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Further evidence on exchange rate expectations

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This paper considers a previously unexploited survey data set of exchange rate expectations, which allows us to focus on differences between EMS and dollar exchange rates. We corroborate the earlier finding in the literature that exchange rate forecasts are not rational and that agents do not use all available information efficiently. Although extrapolative and adaptive expectations formation mechanisms describe non-EMS exchange rate expectations to a certain extent, EMS exchange rates forecasts seem to follow long-run fundamentals more closely and would suggest that agents believe that EMS exchange rate expectations 'undershoot' their long-run equilibrium values. (JEL F31)

The debate regarding the rationality of agents' expectations and the informational efficiency of financial markets continues to be an issue of central concern in the financial economics literature—see Fama (1991) and Cutler *et al.* (1990), for instance. These propositions have been tested recently in the foreign exchange market by analyzing survey data for some of the major currencies (French Franc, British Pound, German Mark, Japanese Yen, and Swiss Franc) relative to the United States Dollar—see Dominguez (1986), Frankel and Froot (1987a, 1987b), Froot and Frankel (1990), Ito (1990), MacDonald and Torrance (1990), Taylor (1989), and the literature surveys of Takagi (1991) and Froot and Thaler (1990). The principal benefit of using such data is that one obtains a direct measure of agents' beliefs, thus allowing for separate testing of an underlying model of

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exchange rate determination and a hypothesis about expectations. On the other hand, critics of survey data often question the extent to which such data is representative of 'the markets'' expectations. Furthermore, the rather narrow survey data sets that are collected often limit the scope of investigative analysis.

This paper extends the seminal work of Frankel and Froot (1987a) to a new data set that covers a wider range of currencies over a different sample period. The data set allows us to focus on differences between EMS and dollar exchange rate expectations. Previous work, as listed above, has focused mainly on the early 1980s period associated with the sustained US dollar appreciation. Our data set begins in January 1986 and ends in December 1990 covering a period of US dollar depreciation (and Deutschmark appreciation) relative to the currencies we review; the different sample period and different overall pattern of currency movements thus permit an additional test of the robustness of previously reported results. In addition to exploring differences between EMS and dollar exchange rates, we address three questions that were considered earlier by Frankel and Froot (1987a) and Dominguez (1986): whether economic agents' exchange rate forecasts are unbiased, whether economic agents use all available information efficiently and which time series process best characterizes investors' expectations formation. Results using the available cross exchange rate forecasts over relatively long horizons (three, six, and twelve months) covering nearly all EMS currencies provide an interesting complement to previous work that has largely focused on the five most actively traded currencies (*vis-à-vis* the US dollar). The breadth of our sample of currencies across forecast horizons is exploited by providing statistical tests on an individual currency basis rather than adopting the pooling technique of Frankel and Froot (1987a). As our data set is based only on three-, six-, and 12-month expectations, we do not consider the widely discussed topic of how longer-term expectations might differ from shorter-term expectations.

The paper is presented in four sections. In Section I, the construction of the exchange rate survey is outlined and summary statistics describing the data are provided. In Section II, the rationality of the survey forecasts is examined as well as the efficiency with which economic agents use publicly available information. Alternative models characterizing the formation of exchange rate expectations are considered in Section III. In Section IV, the results of this investigation are summarized.

I. The survey data

Since 1985, Business International Corporation has been conducting a monthly survey of exchange rate expectations covering ten currencies relative to the dollar and eight currencies relative to the Deutschmark which are published in its *Cross Rates Bulletin*. For publication purposes, survey participants are asked a few days prior to month's end to fax three-, six-, and 12-month ahead expectations of a number of currencies with projections being made from the beginning of the following month. Thus, for instance, the three-, six-, and 12-month ahead expected Deutschmark/dollar rate recorded on December 27, 1989 reflect a slightly longer forecast horizon as they represent the expected spot rate on April 1st, 1990, June 1st, 1990, and January 2nd, 1991, respectively.[1] The dates when the surveys are conducted have been recorded as well as the spot, three-, six-, and 12-month-ahead forward rates recorded on that particular day.

The 30-odd participants of the survey are treasurers of multinationals and private banks residing in four of the world's continents. Although not all participants will provide their views regarding a particular currency, the response rate is at worst 60 per cent. The *Cross Rates Bulletin* reports the geometric mean forecast of the responses received thus minimizing the effect of extreme forecasts. Unfortunately disaggregated survey respondent data are not available, although the standard deviation of the respondents' expectation is reported.

Tables 1a and 1b provide summary statistics for the actual and expected annualized exchange rate depreciation across forecast horizon and across currencies. The summary statistics for the annualized survey forecast error across horizon and across currencies are reported in Table 1c. Four currency 'groups' are presented—non-EMS currencies relative to the US dollar, EMS currencies relative to the US dollar, non-EMS currencies relative to the Deutschmark, EMS currencies relative to the Deutschmark. In the tables, as in the rest of the paper, S_t is defined as the natural logarithm of the spot exchange rate at time t and $E_t S_{t+k}$ is defined as the expected logarithm of the spot exchange rate at time $t + k$ formed at time t.

For the period analyzed (January 1st, 1986 through December 1st, 1990), the

TABLE 1A. Summary statistics of actual depreciation: $S_{t+k} - S_t$ (per cent per annum) (January 1, 1986 through December 1, 1990).

	3 months		6 months		12 months	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
JY/US	−11.48	30.26	−7.72	19.86	−5.05	13.57
SF/US	−14.04	28.11	−11.16	19.86	−7.71	14.79
BP/US	−8.08	26.58	−6.50	16.67	−5.07	11.22
CD/US	−5.32	7.46	−4.84	4.27	−4.75	2.76
FF/US	−11.40	22.85	−9.12	15.52	−7.04	11.25
DF/US	−14.12	25.69	−11.26	17.48	−8.77	12.65
IL/US	−11.28	22.91	−8.92	15.55	−6.56	10.76
BF/US	−13.04	24.78	−10.64	17.16	−8.32	12.64
DM/US	−14.04	25.40	−11.20	17.28	−8.72	12.41
IP/US	−11.76	25.33	−8.62	16.22	−6.56	11.02
JY/DM	2.53	22.38	3.47	16.61	3.67	12.33
SF/DM	0.12	9.98	0.13	5.77	1.04	3.22
BP/DM	5.48	21.44	4.44	15.20	3.52	9.54
CD/DM	8.17	26.80	6.12	18.70	3.87	13.61
FF/DM	2.76	5.66	2.16	4.06	1.70	2.74
DF/DM	0.12	1.19	0.06	0.74	0.00	0.42
IL/DM	2.76	5.45	2.30	3.65	2.16	2.67
BF/DM	0.47	2.90	0.32	1.95	0.23	1.14

Notes: BF = Belgian franc; BP = British pound; CD = Canadian dollar; DF = Dutch guilder; DM = German mark; FF = French franc; IL = Italian lira; IP = Irish pound; JY = Japanese yen; US = US dollar.

TABLE 1B. Summary statistics of expected depreciation: $E_t S_{t+k} - S_t$ (per cent per annum) (January 1, 1986 through December 1, 1990).

