Rational Expectations, Risk Premia and the Efficiency of the Foreign Exchange Markets

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I. Introduction

Since the advent of the floating exchange rate system in 1973, there has been a significant interest among policy makers, commercial bankers, and academic economists in the functioning and efficiency of the foreign exchange markets. The resulting efficient market studies have been usually carried out in the context of rational expectations, risk neutral agents, and perfectly competitive markets with no transaction costs. The implications of the models in this setting are that the forward exchange rate is the unbiased predictor of the future spot rate, and that the expected return from speculation in the forward exhange market is zero. While many early studies have presented results supporting this unbiasedness hypothesis (see Frenkel (1977), Levich (1979)), there are equally many studies which suggest that the foreign exchange market has exhibited a significant departure from efficiency in the 1970s (see Geweke and Feige (1979), Hakkio (1981a, b), Hansen and Hodrick (1980, 1983)).

A theoretical reason underlying the empirical rejections of this unbiasedness hypothesis is the existence of the risk premium in the forward exchange market. Forward exchange rates are tied to known, current spot exchange rates and the distributions of unknown, future spot exchange rates through covered interest arbitrage and speculation. While covered interest arbitrage does not entail any risk, speculation entails a foreign exchange risk. If one currency is, in some sense, riskier than the other, and the risk is not completely diversifiable, then a premium should be paid to induce the risk-averse speculators to assume the risk in the forward exchange market. Theoretical models of Grauer, Litzenberger and Stehle

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(1976), Lucas (1978, 1982), Breeden (1979), Fama and Farber (1979), and Brock (1980) provide the result that the forward exchange rate diverges from the expected future spot rate by the risk premium. The risk premium in these models is induced by the covariation between the intertemporal marginal rates of substitution on monies and the nominal returns of assets.

The primary objective of this paper is to test the hypothesis that the foreign exchange market is "efficient." We will test the following implications of the efficiency hypothesis: that the forward premium is an unbiased pedictor of the expected holding-period return, and that the expected risk premium is zero. We will also investigate whether the time varying risk premium, if it exists, contributes to the departure, if any, of the forward exchange market from efficiency. We define the expected risk premium as the expected rate of gains from speculation in excess of the forward premium. In an efficient market, this expected risk premium is identically zero.

This paper is organized as follows. In section 2, we explain the efficient market hypothesis and its implications in the context of the foreign exchange market. We also discuss some statistical procedures to test the hypothesis. Section 3 includes discussions of efficient estimation techniques. Empirical results and their interpretations are also included. Summary and conclusions comprise section 4.

II. The Hypothesis of Efficient Foreign Exchange Market

The hypothesis of an efficient asset market implies that there are no unexploited profit opportunities in the market. If we assume rational use of information, risk-neutral market participants, and perfectly competitive foreign exchange markets with no transaction costs, then the forward exchange rate summarizes all available, relevant information in forecasting the future spot exchange rate. A hypothesis in this vein is that the forward rate equals the expected future spot exchange rate. Testing this hypothesis of efficiency would require a joint test of efficiency and an equilibrium model.

In slightly different language, however, the efficiency hypothesis can be thought of as a combination of two different hypotheses: the hypothesis of rational expectations which states that the market's subjective expectation of the future spot rate equals the true, mathematical expectation of it, and the hypothesis that the forward rate equals the market's subjective expectation of the future spot rate, implying the absence of risk premium. Therefore, any test of the hypothesis of an efficient foreign exchange market will be a joint test of these two hypotheses.

The forward exchange rate $F_{t,k}$ observed at time t for a delivery at time t + k is the market determined certainty equivalent of the expected future spot rate, S_{t+k}. Thus, the efficiency hypothesis can be written as

$$F_{t,k} = E(S_{t+k} / I_t) \tag{1}$$

where I_t is the information set available to all market participants at time t, and E is the mathematical expectations operator.

In terms of the rational expectations hypothesis and the absence of risk premium hypothesis, the efficiency hypothesis can be written as

$$M(S_{t+k} / I_t) = E(S_{t+k} / I_t), \text{ and} \tag{2}$$

$$F_{t,k} = M(S_{t+k} / I_t), \tag{3}$$

where M is the market's subjective expectations operator. Obviously, equations (2) and (3) imply (1).

If we assume that the current spot rate, S_t, and the current forward rate, $F_{t,k}$, are contained in the information set, I_t, then eq. (1) implies that:

$$(F_{t,k} - S_t) = E(S_{t+k} / I_t) - S_t\ . \tag{4}$$

The k-period forward premium is an unbiased predictor of the k-period holding-period return.

It also follows from eq. (4) that the expected risk premium, defined as the expected rate of return from holding a currency in excess of the forward premium, is identically zero. That is,

$$R_{t,k} = E(S_{t+k} / I_t) - F_{t,k} = 0 \tag{5}$$

where R_{t+k} is the expected k-period risk premium.

