Behavioral Biases in Forward Rates as Forecasts of Future Exchange Rates: Evidence of Systematic Pessimism and Under-Reaction

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Even though the forward-spot relationship in currency markets is very important for policy makers and for corporate and investment managers, it remains a theoretical and empirical puzzle. In theory the forward rate should be an unbiased forecast of the future spot rate, but this hypothesis has little empirical support. For the currencies of the nine major industrialized countries, this paper documents that in spite of the very high trading volumes in currency markets, consistent with evidence for other asset markets, revisions in the forward rate forecasts of the future spot exchange rate reflect systematic pessimism and under-reaction to new information (JEL: F31, G14, F47, G15).

Keywords: exchange rates, forward bias, market rationality, under-reaction

I. Introduction

The relation between forward and spot rates in foreign exchange markets remains very interesting, not only to policy makers but also to corporate and investment managers. Many investment, hedging, and macroeconomic decisions are influenced and determined by the nature of this relationship (the effectiveness of the forward rate as a forecast of the future spot rate). However, the currency market forward-spot

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relation remains an empirical and theoretical puzzle.

According to the theoretically elegant and widely assumed "Rational Expectations" paradigm, markets use all available information efficiently in forming expectations and such expectations are rational and unbiased so that forecast errors are uncorrelated and have zero mean. Among the empirical results that seem to contradict this theoretically elegant hypothesis, is evidence from the most liquid of all markets, the foreign exchange markets, where forward rates (and survey forecasts) have been documented to be consistently biased forecasts of future spot rates, as changes in the future spot rates are generally negatively related to the forward discount. Forward rate forecasts of future spot rates clearly violate the rational expectations hypothesis (Chernenko et al. [2004]). So far, risk premia or other foreign exchange models are unable to explain this bias and non-rationality (e.g., the survey by Engel [1996]).

The wide range of models of risk premia in the foreign exchange market that have been tested unsuccessfully include the capital asset pricing model, models of changing second moments (Hansen and Hodrick [1983], Cumby [1988]), consumption based asset pricing models including models to account for non-additive preferences (Backus et al. [1993], Bansal et al. [1995]), deviations from expected utility (Bekaert et al. [1997]), and trade frictions (Hollifield and Uppal [1997]). While other literature on this topic has explored the role of peso problems, learning, and irrational expectations (Lewis [1995], Frankel and Rose [1994]). Even though this research is occasionally promising, it has also not resulted in any significant changes in the overall conclusions of significant non-rationality in forward currency markets noted above (Aggarwal [2004]).

A recent body of research on equity markets has documented systematic over-reaction at long horizons and under-reaction at short horizons (Jackson and Johnson [2006], Poteshman [2001], Daniel et al. [1998]). Others have noted systematic pessimism or optimism in market responses to new information (Ball and Croushore [2001]). These systematic behavioral patterns are also supported by studies of the forecast revisions of financial analysts responding to updated accounting information (Karamanou and Raedy [2000]) and of economic forecasters with macroeconomic data (Ghosh [1997]). Such deviations from rationality and efficiency also seem to reflect well-documented behavioral patterns among investors (Barberis et al. [1998], Hirshleifer [2001]). These systematic non-rational behavioral patterns may persist due to limited arbitrage (e.g., Shleifer and Vishny

[1997]). Even though trading volumes in currency markets are much higher, systematic deviations from rationality have also been documented in these markets (Lewis, [1989]). Are foreign exchange markets characterized by the behavioral biases seen in equity markets?

This paper examines the ability of currency forward rates to forecast future spot rate changes and to revise such forecasts with the availability of updated information. In particular, this paper examines if revisions in the forward rate forecasts of future spot currency rates reflect systematic over- or under-reaction and if they are systematically pessimistic or optimistic? We find that the nine major currencies examined share similar patterns in the forecast revision processes and we document significant systematic under-reaction to new information and consistent pessimism in forecast revisions.

Next we review the literature on biases in forward rates, on investor belief revisions, and on the common methodologies for testing forward rates as unbiased predictors of future spot rates. Following that we describe the data and methodology used in this paper, present the empirical results, and the final section concludes.