	3 months		6 months		12 months	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
JY/US	−3.64	7.79	−2.46	6.90	−0.48	3.56
SF/US	−3.16	8.79	−1.56	6.03	−0.30	3.77
BP/US	1.48	8.24	2.32	4.68	2.34	2.52
CD/US	2.28	4.19	2.10	2.27	1.46	1.16
FF/US	−1.00	7.87	0.32	4.88	1.27	3.24
DF/US	−2.52	8.96	−1.66	5.25	−0.36	3.26
IL/US	0.52	11.58	1.74	5.92	2.13	3.66
BF/US	−1.84	9.98	−0.70	6.49	0.27	3.88
DM/US	−3.32	8.26	−1.56	5.35	−0.41	3.33
IP/US	−3.28	13.96	−0.52	8.49	1.08	4.79
JY/DM	−1.01	5.11	−1.42	5.90	−0.27	1.95
SF/DM	−1.78	8.20	−0.65	2.59	−0.42	1.18
BP/DM	5.08	7.12	3.65	2.72	2.63	2.07
CD/DM	4.32	10.52	2.40	6.37	1.09	3.70
FF/DM	2.48	2.30	2.40	2.06	1.76	1.26
DF/DM	1.24	3.46	0.22	1.15	0.10	0.78
IL/DM	4.04	8.54	4.04	2.65	2.96	1.88
BF/DM	1.32	4.47	1.41	2.30	0.96	1.40

See notes for Table 1A.

mean expected depreciation declines in absolute value as the forecast horizon increases. Thus, survey respondents implicitly believe that there exists a mean reverting component in exchange rate changes as is implied by the Dornbusch (1976) asset model of exchange rate determination. This empirical regularity differs from summary statistics reported by Frankel and Froot (1987a, 1987b), MacDonald and Torrance (1990), and Dominguez (1986), which broadly suggest that the expected short-term depreciations were smaller than the expected 'long-term' depreciations over the 1984–86 period.[2]

It is interesting to note that—with the exception of the Canadian dollar—the standard deviations of the expected depreciation across the three-, six-, and 12-month horizons are generally smaller both for EMS and non-EMS currencies measured relative to the Deutschmark than the standard deviations of mean expected depreciations for the same currencies relative to the US dollar.

Both the absolute values and the standard deviations of the mean forecast errors—reported in Table 1C—fall markedly as the length of the forecast horizon rises from three months to 12 months. This finding could indicate that fundamentals are of more use in predicting the exchange rate in the longer term. The finding contrasts with the results of Dominguez (1986), who found that one-week- and two-week-ahead forecast error variances were smaller than one-month- and three-month-ahead forecast error variances. Frankel and Froot (1987a) report that the *Economist* survey data with three-, six-, and

TABLE 1C. Summary statistics of survey forecast error: $S_{t+k} - E_t S_{t+k}$ (per cent per annum) (January 1, 1986 through December 1, 1990).

	3 months		6 months		12 months	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
JY/US	−7.84	32.96	−5.26	21.33	−4.57	15.61
SF/US	−10.92	32.36	−9.58	22.82	−7.41	15.97
BP/US	−9.52	28.15	−8.82	17.40	7.42	11.98
CD/US	−7.60	8.25	−6.94	4.90	−6.22	3.19
FF/US	−10.40	25.14	−9.44	16.68	−8.31	11.72
DF/US	−11.60	29.44	−9.60	19.54	−8.41	13.44
IL/US	−11.80	28.30	−10.66	17.98	−8.70	12.36
BF/US	−11.20	29.29	−9.40	20.25	−8.60	14.21
DM/US	−10.68	28.60	−9.64	19.38	−8.31	13.33
IP/US	−8.48	26.51	−8.12	16.22	−7.65	10.26
JY/DM	3.54	23.89	4.90	17.34	3.94	12.26
SF/DM	1.90	12.88	0.78	5.77	1.45	3.24
BP/DM	0.39	22.28	0.88	14.94	0.89	8.58
CD/DM	3.85	31.64	3.72	22.26	2.77	14.50
FF/DM	0.24	5.30	−0.24	3.99	−0.07	2.72
DF/MM	−1.12	3.59	−0.16	1.19	−0.10	0.79
IL/DM	−1.28	9.86	−1.74	4.62	−0.79	3.05
BF/DM	−0.86	5.12	−1.09	2.30	−0.73	1.50

See notes for Table 1A.

12-month-ahead expectations exhibit rising absolute forecast errors with the forecast horizon and relatively level forecast error variances with the forecast horizon. It should be noted that in Frankel and Froot (1986) the variance of three-, six-, and 12-month-ahead survey prediction errors for the *Economist* data set *declines* with the forecast horizon; this empirical observation is reversed in Frankel and Froot (1987a) when four data points are added to the sample. In Frankel and Froot (1986), the mean forecast errors at the six-month horizon exceed those at the three-month horizon and are higher than mean forecast errors at the 12-month horizon.

It is also interesting to note that both the absolute value and the standard deviation of the mean forecast errors are significantly smaller for EMS currencies relative to the Deutschmark than for non-EMS currencies relative to the Deutschmark and relative to the US dollar. This corroborates the findings of other research—Artis and Taylor (1988), Giavazzi and Giovannini (1989), and Nieuwland *et al.* (1991)—namely that the European Monetary System has acted to reduce the volatility of exchange rate changes and thus has exerted a stabilizing role on exchange rate expectations. As is shown in Section III, this need not imply that exchange rate forecasts are unbiased predictors of future exchange rates.

Comparing Tables 1a and 1b, one notes that in general both the absolute value and the standard deviation of the mean realized depreciation are larger than

those of the expected mean depreciation. This confirms the results of Frankel and Froot (1987a) and Dominguez (1986). However, we find three noteworthy exceptions to this empirical regularity all applicable to EMS currencies relative to the Deutschmark: the Dutch guilder and Belgian franc for all forecast horizons and the Italian lira for the three-month forecast horizon. Although at first sight surprising, it is important to note that the summary statistics may be affected by large extreme values resulting from expectations of realignments.

II. The rationality of the survey data

Hodrick's (1987) and Levich's (1985) reviews of the literature on the efficiency of foreign exchange markets suggest that there is overwhelming evidence in favor of the view that forward rates are biased predictors of future spot rates. Rejection of the unbiasedness hypothesis may be attributable to the irrationality of market participants (as suggested by Cumby and Obstfeld, 1984; and Longworth, 1981), or to the existence of a risk premium (as suggested by Fama, 1984; Hodrick and Srivastava, 1984; and Wolff, 1987a), or to some combination of both of these phenomena. The availability of survey data enables us to identify the relative importance of the explanations. In this paper we focus our attention on the rationality issue and in a companion paper we examine the economic importance of the risk premium explanation.