We will test the efficiency of the foreign exchange market based on the implications of eq. (4) and eq. (5). Assuming that the expectational relationship is linear, from eq. (4) we specify the regression equation as

$$(S^i_{t+k} - S^i_t)/S^i_t = \alpha^i + \sum_{j=1}^{N} \beta_{ij} [(F^j_{t,k} - S^j_t)/S^j_t] + \varepsilon^i_{t,k}\ . \tag{6}$$

The rate of holding-period, or the rate of appreciation of a currency is regressed on the forward premium of the same currency and on the forward premia of six other currencies. This is a semi-strong form test of efficiency.[1]

Another way of testing the efficiency of the forward exchange market is to test the null hypothesis that the risk premium in the forward market is identically zero. There is little consensus in the literature on the existence

1. Tryon (1979) argues that this method of testing the rational expectations is more stringent than the conventional method (Frenkel, 1976), and that it provides additional insights into the behavior of the forward exchange market.

of time varying premia in forward rates. Frenkel (1982) fails to identify such premia, while Hsieh (1982), Hansen and Hodrick (1983), Hodrick and Srivastava (1983) find evidence consistent with time varying premia. Frenkel and Razin (1980) have derived a relationship between the forward exchange rate and the expected future spot rate in which the attitude toward risk, the initial asset positions, and the stochastic pattern of prices induce a discrepancy between the two rates. Under rather stringent assumptions that the covariance between the exchange rate and the price level is zero and that individuals are risk neutral, they derive that

$$E_t\,(S^i_{t+k} - F^i_{t,k}) = 0.$$ [2]

This is equivalent to the null hypothesis of no risk premium when the risk premium in the forward market is defined as the expected gain in excess of the forward premium.

From eq. (5), we specify that

$$(S^i_{t+k} - F^i_{t,k})/S^i_t = r_i + \sum_{j=1}^{N} \delta_{ij}\,[(S^j_{t+k-1} - F^j_{t-1,k})/S^j_t] + \omega^i_{t-1,k} \qquad (7)$$

for i=1, . . . , 7,
for j=1, . . . , 7.

The risk premium is regressed on its own lagged value and on the lagged risk premia of six other currencies. Some recent studies have demonstrated that the forward premia should also be included in the regressors (see Hansen and Hodrick (1983)). With this addition, eq. (7) becomes

$$(S^i_{t+k} - F^i_{t,k})/S^i_t = a + \sum_{j=1}^{N} b_{ij}\,[(S^j_{t+k-1} - F^j_{t-1,k})/S^j_t] + \sum_{j=1}^{N} c_{ij}\,[(F^j_{t,k} - S^j_t)/S^j_t] + \omega^i_{t-i,k} \qquad (7')$$

for i=1, . . . , 7,
for j=1, . . . , 7.

2. Citing Frenkel and Razin (1980), Singleton (1983) criticizes the practice of using $E^z_t(S^j_{t+k})\ F^j_{t,k} = a_j$, where the lower case letters are the logarithms of the uppercase counterpart, as the risk premium, arguing that the assumptions of perfect financial markets, rational expectations, risk neutral agents, and no uncertainty about future purchasing power imply that $E_t(S^j_{t+k} - F^j_{t,k}) = 0$, not that $E^z_t(S^j_{t+k})\ F^j_{t,k} = a_j$.

Many recent studies have used logarithms in the above equations partly to avoid the problem of the Siegel's Paradox[3] and partly to reduce the problem of nonstationarity of the data.[4]

III. Empirical Results

3.1 Econometric Problems

An econometric problem frequently encountered in empirical studies of forward exchange market efficiency is serial correlation of the disturbance terms when the data is more finely collected than the forward contract intervals in the foreign exchange market. Consider a linear form of eq.(1).

$$S_{t+k} = a + b F_{t,k} + u_{t,k} . \qquad (1')$$

It follows that the k-step forecast errors, $u_{t,k} = S_{t+k} - E(S_{t+k} / I_t)$ are serially uncorrelated for any $j \geq k$. That is, $E(u_{t,k} u_{t+j,k}) = O$ for $j \geq k$. For any $j < k$, they are serially correlated.

Another problem in this context concerns the strict exogeneity of the regressors. The generalized least squares method which handles the problem of serial correlation requires that the regressors be strictly exogenous. However, many of the regressors used in foreign exchange market efficiency studies are not strictly exogenous. For example, past forecast errors or current forward exchange rates are frequently used as regressors, but knowledge of the future values of these variables would provide useful information in predicting the future spot rates or forecast errors.

Many of the previous studies (Cornell (1977), Frenkel (1977), Geweke and Feige (1979)) use only nonoverlapping observations to equate the sampling interval with the forecasting interval, thereby circumventing these problems. Hansen and Hodrick (1980) explain these problems and propose an estimation procedure based on Hansen (1982), which is not fully efficient, but which outperforms the conventional practice of using only

3. The Siegel's Paradox (Siegel, 1972) states that it is generally not true that the expected value of the future spot exchange rate equals the forward rate and that the expected value of the reciprocal of the future spot rate equals the reciprocal of the forward rate. Its mathematical explanation is simply Jensen's Inequality and the convexity of the inverse function, and its magnitude will depend on the shape of the joint distribution of the spot and forward rates. McCulloch (1975) argued, however, that this is empirically trivial.