II. Rationality and Efficiency in Asset Markets

Previous tests of rationality of forward expectations mostly focus on the one-period ahead forecasts. In this paper we note that investors and markets continually revise their expectations with new information. However, as the burgeoning literature on over- and under-reaction in equity markets notes, such revisions may be influenced by behavioral patterns that allow prices to deviate from market rationality and efficiency (Abel [2002], Barberis et al. [1998]). As this literature notes, costly and asymmetric information and limitations in arbitrage can lead to systematic deviations from rational expectations and to biased forecasts. Fortunately, recent literature on asset price behavior has started to explain how the intersection of psychology and decision science can illuminate systematic behavioral patterns observed in asset markets.

A. Theoretical Bases for Behavioral Biases

Market participants generally have limited ability to assess and process information and reflect many behavioral biases including overconfidence (e.g., Daniel and Titman, [1999]). Overconfidence among market participants has two effects, i.e., investor's overweight

prior beliefs and underweight new information (Barberis et al. [1998]). Recent work by Cecchetti et al. (2000) develops a model that explains why investors may be systematically pessimistic as they violate rational expectations by being unusually risk averse. Barberis et al. (1998) develop a theoretical model that explains short horizon under-reaction and long horizon over-reaction based on investors being subject to conservatism and representativeness - two well-known cognitive biases. With conservatism, an investor sticks to prior beliefs more strongly that is warranted while with representativeness investors finds patterns in data too readily. The interaction of these two behavioral biases makes investors under-react to information that is preceded by an inadequate quantity of similar information and investors over-react to information preceded by large amounts of similar information.

B. Empirical Evidence of Behavioral Biases in Asset Markets

The empirical literature documents these theoretical predictions of systematic deviations from rational expectations. Aggarwal, Mohanty, and Song (1995) document systematic deviations from rationality for professional forecasts of a number of major macroeconomic series. Similar results are found for revisions among economic forecasters (Ghosh [1997]). Ashiya and Doi (2001) show extensive herding among Japanese institutional forecasters. Others have noted systematic pessimism in market responses to new information in forecasts of inflation (Ball and Croushore [2001]). Karamanou and Raedy (2000), and Amir and Ganzach (1998) show that security analysts under- react to new information and Jackson and Johnson (2006) show a generalized pattern of under-reaction in equity markets.

A recent body of equity markets literature has started to explore systematically the reasons for such deviations from rationality and efficiency. This literature has noted that financial markets are not frictionless (e.g., transactions and information costs) and face limits on the nature and extent of arbitrage (e.g., Schleifer and Vishny [1997]). For example, arbitrage requires capital and is usually risky. Because of the skill and connections required, arbitrage may be limited by agency problems between specialized skilled arbitrageurs and other investors. In addition to limited arbitrage, market prices may deviate from rational efficient levels due to positive feedback trading as informed investors try to take advantage of the uninformed (De Long et al. [1990]). Indeed, investors and mutual fund managers have been shown to engage in herding behavior (e.g., Wermers [1999], Nofsinger and Sias [1999]).

In addition to institutional factors, there are systematic behavioral biases that contribute to deviations from rational efficient markets. These systematic deviations from rationality and efficiency seem to reflect well-documented behavioral patterns among investors and other economic agents (Barberis et al. [1998], Hirshleifer [2001]). Shiller (2002) assesses and summarizes much of this literature on the behavioral biases in investor decisions.

Several recent papers (Lakonishok et al. [1994], La Porta [1996]) that study stock market price behavior contend that investors irrationally extrapolate recent prices and thus make wrong forecasts. For example, investors observe abnormal price movement and erroneously project that the trend is to continue. Abel (2002) shows that systematic pessimism and doubt are consistent with observed equity market behavior. There is evidence among investors that they are prone to pessimism and over-reaction at long horizons and under-reaction at short horizons (Poteshman [2001], Daniel et al. [1998]). These systematic deviations from rationality and efficiency seem to reflect well-documented behavioral patterns among investors and other economic agents (Barberis et al. [1998], Hirshleifer [2001]).