To test the rationality of the survey data, two fairly standard tests (see Pesaran, 1987) are considered—the unbiasedness test and the orthogonality test. The unbiasedness test examines whether the expected exchange rate is an unbiased predictor of the future spot rate, whereas the orthogonality test aims to assess whether agents use information that is available to them efficiently to forecast future exchange rates. In both cases the tests are performed on bilateral rates relative to the US dollar and bilateral rates relative to the Deutschmark. In a sense, if the null hypothesis of irrationality held, then the Deutschmark based tests would be redundant as they represent linear combinations of bilateral US dollar tests; however, rejection of the null hypothesis for US dollar rates does not imply rejection of the null for Deutschmark rates. The advent of the European Monetary System implying a market-wide concern for fluctuations of member currencies relative to the DM warrants the examination of such tests.

Define the exchange rate forecast error, e_{t+k}, as $S_{t+k} - E_t S_{t+k}$. The null hypothesis of rational expectations (unbiasedness) implies that $\alpha = 0$ and $\beta = 1$ in regressions of the following form:[3]

$$\langle 1 \rangle \qquad S_{t+k} - S_t = \alpha + \beta(E_t S_{t+k} - S_t) + e_{t+k},$$

where e_{t+k} is a random error term. Equation $\langle 1 \rangle$ was fitted for each currency and for each forecast horizon ($k = 3$, 6, and 12). Realized spot exchange rates were obtained from Datastream.[4] Hansen and Hodrick (1980) demonstrate that when the forecast horizon is longer than the observational frequency, the forecast error e_{t+k} will be serially correlated. While OLS point estimates of β remain consistent in spite of the serially correlated residuals, the OLS standard errors for the regression coefficient are biased. Hansen (1982) provides an estimator for the covaraince matrix that is consistent in the presence of heteroskedasticity and serial correlation.

The method of moments estimate of the sample covariance matrix of the OLS estimate, $\hat{\beta}$ is given by

$$\langle 2 \rangle \qquad \hat{V}(\hat{\beta}) = T(X'X)^{-1}\hat{\Omega}(X'X)^{-1},$$

where $X = (x_1', \ldots, x_T')'$ is the matrix of observations on the explanatory variables x_t. The matrix $\hat{\Omega}$ refers to the following matrix

$$\langle 3 \rangle \qquad \hat{\Omega} = \sum_{L=-k}^{k} (1/T) \sum_{t=1}^{T} \hat{u}_t x_t x_{t-L}' \hat{u}_{t-L},$$

where K is the order of the moving average autocorrelation, and $\hat{u}_t$ is the OLS residual for observation t. However, there is one rather serious complication with the estimate of $\hat{\Omega}$. If K is non-zero, there is no guarantee that the estimate of $\hat{\Omega}$ becomes positive definite in small samples. To ensure positive-definiteness of the estimator of $\hat{\Omega}$, both frequency domain and time domain techniques have been proposed in the literature. Newey and West (1987) provide a consistent estimate of $\hat{\Omega}$ that discounts the Lth-order autocovariance by $1 - [|L|/(K+1)]$, and is positive definite in small samples. The Newey–West estimator is given by

$$\langle 4 \rangle \qquad \hat{V}(\hat{\beta}) = T(X'X)^{-1}\hat{W}(X'X)^{-1},$$

where $\hat{W}$ is formed by

$$\langle 5 \rangle \qquad \hat{W} = \sum_{L=-k}^{k} (1/T)[1 - (|L|/(K+1)] \sum_{t=1}^{T} \hat{u}_t x_t x_{t-L}' \hat{u}_{t-L}.$$

Serial correlation of the forecast errors is dealt with by making K non-zero. This corrects the covariance matrix for serial correlation in the form of a moving average process of order K. The k-month-ahead forecast equations in this section are estimated with the Newey–West estimator, assuming a moving average process of order K for the monthly k-month ahead forecast errors. Note that the k-month-ahead forecast is in reality a k-month *plus* a few days ahead forecast. Tables 2a, 2b, and 2c report the results of fitting equation $\langle 1 \rangle$ via the generalized method of moments (GMM) procedure. Overall, the evidence presented suggests a fairly consistent rejection of the null hypothesis that the expected depreciation is an unbiased predictor of the realized depreciation. Rejection of the null is attributable to both α being significantly different from zero and β being significantly different from one. In fact, it is generally the case that the β-coefficient is significantly negative. Thus survey respondents predicted the wrong direction of exchange rate depreciation. Similar results were obtained by Dominguez for exchange rate forecasts of the four major currencies relative to the US dollar over the three-month forecast horizon, and by MacDonald and Torrance (1988) for the Deutschmark over the one-week and one-month forecast horizons. Their results cover the 1983–84 and 1983–86 period, whereas our results cover the post-1986 period. It is interesting to note though that the significance of the level bias in our tests, which can be verified via a standard t-test on the estimated α-coefficient, declines as the length of the forecast horizon increases. At the three-month forecast horizon the estimated coefficient was significantly different from zero at the 5 per cent level in 11 of the 18 bilateral exchange rates, whereas at the 12-month horizon rejection was obtained in only two of 18 cases. It is interesting to note that the forecasted exchange rate appreciations for both EMS

TABLE 2A. Tests of unbiasedness: $S_{t+3} - S_t = \alpha + \beta(E_t S_{t+3} - S_t) + e_{t+3}$ (January 1, 1986 through December 1, 1990: 57 observations).

	$\hat{\alpha}$	$\hat{\beta}$	χ^2
JY/US	−0.0369**	−0.9054**	14.70**
	(0.0154)	(0.5563)	(0.000)
SF/US	−0.0442**	−1.1597**	89.67**
	(0.0103)	(0.4389)	(0.000)
BP/US	−0.0197	−0.1343*	11.08**
	(0.0144)	(0.5605)	(0.004)
CD/US	−0.0142**	0.1440**	30.03**
	(0.0034)	(0.3378)	(0.000)
FF/US	−0.0295*	−0.3852*	46.24**
	(0.0110)	(0.3830)	(0.000)
DF/US	−0.0402**	−0.7921**	79.50**
	(0.0108)	(0.3886)	(0.000)
IL/US	−0.0275**	−0.5297**	96.26**
	(0.0112)	(0.2100)	(0.000)
BF/US	−0.0359**	−0.7223**	183.97**
	(0.0108)	(0.2820)	(0.000)
DM/US	−0.0414**	−0.7592**	76.04**
	(0.0098)	(0.4225)	(0.000)
IP/US	−0.0266*	0.3424**	15.89**
	(0.0121)	(0.2831)	(0.000)
JY/DM	0.0043	−0.8196*	4.59
	(0.0122)	(0.8599)	(0.101)
SF/DM	0.0003	0.0052**	59.11**
	(0.0052)	(0.1392)	(0.000)
BP/DM	0.0121	0.1289**	10.05**
	(0.0137)	(0.2945)	(0.007)
CD/DM	0.0289**	0.7794	47.87**
	(0.0104)	(0.3703)	(0.000)
FF/DM	0.0014	0.8714	0.20
	(0.0032)	(0.4891)	(0.904)
DF/DM	0.0003	0.0209**	2136.59**
	(0.0006)	(0.0314)	(0.000)
IL/DM	0.0065*	0.0385**	279.27**
	(0.0030)	(0.0580)	(0.000)
BF/DM	0.0010	0.0542**	56.47**
	(0.0015)	(0.1259)	(0.000)

The standard errors of the coefficients are given in parentheses; * (**) denotes rejection at the 5 per cent (1 per cent) level for the hypotheses that $\alpha = 0$ or $\beta = 1$. The Chi-square statistic pertains to the joint hypothesis that $\alpha = 0$ and $\beta = 1$ (p-values are given in parentheses).

and non-EMS currencies relative to the Deutschmark are generally of the same sign as those for the actual appreciations. Another important feature is that the null hypothesis was rejected for all but one EMS exchange rate (the FF/DM rate).

