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FORWARD AND SPOT EXCHANGE RATES*

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There is a general consensus that forward exchange rates have little if any power as forecasts of future spot exchange rates. There is less agreement on whether forward rates contain time varying premiums. Conditional on the hypothesis that the forward market is efficient or rational, this paper finds that both components of forward rates vary through time. Moreover, most of the variation in forward rates is variation in premiums, and the premium and expected future spot rate components of forward rates are negatively correlated.

1. Introduction

There is much empirical work on forward foreign exchange rates as predictors of future spot exchange rates. [See, for example, Hansen and Hodrick (1980), Bilson (1981), and the review article by Levich (1979).] There is also a growing literature on whether forward rates contain variation in premiums. [See, for example, Frankel (1982), Hsieh (1982), Korajczyk (1983), Hansen and Hodrick (1983), Hodrick and Srivastava (1984), and Domowitz and Hakkio (1983).] There is a general concensus that forward rates have little if any power to forecast changes in spot rates. There is less consensus on the existence of time varying premiums in forward rates. Frankel (1982) and Domowitz and Hakkio (1983) fail to identify such premiums, while Hsieh (1982), Hansen and Hodrick (1983), Hodrick and Srivastava (1984), and Korajczyk (1983) find evidence consistent with time varying premiums.

This paper tests a model for joint measurement of variation in the premium and expected future spot rate components of forward rates. Conditional on the hypothesis that the forward market is efficient or rational, we find reliable evidence that both components of forward rates vary through time. More startling are the conclusions that (a) most of the variation in forward rates is variation in premiums, and (b) the premium and expected future spot rate components of forward rates are negatively correlated.

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2. Theoretical framework

The forward exchange rate f_t observed at time t for an exchange at $t+1$ is the market determined certainty equivalent of the future spot exchange rate s_{t+1}. One way to split this certainty equivalent into an expected future spot rate and a premium is

$$F_t = \mathrm{E}(S_{t+1}) + P_t, \tag{1}$$

where $F_t = \ln f_t$, $S_{t+1} = \ln s_{t+1}$, and the expected future spot rate, $E(S_{t+1})$, is the rational or efficient forecast, conditional on all information available at t. Logs are used (a) to make the analysis independent of whether exchange rates are expressed as units of currency i per unit of currency j or units of j per unit of i, and (b) because some models for the premium [for example, Fama and Farber (1979) and Stulz (1981)] can be stated in logs.

Eq. (1) is no more than a particular definition of the premium component of the forward rate. To give the equation economic content, a model that describes the determination of P_t is required. Examples of such models are discussed later. For the statistical analysis of the premium and expected future spot rate components of the forward rate, however, it suffices that the forward rate is the market determined certainty equivalent of the future spot rate.

2.1. Statistics

From (1) the difference between the forward rate and the current spot rate is

$$F_t - S_t = P_t + \mathrm{E}(S_{t+1} - S_t). \tag{2}$$

Consider the regressions of $F_t - S_{t+1}$ and $S_{t+1} - S_t$ (both observed at $t+1$) on $F_t - S_t$ (observed at t),

$$F_t - S_{t+1} = \alpha_1 + \beta_1(F_t - S_t) + \varepsilon_{1,t+1}, \tag{3}$$

$$S_{t+1} - S_t = \alpha_2 + \beta_2(F_t - S_t) + \varepsilon_{2,t+1}. \tag{4}$$

Estimates of (4) tell us whether the current forward-spot differential, $F_t - S_t$, has power to predict the future change in the spot rate, $S_{t+1} - S_t$. Evidence that β_2 is reliably non-zero means that the forward rate observed at t has information about the spot rate to be observed at $t+1$. Likewise, since $F_t - S_{t+1}$ is the premium P_t plus $\mathrm{E}(S_{t+1}) - S_{t+1}$, the random error of the rational forecast $\mathrm{E}(S_{t+1})$, evidence that β_1 in (3) is reliably non-zero means that the premium component of $F_t - S_t$ has variation that shows up reliably in $F_t - S_{t+1}$.

With the assumption that the expected future spot rate in the forward rate is efficient or rational, the regression coefficients in (3) and (4) are

$$\beta_1 = \frac{\operatorname{cov}(F_t - S_{t+1}, F_t - S_t)}{\sigma^2(F_t - S_t)},$$

$$= \frac{\sigma^2(P_t) + \operatorname{cov}(P_t, \mathrm{E}(S_{t+1} - S_t))}{\sigma^2(P_t) + \sigma^2(\mathrm{E}(S_{t+1} - S_t)) + 2\operatorname{cov}(P_t, \mathrm{E}(S_{t+1} - S_t))}, \tag{5}$$

$$\beta_2 = \frac{\operatorname{cov}(S_{t+1} - S_t, F_t - S_t)}{\sigma^2(F_t - S_t)}$$

$$= \frac{\sigma^2(\mathrm{E}(S_{t+1} - S_t)) + \operatorname{cov}(P_t, \mathrm{E}(S_{t+1} - S_t))}{\sigma^2(P_t) + \sigma^2(\mathrm{E}(S_{t+1} - S_t)) + 2\operatorname{cov}(P_t, \mathrm{E}(S_{t+1} - S_t))}. \tag{6}$$

In the special case where P_t and $\mathrm{E}(S_{t+1} - S_t)$ are uncorrelated, the regression coefficients β_1 and β_2 split the variance of $F_t - S_t$ into two parts: the proportion due to the variance of the premium and the proportion due to the variance of the expected change in the spot rate. When the two components of $F_t - S_t$ are correlated, the contribution of covariation between P_t and $\mathrm{E}(S_{t+1} - S_t)$ to $\sigma^2(F_t - S_t)$ is divided equally between β_1 and β_2. The regression coefficients still include the proportions of $\sigma^2(F_t - S_t)$ due to $\sigma^2(P_t)$ and $\sigma^2(\mathrm{E}(S_{t+1} - S_t))$, but the simple interpretation of β_1 and β_2 obtained when P_t and $\mathrm{E}(S_{t+1} - S_t)$ are uncorrelated is lost. The troublesome $\operatorname{cov}(P_t, \mathrm{E}(S_{t+1} - S_t))$ in (5) and (6) is a central issue in the empirical tests.

Since $F_t - S_{t+1}$ and $S_{t+1} - S_t$ sum to $F_t - S_t$, the sum of the intercepts in (3) and (4) must be zero, the sum of the slopes must be 1.0, and the disturbances, period-by-period, must sum to 0.0. In other words, regressions (3) and (4) contain identical information about the variation of the P_t and $\mathrm{E}(S_{t+1} - S_t)$ components of $F_t - S_t$, and in principle there is no need to show both. I contend, however, that joint analysis of the regressions is what makes clear the information that either contains.

Thus, regression (4) of the change in the spot rate, $S_{t+1} - S_t$, on the forward rate minus the current spot rate, $F_t - S_t$, is common in the literature. [See, for example, Bilson (1981) and Levich (1979, table 2).] It is also widely recognized that deviations of β_2 in (4) from 1.0 can somehow be due to a time varying premium in the forward rate. To my knowledge, however, the explicit interpretation of the regression coefficients provided by (5) and (6) is not well known. In particular, it is not widely recognized that, given an efficient or rational exchange market, the deviation of β_2 from 1.0 is a direct measure of the variation of the premium in the forward rate. The complementarity of the regression coefficients in (3) and (4) which is described in (5) and (6) helps us to interpret some of the anomalous results observed for estimates of (4).