C. Evidence of Behavioral Biases in Currency Markets

Even though trading volumes in currency markets are much higher than in equity markets, deviations from rationality have been documented in these markets as well (DeGrauwe et al. [2005]; Frankel and Froot [1986]; Levich [1979]; Ashiya [2002]; Villanueva [2005]). Lewis (1989) suggests that such deviations from rationality may be due to a combination of Bayesian learning and risk premia. More specifically, Bekaert and Hodrick (2001) summarize three potential reasons for the rejection of forward rate as an unbiased future spot rate. The first is that the expectation hypothesis (*EH*) is based on the assumption of rational expectations and unlimited arbitrage. The second is the presence of time-varying risk premiums. The third is that the tests themselves may lead to false rejections because of poor properties in finite samples. So, forward rates may not be rational forecasts of future spot rates and it may be difficult to assess sources of such bias.

Nevertheless, like other asset markets, currency markets may also be subject to speculative excesses. Frankel and Froot (1990) contend that the mid 1980s over-valuation of the U.S. dollar is an example of a speculative bubble. DeGrauwe et al. (2005) suggest that bias in forward exchange rates may result from behavioral bubbles that arise when

investors use trading rules that have been profitable in prior periods. Another factor contributing to deviations from rationality in currency markets is intervention by central banks, a powerful well informed group of market participants whose goals may deviate greatly from economic profit maximization (e.g., Bonser-Neal [1996], Humpage [1987]). Bacchetta and Wincoop (2005) develop a model based on costly information and rational inattention in another theoretical attempt to explain forward exchange rate biases. However, in spite of these recent models that try to explain forward exchange rate biases, there is little empirical literature on behavioral biases in currency markets and there does not seem to be any empirical literature on optimism and pessimism in foreign exchange forward markets.

As this brief literature review indicates, it has been widely documented that forward rates reflect systematic biases as forecasts of future spot rates. However, the sources of this bias are still unclear. In this paper we not only test the rationality of the forward rate as a forecast of the future spot rate, but we also examine how new information is incorporated in changes in the forward rate as the forecast period shortens and new information becomes available. We test if the resulting revisions in the forward rate forecast of the future spot rate are characterized by systematic behavioral biases of under/over reaction and optimism and pessimism.

Specifically, in this paper, we investigate the nature of the revision process reflected in how the forward exchange rate changes as a forecast of a future spot rate (as reflected in the differences between six month and three month forward rates as forecasts of the same future spot rate). We examine if the biases and deviations from rationality and efficiency noted in studies of other asset markets also hold for the much more liquid foreign exchange market. In investigating revisions in forward rates as forecasts of future spot rates, we separate the effects of systematic optimism/pessimism from the effects of under/over- reaction to new information.

III. Research Design and Data

A. Biased Forward Exchange Rates and Forecast Revisions

Forward Rates as Unbiased Predictors of Future Spot Rates

Engel (1996) provides a comprehensive review of the literature on spot and forward exchange rate relationships. As Engel (1996) notes, with

the assumption of rationality and risk neutrality, the forward exchange rate unbiasness is expressed as:

$$E_t [S_{t+1}] = F_t, \tag{1}$$

which states the expected spot rate at t+1 conditional on the information available at time t should be the same as the forward rate at time t. The hypothesis is usually expressed as the levels relationship:

$$S_{t+1} = f_t + \zeta_{t+1}, \tag{1a}$$

where ζ_{t+1} is a random variable (rational expectations forecast error) with $E_t[\zeta_{t+1}] = 0$.

Two different regression equations have generally been used to test the hypothesis of unbiasness of forward exchange rates. The first one is the "levels regression":

$$S_{t+1} = \mu + \beta_f f_t + \mu_{t+1}, \tag{2}$$

where the null hypothesis requires that $\mu = 0$, $\beta_f = 1$ and $E_t[\mu_{t+1}] = 0$. Studies using equation (2) have found varying estimates of β_f, some but not all of them close to 1 and, thus, there is mixed support for the unbiasness of forward rates. In testing the orthogonality condition $E_t[\mu_{t+1}] = 0$, not rejecting the hypothesis is a test of forward market efficiency under- rational expectations and risk neutrality. Empirical evidence shows that S_t and f_t have unit roots, and the hypothesis of unbiasness requires that S_{t+1} and f_t be cointegrated with vector (1, –1) and that the stationary, cointegrating residual μ_{t+1} satisfy $E_t[\mu_{t+1}] = 0$. The second regression equation used to test this hypothesis is the "differences equation":