4. That the variables are created by the first differencing of logs or as the difference of two different log values helps us to reduce the problem of nonstationarity as well as that of Siegel's Parodox. Hakkio (1981) argues that $\ln S_t$, and $\ln F_t$, are non-stationary, but that first differencing of these variables makes them closer to being stationary.

non-overlapping data points. Hakkio (1981) proposes another estimation procedure which uses all the overlapping and nonoverlapping data to give rise to yet fully efficient estimates.

3.2 Empirical Results

In this section, we estimate the equations following the coventional practice of using only nonoverlapping observations.[5] Every fourth observation is taken to form a one month forward contract.[6] Weekly spot rates and one month forward rates for seven major currencies are used for the period July 20, 1973 to April 13, 1984. The currencies include the Belgium franc, Canadian dollar, French franc, German mark, Dutch guilder, Swiss franc, and U.K. pound. All exchange rates are expressed as the U.S. dollar per unit of these currencies. All equations are estimated using ordinary least squares (OLS).

Table 1 presents some preliminary comparisons between S_{t+1} - S_t (the four-week rate of change in the spot rate), $F_t - S_t$ (the forward premium), and $S_{t+1} - F_t$ (the risk premium) in terms of their means, standard deviations, and autocorrelations. Since the spot and forward rates are logs and the differences are multiplied by 100, the three variables are on a percent per month basis. The standard deviations of $S_{t+1} - F_t$ are larger than the standard deviations of $S_{t+1} - S_t$. Thus, in terms of the standard deviation of forecast errors, the current spot rate is a better predictor of the future spot rate than the current forward rate. The forward premium shows significant autocorrelation over time, while the rate of change of the spot rate and the risk premium do not.

We first ran regressions by OLS of the change of the spot rate, $(S_{t-1} - S_t)/S_t$ on the forward premium, $(F_t - S_t)/S_t$ of the same currency. (This result is not shown here.) The null hypothesis to be tested is that $a = 0$ and $b = 1$. This single market efficiency test strongly rejects the null hypothesis for all seven currencies. In one of the seven cases, the intercept was significantly different from zero, while in all seven cases, the slope was significantly different from one. The F test for $a = 0$ and $b = 1$ shows that the null hypothesis was rejected at an extremely low marginal significance level for all seven currencies.

Table 2 shows the estimation of the change in the spot rates regressed on the forward premium of the same currency and the forward premia of the

5. In a later version of this paper, we will use Hakkio's efficient estimation procedure.

6. Hakkio (1981, 1983) correctly argues that the forward rates should be matched exactly with the spot rates of one month hence. However, Hsieh (1982) matches the data exactly taking account of holidays and still obtains the evidence against the unbiasedness hypothesis.

six other currencies. We here test the null hypothesis that all the coefficients of the regressors are simultaneously zero, i.e., $\beta_1 = \beta_2 = \ldots = \beta_7 = 0$. This 'weak' multimarket efficiency test is rejected for the U.K. pound at the 1.8% significance level, while it is rejected for the Belgium franc, Dutch guilder, and Swiss franc at the 16% or less significance level. However, when we test for $\beta_1 = \beta_2 = \ldots = \beta_7 = 1$ (the results are not reported here), the null hypothesis is strongly rejected for all seven currencies.

As to the test of the second hypothesis that the risk premium is identically zero, we first ran regressions for the single market test (the results are not reported here). The null hypothesis that $a = b = 0$ is rejected at the 0.1 significance level or lower for the Belgium franc, French franc, German mark, Dutch guilder, and Swiss franc. This implies that the risk premium is not serially uncorrelated.

Table 3 shows that the semi-strong form test of the hypothesis that the risk premium for the forward exchange rate is zero. The null hypothesis is that $\delta_1 = \delta_2 = \ldots = \delta_7 = 0$. The F test indicates that the null hypothesis is rejected at the 2 percent or less significance level for the French franc, German mark, Dutch guilder, Swiss franc, and British pound. Only the Belgium franc and the Canadian dollar show evidence consistent with the efficient market hypothesis.

In Table 4, we present equations with the forward premia of all currencies included in addition to the lagged risk premia of all currencies. The null hypothesis that all the b's and c's are simultaneously zero is soundly rejected at the 0.45 percent or lower marginal significance level for all seven currencies. The importance of the currency's own forward premium and the six other forward premia is demonstrated in the F test for $H_0 : c_1 = c_2 = \ldots c_7 = 0$. This null hypothesis is rejected at the 2.4 percent or lower marginal significance level for the Canadian dollar, U.K. pound, French franc, and Dutch guilder. It appears that the forward premia are not important in predicting the risk premium only for the German mark and Swiss franc. It is surprising that the forward premiums are more significant in explaining the risk premium than the lagged risk premia. However, this result is consistent with the previous findings (see Hansen and Hodrick (1983)).