2.2. Economics

Since a major conclusion of the empirical work is that variation in forward rates is mostly variation in premiums, some discussion of the economics of premiums is warranted. Using more precise notation, let f_t^{ij} and s_t^{ij} be the forward and spot exchange rates (units of currency i per unit of currency j) observed at t, and let R_{it} and R_{jt} be the nominal interest rates observed at t on discount bonds denominated in currencies i and j. The bonds have either zero or identical default risks, and they have the same maturity as f_t^{ij}.

With open international bond markets, the no arbitrage condition of interest rate parity (IRP) implies

$$f_t^{ij}/s_t^{ij} = (1+R_{it})/(1+R_{jt}). \tag{7}$$

Thus, the difference between the forward and spot exchange rates observed at t is directly related to the difference between the interest rates on nominal bonds denominated in the two currencies. Any premium in the forward rate must be explainable in terms of the interest rate differential.

For example (and keep in mind that it is just an example), suppose (a) that exchanges rates are characterized by complete purchasing power parity (PPP), and (b) that the Fisher equation holds for nominal interest rates. Let V_{it} and V_{jt} be the price levels in the two countries, let $\Delta_{i,t+1} = \ln(V_{i,t+1}/V_{it})$ and $\Delta_{j,t+1} = \ln(V_{j,t+1}/V_{jt})$ be their inflation rates, and let $r_{i,t+1}$ and $r_{j,t+1}$ be the *ex post* continuously compounded real returns on their nominal bonds. Taking logs in (7) and applying the Fisher equation to the resulting continuously compounded nominal interest rates, we have

$$\begin{aligned} F_t^{ij} - S_t^{ij} &= \left[\mathrm{E}(r_{i,t+1}) + \mathrm{E}(\Delta_{i,t+1})\right] - \left[\mathrm{E}(r_{j,t+1}) + \mathrm{E}(\Delta_{j,t+1})\right] \\ &= \left[\mathrm{E}(r_{i,t+1}) - \mathrm{E}(r_{j,t+1})\right] + \left[\mathrm{E}(\ln V_{i,t+1}) - \mathrm{E}(\ln V_{j,t+1})\right] \\ &\quad - \left[\ln V_{it} - \ln V_{jt}\right]. \end{aligned} \tag{8}$$

With complete PPP, $s_t^{ij} = V_{it}/V_{jt}$, that is, the spot exchange rate is the ratio of the price levels in the two countries, and (11) reduces to

$$F_t^{ij} = \left[\mathrm{E}(r_{i,t+1}) - \mathrm{E}(r_{j,t+1})\right] + \mathrm{E}(S_{t+1}^{ij}). \tag{9}$$

In words, with the Fisher equation, interest rate parity and purchasing power parity, the premium P_t in the forward rate expression (1) is just the difference between the expected real returns on the nominal bonds of the two countries. Thus, the variables that determine the difference between the expected real returns on the nominal bonds (for example, differential purchasing power risks of their nominal payoffs) also explain the premium in the forward rate. This interpretation applies to any model of international capital market equilibrium characterized by IRP, PPP, and the Fisher equation for nominal interest rates. Examples are the international version of the Sharpe (1964) and Lintner (1965) model discussed by Fama and Farber (1979) or the version of the Lucas (1978) model discussed by Hodrick and Srivastava (1984).

The lock between the premium in the forward exchange rate and the interest rates on the nominal bonds of two countries is the direct consequence of the interest rate parity condition (7) of an open international bond market. For example, using IRP and an international version of the Breeden (1979) model, Stulz (1981) derives an expression for the forward rate similar to (1) or (9), but for a world in which (a) complete PPP does not hold, and (b) differential tastes for consumption goods combine with uncertainty about relative prices to strip the Fisher equation of its meaning.

3. Data and summary statistics

Spot exchange rates and thirty-day forward rates for nine major currencies are taken from the Harris Bank Data Base supported by the Center for Studies in International Finance of the University of Chicago. The rates are Friday closes sampled at four-week intervals. There are 122 observations covering the period August 31, 1973, to December 10, 1982. All rates are U.S. dollars per unit of foreign currency.

Table 1 shows means, standard deviations, and autocorrelations of $S_{t+1}-S_t$ (the four-week change in the spot rate), F_t-S_{t+1} (the thirty-day forward rate minus the spot rate observed four weeks later), and F_t-S_t (the forward rate minus the current spot rate). Since the forward and spot rates are in logs and the differences are multiplied by 100, the three variables are on a percent per month basis.

The standard deviations of F_t-S_{t+1} in table 1 are larger than the standard deviations of $S_{t+1}-S_t$. Thus, in terms of standard deviation of forecast errors, the current spot rate is a better predictor of the future spot rate than the current forward rate. However, variation in the premium component of the forward rate can obscure the power of the prediction of the future spot rate in the forward rate. This is the problem that the complementary regressions (3) and (4) are meant to alleviate.

Consistent with the previous literature, the autocorrelations of changes in spot rates, $S_{t+1}-S_t$, are close to zero. Thus, if the expected component of the

Table 1

Autocorrelations, means, and standard deviations: 5/31/73–12/10/82, $N = 122$.[a]