These results should be interpreted with some caution. If conditional forecasts are formed rationally, allowing for a small probability of a large exchange rate

TABLE 2B. Tests of unbiasedness: $S_{t+6} - S_t = \alpha + \beta(E_t S_{t+6} - S_t) + e_{t+6}$ (January 1, 1986 through December 1, 1990: 54 observations).

	$\hat{\alpha}$	$\hat{\beta}$	χ^2
JY/US	−0.0403	−0.1406*	7.97*
	(0.0250)	(0.5323)	(0.020)
SF/US	−0.0655**	−1.2370**	91.38**
	(0.0213)	(0.3475)	(0.000)
BP/US	−0.0319	−0.0626	5.64
	(0.0242)	(0.7832)	(0.059)
CD/US	−0.0235**	−0.0607**	59.15**
	(0.0040)	(0.1759)	(0.000)
FF/US	−0.0451*	−0.2854**	23.89**
	(0.0213)	(0.3759)	(0.000)
DF/US	−0.0636**	−0.8865**	43.64**
	(0.0205)	(0.3773)	(0.000)
IL/US	−0.0388*	−0.6610**	39.04**
	(0.0191)	(0.3032)	(0.000)
BF/US	−0.0562**	−0.8750**	99.86**
	(0.0199)	(0.2597)	(0.000)
DM/US	−0.0627**	−0.8555**	52.76**
	(0.0192)	(0.3999)	(0.000)
IP/US	−0.0418	0.5030*	9.02*
	(0.0218)	(0.2361)	(0.011)
JY/DM	0.0184	0.1418**	6.43*
	(0.0249)	(0.3618)	(0.040)
SF/DM	0.0023	0.4987	5.12
	(0.0075)	(0.2724)	(0.077)
BP/DM	0.0036	1.0445	0.05
	(0.0281)	(0.8013)	(0.975)
CD/DM	0.0462**	−1.2974**	27.50**
	(0.0181)	(0.5049)	(0.000)
FF/DM	0.0041	0.5568	0.85
	(0.0060)	(0.5004)	(0.655)
DF/DM	0.0001	0.1747**	170.38**
	(0.0008)	(0.0642)	(0.000)
IL/DM	0.0130*	−0.0757**	33.09**
	(0.0057)	(0.1873)	(0.000)
BF/DM	−0.0009	0.3569**	74.95**
	(0.0027)	(0.1044)	(0.000)

See notes for Table 2A.

movement, then forecasts will appear to be biased when judged from *ex-post* forecast errors. The forecast bias that is obtained in our small sample tests need not imply that expectations are formed irrationally. If conditional forecasts are formed rationally, allowing for a small probability of a large exchange rate movement, then forecasts will appear biased when judged from *ex-post* forecast errors—this is the familiar 'peso problem' (see Krasker, 1980). It should also be noted that our test assumes that expectations are homogeneous. Ito (1990) presents evidence which suggests that exchange rate expectations are

TABLE 2C. Tests of unbiasedness: $S_{t+12} - S_t = \alpha + \beta(E_t S_{t+12} - S_t) + e_{t+12}$ (January 1, 1986 through December 1, 1990: 48 observations).

	$\hat{\alpha}$	$\hat{\beta}$	χ^2
JY/US	−0.0587	−1.7180**	141.09**
	(0.0365)	(0.4960)	(0.000)
SF/US	−0.0795	−0.7778**	16.30**
	(0.0542)	(0.5465)	(0.000)
BP/US	−0.0297	−0.8959**	26.17**
	(0.0433)	(0.5171)	(0.000)
CD/US	−0.0409**	−0.4508**	68.67**
	(0.0097)	(0.2491)	(0.000)
FF/US	−0.0701	−0.0174	6.07
	(0.0445)	(0.5887)	(0.050)
DF/US	−0.0895	−0.4756**	14.78**
	(0.0495)	(0.4032)	(0.000)
IL/US	−0.0468	−0.8817**	25.95**
	(0.0409)	(0.4744)	(0.000)
BF/US	−0.0808	−0.9005**	18.35**
	(0.0460)	(0.4899)	(0.000)
DM/US	−0.0895	−0.5586**	16.71**
	(0.0472)	(0.4613)	(0.000)
IP/US	−0.0748*	0.8056	4.64
	(0.0385)	(0.2586)	(0.099)
JY/DM	0.0386	0.7351	0.56
	(0.0513)	(0.8525)	(0.752)
SF/DM	0.0122	0.4452	3.08
	(0.0093)	(0.3600)	(0.214)
BP/DM	−0.0316	2.5370**	10.89**
	(0.0304)	(0.4774)	(0.004)
CD/DM	0.0432	−0.4106**	11.39**
	(0.0524)	(0.4293)	(0.003)
FF/DM	0.0073	0.5504	1.96
	(0.0111)	(0.3251)	(0.376)
DF/DM	−0.0001	0.1423**	193.97**
	(0.0012)	(0.0625)	(0.000)
IL/DM	0.0159	0.1920**	22.89**
	(0.0101)	(0.1760)	(0.000)
BF/DM	−0.0001	0.2541**	48.31**
	(0.0052)	(0.1605)	(0.000)

See notes for Table 2A.

heterogeneous and that economic agents exhibit 'wishful expectations' behavior; namely, exporters have a depreciation bias while importers have an appreciation bias. Thus, rejection of the unbiasedness hypothesis need not imply that all economic agents are irrational; indeed, the disaggregated expectations data used by Ito shows that bankers' expectations are unbiased at all forecast horizons. An alternative explanation would be that the time series process which describes the expected exchange depreciation is not ergodic as is implied in the application of the GMM procedure.

The second type of test of the rational expectations hypothesis is concerned with the efficient use of information available at the time expectations are formed. If economic agents use all available information efficiently, the expectational errors must be orthogonal to any variable in the set of information known to agents at the time they formed their expectations. The null hypothesis of rational expectations (orthogonality) implies that $\alpha = 0$ and $\beta = 0$ in regressions of the

TABLE 3A. Tests of orthogonality: $S_{t+3} - E_t S_{t+3} = \alpha + \beta({}_tF_{t+3} - S_t) + e_{t+3}$ (January 1, 1986 through December 1, 1990: 57 observations).