$$\Delta S_{t+1} = \mu^* + \alpha_s(f_t - S_t) + \mu^*_{t+1}, \tag{3}$$

where the null hypothesis requires that $\mu^* = 0$, $\alpha_s = 1$, and $E_t[\mu^*_{t+1}] = 0$. Empirical results based on the differences equation strongly reject the hypothesis of unbiased forward exchange rate forecast. The typical estimates of α_s across a wide range of currencies and sampling frequencies are significantly negative. This result is often referred to as the forward discount anomaly, or forward discount puzzle.

Zivot (2000) argues that the hypothesis of unbiased forward exchange rates requires not only that S_{t+1} and f_t be cointegrated and that the cointegrating vector be (1,–1), but also that S_t and f_t be cointegrated

and the cointegrating vector be (1,–1). Zivot (2000) investigates the relationship between the two models of cointegration and argues that the simple model of cointegration between S_t and f_t captures the stylized facts of typical exchange rate data better than the simple model of cointegration between S_{t+1} and f_t and so serves as a natural starting point for the analysis of exchange rate behavior. This conclusion implies that standard VAR methods are not appropriate for modeling the cointegrating vector of (S_{t+1}, f_t), and the use of such methods can lead to erroneous inferences regarding the unbiasness hypothesis regarding the forward rate as a forecast of the future spot rate. Zivot (2000) confirms the contention in Baillie (1989), who points out VAR is misspecified considering the cointegration of spot rate and forward rate, and an error correction term needs to be added.

Test for Rationality of Forward Rates as Spot Rate Forecasts

MacDonald and Taylor (1992) review the literature on exchange rate determination and tests of the rationality of forward expectations. Expectations have been measured directly based on surveys (Cavaglia et al. [1994]) or indirectly based on an asset pricing model. Generally the traditional orthogonality test for rationality is tested in the regression:

$$S_{t+k} - E_t[S_{t+k}] = \alpha_1 + \beta_1 ({}_tF_{t+k} - S_t) + v_{t+k}, \tag{4}$$

where the left-hand side is the exchange rate forecast error. The null hypothesis of rational expectations implies that $\alpha_1 = 0$ and $\beta_1 = 0$. In Cavaglia et al. (1994), the orthogonality regression was fitted via *OLS* for each currency and for each forecast horizon, standard errors are corrected to allow for a k–1 order moving average. The findings reject the forward exchange rate as an unbiased predictor of the future spot rate, and the bias in the forward rate is attributed to both irrational expectations and a risk premium. Froot and Frankel (1989) analyze survey data on exchange rate expectations and show that not all the biases in the forward discount are due to time varying risk premia and at least some bias may be attributable to systematic expectational errors in that changes in the forward discount reflect changes in expected depreciation with the market risk premium constant.

In this paper we not only test the rationality of the forward rate as a forecast of the future spot rate, but we also examine how new information is incorporated in changes in the forward rate as the forecast period shortens and new information becomes available. We

test if these revisions in the forward rate forecast of the future spot rate are characterized by systematic behavioral biases of under/over-reaction and optimism and pessimism.

B. Rationality, Under- or Over-Reaction and Pessimism vs. Optimism

Assume at time t–1, market participants form the forecast of the future spot rate at times t and t+1, which are the forward rates ${}_{t-1}F_t$ and ${}_{t-1}F_{t+1}$ respectively. At time t, market participants learn that their prior expectation (formed at t–1) is not accurate and they use the forecast error as part of the new information to revise their forecast for t+1. Market participants revise their forecast of the future spot rate for time t+1 (originally formed at time t–1, and reflected in the forward rate ${}_{t-1}F_{t+1}$), and now form a new expectation for the spot rate at t+1, the forward rate ${}_tF_{t+1}$. This paper focuses on the relationship between the forecast revision, ${}_tF_{t+1}-{}_{t-1}F_{t+1}$ and the forecast error, ${}_tF_{t+1}-S_{t+1}$. Before investigating the belief revision process, in this paper we check the stationarity of each time series.