Country	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	ρ_8	ρ_9	ρ_{10}	ρ_{11}	ρ_{12}	Mean	Std. dev.
						$S_{t+1} - S_t$								
Belgium	0.05	0.08	0.07	−0.03	0.02	−0.03	−0.01	0.06	0.14	−0.07	0.20	0.01	−0.25	3.11
Canada	0.13	−0.24	0.08	0.05	0.03	0.00	−0.16	0.06	0.07	−0.15	0.16	0.03	−0.17	1.12
France	−0.04	0.06	0.14	−0.02	0.14	0.04	0.01	−0.02	0.10	−0.12	0.11	−0.01	−0.43	3.01
Italy	0.01	0.15	−0.03	−0.11	0.09	−0.01	0.09	0.04	0.14	−0.17	0.12	−0.01	−0.73	2.80
Japan	0.16	−0.11	0.03	0.13	0.15	−0.09	−0.04	0.07	0.05	−0.09	−0.10	0.11	0.07	3.05
Netherlands	0.02	0.05	0.05	−0.14	−0.01	−0.01	−0.01	0.04	0.04	−0.06	0.17	−0.02	−0.04	3.01
Switzerland	0.01	0.08	0.03	−0.11	0.09	0.01	−0.05	−0.08	0.01	−0.04	0.07	−0.01	0.26	3.76
United Kingdom	0.15	0.04	0.10	−0.07	0.09	0.04	0.16	0.01	0.02	0.07	0.08	0.14	−0.36	2.58
West Germany	0.01	0.08	0.01	−0.13	0.00	−0.04	0.02	0.06	0.07	−0.05	0.17	−0.00	−0.03	3.08
						$F_t - S_{t+1}$								
Belgium	0.11	0.10	0.08	−0.02	0.02	−0.05	−0.03	0.04	0.11	−0.08	0.19	0.00	0.09	3.22
Canada	0.17	−0.21	0.07	0.04	0.01	−0.01	−0.16	0.04	0.06	−0.14	0.15	0.02	0.08	1.16
France	0.01	0.09	0.16	−0.01	0.14	0.04	0.00	−0.02	0.06	−0.10	0.12	−0.01	0.17	3.10
Italy	0.08	0.17	−0.02	−0.11	0.07	−0.03	0.08	0.03	0.11	−0.17	0.07	−0.03	−0.07	2.95
Japan	0.21	−0.05	0.07	0.13	0.14	−0.09	−0.05	0.05	0.05	−0.07	−0.08	0.12	0.10	3.15
Netherlands	0.07	0.08	0.07	−0.11	0.01	−0.00	−0.00	0.04	0.04	−0.05	0.19	0.01	0.21	3.08
Switzerland	0.05	0.10	0.06	−0.09	0.09	0.01	−0.04	−0.08	0.01	−0.02	0.08	0.01	0.23	3.82
United Kingdom	0.19	0.08	0.12	−0.06	0.09	0.03	0.15	0.01	0.01	0.05	0.07	0.13	0.13	2.65
West Germany	0.03	0.09	0.03	−0.12	0.00	−0.04	0.02	0.05	0.07	−0.04	0.18	0.02	0.33	3.12
						$F_t - S_t$								
Belgium	0.67	0.44	0.33	0.33	0.18	0.04	−0.01	0.01	0.00	−0.01	0.00	−0.01	−0.16	0.41
Canada	0.82	0.63	0.49	0.38	0.36	0.32	0.33	0.36	0.36	0.35	0.26	0.23	−0.09	0.17
France	0.65	0.45	0.36	0.28	0.24	0.18	0.17	0.18	0.23	0.28	0.26	0.23	−0.25	0.44
Italy	0.68	0.47	0.37	0.28	0.23	0.19	0.18	0.19	0.19	0.14	0.03	0.04	−0.80	0.66
Japan	0.85	0.69	0.61	0.47	0.34	0.30	0.22	0.16	0.21	0.24	0.22	0.20	0.17	0.64
Netherlands	0.72	0.55	0.40	0.28	0.24	0.20	0.20	0.23	0.22	0.21	0.15	0.09	0.17	0.32
Switzerland	0.86	0.73	0.61	0.52	0.47	0.46	0.48	0.49	0.50	0.49	0.44	0.40	0.48	0.37
United Kingdom	0.87	0.75	0.64	0.51	0.43	0.36	0.31	0.28	0.25	0.20	0.16	0.15	−0.23	0.35
West Germany	0.78	0.56	0.39	0.26	0.20	0.20	0.26	0.34	0.42	0.46	0.40	0.33	0.30	0.24

[a]All exchange rates are U.S. dollars per unit of foreign currency. $S_{t+1} - S_t$ is the four-week change in the spot exchange rate; $F_t - S_{t+1}$ is the thirty-day forward rate minus the spot rate observed four weeks later; $F_t - S_t$ is the forward rate minus the current spot rate. The means and standard deviations of the variables are on a percent per month basis. Under the hypothesis that the true autocorrelations are 0.0, the standard error of the sample autocorrelations is about 0.09.

changes, $E(S_{t+1} - S_t)$, varies in an autocorrelated way, this is not evident in the behavior of the observed changes. The $F_t - S_{t+1}$ for different countries also show little autocorrelation. $F_t - S_{t+1}$ is the premium, P_t, plus the forecast error, $E(S_{t+1}) - S_{t+1}$, which should be white noise. Thus, any autocorrelation of the premium is not evident in the time series behavior of $F_t - S_{t+1}$.

The autocorrelations of $F_t - S_t$ tell a different story. The first-order autocorrelations are 0.65 or greater, and the decay of the autocorrelations at successive lags suggests a first-order autoregressive process. This is confirmed by the partial autocorrelations (not shown) which are large at lag 1 but close to zero at higher-order lags. Since $F_t - S_t$ is the premium, P_t, plus the expected change in the spot rate, $E(S_{t+1} - S_t)$, the autocorrelations of $F_t - S_t$ indicate that P_t and/or $E(S_{t+1} - S_t)$ vary in an autocorrelated way.

The difference between the behavior of the autocorrelations of $F_t - S_t$ and those of $S_{t+1} - S_t$ and $F_t - S_{t+1}$ is easily explained. The standard deviations of $F_t - S_t$ are between 0.17 and 0.66 percent per month, whereas those of either $S_{t+1} - S_t$ or $F_t - S_{t+1}$ are typically greater than 3.0 percent per month. Thus, the autocorrelation of P_t and/or $E(S_{t+1} - S_t)$, which shows up in the time series behavior of $F_t - S_t$, is buried in the high variability of the unexpected components of $F_t - S_{t+1}$ and $S_{t+1} - S_t$.

4. Regression tests

4.1. OLS estimates

Table 2 shows the estimated regressions of $F_t - S_{t+1}$ and $S_{t+1} - S_t$ on $F_t - S_t$. Only one set of coefficient standard errors, residual standard errors and residual autocorrelations is shown for each country. This reflects the complementarity of the $F_t - S_{t+1}$ and $S_{t+1} - S_t$ regressions for each country. The intercept estimates in the two regressions sum to zero, the slope coefficients sum to one, and the sum of the two residuals is zero on a period-by-period basis.

Since the regressor $F_t - S_t$ has low variation relative to $F_t - S_{t+1}$ and $S_{t+1} - S_t$, the coefficients of determination (R_1^2 and R_2^2) for the regressions are small, and they are smaller for the $S_{t+1} - S_t$ regressions than for the $F_t - S_{t+1}$ regressions. The regression residuals, like the dependent variables, show little autocorrelation.

The anomalous numbers in table 2 are the estimates of the regression slope coefficients, $\hat{\beta}_1$ and $\hat{\beta}_2$. According to (5) and (6), the slope coefficient in the regression of $F_t - S_{t+1}$ on $F_t - S_t$ contains the proportion of the variance of $F_t - S_t$ due to variation in its premium component, P_t, while the slope coefficient in the regression of $S_{t+1} - S_t$ on $F_t - S_t$ contains the proportion of the variance of $F_t - S_t$ due to variation in the expected change in the spot rate, $E(S_{t+1} - S_t)$. The coefficients clearly cannot be interpreted in terms of these

Table 2

OLS regressions: 8/31/73–12/10/82, $N = 122$.[a]

$$F_t - S_{t+1} = \hat{\alpha}_1 + \hat{\beta}_1(F_t - S_t) + \hat{\varepsilon}_{1,t+1}, \qquad S_{t+1} - S_t = \hat{\alpha}_2 + \hat{\beta}_2(F_t - S_t) + \hat{\varepsilon}_{2,t+1}.$$

