	-1.7
Q3	11.6	9.4	11.5	2.2	0.1
Q4	10.6	10.0	8.9	0.6	1.7
1975:Q1	7.3	8.9	9.0	-1.6	-1.7
Q2	7.2	10.7	14.2	-3.5	-7.0
Q3	8.3	9.7	8.5	-1.4	-0.2
Q4	9.2	8.0	5.4	1.2	3.8
1976:Q1	9.4	7.7	6.2	1.7	3.2
Q2	9.7	6.6	6.1	3.1	3.6
Q3	9.5	5.9	6.0	3.5	3.5
Q4	9.0	8.8	9.0	0.2	0.0
1977:Q1	7.9	7.7	9.6	0.2	-1.7
Q2	7.4	9.5	9.1	-2.1	-1.7
Q3	7.3	9.0	8.9	-1.7	-1.6

Appendix Table 2: Germany

Period	Nominal Rate of Interest	Inflation Next Period: Expected	Inflation Next Period: Actual	Real Rate of Interest: Expected	Real Rate of Interest: Actual
1971:Q1	7.4	4.5	5.9	2.9	1.5
Q2	6.4	1.0	2.7	5.4	3.7
Q3	7.6	4.4	4.2	3.2	3.4
Q4	7.0	11.0	8.5	-4.0	-1.5
1972:Q1	5.0	6.8	4.5	-1.8	0.5
Q2	4.7	2.8	5.2	1.9	-0.5
Q3	4.9	3.3	6.6	1.6	-1.7
Q4	7.9	7.7	9.5	0.2	-1.6
1973:Q1	8.1	5.6	7.8	2.5	0.3
Q2	12.4	6.7	3.8	5.7	8.6
Q3	14.3	7.5	8.3	6.8	6.0
Q4	13.6	10.5	9.9	3.1	3.7
1974:Q1	11.3	6.7	6.6	4.6	4.7
Q2	9.4	4.2	3.8	5.2	5.6
Q3	9.4	8.1	5.4	1.3	4.0
Q4	9.0	9.9	7.9	-0.9	1.1
1975:Q1	6.5	6.5	7.8	0.0	-1.3
Q2	4.8	2.8	3.0	2.0	1.8
Q3	4.1	4.7	3.6	-0.6	0.5
Q4	4.1	8.6	6.9	-4.5	-2.8
1976:Q1	3.8	8.0	6.2	-4.2	-2.4
Q2	3.8	2.7	0.3	1.1	3.5
Q3	4.5	3.0	2.0	1.5	2.5
Q4	4.7	6.3	7.8	-1.6	-3.1
1977:Q1	4.7	5.3	5.4	-0.6	-0.7
Q2	4.4	0.0	1.1	4.4	3.3
Q3	4.1	2.8	0.8	1.3	3.3

Appendix Table 3: United Kingdom

Period	Nominal Rate of Interest	Inflation Next Period: Expected	Inflation Next Period: Actual	Real Rate of Interest: Expected	Real Rate of Interest: Actual
1971:Q1	7.6	12.8	15.2	-5.2	-7.6
Q2	6.6	10.3	5.6	-3.7	1.0
Q3	5.8	8.5	5.2	-2.7	0.6
Q4	4.1	8.3	6.2	-4.2	-2.1
1972:Q1	4.9	10.5	7.6	-5.6	-2.7
Q2	5.2	8.3	7.1	-3.1	-1.9
Q3	7.7	10.6	9.8	-2.9	-2.1
Q4	8.0	11.3	7.5	-3.3	0.5
1973:Q1	10.0	12.6	13.3	-2.6	-3.3
Q2	9.2	8.4	6.1	0.8	3.1
Q3	12.0	12.3	14.4	-0.3	-2.4
Q4	14.2	14.5	17.9	-0.3	-3.7
1974:Q1	15.4	23.0	25.8	-7.6	-10.4
Q2	13.3	9.0	10.5	4.3	2.8
Q3	12.7	20.8	19.3	-8.1	-6.6
Q4	12.1	25.3	26.4	-13.2	-14.3
1975:Q1	11.2	41.6	43.2	-30.4	-32.1
Q2	9.8	19.4	18.7	-9.6	-8.9
Q3	10.3	14.7	14.6	-4.4	-4.3
Q4	11.3	15.5	15.4	-4.2	-4.1
1976:Q1	9.3	16.7	15.3	-7.4	-6.0
Q2	10.2	8.0	9.6	2.2	0.6
Q3	11.5	18.5	19.8	-7.0	-8.3
Q4	14.5	21.6	21.7	-7.1	-7.2
1977:Q1	11.8	19.4	19.0	-7.6	-7.2
Q2	8.0	3.7	6.4	4.3	1.6
Q3	6.9	8.8	6.0	-1.9	0.9