Our results thus far provide evidence unfavorable to the unbiasedness hypothesis. One possible explanation for these findings would be the existence of a time-varying risk premium. If the time-varying risk premium exists, the forward exchange rate deviates from the expected future spot exchange rate in equilibrium. The time-varying risk premium can partially explain the departure of the foreign exchange market from efficiency.

As demonstrated in recent studies of intertemporal asset pricing, the risk premium depends on the intertemporal marginal rates of substitution of the currencies and the rates of return to nominal assets. Therefore, any change in the variance of money growth can cause the risk premium to vary over time.[7]

In equations (7) or (7′), we are imposing an assumption, as we did in eq. (6), that the conditional expectation is a linear function of the variables such as the lagged risk premiums or the forward premiums which are contained in the information set. However, the true conditional expectation may be a nonlinear function of those variables.

The nonlinearity of conditional expectation of the risk premium is supported by the fact that when we included the squared forward premiums as instruments, their coefficients turned out to be highly significant. In Table 5, we show the F test, among others, for the null hypothesis that all coefficients for squared terms equal zero. The null hypothesis is rejected at the 2.02 percent or less significance level. In a similar test for the null hypothesis that all coefficients for squared risk premiums equal zero (this is not reported here), the null hypothesis is again rejected at a very low significance level.

The nonlinearity of conditional expectation of the risk premium in the lagged risk premia or the forward premia, as is reported in this study, is inconsistent with the assumed constancy of the beta's in linear regression models. Hodrick and Srivastava (1983) argue that this is the likely reason for the rejection of models of Hansen and Hodrick (1983), and we accept their interpretation.

It should be noted, however, that while nonlinearity appears to explain partially the time-varying risk premium and the rejection of the unbiasedness hypothesis, this does not provide knowlege about the extent to which the time varying risk premium per se is responsible for the evidence against the unbiasedness hypothesis. There are too many factors which have not been accounted for. For example, significant nonzero transaction costs, or government intervention in the spot exchange markets could explain a large portion of the departure of the market from efficiency.

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7. This could also lead to the conditional heteroscedasticity in the residuals. Hodrick and Srivastava (1983) test for the existence of the heteroscedasticity in the residuals and find evidence against the conditional homoscedasticity for the French franc, Swiss franc, and German mark. However, we do not attempt to investigate the behavior of the residuals.

IV. Summary and Conclusions

An efficient asset market would be a market in which all available information is used in decision-making so that there are no unexploited profit opportunities in the market. When applied to the foreign exchange market, this would imply that the forward exchange rate equals the expected future spot rate. An implication of this hypothesis is that the forward premium of the forward rate is an unbiased predictor of the holding-period return. We started out our empirical test of foreign exchange market efficiency by testing this hypothesis. The single market test strongly rejects the efficiency hypothesis for all seven currencies: while the intercepts were not significantly different from zero in six of the seven currencies, the slope coefficient was significantly different from one in all seven currencies.

In the multimarket efficiency test, the null hypothesis that all coefficients are simultaneously zero is rejected at a small significance level for the U.K. pound and at the 16 percent marginal significance level for the Belgium franc, Dutch guilder, and Swiss franc. But when the null hypothesis is that all of the coefficients equal one, it is rejected at a very low significance level for all currencies.

In the second test of efficiency, we investigated if the risk premium, defined as the gains from speculation in excess of the forward premium, is identically zero in the foreign exchange market. In the single market test, the null hypothesis that $a = b = 0$ is rejected at an extremely low significance level in five currencies out of seven. In the multimarket test, the null hypothesis that all the coefficients equal zero is rejected at the 2 percent or less significance level for five currencies out of seven. Only the Belgium franc and Canadian dollar lend support to the efficiency hypothesis.

Following Hansen and Hodrick (1983), we included the forward premiums as additional regressors for the risk premium, and tested if the forward premiums are significant factors. The F test indicates that they are significant at a very low marginal significance level, and this is consistent with previous findings.

Our results are in general unfavorable to the unbiasedness hypothesis. To trace some factors responsible for the results, we checked if the risk premium thus defined is time varying by running regressions for risk premium on some quadratic terms. The significant squared terms suggest that the conditional expectation is nonlinear on the variables. This nonlinear expectational relationship of the risk premium suggests that the risk premium makes the forward exchange rate differ from the expected future spot exchange rate in equilibrium, we do not know the extent to which the time varying risk premium per se is responsible for departure of the foreign exchange market from efficiency. There are simply too many factors which have not been accounted for in this context.