Consider two behavioral factors that influence a forecast and revisions to such forecasts with the arrival of new information: optimism versus pessimism and over-reaction versus under- reaction. Forecasters are optimistic when their forecast errors tend to be positive and are pessimistic when the errors are negative. If forecasters over-react to new information, then their forecast revisions are positive and their errors are negative or when their revisions are negative and their errors are positive. In other words, forecasters overreact when their revisions and errors are of the opposite signs. Similarly, they under-react when their revisions and errors are of the same sign. In order to distinguish between the effects of optimism/pessimism from the effects of over/under reaction more formally, forecast errors are regressed on forecast revisions. Assume forecast error for time t is $FE_t = {}_tF_{t+1}-S_{t+1}$, and the forecast revision for time t is $FR_t = {}_{t-1}F_{t+1} - {}_tF_{t+1}$, the regression is:

$$FE_t = \alpha + \beta FR_t + \mu_t. \tag{5}$$

The null hypothesis of rationality is $\alpha = \beta = 0$. Positive α implies optimism, while negative α implies pessimism. Positive β implies over-reaction and negative β implies under- reaction to new information. A finding of negative beta would be consistent with the widely replicated and accepted bias of conservatism (Shiller [2002]). Tables 1a

and 1b report the descriptive statistics for *FE* and *FR* for each currency. While the mean forecast errors are almost uniformly negative, there do not seem to be any major surprises in these tables.

Impact of Prior Period Changes

Under- or Over-reaction: In order to assess systematic over- or under-reaction to information in forward rates as forecasts of future spot rates, we first examine whether the prior period spot rate change would have any effect on the forecast error and we run the following regression for each currency:[1]

$$FE_t = \alpha_0 + \alpha_1 PSCH_{t-1} + e_t, \tag{6}$$

where FE_t is the time t forecast error, and $PSCH_t$ is the prior spot rate change $(S_{t-1}–S_{t-2})$.[2] The estimated slope for regression (6) should indicate if the forward rate forecasts are under- (positive coefficient) or over-reactions (negative coefficient) to prior changes in the spot rate.

Systematic pessimism versus optimism: The results from the above regressions, however, do not allow us to separate under- or over-reaction from optimism or pessimism in the foreign exchange markets. For example, a positive coefficient can result from under-reaction to new information or from systematically optimistic forecasts. In order to differentiate between these effects (under- or over-reaction versus optimism or pessimism), we group our observations into high, low, and medium changes of how prior changes impact forecasted changes in exchange rates:

$$\begin{aligned} PredCh = {} & \alpha_0 + \alpha_1 LoPSCH_{t-1} + \alpha_2 HiPSCH_{t-1} \\ & + \alpha_3 PSCH_{t-1} + \alpha_4 DLPSCH_{t-1} + \alpha_5 DHPSCH_{t-1} + e_t, \end{aligned} \tag{7}$$

1. We follow Easterwood and Nutt (1999) in attempting to examine whether forward foreign exchange markets are systematic optimistic or systematic pessimistic.

2. One possible shortcoming of this regression is that the independent variable may contain both the expected and unexpected components of the spot rate change. To single out the effect of the unexpected change in spot rate, one additional regression is used to supplement the above forecast regression. In this additional regression, the independent variable is changed to reflect the unexpected change in the prior spot rates $UPCH_{t-1}$, which is $PSCH_{t-1}$ minus the average change of the prior 3-month spot rates. However, this change does not result in any changes in the conclusions and the results are not reported here but are available from the authors.

where *PredCh* is the predicted change of the future spot rate defined as the ${}_{t-1}F_t - S_{t-1}$, and $PSCH_{t-1}$ is the prior spot rate change ($S_{t-1} - S_{t-2}$). We define two dummy variables, $LoPSCH_{t-1}$ and $HiPSCH_{t-1}$, that equal one if $PSCH_{t-1}$ is in the lower or upper quartile respectively for changes in exchange rates $PSCH_{t-1}$, and 0 otherwise. These two dummy variables are also included as the interactive term between $PSCH_{t-1}$ and $LoPSCH_{t-1}$ and $HiPSCH_{t-1}$ so that $DLPSCH_{t-1}$ equals $PSCH_{t-1}$ times $LoPSCH_{t-1}$, and $DHPSCH_{t-1}$ equals $PSCH_{t-1}$ times $HiPSCH_{t-1}$.