										Residual autocorrelations					
Country	$\hat{\alpha}_1$	$\hat{\beta}_1$	$\hat{\alpha}_2$	$\hat{\beta}_2$	$s(\hat{\alpha})$	$s(\hat{\beta})$	R_1^2	R_2^2	$s(\hat{\varepsilon})$	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6
Belgium	0.50	2.58	−0.50	−1.58	0.30	0.68	0.11	0.04	3.05	0.01	0.06	0.06	−0.03	0.02	0.02
Canada	0.25	1.87	−0.25	−0.87	0.11	0.61	0.07	0.01	1.12	0.12	−0.23	0.10	0.07	0.06	0.03
France	0.64	1.87	−0.64	−0.87	0.31	0.63	0.07	0.01	3.00	−0.07	0.04	0.13	−0.03	0.15	0.04
Italy	1.14	1.51	−1.14	−0.51	0.40	0.38	0.11	0.01	2.79	−0.00	0.16	−0.01	−0.09	0.10	0.01
Japan	−0.12	1.29	0.12	−0.29	0.29	0.43	0.07	0.00	3.06	0.15	−0.12	0.03	0.13	0.16	−0.08
Netherlands	−0.21	2.43	0.21	−1.43	0.31	0.86	0.06	0.01	2.99	−0.03	0.03	0.02	−0.17	−0.01	−0.02
Switzerland	−0.81	2.14	0.81	−1.14	0.56	0.92	0.04	0.00	3.75	−0.02	0.06	0.01	−0.12	0.10	0.02
United Kingdom	0.57	1.90	−0.57	−0.90	0.28	0.66	0.06	0.01	2.57	0.13	0.03	0.11	−0.06	0.10	0.05
West Germany	−0.36	2.32	0.36	−1.32	0.44	1.15	0.03	0.00	3.08	−0.01	0.07	0.00	−0.13	0.01	−0.03

[a] R_1^2 and R_2^2 are the coefficients of determination (regression R^2) for the $F_t - S_{t+1}$ and $S_{t+1} - S_t$ regressions. The complete complementarity of the $F_t - S_{t+1}$ and $S_{t+1} - S_t$ regressions for each country means that the standard errors $s(\hat{\alpha})$ and $s(\hat{\beta})$ of the estimated regression coefficients, the residual standard error $s(\hat{\varepsilon})$, and the residual autocorrelations, ρ_τ, are the same for the two regressions. Under the hypothesis that the true autocorrelations are zero, the standard error of the estimated residual autocorrelations is about 0.09.

proportions alone, since the coefficients in the $S_{t+1} - S_t$ regressions are always negative so that those in the $F_t - S_{t+1}$ regressions are greater than 1.0.

Inspection of (5) and (6) indicates an explanation for the strange estimates of β_1 and β_2. Since $\sigma^2(\mathrm{E}(S_{t+1} - S_t))$ in (6) must be non-negative, a negative estimate of β_2 implies that $\mathrm{cov}(P_t, \mathrm{E}(S_{t+1} - S_t))$ is negative and larger in magnitude than $\sigma^2(\mathrm{E}(S_{t+1} - S_t))$. The complementary estimate of $\beta_1 > 1$ then implies that $\mathrm{cov}(P_t, \mathrm{E}(S_{t+1} - S_t))$ is smaller in absolute magnitude than $\sigma^2(P_t)$, and thus that $\sigma^2(P_t)$ is larger than $\sigma^2(\mathrm{E}(S_{t+1} - S_t))$.

The non-zero covariance between P_t and $\mathrm{E}(S_{t+1} - S_t)$ prevents us from using the regression coefficients to estimate the levels of $\sigma^2(P_t)$ and $\sigma^2(\mathrm{E}(S_{t+1} - S_t))$. With (5) and (6), however, we can estimate the difference between the two variances as a proportion of $\sigma^2(F_t - S_t)$,

$$\beta_1 - \beta_2 = \frac{\sigma^2(P_t) - \sigma^2(\mathrm{E}(S_{t+1} - S_t))}{\sigma^2(F_t - S_t)}. \tag{10}$$

The differences between the estimates of β_1 and β_2 in table 2 range from 1.58 (Japan) to 4.16 (Belgium). Except for Japan, all the differences between the estimated coefficients are greater than 2.0. Thus, the point estimates are that the difference between the variance of the premium, P_t, and the variance of the expected change in the spot rate, $\mathrm{E}(S_{t+1} - S_t)$, in $F_t - S_t$ is typically more than twice the variance of $F_t - S_t$. Moreover, since $\hat{\beta}_1$ and $\hat{\beta}_2$ sum to 1.0, the estimates of the regression coefficients are perfectly negatively correlated, and the standard error of their difference is twice their common standard error. Only the estimates of $\beta_1 - \beta_2$ for Japan, Switzerland, and West Germany are less than two standard errors from zero, and all are more than 1.5 standard errors from zero. Thus, we can conclude that $\sigma^2(P_t)$ is reliably greater than $\sigma^2(\mathrm{E}(S_{t+1} - S_t))$.

In short, negative covariation between P_t and $\mathrm{E}(S_{t+1} - S_t)$ attenuates the variability of $F_t - S_t$ and obscures the interpretation of the regression slope coefficients in (3) and (4). Nevertheless the regression slope coefficients provide the interesting information that both the premium, P_t, and the expected change in the spot rate, $\mathrm{E}(S_{t+1} - S_t)$, in $F_t - S_t$ vary through time, and $\sigma^2(P_t)$ is large relative to $\sigma^2(\mathrm{E}(S_{t+1} - S_t))$.

A good story for negative covariation between P_t and $\mathrm{E}(S_{t+1} - S_t)$ is difficult to tell. For example, in the PPP model for the exchange rate underlying (9), the dollar is expected to appreciate relative to a foreign currency, that is, $\mathrm{E}(S_{t+1} - S_t)$ is negative, when the expected inflation rate in the U.S. is lower than in the foreign country. (Remember that the exchange rates are all expressed as dollars per unit of foreign currency.) A negative $\mathrm{cov}(P_t, \mathrm{E}(S_{t+1} - S_t))$ then implies a higher purchasing power risk premium in the expected real returns on dollar denominated bonds relative to foreign currency bonds when the anticipated U.S. inflation rate is low relative to the anticipated foreign inflation rate.

We return to economic interpretations of the negative covariance between the P_t and $\mathrm{E}(S_{t+1}-S_t)$ components of $F_t - S_t$ after exploring some purely statistical possibilities.

4.2. SUR estimates

The apparent negative covariation between P_t and $\mathrm{E}(S_{t+1}-S_t)$ may be sampling error. All the slope coefficients in the $F_t - S_{t+1}$ regressions are more than two standard errors above 0.0, but only one (Belgium) is more than two standard errors above 1.0. Equivalently, only one of the negative slope coefficients in the $S_{t+1} - S_t$ regressions (Belgium) is more than two standard errors below zero. Perhaps the appropriate conclusion is that all variation through time in $F_t - S_t$ is variation in premiums, and there is no variation in expected changes in spot rates.