We started out with eq. (1) as a joint hypothesis of equations (2) and (3), and have found evidences unfavorable to eq. (1). This could entail rejection of either the rational expectations hypothesis or no risk premium hypothesis or both. But we have found evidences indicating the existence of a time varying risk premium. This does not, however, preclude the possibility of the rational expectations hypothesis being rejected. Hsieh (1983) argues in a similar situation that, "given the low infomation costs, it is difficult to imagine that after five years of floating rate experience, market participants in 1978 are still not fully utilizing information." I would add that an additional five years of experience (as in our sample period) makes the argument even more convincing.

Data Appendix

The weekly data of the spot and 1-month forward exchange rates were obtained from the data tape of the Harris Bank of Chicago. The currencies include the Canadian dollar, Pound sterling, Belgium franc, German mark, Dutch guilder, French franc, and Swiss franc. The exchange rates are all expressed as U.S. dollars per unit of these currencies. The period to be analyzed is July 20, 1973 through April 13, 1984. Both rates are wholesale bid rates quoted in Chicago at 1:00-1:30 PM on each Friday. Every fourth observation was used to represent a one month forward contract.

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[Table 1] Means, Standard Deviations and Autocorrelations:

Country	Mean	Std. Dev.	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}	e_{11}	e_{12}
							S_{t+1} S_t							
Belgium	0.294	2.768	0.300	0.021	0.049	0.016	0.026	0.116	0.021	0.133	0.047	0.033	0.078	0.060
Canada	0.173	1.187	0.081	0.075	0.007	0.083	0.096	-0.044	-0.135	0.002	0.032	-0.033	0.010	0.148
France	0.496	2.736	0.218	-0.010	0.076	0.046	0.115	0.020	-0.044	0.054	0.073	0.027	0.076	0.000
Germany	0.091	2.666	0.261	0.042	0.005	-0.095	0.013	-0.074	0.002	0.076	0.003	0.063	0.074	0.006
Netherlands	0.098	2.615	0.260	0.015	0.012	0.067	0.007	0.048	0.002	0.031	0.027	0.065	0.043	0.002
Switzerland	0.194	3.128	0.251	0.094	-0.027	-0.061	0.026	0.035	-0.069	-0.002	0.072	0.004	0.020	-0.025
United Kingdom	0.405	2.476	0.219	0.071	0.002	0.049	0.094	0.148	0.014	0.012	0.099	0.039	0.042	0.192
							F_t S_t							
Belgium	0.100	1.133	0.275	0.203	0.314	0.199	0.188	0.211	0.150	0.112	0.181	0.171	0.212	0.186
Canada	0.114	1.587	0.048	0.043	0.044	0.042	0.015	0.030	0.027	-0.013	0.037	0.024	0.035	0.022
France	0.040	1.112	0.396	0.415	0.360	0.257	0.228	0.254	0.264	0.091	0.121	0.101	-0.070	0.178
Germany	0.413	0.443	0.487	0.486	0.510	0.482	0.317	0.313	0.389	0.174	0.234	0.291	0.270	0.208
Netherlands	0.270	0.476	0.566	0.530	0.602	0.444	0.394	0.342	0.388	0.324	0.250	0.395	0.255	0.219
Switzerland	0.571	0.534	0.534	0.444	0.482	0.382	0.294	0.347	0.437	0.309	0.329	0.301	0.169	0.240
United Kingdom	0.698	3.075	0.040	0.023	0.025	0.026	0.018	0.003	-0.002	0.003	0.007	-0.008	-0.015	0.016
							S_{t+1} F_t							
Belgium	0.397	3.035	0.379	0.167	0.235	0.069	0.110	-0.026	0.052	0.197	0.088	0.120	0.142	0.094
Canada	0.287	1.974	0.063	0.146	0.133	0.102	0.063	0.003	0.023	0.024	0.081	-0.094	-0.022	0.095
France	0.539	3.083	0.320	0.118	0.198	0.155	0.184	0.123	0.004	0.066	0.061	0.015	0.034	0.131
Germany	0.504	2.746	0.304	0.110	0.039	-0.067	0.003	-0.038	0.031	0.094	0.020	0.087	0.111	0.053
Netherlands	0.367	2.757	0.314	0.097	0.080	0.007	0.023	0.003	0.030	0.056	0.004	0.092	0.096	0.053
Switzerland	0.376	3.236	0.293	0.162	0.041	0.013	0.053	0.013	0.057	0.013	-0.057	0.022	0.052	0.012
United Kingdom	0.299	3.582	0.078	0.087	0.046	0.017	0.026	-0.052	-0.108	-0.032	0.035	0.002	0.003	0.084

All exchange rates are U.S. dollars per unit of foreign currency. S_{t+1} S_t is the rate of change of the spot rate, F_t S_t, the forward premium and S_{t+1} F_t, the (expost) risk premium. The means and standard deviations of the variables are on a percent per month basis. The sample period is 7/20/73 4/13/84 and N 140.