	$\hat{\alpha}$	$\hat{\beta}$	χ^2
JY/US	−0.1000**	−12.1662**	13.41**
	(0.0308)	(3.3247)	(0.001)
SF/US	−0.0721**	−6.7123**	28.40**
	(0.0137)	(2.8588)	(0.000)
BP/US	0.0067	−3.1121	5.66
	(0.0249)	(2.0174)	(0.059)
CD/US	0.0252**	1.0658	24.93**
	(0.0061)	(0.7175)	(0.000)
FF/US	−0.0088	−6.068**	28.93**
	(0.0144)	(1.7240)	(0.000)
DF/US	−0.0671**	−9.2252**	22.65**
	(0.0147)	(2.6906)	(0.000)
IL/US	0.0655**	−9.3296**	149.16**
	(0.0212)	(1.2599)	(0.000)
BF/US	−0.0211	−6.1255	6.14*
	(0.0139)	(3.5111)	(0.046)
DM/US	−0.0710**	−7.4329**	16.64**
	(0.0174)	(2.6525)	(0.000)
IP/US	−0.0211	−0.1015	2.62
	(0.0147)	(0.7055)	(0.270)
JY/DM	0.0013	−8.3810**	10.79**
	(0.0108)	(2.5654)	(0.004)
SF/DM	0.0028	−4.5878	2.45
	(0.0050)	(3.3956)	(0.294)
BP/DM	−0.0113	0.8701	0.29
	(0.0280)	(1.6859)	(0.867)
CD/DM	0.0332	−2.3138	1.13
	(0.0382)	(4.2222)	(0.569)
FF/DM	−0.0025	0.2985	3.20
	(0.0030)	(0.1676)	(0.202)
DF/DM	0.0005	−1.5749	4.93
	(0.0029)	(1.4305)	(0.085)
IL/DM	0.0328*	−2.2080**	17.40**
	(0.0142)	(0.7341)	(0.000)
BF/DM	−0.0021	−0.0101	1.25
	(0.0031)	(0.2360)	(0.536)

The standard errors of the coefficients are given in parentheses; * (**) denotes rejection at the 5 per cent (1 per cent) level for the hypotheses that $\alpha = 0$ or $\beta = 0$. The Chi-square Statistic pertains to the joint hypothesis that $\alpha = 0$ and $\beta = 0$ (p-values are given in parentheses).

following form:

$$\langle 6 \rangle \qquad S_{t+k} - E_t S_{t+k} = \alpha + \beta(X_t) + e_{t+k},$$

where the left-hand-side variable is the exchange rate forecast error, X_t is a set of information known at time t, and e_{t+k} is a random error term. In order to test whether economic agents use all available information efficiently, equation $\langle 6 \rangle$ was fitted for each currency and for each forecast horizon. The information set X_t included the forward premium, which is *known* at the time expectations are formed.

TABLE 3B. Tests of orthogonality: $S_{t+6} - E_t S_{t+6} = \alpha + \beta({}_tF_{t+6} - S_t) + e_{t+6}$ (January 1, 1986 through December 1, 1990: 54 observations).

	$\hat{\alpha}$	$\hat{\beta}$	χ^2
JY/US	−0.1581	−9.7537**	14.63**
	(0.0473)	(2.5536)	(0.000)
SF/US	−0.1011**	−4.1794**	16.96**
	(0.0255)	(1.7911)	(0.000)
BP/US	0.0279	−4.0545*	10.28**
	(0.0430)	(1.9094)	(0.006)
CD/US	−0.0387**	0.3830	33.44**
	(0.0106)	(0.6892)	(0.000)
FF/US	−0.0196	−4.9512**	26.92**
	(0.0248)	(1.4773)	(0.000)
DF/US	−0.1210**	−7.8593**	20.40**
	(0.0269)	(2.8380)	(0.000)
IL/US	0.0953**	−7.4155**	89.24**
	(0.0307)	(1.003)	(0.000)
BF/US	−0.0488**	−8.0886**	36.43**
	(0.0177)	(1.4463)	(0.000)
DM/US	−0.1339**	−7.1149**	32.19**
	(0.0238)	(2.3486)	(0.000)
IP/US	−0.0378	−0.4203	5.94
	(0.0258)	(0.8623)	(0.051)
JY/DM	0.0058	−9.9223**	21.06**
	(0.0159)	(2.2635)	(0.000)
SF/DM	0.0033	−1.3154**	67.92**
	(0.0053)	(0.1927)	(0.000)
BP/DM	−0.0374	1.4573	0.87
	(0.0572)	(1.7141)	(0.646)
CD/DM	0.1259**	−5.1209	10.81**
	(0.0488)	(3.3532)	(0.005)
FF/DM	−0.0153*	0.8080	4.46
	(0.0073)	(0.5261)	(0.107)
DF/DM	0.0004	−0.3628	1.61
	(0.0010)	(0.3093)	(0.447)
IL/DM	0.0142	−0.7221**	16.41**
	(0.0114)	(0.2434)	(0.000)
BF/DM	−0.0048	−0.03516	6.21*
	(0.0048)	(0.3575)	(0.045)

See notes for Table 3A.

TABLE 3C. Tests of orthogonality: $S_{t+12} - E_t S_{t+12} = \alpha + \beta({}_tF_{t+12} - S_t) + e_{t+12}$ (January 1, 1986 through December 1, 1990: 48 observations).

	$\hat{\alpha}$	$\hat{\beta}$	χ^2
JY/US	−0.3655**	−10.8515**	197.44**
	(0.0272)	(0.9510)	(0.00)
SF/US	−0.3945**	−9.6890**	91.99**
	(0.0415)	(1.6479)	(0.000)
BP/US	0.0950	−6.0015**	108.31**
	(0.0534)	(0.9612)	(0.000)
CD/US	−0.0786**	0.9239	30.64**
	(0.0257)	(1.1382)	(0.000)
FF/US	−0.0479	−4.0361**	19.07**
	(0.0443)	(1.2017)	(0.000)
DF/US	−0.1642**	−3.5131	24.36**
	(0.0346)	(2.4505)	(0.000)
IL/US	0.1326*	−5.9175**	55.02**
	(0.0615)	(1.0629)	(0.000)
BF/US	−0.0857	−0.1558	2.71
	(0.0565)	(0.6983)	(0.258)
DM/US	−0.2987**	−7.8569**	59.45**
	(0.0406)	(1.9181)	(0.000)
IP/US	−0.0671	−0.7272	17.78**
	(0.0413)	(0.5925)	(0.000)
JY/DM	0.0282	−6.8126*	6.80*
	(0.0369)	(3.1927)	(0.033)
SF/DM	−0.0017	−3.5367**	20.79**
	(0.0083)	(0.9188)	(0.000)
BP/DM	−0.2110*	4.0824**	5.86
	(0.0994)	(1.7339)	(0.053)
CD/DM	0.4099*	−8.7447**	36.28**
	(0.0768)	(2.4039)	(0.000)
FF/DM	−0.0299**	0.8212**	8.58*
	(0.0102)	(0.3709)	(0.014)
DF/DM	−0.0006	−0.0526	1.65
	(0.0014)	(0.1418)	(0.438)
IL/DM	−0.0075	−0.0074	0.84
	(0.0209)	(0.1966)	(0.657)
BF/DM	−0.0207*	0.5351	10.38**
	(0.0091)	(0.3850)	(0.006)

See notes for Table 3A.