Individually testing the $\hat{\beta}_1$ coefficients in table 2 against 1.0 (or the $\hat{\beta}_2$ coefficients against 0.0) does not provide the appropriate joint test that all $\beta_1 = 1.0$ (or all $\beta_2 = 0$). An appropriate joint test takes into account the high correlation of $F_t - S_{t+1}$ (or $S_{t+1} - S_t$) across currencies, documented in table 3. Such cross-correlation is to be expected given that (a) all exchange rates are measured relative to the U.S. dollar, and (b) most of the European countries are involved in attempts to control the movements of their exchange rates relative to one another during the sample period. Table 3 also indicates that, with the possible exception of Canada, the correlations of the regressor variable $F_t - S_t$ across countries are generally lower than the correlations of $S_{t+1} - S_t$ or $F_t - S_{t+1}$ across the countries. Thus, there is reason to suspect that joint estimation of the $F_t - S_{t+1}$ (or the $S_{t+1} - S_t$) regressions for different countries will improve the precision of the coefficient estimates.

The coefficient estimates obtained when Zellner's (1962) 'seemingly unrelated regression' (SUR) technique is used to estimate either the $F_t - S_{t+1}$ regressions for different countries or the $S_{t+1} - S_t$ regressions are summarized in part A of table 4. As anticipated, joint estimation substantially improves the precision of the estimated slope coefficients. The $s(\hat{\beta})$ in table 4 are often less than half those for the OLS estimates in table 2. Moreover, the slope coefficients in the SUR versions of the $S_{t+1} - S_t$ regressions are generally closer to zero than in the OLS regressions which means that the coefficients in the complementary $F_t - S_{t+1}$ regressions are generally closer to 1.0. (Canada and Switzerland are exceptions.)

Table 4 also shows F tests on various joint hypotheses on the coefficients. The hypothesis that all the slope coefficients β_2 in the $S_{t+1} - S_t$ regressions (or all the slope coefficients β_1 in the $F_t - S_{t+1}$ regressions) are equal is consistent with the data. However, the hypothesis that all $\beta_2 = 0.0$ (or all $\beta_1 = 1.0$) yields

Table 3

Correlations of $S_{t+1} - S_t$, $F_t - S_{t+1}$ and $F_t - S_t$ across countries.[a]

	Belgium	Canada	France	Italy	Japan	Netherlands	Switzerland	United Kingdom	West Germany
					$S_{t+1} - S_t$				
Belgium	1.00								
Canada	0.19	1.00							
France	0.84	0.18	1.00						
Italy	0.69	0.10	0.77	1.00					
Japan	0.52	0.04	0.56	0.48	1.00				
Netherlands	0.94	0.19	0.85	0.72	0.50	1.00			
Switzerland	0.81	0.13	0.76	0.64	0.53	0.81	1.00		
United Kingdom	0.57	0.18	0.54	0.54	0.46	0.56	0.51	1.00	
West Germany	0.94	0.17	0.84	0.71	0.54	0.96	0.85	0.53	1.00
					$F_t - S_{t+1}$				
Belgium	1.00								
Canada	0.20	1.00							
France	0.85	0.16	1.00						
Italy	0.69	0.07	0.74	1.00					
Japan	0.51	0.07	0.55	0.46	1.00				
Netherlands	0.94	0.20	0.85	0.71	0.51	1.00			
Switzerland	0.80	0.14	0.76	0.61	0.55	0.80	1.00		
United Kingdom	0.55	0.16	0.51	0.51	0.47	0.56	0.50	1.00	
West Germany	0.93	0.18	0.84	0.69	0.56	0.96	0.85	0.53	1.00
					$F_t - S_t$				
Belgium	1.00								
Canada	0.55	1.00							
France	0.57	0.43	1.00						
Italy	0.59	0.43	0.51	1.00					
Japan	0.31	0.12	0.36	0.32	1.00				
Netherlands	0.54	0.40	0.31	0.49	0.49	1.00			
Switzerland	0.38	0.25	0.51	0.43	0.77	0.59	1.00		
United Kingdom	0.45	0.36	0.31	0.47	0.65	0.74	0.63	1.00	
West Germany	0.49	0.50	0.52	0.49	0.73	0.69	0.88	0.72	1.00

[a] $S_{t+1} - S_t$ is the four-week change in the spot exchange rate; $F_t - S_{t+1}$ is the thirty-day forward rate minus the spot rate observed four weeks later; $F_t - S_t$ is the forward rate minus the current spot rate.

Table 4

SUR regressions: 8/31/73–12/10/82, $N = 122$.[a]

$F_t - S_{t+1} = \hat{\alpha}_1 + \hat{\beta}_1(F_t - S_t) + \hat{\varepsilon}_{1,t+1}$, $\quad S_{t+1} - S_t = \hat{\alpha}_2 + \hat{\beta}_2(F_t - S_t) + \hat{\varepsilon}_{2,t+1}$.

Part A: Unconstrained

Country	$\hat{\alpha}_2(= -\hat{\alpha}_1)$	$\hat{\beta}_2(= 1 - \hat{\beta}_1)$	$s(\hat{\alpha})$	$s(\hat{\beta})$
Belgium	−0.36	−0.72	0.28	0.24
Canada	−0.26	−1.04	0.11	0.59
France	−0.48	−0.21	0.28	0.30
Italy	−1.08	−0.44	0.32	0.24
Japan	0.12	−0.28	0.28	0.35
Netherlands	0.10	−0.78	0.27	0.25
Switzerland	0.81	−1.15	0.42	0.50
United Kingdom	−0.52	−0.69	0.26	0.51
West Germany	0.23	−0.89	0.29	0.32

F tests

1. All β_2 (or β_1) equal $\quad F = 0.73 \quad P$ level = 0.66
2. All α_2 (or α_1) equal $\quad F = 5.14 \quad P$ level = 0.0001
3. All $\beta_2 = 0.0$ (or $\beta_1 = 1.0$) $\quad F = 2.81 \quad P$ level = 0.003

Part B: Constrained

$$S_{t+1} - S_t = \hat{\alpha}_B + \hat{\alpha}_C + \hat{\alpha}_F + \hat{\alpha}_I + \hat{\alpha}_J + \hat{\alpha}_N + \hat{\alpha}_S + \hat{\alpha}_{UK} + \hat{\alpha}_{WG} + \hat{\beta}_2\,(F_t - S_t)$$

$\hat{\alpha}_B$	$\hat{\alpha}_C$	$\hat{\alpha}_F$	$\hat{\alpha}_I$	$\hat{\alpha}_J$	$\hat{\alpha}_N$	$\hat{\alpha}_S$	$\hat{\alpha}_{UK}$	$\hat{\alpha}_{WG}$	$\hat{\beta}_2$
−0.34	−0.22	−0.57	−1.20	0.17	0.07	0.54	−0.49	0.14	−0.58
(0.28)	(0.10)	(0.27)	(0.27)	(0.28)	(0.27)	(0.35)	(0.23)	(0.28)	(0.13)

F test $\quad$ All α equal $\quad F = 5.68 \quad P$ level = 0.0001

[a] Like the OLS regressions in table 2, the SUR regressions are completely complementary; that is, the intercepts in the $F_t - S_{t+1}$ and $S_{t+1} - S_t$ regressions sum to 0.0, the slopes sum to 1.0, and the residuals sum to 0.0 period-by-period. The subscripts on the $\hat{\alpha}$ in the constrained $S_{t+1} - S_t$ regressions indicate countries.

a test statistic far out in the tail of the F distribution (beyond the 0.997 fractile) which suggests rejection of the hypothesis. Thus, we are left with the uncomfortable conclusion that the negative estimates of β_2 in the regressions of $S_{t+1} - S_t$ on $F_t - S_t$ are the result of negative covariation between the P_t and $\mathrm{E}(S_{t+1} - S_t)$ components of $F_t - S_t$.