[Table 2] $(S^i_{t+k} - S^i_t)/S^i_t = \alpha^i + \sum_{j=1}^{7} \beta_{ij} \{ (F^j_{t,k} - S^j_t)/S^j_t \} + \varepsilon^i_{t,k}$

Currency	$\hat{\alpha}_i$ (std. err.) confidence	$\hat{\beta}_{i1}$ (std. err.) confidence	$\hat{\beta}_{i2}$ (std. err.) confidence	$\hat{\beta}_{i3}$ (std. err.) confidence	$\hat{\beta}_{i4}$ (std. err.) confidence	$\hat{\beta}_{i5}$ (std. err.) confidence	$\hat{\beta}_{i6}$ (std. err.) confidence	$\hat{\beta}_{i7}$ (std. err.) confidence	D.W.	F(7,131) All β_{ij} = 0 (confidence)	R^2
Belgium franc	0.6177 (0.0042) 0.8567	0.0089 (0.1341) 0.0528	0.0417 (0.1049) 0.3086	0.1658 (0.2396) 0.5100	-0.5187 (0.2939) 0.9201	0.8076 (1.1006) 0.5356	1.7735 (0.9012) 0.9488	0.8506 (0.7705) 0.7247	1.521	1.547 (0.844)	0.076
Canadian dollar	0.1844 (0.0019) 0.6774	0.0060 (0.0594) 0.0804	0.600 (0.0465) 0.8010	0.0986 (0.1061) .6456	0.0502 (0.1302) .2996	0.2508 (0.4876) .3921	0.5604 (0.3992) .8372	0.0977 (0.3440) .2231	2.179	0.475 (0.148)	0.025
French franc	-0.6108 (0.0042) 0.8516	0.1359 (0.1343) 0.6865	0.0659 (0.1050) 0.4684	0.1920 (0.2400) 0.5749	0.3598 (0.2944) 0.7761	0.8458 (1.1026) 0.5556	1.4529 (0.9028) 0.8900	0.4412 (0.7778) 0.4285	1.601	0.916 (0.502)	0.047
German mark	0.3807 (0.041) 0.5487	0.0717 (0.1301) 0.4175	0.1136 (0.1018) 0.7337	0.1870 (0.2325) 0.5774	0.5740 (0.2852) 0.9538	0.3515 (1.0680) 0.2574	0.7008 (0.8745) 0.5756	1.0189 (0.7534) 0.8214	1.604	1.390 (0.786)	0.069
Dutch guilder	0.2239 (0.0040) 0.4258	0.1363 (0.1271) 0.7145	0.0509 (0.0994) 0.3903	0.2026 (0.2271) 0.6261	0.3210 (0.2786) 0.7487	0.1769 (1.0432) 0.1344	1.7161 (0.8542) 0.9534	0.8606 (0.7359) 0.7556	1.670	1.639 (0.871)	0.081
Swiss franc	0.0213 (0.0048) 0.0353	0.2290 (0.1535) 0.8620	0.0576 (0.1200) 0.3679	0.0954 (0.2742) 0.2717	0.8318 (0.3363) 0.9853	0.4355 (1.2595) 0.2688	0.4828 (1.0313) 0.3595	0.1445 (0.8886) 0.1289	1.631	1.539 (0.841)	0.076
U.K. Pound	0.7211 (0.0037) 0.9479	0.0710 (0.1176) 0.4528	0.1996 (0.0920) 0.9681	0.2995 (0.2102) 0.8434	0.7293 (0.2578) 0.8946	0.1208 (0.9656) 0.0893	0.9778 (0.7906) 0.7816	1.1991 (0.6812) 0.9193	1.705	2.518 (0.982)	0.119

Note: Sample period: July 20, 1973 to April 13, 1984. Number of observations: 140. Confidence is one minus the marginal level of significance. Values of the confidence term which are close to one indicate evidence against the null hypothesis that the set of coefficients equal zero. All variables are multiplied by 100, making them interpretable as percent at a monthly rate.

[Table 3] $(S^i_{t+k} - F^i_{t,k})/S^i_t = r_i + \sum_{j=1}^{7} \delta_{ij} \{ (S^j_{t+k-1} - F^j_{t-1,k})/S^j_t \} + \omega^i_{t-1,k}$