Tables 3a, 3b, and 3c report regressions of the forecast error on the respective forward premia. The results provide a fairly consistent rejection of the null hypothesis for all currencies relative to the US dollar. This indicates that the forward premium contains additional information for the exchange rate forecasts of the major currencies relative to the US dollar. Similar results were obtained by Dominguez (1986) for data over the three-month forecast horizon. In contrast, the results for the exchange rates relative to the Deutschmark provide a less consistent rejection of the null hypothesis.[5]

Taken together, the results of both the unbiasedness test and the orthogonality test (see note 5) provide a strong rejection of the rational expectations hypothesis for exchange rates relative to the US dollar. This is not an isolated finding, but is in line with the general conclusion that so far has emerged from the analysis of survey results on exchange rate expectations for some of the major currencies relative to the US dollar. However, the results for the currencies relative to the Deutschmark suggest that it may be difficult to find publicly available information that would help improve the forecast accuracy of economic agents. Thus, although the rational expectations hypothesis has considerable appeal as a theoretical model, it does not appear to provide an adequate explanation of US dollar exchange rate expectation in the sampled period. It is therefore important to consider other models of expectation formation. In the next section we examine three alternative models: extrapolative, adaptive, and long-run expectations.

III. Models of expectations formation

Although recent empirical evidence suggests that exchange rates exhibit mean reverting behavior (see Huizinga, 1987; and Cavaglia, 1991), it would seem that the random walk hypothesis is a relatively accurate characterization of the time series of exchange rates. Indeed, Meese and Rogoff (1983a, 1983b) and Wolff (1987b) show that standard models of exchange rate determination fail to outperform the predictive power of the random walk hypothesis even when allowing for time varying model parameters. Fama (1984) finds that most of the forward discount is attributable to a risk premium, and thus one might conclude that the random walk may also be a proper characterization of investor's expectations formation, namely that $E_t S_{t+k} - S_t = 0$. Allen and Taylor (1990) present survey based evidence that foreign exchange dealers utilize some combination of charts and fundamentals in predicting currency movements with greater weight being given to fundamentals as the forecast horizon lengthens. The availability of survey data permits us to test directly how economic agents form their expectations of future appreciation of a currency. In this section, three alternative models of expectations formation are considered—the extrapolative, the adaptive, and the 'fundamentals'—against the null hypothesis that expectations are static. As in Section II, we chose not to pool across currencies; although results for linear models of bilateral exchange rates relative to the Deutschmark may be infered from the models of exchange rates relative to the US dollar, these are presented for completeness. The extrapolative expectations model is first considered; namely, economic agents extrapolate the most recent trend into the future, formally:

$$\langle 7 \rangle \qquad \Delta E_t S_{t+k} = \beta(\Delta S_t),$$

where ΔS_t is the most recent change in the exchange rate. If β is greater than zero, then exchange rate expectations are said to exhibit bandwagon effects, and if β equals zero then expectations are said to be static. Thus the following equation was fitted for each currency and for each forecast horizon ($k = 3$, 6, and 12):[6]

$$\langle 8 \rangle \qquad E_t S_{t+k} - S_t = \alpha + \beta(S_t - S_{t-1}) + e_t.$$

The results of fitting equation $\langle 8 \rangle$ are reported in Table 4.

TABLE 4. Extrapolative expectations: $E_t S_{t+k} - S_t = \alpha + \beta(S_t - S_{t-1}) + e_t$ (January 1, 1986 through December 1, 1990: 59 observations).

	3 months		6 months		12 months	
	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\alpha}$	$\hat{\beta}$
JY/US	−0.0114**	−0.3019**	−0.0153**	−0.4649**	−0.0067	−0.4982**
	(0.0021)	(0.0573)	(0.0039)	(0.1053)	(0.0039)	(0.1038)
SF/US	−0.0118**	−0.3951**	0.0095**	−0.5693**	0.0031	−0.6443**
	(0.0020)	(0.0544)	(0.0034)	(0.0922)	(0.0048)	(0.1303)
BP/US	0.0010	−0.3590**	0.0101**	−0.4373**	−0.0272**	−0.5049**
	(0.0020)	(0.0583)	(0.0023)	(0.0674)	(0.0028)	(0.0804)
CD/US	0.0048**	−0.22112	0.0091**	−0.2707	0.0151**	−0.2384
	(0.0014)	(0.1146)	(0.0017)	(0.1404)	(0.0017)	(0.1432)
FF/US	−0.0061**	−0.4044**	−0.0015	−0.5292**	0.0164**	−0.6233**
	(0.0020)	(0.0696)	(0.0026)	(0.0879)	(0.0044)	(0.1489)
DF/US	−0.0109**	−0.4391**	−0.0115**	−0.5353**	0.0016	−0.6097**
	(0.0022)	(0.0707)	(0.0029)	(0.0902)	(0.0046)	(0.1446)
IL/US	−0.0029	−0.4756**	0.0040	−0.6567**	0.0215**	−0.6737**
	(0.0034)	(0.1234)	(0.0031)	(0.1109)	(0.0043)	(0.1531)
BF/US	−0.0097**	−0.4505**	−0.0092**	−0.6401**	0.0057	−0.7447**
	(0.0026)	(0.0827)	(0.0035)	(0.1115)	(0.0050)	(0.1591)
DM/US	−0.01251**	−0.3873**	−0.0106**	−0.4971**	0.0017	−0.5653**
	(0.0021)	(0.0626)	(0.0030)	(0.0896)	(0.0048)	(0.1428)
IP/US	0.0133**	−0.5832**	−0.0078	−0.7057**	0.0158**	−0.6524**
	(0.0039)	(0.1141)	(0.0045)	(0.1312)	(0.0056)	(0.1630)
JY/DM	−0.0016	−0.2762**	−0.0074**	−0.4730**	−0.0104**	−0.3797**
	(0.0013)	(0.0510)	(0.0034)	(0.1307)	(0.0030)	(0.1155)
SF/DM	−0.0031	−0.3049	−0.0008	−0.3534**	−0.0018	−0.3091**
	(0.0025)	(0.1674)	(0.0012)	(0.0804)	(0.0015)	(0.0975)
BP/DM	0.0137**	−0.3330**	0.0177**	−0.1944**	0.0217**	−0.1138
	(0.0021)	(0.0916)	(0.0017)	(0.0744)	(0.0028)	(0.2109)
CD/DM	0.0142**	−0.3748**	0.0144**	−0.4351**	0.0085*	−0.6558**
	(0.0028)	(0.0833)	(0.0037)	(0.1090)	(0.0043)	(0.1282)
FF/DM	0.0062**	−0.1101	0.0109**	−0.4678*	0.0163**	−0.2221
	(0.0008)	(0.1160)	(0.0015)	(0.2164)	(0.0017)	(0.2474)
DF/DM	0.0031**	−0.4167	0.0007	−0.3276	0.0000	−0.2609
	(0.0011)	(0.4637)	(0.0008)	(0.3133)	(0.0011)	(0.4567)
IL/DM	0.01105**	−0.7239	0.0187**	−0.3614	0.0246**	−0.6993
	(0.0028)	(0.3859)	(0.0020)	(0.2753)	(0.0029)	(0.4009)
BF/DM	0.0035**	−0.3467	0.0068**	−0.0356	0.0084**	−0.8087*
	(0.0015)	(0.3146)	(0.0015)	(0.3231)	(0.0018)	(0.3839)

Standard errors are given in parentheses.
* = significant at the 5 per cent level.
** = significant at the 1 per cent level.