In this regression estimate, α_3 measures the impact for the middle two quartiles while the composite coefficient $\alpha_3+\alpha_4$ represents the impact for the lower quartile and $\alpha_3+\alpha_5$ represents the impact for the upper quartile. If there is systematic pessimism, forecasts should over-react to lower quartile changes (have a negative coefficient) and under-react to upper quartile changes (have a positive coefficient). The opposite signs in this set of coefficients would indicate systematic optimism. Thus, this specification should allow us to assess both the under- or over-reaction effect as well as the pessimism or optimism effects.

Forecast Revisions

In addition to estimating one-period forecasts, we extend our study to include two periods and examine the effect of forecast error on the revision of traders' forecasts. Forecast revision is defined as $FR_t = {}_{t-1}F_t - {}_{t-2}F_t$. We estimate the following regression:

$$FR_t = \beta_0 + \beta_1 LoFE_{t-1} + \beta_2 HiFE_{t-1} + \beta_3 Fe_{t-1} + \beta_4 DLFE_{t-1} + \beta_5 DHFE_{t-1} + e_t, \quad (8)$$

where Fe_{t-1} is the prior period forecast error.[3] Once again, we define two dummy variables, $LoFE_{t-1}$ and $HiFE_{t-1}$ that equal one if Fe_{t-1}

3. It is possible to divide the over-reaction conditions into two further categories. Some cases of over- reaction can be re-classified as mis-reactions. Mis-reaction occurs when, in some cases, the forecast revision is excessive with respect to the two-period forecast error. This can happen when the forecast revision, the second period forecast error, and the two period forecast error are all positive or are all negative. In such cases, the forecast revision is in the wrong direction with respect to the two period forecast error, i.e., the difference between the *t*–2 forward rate for time *t* and the future spot rate for time *t*. As a robustness check, we estimate our main regression excluding the observations reflecting mis-reaction. Though the results are not reported in this paper, our conclusions in this paper hold and are actually strengthened when excluding the mis-reaction observations from our data.

TABLE 1A. Descriptive Statistics for Spot Rates and Forward Rates (1981–1994)

	CAD	GBP	BEF	FRF	DEM	ITL	NGL	CHF	JPY
A. Spot Rates									
Mean	0.797	1.629	0.025	0.160	0.511	0.001	0.456	0.600	0.006
Median	0.808	1.610	0.026	0.167	0.540	0.001	0.478	0.635	0.007
Maximum	0.893	2.409	0.035	0.219	0.713	0.001	0.634	0.807	0.010
Minimum	0.702	1.064	0.015	0.096	0.293	0.000	0.259	0.344	0.004
Std. Dev.	0.049	0.217	0.005	0.026	0.106	0.000	0.094	0.118	0.002
Skewness	–0.148	0.397	–0.456	–0.548	–0.272	0.033	–0.295	–0.262	0.102
Kurtosis	1.779	3.901	2.114	2.508	1.783	2.671	1.841	1.875	1.836
Observations	731	731	731	731	731	731	731	731	731
B. 90-Day Forward Rates									
Mean	0.794	1.620	0.025	0.159	0.513	0.071	0.456	0.603	0.649
Median	0.805	1.598	0.026	0.166	0.543	0.072	0.481	0.641	0.691
Maximum	0.888	2.435	0.034	0.223	0.702	0.107	0.624	0.808	1.043
Minimum	0.696	1.053	0.015	0.096	0.296	0.046	0.260	0.347	0.363
Std. Dev.	0.048	0.217	0.005	0.026	0.103	0.011	0.091	0.115	0.189
Skewness	–0.210	0.505	–0.470	–0.518	–0.310	0.066	–0.334	–0.278	0.115
Kurtosis	1.796	4.237	2.111	2.506	1.811	2.751	1.877	1.940	1.863
Observations	731	731	731	731	731	731	731	731	731

(*Continued*)

TABLE 1A. (Continued)