Finally, since the hypothesis that the slope coefficients in the $S_{t+1} - S_t$ (or $F_t - S_{t+1}$) regressions are equal across countries is consistent with the data, we can use the SUR technique to estimate the regressions subject to the equality constraint. The results for the $S_{t+1} - S_t$ regressions are shown in part B of table 4. For all but three countries (France, Italy and Japan) the constrained estimate of β_2, -0.58, is closer to 0.0 than the unconstrained estimate in part A of the table. However, constraining the estimate of β_2 to be equal across countries so lowers the standard error of the estimate that $\hat{\beta}_2$ is now more than four standard errors from 0.0.

4.3. Subperiod results

Some argue that the nature of the flexible exchange rate system during our sample period is not well understood by market participants until the late 1970's. [See, for example, Hansen and Hodrick (1983).] Thus, the properties of forward exchange rates as predictors of future spot rates may be different during later years. To check on this possibility, the tests in tables 1 to 4 are replicated for the two 61-month subperiods covered by the data. The results are summarized in tables 5 to 7. The subperiod results also help to alleviate any statistical problems caused by changes in variance during the sample period.

There are some differences between the two subperiods. For example, the summary statistics of table 5 document an increase in the variability of $S_{t+1} - S_t$ and $F_t - S_{t+1}$ for the later period. There is no corresponding increase in the variability of $F_t - S_t$. The implied conclusion is that the higher variability of $S_{t+1} - S_t$ and $F_t - S_{t+1}$ in later years reflects increased uncertainty about the *ex post* change in the spot rate with no corresponding increase in the variability of the *ex ante* $\mathrm{E}(S_{t+1} - S_t)$ and P_t components of $F_t - S_t$.

The mean values of the variables do not suggest improved market forecasts of future spot rates during the later subperiod. The mean of $F_t - S_t$ more often has the same sign as the mean of $S_{t+1} - S_t$ during the earlier subperiod (seven of nine versus five of nine for the later period). Moreover, although the dollar appreciates relative to all nine currencies during the later period (the means of $S_{t+1} - S_t$ are all negative), all the means of $F_t - S_t$ move upward. Thus, either the forward rate on average becomes a less rational predictor of the future spot rate during the later period, or, as suggested by the regression results, there is opposite movement in the premium component of $F_t - S_t$ which more than offsets movement in the expected change in the spot rate.

Table 5

Autocorrelations, means and standard deviations for 61-month subperiods.[a]

Country	First subperiod: 8/31/73–4/7/78						Second subperiod: 5/5/78–12/10/82					
	Autocorrelations						Autocorrelations					
	ρ_1	ρ_2	ρ_3	ρ_4	Mean	Std dev	ρ_1	ρ_2	ρ_3	ρ_4	Mean	Std. dev
	$S_{t+1}-S_t$						$S_{t+1}-S_t$					
Belgium	0.11	0.16	0.05	−0.13	0.20	2.57	−0.00	0.01	0.06	−0.01	−0.69	3.48
Canada	0.19	−0.05	0.28	0.23	−0.21	1.00	0.11	−0.33	−0.04	−0.07	−0.13	1.23
France	0.09	0.05	0.13	−0.04	−0.16	2.49	−0.11	0.04	0.11	−0.06	−0.69	3.42
Italy	0.19	0.25	−0.18	−0.23	−0.63	2.56	−0.12	0.08	0.08	−0.04	−0.83	3.00
Japan	0.21	0.04	−0.10	−0.06	0.30	2.15	0.15	−0.18	−0.01	0.10	−0.17	3.70
Netherlands	0.07	0.03	0.04	−0.18	0.30	2.66	−0.02	0.07	0.04	−0.13	−0.37	3.27
Switzerland	0.08	0.26	0.13	−0.13	0.69	2.84	−0.03	−0.03	−0.03	−0.13	−0.18	4.43
United Kingdom	0.14	0.18	0.03	−0.16	−0.48	2.31	0.15	−0.06	0.16	0.02	−0.24	2.80
West Germany	0.15	0.13	−0.00	−0.19	0.25	2.64	0.09	0.05	0.01	−0.11	−0.32	3.42
	F_t-S_{t+1}						F_t-S_{t+1}					
Belgium	0.17	0.21	0.07	−0.14	−0.49	2.68	0.02	0.00	0.05	0.01	0.66	3.56
Canada	0.21	−0.03	0.30	0.24	0.10	1.02	0.16	−0.30	−0.06	−0.09	0.07	1.27
France	0.12	0.08	0.14	−0.03	−0.30	2.59	−0.08	0.05	0.11	−0.07	0.64	3.45
Italy	0.26	0.26	−0.17	−0.21	−0.44	2.74	−0.08	0.07	0.08	−0.06	0.30	3.08
Japan	0.22	0.02	−0.17	−0.21	−0.50	2.19	0.19	−0.13	0.03	0.12	0.71	3.77
Netherlands	0.10	0.04	0.04	−0.18	−0.29	2.72	0.02	0.09	0.06	−0.10	0.70	3.30
Switzerland	0.10	0.26	0.12	−0.14	−0.48	2.83	−0.01	−0.02	−0.02	−0.13	0.93	4.47
United Kingdom	0.13	0.16	−0.01	−0.21	0.06	2.33	0.22	0.02	0.20	0.07	0.20	2.91
West Germany	0.16	0.13	−0.00	−0.20	−0.11	2.67	−0.08	0.05	0.02	−0.11	0.77	3.43
	F_t-S_t						F_t-S_t					
Belgium	0.70	0.52	0.28	0.17	−0.28	0.39	0.56	0.20	0.18	0.31	−0.03	0.38
Canada	0.91	0.82	0.74	0.71	−0.12	0.17	0.70	0.39	0.14	−0.07	−0.06	0.16
France	0.46	0.02	−0.06	−0.08	−0.46	0.36	0.63	0.50	0.35	0.18	−0.05	0.40
Italy	0.61	0.36	0.36	0.25	−1.06	0.70	0.60	0.36	0.03	−0.09	−0.53	0.49
Japan	0.73	0.47	0.37	0.15	−0.20	0.66	0.82	0.65	0.41	0.24	0.54	0.33
Netherlands	0.60	0.43	0.29	0.12	0.01	0.30	0.65	0.33	0.04	−0.11	0.33	0.24
Switzerland	0.67	0.42	0.20	−0.00	0.21	0.26	0.69	0.32	−0.03	−0.27	0.76	0.23
United Kingdom	0.83	0.69	0.54	0.35	−0.41	0.29	0.78	0.59	0.42	0.26	−0.04	0.31
West Germany	0.61	0.32	0.12	−0.16	0.14	0.16	0.62	0.18	−0.18	−0.37	0.45	0.21

[a]All exchange rates are U.S. dollars per unit of foreign currency. $S_{t+1}-S_t$ is the four-week change in the spot exchange rate; F_t-S_{t+1} is the forward rate minus the spot rate observed four weeks later; F_t-S_t is the forward rate minus the current spot rate. The means and standard deviations of the variables are on a percent per month basis. Under the hypothesis that the true autocorrelations are zero, the standard error of the sample autocorrelation ρ_τ is approximately 0.13.