We find that the sign of the β-coefficient is negative in all regressions. Thus, past exchange rate depreciations are expected to be reversed in the future. This result is largely consistent with Frankel and Froot (1987a, 1987b, 1990), although the absolute size of our coefficient is higher than theirs.[7] The results for the EMS exchange rates relative to the Deutschmark indicate that, with the exception of

TABLE 5. Adaptive expectations: $E_tS_{t+k} - S_t = \alpha + \beta(S_t - E_{t-k}S_t) + e_t$ (January 1, 1986 through December 1, 1990: 57, 54, and 48 observations).

	3 months		6 months		12 months	
	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\alpha}$	$\hat{\beta}$
JY/US	−0.0122**	−0.1002**	−0.0199**	−0.1289**	−0.0269**	−0.1224**
	(0.0022)	(0.0268)	(0.0044)	(0.0391)	(0.0053)	(0.0319)
SF/US	−0.0130**	−0.1103**	−0.0161**	−0.1423**	−0.0208**	−0.1359**
	(0.0025)	(0.0294)	(0.0035)	(0.0295)	(0.0047)	(0.0261)
BP/US	0.0013	−0.0575	0.0089**	0.0237	0.0147**	−0.0506
	(0.0028)	(0.0383)	(0.0032)	(0.0379)	(0.0045)	(0.0329)
CD/US	0.0069**	0.0662	0.0125**	0.5770**	0.0221**	0.1090*
	(0.0021)	(0.0734)	(0.0030)	(0.0684)	(0.0037)	(0.0473)
FF/US	−0.0079**	−0.1127**	−0.0074**	−0.1401**	−0.0067	−0.1994**
	(0.0022)	(0.0329)	(0.0030)	(0.0325)	(0.0044)	(0.0315)
DF/US	−0.0118**	−0.0959**	−0.0159**	−0.1217**	−0.0175**	−0.1339**
	(0.0027)	(0.0342)	(0.0036)	(0.0324)	(0.0053)	(0.0329)
IL/US	−0.0069*	−0.1171**	−0.0034	−0.1195**	−0.0002	−0.1294**
	(0.0031)	(0.0399)	(0.0031)	(0.0299)	(0.0047)	(0.0305)
BF/US	−0.0124**	−0.1466**	−0.0161**	−0.1378**	−0.0169**	−0.1354**
	(0.0024)	(0.0302)	(0.0035)	(0.0317)	(0.0054)	(0.0325)
DM/US	−0.0133**	−0.1090**	−0.0162**	−0.1390**	−0.0217**	−0.1514**
	(0.0025)	(0.0322)	(0.0033)	(0.0309)	(0.0045)	(0.0279)
IP/US	−0.0120**	−0.19116**	−0.0074	−0.1004	0.0107	−0.1310
	(0.0038)	(0.0536)	(0.0054)	(0.0613)	(0.0078)	(0.0745)
JY/DM	−0.0012	−0.0964**	−0.0051	−0.2307**	−0.0099**	−0.1360**
	(0.0016)	(0.0257)	(0.0035)	(0.0398)	(0.0028)	(0.0397)
SF/DM	−0.0027	−0.0519	−0.0010	−0.0321	−0.0035*	−0.0530
	(0.0028)	(0.0856)	(0.0015)	(0.0623)	(0.0018)	(0.0561)
BP/DM	0.0130**	−0.0333	0.0175**	−0.0420	0.0265**	−0.1653**
	(0.0025)	(0.0460)	(0.0021)	(0.0271)	(0.0025)	(0.0278)
CD/DM	0.0144**	−0.1287**	0.0182**	−0.1378**	0.0178**	−0.1086**
	(0.0031)	(0.0389)	(0.0039)	(0.0336)	(0.0056)	(0.0361)
FF/DM	0.0057**	−0.0201	0.0109**	−0.0272	0.0170**	0.0879
	(0.0007)	(0.0535)	(0.0015)	(0.0727)	(0.0017)	(0.0487)
DF/DM	0.0026**	0.0740	0.0011	−0.0432	0.0013	−0.1384
	(0.0012)	(0.1312)	(0.0008)	(0.1237)	(0.0013)	(0.1795)
IL/DM	0.0071**	−0.0449	0.0177**	−0.0132	0.0233**	0.0282
	(0.0025)	(0.1278)	(0.0017)	(0.0654)	(0.0022)	(0.0666)
BF/DM	0.0031**	−0.1960	0.0048**	−0.0544	0.0077**	0.0583
	(0.0015)	(0.1546)	(0.0014)	(0.1304)	(0.0019)	(0.1266)

See notes for Table 4.

the 12-month expectations for the Belgian Franc, the slope coefficients are insignificant.

Adaptive expectations models were subsequently considered; namely, the expected future spot rate is formed as a weighted average of the current spot rate and the lagged expected rate, or

$$\langle 9 \rangle \qquad E_tS_{t+k} = (1 - b)S_t + bE_{t-k}S_t.$$

TABLE 6. Long-run expectations: $E_tS_{t+3}-S_t=\alpha+\beta(E_tS_{t+12}-E_{t-1}S_{t+11})+e_t$ (January 1, 1986 through November 1, 1990: 59 observations).

	$\hat{\alpha}$	$\hat{\beta}$
JY/US	−0.0123**	0.0296**
	(0.0000)	(0.0028)
SF/US	−0.0125**	−0.2009**
	(0.0000)	(0.0021)
BP/US	0.0009**	0.0730**
	(0.0000)	(0.0036)
CD/US	0.0071**	0.7943**
	(0.0000)	(0.0039)
FF/US	−0.0084**	−0.3102**
	(0.0000)	(0.0041)
DF/US	−0.0104**	−0.0695**
	(0.0001)	(0.0026)
IL/US	−0.0045**	−0.1689**
	(0.0001)	(0.0038)
BF/US	−0.0142**	−0.2412**
	(0.0000)	(0.0021)
DM/US	−0.0129**	−0.1423**
	(0.0001)	(0.0033)
IP/US	−0.0159**	−0.3337**
	(0.0046)	(0.0065)
JY/DM	−0.0019**	−0.2025**
	(0.0000)	(0.0014)
SF/DM	−0.0018**	−0.3713**
	(0.0000)	(0.0041)
BP/DM	0.0106**	−0.0946**
	(0.0000)	(0.0021)
CD/DM	0.0156**	−0.4229**
	(0.0001)	(0.0107)
FF/DM	0.0054**	0.1062**
	(0.0000)	(0.0007)
DF/DM	0.0030**	0.4844**
	(0.0000)	(0.0028)
IL/DM	0.0076**	0.9841**
	(0.0000)	(0.0264)
BF/DM	0.0032**	0.0383**
	(0.0000)	(0.0021)

See notes for Table 4.