Appendix Table 4: United States

Period	Nominal Rate of Interest	Inflation Next Period Expected	Inflation Next Period Actual	Real Rate of Interest Expected	Real Rate of Interest Actual
1971:Q1	4.1	2.4	4.7	1.7	-0.6
Q2	4.7	5.0	4.0	-0.3	0.7
Q3	5.5	3.2	2.2	2.3	3.3
Q4	4.7	3.0	3.2	1.7	1.5
1972:Q1	3.6	2.9	3.3	0.7	0.3
Q2	4.3	3.0	3.7	1.3	0.6
Q3	4.7	3.8	3.7	0.9	1.0
Q4	5.1	3.8	5.7	1.3	-0.6
1973:Q1	6.2	6.0	9.1	0.2	-2.9
Q2	7.5	9.1	9.1	-1.6	-1.6
Q3	9.9	9.8	9.7	0.1	0.2
Q4	9.2	10.7	11.7	-1.5	-2.5
1974:Q1	8.6	11.8	11.8	-3.2	-3.2
Q2	10.7	11.8	12.8	-1.1	-2.1
Q3	11.5	13.1	12.2	-1.6	-0.7
Q4	9.0	12.2	7.5	-3.2	1.5
1975:Q1	6.4	7.8	6.4	-1.4	0.0
Q2	5.6	6.1	8.8	-0.5	-3.2
Q3	6.3	7.2	6.5	-0.9	-0.2
Q4	5.8	6.1	3.9	-0.3	1.9
1976:Q1	5.1	4.8	5.1	0.3	0.0
Q2	5.4	4.9	6.5	0.5	-1.1
Q3	5.3	5.7	4.6	-0.4	0.7
Q4	4.8	4.7	7.2	0.1	-2.4
1977:Q1	4.7	7.8	8.9	-3.1	-4.2
Q2	5.1	8.5	6.0	-3.4	-0.9
Q3	5.7	6.8	4.5	-1.1	1.2

Appendix Table 5: Eurodollars

Period	Nominal Rate of Interest	Inflation (U.S.) Next Period		Real Rate of Interest	
		Expected	Actual	Expected	Actual
1971:Q1	5.5	2.4	4.7	3.1	0.8
Q2	6.7	5.0	4.0	1.7	2.7
Q3	7.7	3.2	2.2	4.5	5.5
Q4	6.4	3.0	3.2	3.4	3.2
1972:Q1	5.2	2.9	3.3	2.3	1.9
Q2	5.1	3.0	3.7	2.1	1.4
Q3	5.5	3.8	3.7	1.7	1.8
Q4	5.9	3.8	5.7	2.1	0.2
1973:Q1	7.4	6.0	9.1	1.4	-1.7
Q2	8.5	9.1	9.1	-0.6	-0.6
Q3	11.0	9.8	9.7	1.2	1.3
Q4	10.1	10.7	11.7	-0.6	-1.6
1974:Q1	9.0	11.8	11.8	-2.8	-2.8
Q2	11.4	11.8	12.8	-0.4	-1.4
Q3	13.2	13.1	12.2	0.1	1.0
Q4	10.4	12.2	7.5	-1.8	2.9
1975:Q1	7.6	7.8	6.4	-0.2	1.2
Q2	6.5	6.1	8.8	0.4	-2.3
Q3	7.3	7.2	6.5	0.1	0.8
Q4	6.8	6.1	3.9	0.7	2.9
1976:Q1	5.5	4.8	5.1	0.7	0.4
Q2	5.9	4.9	6.5	1.0	-0.6
Q3	5.7	5.7	4.6	0.0	1.1
Q4	5.3	4.7	7.2	0.6	-1.9
1977:Q1	5.1	7.8	8.9	-2.7	-3.8
Q2	5.6	8.5	6.0	-2.9	-0.4
Q3	6.2	6.8	4.5	-0.6	1.7