Table 6

OLS regressions for 61-month subperiods.[a]

$F_t - S_{t+1} = \hat{\alpha}_1 + \hat{\beta}_1(F_t - S_t) + \hat{\varepsilon}_{1,t+1}$, $\quad S_{t+1} - S_t = \alpha_2 + \hat{\beta}_2(F_t - S_t) + \hat{\varepsilon}_{2,t+1}$.

Country	$\hat{\alpha}_2$ $(= -\hat{\alpha}_1)$	$\hat{\beta}_2$ $(= 1 - \hat{\beta}_1)$	$s(\hat{\alpha})$	$s(\hat{\beta})$	R_1^2	R_2^2	$s(\hat{\varepsilon})$	ρ_1
First subperiod: 8/31/73–4/7/78								
Belgium	−0.20	−1.42	0.40	0.83	0.13	0.05	2.55	0.05
Canada	−0.25	−0.32	0.16	0.77	0.05	0.00	1.01	0.19
France	−0.79	−1.38	0.51	0.87	0.11	0.04	2.48	0.06
Italy	−1.17	−0.51	0.60	0.47	0.15	0.02	2.58	0.17
Japan	0.37	0.31	0.29	0.42	0.04	0.01	2.18	0.20
Netherlands	0.31	−1.22	0.34	1.14	0.06	0.02	2.68	0.04
Switzerland	0.52	0.81	0.47	1.40	0.00	0.01	2.88	0.10
United Kingdom	−0.47	0.02	0.52	1.04	0.02	0.00	2.35	0.14
West Germany	0.62	−2.60	0.45	2.12	0.05	0.03	2.65	0.14
Second subperiod: 5/5/78–12/10/82								
Belgium	−0.74	−1.32	0.45	1.18	0.06	0.02	3.50	−0.02
Canada	−0.23	−1.64	0.17	0.98	0.11	0.05	1.22	0.06
France	−0.70	−0.22	0.45	1.11	0.02	0.00	3.47	−0.12
Italy	−1.15	−0.60	0.58	0.80	0.06	0.01	3.04	−0.12
Japan	0.82	−1.84	0.92	1.46	0.06	0.03	3.72	0.11
Netherlands	0.02	−1.18	0.73	1.77	0.03	0.01	3.32	−0.06
Switzerland	1.66	−2.44	1.98	2.50	0.03	0.02	4.47	−0.06
United Kingdom	−0.36	−2.83	0.35	1.12	0.17	0.10	2.71	−0.03
West Germany	−0.30	−0.04	1.05	2.10	0.00	0.00	3.48	−0.09

[a] R_1^2 and R_2^2 are the coefficients of determination (regression R^2) for the $F_t - S_{t+1}$ and $S_{t+1} - S_t$ regressions. The complete complementarity of the $F_t - S_{t+1}$ and $S_{t+1} - S_t$ regressions for each country means that the standard errors $s(\hat{\alpha})$ and $s(\hat{\beta})$ of the estimated regression coefficients, the residual standard error $s(\hat{\varepsilon})$, and the residual autocorrelation ρ_1 are the same for the two regressions.

On the other hand, the key aspects of the regression results in tables 6 and 7 are similar for the two subperiods. The slope coefficients in the regressions of $S_{t+1} - S_t$ on $F_t - S_t$ are generally negative, which means that the coefficients in the complementary regressions of $F_t - S_{t+1}$ on $F_t - S_t$ are generally greater than 1.0. In the SUR tests, the hypothesis that all the slope coefficients in the $S_{t+1} - S_t$ regressions are 0.0 (or that the coefficients in the $F_t - S_{t+1}$ regressions are 1.0) is easily rejected in either subperiod.

Under the maintained hypothesis that the market assessments of $\mathrm{E}(S_{t+1} - S_t)$ in $F_t - S_t$ are efficient or rational, the subperiod results confirm the earlier conclusions that (a) there is variation in both the P_t and $\mathrm{E}(S_{t+1} - S_t)$ components of $F_t - S_t$, (b) the variance of the premium component of $F_t - S_t$ is large relative to the variance of the expected change in the spot rate, and (c) negative covariation between P_t and $\mathrm{E}(S_{t+1} - S_t)$ dominates the variance of $\mathrm{E}(S_{t+1} - S_t)$ to produce negative slope coefficients in the regressions of $S_{t+1} - S_t$ on $F_t - S_t$.

Table 7

SUR regressions for 61-month subperiods.[a]

$F_t - S_{t+1} = \hat{\alpha}_1 + \hat{\beta}_1(F_t - S_t) + \hat{\varepsilon}_{1,t+1}$, $S_{t+1} - S_t = \hat{\alpha}_2 + \hat{\beta}_2(F_t - S_t) + \hat{\varepsilon}_{2,t+1}$.

Country	$\hat{\alpha}_2$ (= $-\hat{\alpha}_1$)	$\hat{\beta}_2$ (= $1 - \hat{\beta}_1$)	$s(\hat{\alpha})$	$s(\hat{\beta})$
	First subperiod: 8/31/73–4/7/78			
Belgium	0.00	−0.72	0.33	0.22
Canada	−0.22	−0.01	0.15	0.71
France	−0.37	−0.45	0.41	0.56
Italy	−1.04	−0.39	0.52	0.37
Japan	0.35	0.24	0.29	0.33
Netherlands	0.31	−0.53	0.34	0.31
Switzerland	0.78	−0.41	0.40	0.73
United Kingdom	−0.54	−0.16	0.45	0.79
West Germany	0.57	−2.23	0.35	0.59
F tests	1. All β_2 (or β_1) equal	$F = 2.56$	P level = 0.0095	
	2. All $\beta_2 = 0$ (or $\beta_1 = 1$)	$F = 3.22$	P level = 0.0009	
	3. All α_2 (or α_1) equal	$F = 3.92$	P level = 0.0002	
	Second subperiod: 5/5/78–12/10/82			
Belgium	−0.71	−0.41	0.45	0.41
Canada	−0.24	−1.78	0.16	0.82
France	−0.68	0.24	0.45	0.32
Italy	−1.11	−0.52	0.41	0.22
Japan	1.08	−2.32	0.78	1.15
Netherlands	−0.03	−1.03	0.44	0.37
Switzerland	1.87	−2.71	1.09	1.23
United Kingdom	−0.37	−3.06	0.35	0.78
West Germany	−0.11	−0.46	0.48	0.40
F tests	1. All β_2 (or β_1) equal	$F = 3.17$	P level = 0.0016	
	2. All $\beta_2 = 0$ (or $\beta_1 = 1$)	$F = 4.20$	P level = 0.0001	
	3. All α_2 (or α_1) equal	$F = 3.92$	P level = 0.0002	

[a]Like the OLS regressions, the SUR regressions are completely complementary; that is, the intercepts in the $F_t - S_{t+1}$ and $S_{t+1} - S_t$ regressions sum to 0.0, the slopes sum to 1.0 and the residuals sum to 0.0 period-by-period.