Currency	$\hat{r}_i$ (std. err.) confidence	$\hat{\delta}_{i1}$ (std. err.) confidence	$\hat{\delta}_{i2}$ (std. err.) confidence	$\hat{\delta}_{i3}$ (std. err.) confidence	$\hat{\delta}_{i4}$ (std. err.) confidence	$\hat{\delta}_{i5}$ (std. err.) confidence	$\hat{\delta}_{i6}$ (std. err.) confidence	$\hat{\delta}_{i7}$ (std. err.) confidence	F(7,130) All $\hat{\delta}_{ij}$ 0	R^2
Belgium france	0.0716	0.0015	0.0133	0.1739	0.0033	0.7252	0.3443	0.1226	4.328	0.189
	(0.0025)	(0.1180)	(0.0862)	(0.1717)	(0.1428)	(0.2652)	(0.1442)	(0.100)		
	0.2272	0.0098	0.1222	0.6870	0.0183	0.9850	0.8034	0.6034		
Canadian dollar	0.3710	0.0632	0.0641	0.0045	0.0448	0.0421	0.0097	0.0153	0.648	0.034
	(0.0019)	(0.0905)	(0.0662)	(0.1318)	(0.1096)	(0.2258)	(0.2036)	(0.1106)	0.283	
	0.9471	0.5134	0.6657	0.0271	0.3170	0.1476	0.0379	0.7009		
French franc	0.2204	0.0161	0.1017	0.0388	0.2692	0.2764	0.2147	0.0182	2.655	0.125
	(0.0026)	(0.1231)	(0.0800)	(0.1783)	(0.1490)	(0.3072)	(0.2769)	(0.1505)	(0.989)	
	0.5609	0.1036	0.7391	0.1758	0.9268	0.6300	0.5604	0.1012		
German mark	0.2359	0.0629	0.0021	0.0199	0.0914	0.6043	0.4063	0.0138	2.551	0.121
	(0.0023)	(0.1104)	(0.0807)	(0.1607)	(0.1336)	(0.2755)	(0.2483)	(0.1349)	(0.983)	
	0.6897	0.4299	0.0209	0.0982	0.5049	0.9700	0.8958	0.0813		
Dutch guilder	0.0964	0.1205	0.0014	0.0207	0.0553	0.6936	0.2884	0.1154	3.489	0.158
	(0.0023)	(0.1096)	(0.0801)	(0.1596)	(0.1327)	(0.2735)	(0.2465)	(0.1340)	(0.998)	
	0.3242	0.7262	0.0135	0.1032	0.3222	0.9876	0.7558	0.6094		
Swiss franc	0.1375	0.0647	0.0196	0.0486	0.1731	0.1706	0.4426	0.3235	2.512	0.119
	(0.0028)	(0.1314)	(0.0860)	(0.1912)	(0.1590)	(0.3278)	(0.2954)	(0.1606)	(0.981)	
	0.3814	0.3766	0.1616	0.2043	0.7217	0.3964	0.8635	0.9540		
U.K. pound	0.3964	0.2663	0.0574	0.0508	0.1275	0.0462	0.5019	0.1666	2.473	0.118
	(0.0028)	(0.1336)	(0.0977)	0.1944	(0.1617)	(0.3332)	(0.3004)	(0.1632)	(0.980)	
	0.8405	0.9517	0.4425	0.2055	0.5683	0.1100	0.9029	0.6907		

Note: See Table 2.

[Table 4]

$$(S^i_{t+k} - F^i_{t,k})/S^i_t = \alpha_i + \sum_{j=1}^{7} \beta_{ij} [(S^j_{t+k-1} - F^j_{t-1,k})/S^j_{t-1}] + \sum_{j=1}^{7} r_{ij} [(F^j_{t,k} - S^j_t)/S^j_t] + \omega^i_{t-1,k}$$