Literature Cited

R.Z. Aliber, "The Interest Rate Parity Theorem: A Reinterpretation," Journal of Political Economy, November/December 1973, 81, 1451-59.

G.E.P. Box and G.M. Jenkins, Time Series Analysis: Forecasting and Control, rev. ed., San Francisco, 1976.

J.A. Carlson, "Short-Term Interest Rates as Predictors of Inflation: Comment," American Economic Review, June 1977, 67, 469-75.

M. Dooley and .. Isard, "Capital Controls, Political Risk and Interest Disparities," International Finance Discussion Papers, no. 125, September 1978.

J.W. Elliott, "Measuring the Expected Real Rate of Interest: An Exploration of Macroeconomic Alternatives," American Economic Review, June 1977, 67, 429-44.

E.F. Fama, "Short-Term Interest Rates as Predictors of Inflation," American Economic Review, June 1975, 65, 269-82.

E.F. Fama, "Interest Rates and Inflation: The Message in the Entrails," American Economic Review, June 1977, 67, 487-96.

E.L. Feige and D.K. Pearce, "Economically Rational Expectations: Are Innovations in the Rate of Inflation Independent of Innovations in Measures of Monetary and Fiscal Policy?," Journal of Political Economy, June 1976, 84, 499-522.

J.A. Frenkel and R.M. Levich, "Covered Interest Arbitrage: Unexploited Profits?," Journal of Political Economy, April 1975, 83, 325-38.

J.A. Frenkel and R.M. Levich, "Transaction Costs and Interest Arbitrage: Tranquil versus Turbulent Periods," Journal of Political Economy, December 1977, 85, 1209-26.

K. Garbade and P. Wachtel, "Time Variation in the Relationship between Inflation and Interest Rates," Journal of Monetary Economics, November 1978, 4, 755-65.

C.W.J. Granger, "Investigating Causal Relations by Econometric Models and Cross-Spectral Methods," Econometrica, July 1969, 37, 424-38.

D.W. Henderson, "Modeling the Interdependence of National Money and Capital Markets," American Economic Review, February 1977, 67, 190-99.

P. Isard, Exchange-Rate Determination: A Survey of Popular Views and Recent Models, Princeton Studies in International Finance, no. 42, 1978.

F. McCormick, "Covered-Interest Arbitrage: Unexploited Profits: Comment," Journal of Political Economy, forthcoming.

C.R. Nelson, Applied Time Series Analysis for Managerial Forecasting, San Francisco, 1973.

C.R. Nelson and G.W. Schwert, "Short-Term Interest Rates as Predictors of Inflation: On Testing the Hypothesis that the Real Rate of Interest is Constant," American Economic Review, June 1977, 67, 478-86.

D.A. Pierce and L.D. Haugh, "Causality in Temporal Systems: Characterizations and a Survey," Journal of Econometrics, May 1977, 5, 265-93.

1/ For a discussion of ARIMA models, see George Box and Gwilym Jenkins or Charles Nelson. See David Pierce and Larry Haugh for a discussion of causality and causality tests. Granger causality can be summarized as follows: x causes y if information about some present and past x improves the forecast of present y, given other information, including past y.

2/ See the appendix to this paper for a discussion of the data used in this study. The U.K. sample is longer than the other samples because it was necessary to investigate the effectiveness of the U.K.'s many incomes policies. Inspection of the residuals of the fitted model during incomes-policy periods indicated that inflation expectations probably would not be affected by such policies.