5. Interpretations

Various explanations of the results are suggested by the existing literature and by readers of earlier versions of this paper. Some of these explanations are discussed now. No explanation is necessarily complete, and they are not mutually exclusive. Moreover, generous readers of earlier drafts are not responsible for my paraphrasing of their comments.

5.1. An inefficient foreign exchange market

The interpretation of the results above is based on the hypothesis that the assessment of $E(S_{t+1} - S_t)$ in $F_t - S_t$ is efficient or rational. An alternative hypothesis is that the negative slope coefficients in the regressions of $S_{t+1} - S_t$ on $F_t - S_t$ reflect assessments of $E(S_{t+1} - S_t)$ that are consistently perverse realtive to the true expected value of the change in the spot rate. The large positive coefficients in the $F_t - S_{t+1}$ regressions are then a simple consequence of the complementarity of the $F_t - S_{t+1}$ and $S_{t+1} - S_t$ regressions rather than manifestation of movement in rationally determined premiums. Under this interpretation, the similarity of the regression results for the two subperiods indicates that market irrationality in forecasting exchange rates is not cured by continued experience with flexible exchange rates.

5.2. *Government intervention in the spot exchange market*

A kind of 'market inefficiency', suggested by Richard Roll, can result from government intervention in the spot foreign exchange market. For example, suppose forward rates are determined by the interest rate parity condition (7) and interest rates in different countries rationally reflect their expected inflation rates. Left to the open market forces suggested by purchasing power parity, spot exchange rates would tend to move in the direction implied by the forward-spot differential $F_t - S_t$. Government logic and obstinacy, however, may be inversely related to natural market forces. Governments may support their currencies more vigorously (through open market operations, trade restrictions, and restrictions on capital flows) the stronger are the market forces, like differential expected inflation rates, which indicate that the currency should depreciate. They may try to move back toward a free market equilibrium by changing the direction of the underlying factors pressuring the exchange rate, like differential inflation rates, rather than by letting adjustments take place through the exchange rate.

5.3. *The doomsday theory*

Michael Mussa suggests that there are episodes, often brief, during which the distribution of anticipated changes in exchange rates is highly skewed. For example, market participants may assess a small probability that a country will change its monetary policy so that its inflation rate will rise dramatically relative to other countries. The result may be a highly skewed distribution of anticipated inflation rates, which in turn increases interest rate differentials and forward-spot exchange rate differentials between this country and other countries. Since the phenomenon centers on skewness that exists for brief periods, the *ex post* drawings from the distributions of anticipated inflation rates and changes in exchange rates are likely to be below the *ex ante* means. This creates negative sample correlations between changes in exchange rates and forward-spot differentials which would not be observed if the skewed distributions were sampled over longer periods.

5.4. Stochastic deviations from purchasing power parity

Stockman (1980) and Lucas (1982) develop international models in which shocks to real activity work in part through money demand functions to drive changes in inflation and exchange rates. Fama (1982) also argues that through the workings of a standard money demand function and inertia in money supply, variation in anticipated real activity in the U.S. leads to variation in expected inflation of the opposite sign. Fama and Gibbons (1982) argue that expected real returns on U.S. nominal bonds are also driven by and move in the same direction as anticipated real activity. With a somewhat different story in which monetary shocks cause changes in real variables, Tobin (1965) and Mundell (1963) likewise conclude that the expected real and expected inflation components of nominal interest rates are negatively correlated.

Suppose (a) interest rate parity holds; (b) expected changes in exchange rates reflect expected inflation differentials; and (c) the expected real components of nominal interest rates can vary somewhat independently across countries in response to purely domestic factors. These conditions, along with either the Tobin–Mundell or Fama–Gibbons stories for negative correlation between the expected real and expected inflation components of nominal interest rates, imply negative correlation between the premium, P_t, and the expected change in the spot rate, $E(S_{t+1} - S_t)$, in the forward-spot differential, $F_t - S_t$.

To complete this story, however, we need a subplot to explain how the expected real returns on the nominal bonds of a country can vary in response to domestic factors that do not necessarily imply variation in the risks of the bonds. Segmented international capital markets can produce this result, but then the interest rate parity part of the story is likely to be lost. Alternatively, John Bilson suggests that such independent variation in the expected real returns on the nominal bonds of different countries can arise in open international capital markets when stochastic deviations from purchasing power parity (PPP) lead to strong preferences for borrowing and lending contracts denominated in one's domestic unit of account. Stulz (1981) provides a formal version of this kind of model in which deviations from PPP are due to the existence of nontraded goods. The Stulz model, in turn, can be viewed as a generalization of the Stockman (1980) and Lucas (1978, 1982) models.

6. Conclusions

Large positive autocorrelations of the difference between the forward rate and the current spot rate indicate variation through time in either the premium component of $F_t - S_t$ or in the assessment of the expected change in the spot rate. Moreover, slope coefficients in the regressions of $F_t - S_{t+1}$ and $S_{t+1} - S_t$ on $F_t - S_t$ that are reliably different from zero imply variation in both components of $F_t - S_t$. However, negative covariation between P_t and $E(S_{t+1}$

$-S_t$) leads to negative slope coefficients in the regressions of $S_{t+1} - S_t$ on $F_t - S_t$ and preempts accurate measurement of the variances of P_t and $E(S_{t+1} - S_t)$. Given market efficiency or rationality, the only conclusion we can draw from the negative slope coefficients in the $S_{t+1} - S_t$ regressions and slope coefficients greater than 1.0 in the complementary regressions of $F_t - S_{t+1}$ on $F_t - S_t$ is that the variance of the P_t component of $F_t - S_t$ is much larger than the variance of $E(S_{t+1} - S_t)$.

Any forward rate can be interpreted as the sum of a premium and an expected future spot rate. Thus, our regression approach to examining the components of forward rates has broad applicability to financial and commodity market data. In Fama (1984), I apply the approach to forward and spot interest rates on U.S. Treasury bills, with somewhat more success. For example, unlike the forward exchange rate, which seems primarily to reflect variation in its premium component, the difference between the forward one month interest rate for one month ahead and the current one month spot interest rate, $F_t - R_t$, splits roughly equally between variation in its premium component and variation in the expected change in the one month spot interest rate. Moreover, in the interest rate data, $F_t - R_t$ sometimes has a larger variance than the *ex post* change in the one month spot interest rate, $R_{t+1} - R_t$. Perhaps as a consequence, the *ex ante* $F_t - R_t$ explains from 15 to 70 percent of the variance of the *ex post* change in the spot interest rate, $R_{t+1} - R_t$. All of this is in striking contrast to the weak and somewhat perplexing picture that emerges from the exchange rate data, where variation in the *ex ante* forward-spot differential, $F_t - S_t$, is always small relative to the variation of the *ex post* change in the spot rate, $S_{t+1} - S_t$.

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