Currency	$\hat{\alpha}$ (std. err. confi dence)	$\hat{\beta}_{i1}$ (std. err. confi dence)	$\hat{\beta}_{i2}$ (std. err. confi-dence)	$\hat{\beta}_{i3}$ (std. err. confi dence)	$\hat{\beta}_{i4}$ (std. err. confi dence)	$\hat{\beta}_{i5}$ (std. err. confi-dence)	$\hat{\beta}_{i6}$ (std. err. confi-dence)	$\hat{\beta}_{i7}$ (std. err. confi-dence)	$\hat{r}_{i1}$ (std. err. confi-dence)	$\hat{r}_{i2}$ (std. err. confi dence)	$\hat{r}_{i3}$ (std. err. confi-dence)	$\hat{r}_{i4}$ (std. err. confi-dence)	$\hat{r}_{i5}$ (std. err. confi-dence)	$\hat{r}_{i6}$ (std. err. confi-dence)	$\hat{r}_{i7}$ (std. err. confi-dence)	F(1,123) for all $\hat{\delta}=0$ (confi dence)	F(14,123) for all $\beta_{ij}-\hat{\delta}=0$ (confi-dence)	R^2 j 1 7
Belgium	0.003	0.066	0.015	0.076	0.056	0.861	0.386	0.108	0.001	0.000	0.007	0.005	0.016	0.015	0.000	2.5311	4.7426	0.351
franc	(0.004)	(0.112)	(0.083)	(0.165)	(0.133)	(0.297)	(0.256)	(0.151)	(0.001)	(0.001)	(0.002)	(0.003)	(0.011)	(0.009)	(0.008)	(0.886)	(0.999)	
	0.529	0.445	0.144	0.355	0.325	0.996	0.865	0.527	0.583	0.271	0.998	0.928	0.886	0.891	0.026			
Canadian	0.001	0.111	0.007	0.066	0.026	0.088	0.023	0.027	0.010	0.001	0.001	0.000	0.002	0.005	0.003	5.5349	20.9647	0.705
dollar	(0.002)	(0.053)	(0.039)	(0.078)	(0.063)	(0.141)	(0.122)	(0.071)	(0.001)	(0.000)	(0.001)	(0.001)	(0.005)	(0.004)	(0.004)	(0.980)	(0.999)	
	0.454	0.962	0.148	0.601	0.325	0.468	0.149	0.295	0.999	0.763	0.698	0.258	0.276	0.759	0.514			
French	0.004	0.092	0.095	0.127	0.245	0.422	0.201	0.001	0.002	0.001	0.002	0.013	0.012	0.015	0.002	5.5258	4.8873	0.351
franc	(0.004)	(0.112)	(0.083)	(0.165)	(0.133)	(0.297)	(0.256)	(0.151)	(0.001)	(0.001)	(0.002)	(0.003)	(0.011)	(0.009)	(0.008)	(0.980)	(0.999)	
	0.622	0.589	0.744	0.555	0.932	0.843	0.566	0.006	0.927	0.574	0.634	0.999	0.747	0.902	0.230			
German	0.002	0.105	0.011	0.050	0.065	0.658	0.454	0.004	0.000	0.001	0.002	0.005	0.009	0.007	0.006	0.5717	2.4591	0.219
mark	(0.004)	(0.110)	(0.082)	(0.163)	(0.131)	(0.293)	(0.253)	(0.148)	(0.001)	(0.001)	(0.002)	(0.003)	(0.011)	(0.009)	(0.008)	(0.549)	(0.996)	
	0.322	0.658	0.108	0.240	0.377	0.974	0.925	0.020	0.023	0.790	0.704	0.946	0.585	0.553	0.543			
Dutch	0.001	0.198	0.004	0.079	0.055	0.864	0.460	0.114	0.001	0.000	0.003	0.003	0.010	0.026	0.000	6.4804	3.7474	0.299
guider	(0.004)	(0.106)	(0.079)	(0.157)	(0.126)	(0.281)	(0.243)	(0.143)	(0.001)	(0.001)	(0.002)	(0.003)	(0.010)	(0.009)	(0.008)	(0.988)	(0.999)	
	0.196	0.937	0.036	0.386	0.339	0.997	0.939	0.574	0.328	0.395	0.775	0.723	0.665	0.997	0.009			
Swiss	0.001	0.126	0.051	0.027	0.134	0.489	0.529	0.144	0.001	0.001	0.002	0.008	0.008	0.003	0.012	0.0388	2.4488	0.218
franc	(0.005)	(0.131)	(0.097)	(0.194)	(0.156)	(0.348)	(0.301)	(0.177)	(0.002)	(0.001)	(0.003)	(0.003)	(0.013)	(0.011)	(0.010)	(0.156)	(0.996)	
	0.095	0.661	0.395	0.110	0.608	0.837	0.919	0.582	0.626	0.485	0.442	0.983	0.481	0.256	0.785			
U.K	0.004	0.304	0.047	−0.050	0.142	0.472	0.132	−0.200	0.000	−0.008	−0.004	−0.007	0.009	−0.007	0.002	5.2505	11.4836	0.567
pound	(0.004)	(0.099)	(0.074)	(0.147)	(0.118)	(0.263)	(0.227)	(0.134)	(0.001)	(0.001)	(0.002)	(0.002)	(0.010)	(0.008)	(0.007	(.976)	(0.999)	
	0.763	0.997	0.472	0.264	0.771	0.925	0.437	0.864	0.51	0.999	0.919	0.996	0.626	0.594	0.215			

Note: See Table 2.

[Table 5]

$$(S^i_{t+k} - F^i_{t,k})/S^i_t = a_i + \sum_{j=1}^{7} b_{ij} \, [(F^j_{t,k} - S^j_t)/S^j_t] + \sum_{j=1}^{7} c_{ij} \, [(F^j_{t,k} - S^j_t/S^j_t]^2 + u^i_{t+1}$$

Currency	$F(7,124)$ for $\hat{b}_{ij} = 0 \quad j = 1, \cdots, 7$ (confidence)	$F(7,124)$ for $\hat{c}_{ij} = 0 \quad j = 1, \cdots, 7$ (confidence)	$F(14,124)$ for $\hat{b}_{ij} = \hat{c}_{ij} = 0 \quad j = 1, \cdots, 7$ (confidence)
Belgium	4.0055	1.3458	3.5342
franc	(0.9994)	(0.7662)	(0.9998)
Canadian	0.8225	2.2374	23.1302
dollar	(0.4283)	(0.9647)	(0.9999)
French	3.4414	2.5422	4.7763
franc	(0.9978)	(0.9823)	(0.9999)
German	1.6488	1.3982	2.0344
mark	(0.8729)	(0.7889)	(0.9798)
Dutch	2.8020	1.3653	2.6688
guilder	(0.9702)	(0.8254)	(0.9908)
U.K.	3.3179	1.7095	10.2054
pound	(0.9971)	(0.8881)	(0.9999)

Note: Sample period: July 20 1973 to April 13, 1984. Number of observations: 140.