3/ One might expect the consumer to combine $\tilde{p}_t$ and $\hat{p}_t$ to obtain his actual forecast of p_t. Since both $\tilde{p}_t$ and $\hat{p}_t$ are unbiased, a linear combination of the forecasts is:

$$p_t = \varphi\tilde{p}_t + (1-\varphi)\hat{p}_t + u_t ,$$

or,

$$p_t - \hat{p}_t = \varphi(\tilde{p}_t - \hat{p}_t) + u_t .$$

OLS estimates of φ for both Canada and the United Kingdom were not significantly different from unity. Therefore the equation $p^*_t = \tilde{p}_t$ is used here. In equations (2) and (3) lag lengths of 10 were assumed. No constraints were placed on the curves because of the absence of prior notions of what the curves might look like (even smoothness cannot be expected). The collinearity of the data means that caution must be used when interpreting the individual coefficient estimates in Table 2.

4/ H2 could be combined with H1 to yield the hypothesis that not only is there a world interest rate but also that it is constant. This hypothesis will not be tested here explicitly, although it will be tested implicitly when H1 and H2 are investigated.

5/ If the forward premium is substituted for e^*_{ji} in equations (4) and (5), hypothesis H4 states that covered interest parity holds. In fact, hypotheses H2 and H4 could be viewed as being derived from the proposition of covered interest parity in a series of steps. First, covered interest parity asserts:

$$R_i = R_j + f_{ji} + f_{ji}R_j ,$$

where f_{ji} is the forward premium of country j's currency with respect to country i's currency. Covered interest parity states that arbitrage removes all riskless profit opportunities. The next step would be to assert that arbitrage removes all expected profit opportunities. Thus e^*_{ji} would replace f_{ji} and one would obtain equations (4) and (5), i.e., hypothesis H4. To obtain hypothesis H2, one could then assume that exchange-rate expectations are equal to expected inflation differentials, i.e., $e^*_{ji} = p^*_i - p^*_j$, and that the term $e^*_{ji}R_j$ is small enough to be ignored.

6/ A "twice-the-standard-error" rule of thumb is used here and in similar situations throughout this paper as the test for statistical significance. Note that the hypotheses in this paper refer to the average interest rate during the quarter.

7/ F-tests indicate that the increases in the R^2's due to the inclusion of p^* are significant. That is, information on p^* is not just duplicating the information in R; rather, p^* contains more information about p than does R.

8/ Kenneth Garbade and Paul Wachtel present evidence that U.S. markets are efficient and that the U.S. real rate of interest is not constant.

9/ On the other hand, the correlations between nominal interest rates are as follows:

	Canada	Germany	U.K.	U.S.	Eurodollar
Canada	1	.10	.78	.65	.52
Germany		1	.39	.73	.76
U.K.			1	.66	.53
U.S.				1	.97
Eurodollar					1

10/ For a discussion of exchange and political risks, see the study by Robert Aliber.

11/ The proposition of covered-interest parity is fairly well established empirically with regard to Eurocurrency deposits; see the survey by Peter Isard, p. 12, note 8 and the studies cited there. The results reported in the present study go somewhat further in that both the country of issue as well as the currency denomination of the financial assets can differ.

12/ See the study by Michael Dooley and Isard for a discussion of the effects of German capital controls and uncertainties about future controls on interest-rate differentials during the period 1970-1974. It is interesting that the four largest (in absolute value) residuals in the German regressions reported in Table 10 are in 1972:Q3, 1973:Q1, 1973:Q2, and 1974:Q1. (The first three are underpredictions, while the fourth is an overprediction.) According to the chronology of German capital controls reported in Dooley and Isard, the German government took measures to prohibit purchases of domestic fixed-interest securities by non-residents in 1972:Q3, and in 1973:Q1 the government extended the prohibition to include many other capital transactions with non-residents as well. In 1974:Q1 most of the restrictive measures were terminated. Thus three of the four largest residuals (in terms of absolute value) in the German regressions in Table 10 correspond to quarters in which there were changes in capital controls and this correspondence suggests that changes in capital controls probably are an important omitted factor in the German case.

13/ Henderson's criterion for perfect substitutability is whether or not the home (nominal) interest rate equals the foreign (nominal) interest rate plus the expected rate of depreciation, which is essentially the same criterion as the one used here.