Alternatively, one can view the expected depreciation as a function of past forecast errors, and then the following equation may be fitted:

$$\langle 10\rangle \qquad E_tS_{t+k} - S_t = \alpha + \beta(S_t - E_{t-k}S_t) + e_t.$$

Equation $\langle 10\rangle$ corresponds to equation $\langle 9\rangle$ if we set $\alpha = 0$ and $\beta = -b$. The results of fitting the above equation for each currency for all forecast horizons are reported in Table 5.

Significantly negative slope coefficients are obtained for nearly all currencies relative to the US dollar and for some non-EMS currencies relative to the Deutschmark. Once again, models for EMS currencies relative to the Deutschmark did not yield significant slope coefficients. Interpreting the regression coefficient for the yen/dollar exchange rate at the three-month horizon, an unexpected depreciation of 1 per cent in the yen implies an expected appreciation over the next three months of 0.1 per cent. These results are similar to those obtained by Frankel and Froot (1987b).[8]

Finally, we considered expectations models which incorporate agents' views regarding long-run fundamentals. In the Dornbusch (1976) overshooting model, a monetary shock induces the exchange rate to jump and subsequently mean-revert to its long-run PPP value. Mussa (1984) has extended this model to allow for a time-varying long-run equilibrium value of the exchange rate that is consistent with desired steady-state asset holdings. Thus a distinction is drawn between the response of nominal and real exchange rates to 'equilibrium' and 'disequilibrium' disturbances. He shows that expected exchange rate changes are a function of changes in the long-run equilibrium value of the exchange rate and of the parameters which define differing speeds of adjustment in the goods market and asset markets. Frankel and Froot (1987a) fitted models of expected exchange rate changes using different proxies for the long value of the exchange rate. An alternative approach is to assume that the 12-month ahead expectation serves as a relatively good proxy for the long-run value of the exchange rate. Thus, we fitted the following model for the three-month ahead expected exchange rate:[9]

$$\langle 11 \rangle \qquad E_t S_{t+3} - S_t = \alpha + \beta(E_t S_{t+12} - E_{t-1} S_{t+11}) + e_t.$$

Equation $\langle 11 \rangle$ estimates the extent to which revisions in long-run fundamentals are reflected in short-term expectations. The results of fitting $\langle 11 \rangle$ to our survey data are reported in Table 6. The coefficient estimates are all significant at the 1 per cent level.

We note that for EMS exchange rates relative to the Deutschmark, we now obtain positive coefficients. This suggests that EMS exchange rate expectations 'undershoot' their long-run values. If long-run EMS exchange rates (proxied by 12-month ahead exchange rate forecasts) decline, then exchange rates are expected to depreciate over the 'short term' (the next three months) by a smaller amount. On the other hand, non-EMS currencies relative to the US dollar and relative to the Deutschmark generally behave differently, as reflected in the negative slope coefficients; a positive innovation in long-run fundamentals is associated with a negative change in short-run (three-month) expectations, suggesting subsequent 'overshooting'.[10]

IV. Conclusions

This paper has extended the analyses of Frankel and Froot (1987a), Dominguez (1986), and MacDonald and Torrance (1990) to consider a new data set of exchange rate expectations which allows us to focus on differences between EMS and dollar exchange rate expectations. We corroborate the finding that exchange rate forecasts are not rational and that agents do not use all available information in an efficient manner; this finding applies to the post-1986 period, thus questioning the assertion of Frankel and Froot (1987a) that 'the nature of the

rejection of rational expectations strongly depends on the sample period.' Although extrapolative and adaptive expectations formation mechanisms describe non-EMS exchange rate expectations to a certain extent, EMS exchange rate forecasts seem to follow their long-run fundamentals more closely and would suggest that agents believe that EMS currencies 'undershoot' their long-run equilibrium values.

In the current paper, we have focused our attention on characterizing the formation of expectations at various forecast horizons for a set of exchange rates. Our analysis is extended in a companion paper[11] which examines the consistency of expectations models across the different forecast horizons and where we use forward rates to impute exchange rate risk premia to assess whether the rejection of the forward rate as an unbiased predictor of the spot rate is predominantly attributable to irrationality (as evidenced in this paper) or significant variation in risk premia.

Notes

1. Although the notation used in Sections II and III will be presented as if the survey was constructed on December 31 (in the example at hand), care has been exercised throughout the empirical analysis to ensure that conditional expectations are computed on the proper information set.
2. In Table 1b, one may note that the standard deviation of the mean expected depreciation declines with the forecast horizon. The data analyzed by Frankel and Froot (1987a) exhibit somewhat different properties; the standard deviations of the mean expected depreciation rises for the six-month forecast horizon and then declines for the 12-month forecast horizon, relative to the three-month forecasts.
3. The equation is fitted in first difference form following Meese and Singleton (1982).
4. As is suggested in Section I, the surveys are collected at month end; survey forecast dates and matching exchange rate expectations and survey data are reported in the *Business International* publication. Using the notation in Section II, $E_t S_{t+k}$ represents the k-period-ahead forecast starting from the first day of the following month. The realized spot rate, S_{t+k}, is the average of the bid and ask quotes reported by Datastream. When k-period-ahead forecasts fall on a weekend or holiday, the next business day is chosen.
5. The orthogonality of forecast errors with lagged forecast errors was also examined. These results have not been reported, but are available from the authors on request. It should be noted that if one combines the results of this test with those reported in Tables 3a, 3b, and 3c, then one can reject the orthogonality hypothesis for exchange rates relative to the Deutschmark in 70 per cent of the cases.
6. In this section, where the expected depreciation is on the left-hand side of the regressions, forecast horizons longer than the observational frequency do not themselves imply that the error term is serially correlated, since expectations are formed using only contemporaneous and past information. Therefore, equations ⟨8⟩ and ⟨10⟩ were estimated using the standard OLS procedure.
7. The comparison in the text refers to results obtained for survey expectations of the same horizon. It should be noted that for short horizon expectations (one week and one month) Frankel and Froot (1987b and 1990) and MacDonald and Torrance (1988) obtain parameter estimates suggesting destabilizing expectations models.
8. Frankel and Froot (1987b) and MacDonald and Torrance (1988) obtain for short-term expectations (one week and one month ahead) a regression coefficient that is opposite in sign to that of long-term expectations (three, six, and 12 months ahead).
9. Because ordinary least squares estimates would be inconsistent in the context of equation ⟨11⟩, we implemented the instrumental variables estimation technique outlined in Hansen (1982). Instruments used were a constant term and lagged exchange rate returns.
10. We investigate whether changes in exchange rate *expectations* (not actual levels) overshoot their long-run values in the short term. Our concept of overshooting is linked to work by

Mussa (1984), who shows that expected exchange rate changes are a function of changes in the long-run equilibrium value of the exchange rate.

11. See Cavaglia *et al.* (1991).

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