	CAD	GBP	BEF	FRF	DEM	ITL	NGL	CHF	JPY
C. 180-Day Forward Rates									
Mean	0.791	1.612	0.025	0.158	0.514	0.070	0.457	0.607	0.653
Median	0.803	1.587	0.026	0.165	0.546	0.071	0.483	0.645	0.694
Maximum	0.884	2.455	0.034	0.224	0.691	0.106	0.614	0.810	1.052
Minimum	0.692	1.050	0.015	0.095	0.298	0.046	0.263	0.352	0.366
Std. Dev.	0.047	0.218	0.005	0.026	0.101	0.011	0.089	0.112	0.188
Skewness	–0.261	0.611	–0.485	–0.501	–0.340	0.088	–0.366	–0.289	0.132
Kurtosis	1.811	4.523	2.109	2.494	1.840	2.791	1.914	1.999	1.896
Observations	731	731	731	731	731	731	731	731	731

Note: This table reports the descriptive statistics of the spot rate (Panel A) and the forward rates of 90 days (Panel B) and 180 days (Panel C) of the nine currencies. CAD is Canadian Dollar, GBP is British Pound, BEF is Belgium Franc, FRF is French Franc, DEM is German Mark, ITL is Italian Lira, NGL is Netherlands Guilder, CHF is Switzerland Franc, and JPY is Japanese Yen.

TABLE 1B. Descriptive Statistics for Forecast Errors and Forecast Revisions

		Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Observations
CAD	*FE*	–0.002	–0.003	0.053	–0.044	0.017	0.229	2.850	707
	FR	0.001	0.002	0.047	–0.058	0.017	–0.280	3.077	707
GBP	*FE*	–0.001	–0.003	0.455	–0.295	0.108	0.423	3.912	707
	FR	–0.005	–0.005	0.289	–0.435	0.111	–0.380	3.516	707
BEF	*FE*	0.000	0.000	0.005	–0.004	0.002	0.254	2.936	707
	FR	0.000	0.000	0.004	–0.005	0.002	–0.283	2.836	707
FRF	*FE*	–0.001	–0.002	0.030	–0.025	0.010	0.275	2.855	707
	FR	0.001	0.001	0.024	–0.035	0.010	–0.488	3.242	707
DEM	*FE*	–0.002	–0.001	0.106	–0.091	0.032	0.092	2.928	707
	FR	0.001	0.001	0.087	–0.106	0.032	–0.101	2.802	707
ITL	*FE*	–0.001	–0.001	0.019	–0.011	0.004	0.474	3.807	707
	FR	0.000	0.000	0.010	–0.018	0.005	–0.635	3.727	707
NGL	*FE*	–0.002	–0.002	0.093	–0.077	0.028	0.110	2.880	707
	FR	0.001	0.001	0.074	–0.093	0.029	–0.135	2.770	707
CHF	*FE*	–0.002	–0.001	0.118	–0.116	0.041	–0.028	2.676	707
	FR	0.001	0.000	0.116	–0.120	0.042	0.020	2.630	707
JPY	*FE*	–0.006	–0.003	0.087	–0.124	0.037	–0.243	2.737	707
	FR	0.005	0.002	0.125	–0.091	0.038	0.264	2.695	707

Note: This table reports the descriptive statistics for forecast errors (*FE*) and forecast revisions (*FR*) for each currency, where $FE_t = {}_{t-1}F_t - S_t$, and $FR_t = {}_{t-1}F_t - {}_{t-2}F_t$. CAD is Canadian Dollar, GBP is British Pound, BEF is Belgium Franc, FRF is French Franc, DEM is German Mark, ITL is Italian Lira, NGL is Netherlands Guilder, CHF is Switzerland Franc, and JPY is Japanese Yen.

TABLE 2. Unit Root Tests

	CAD	GBP	BEF	FRF	DEM	ITL	NGL	CHF	JPY
Spot Rate	**–0.818**	**–3.600**	**–2.969**	**–3.211**	**–2.559**	**–2.523**	**–2.641**	**–2.482**	**–2.430**
(First Difference)	–12.892	–11.130	–11.206	–11.490	–11.335	–11.162	–11.259	–11.161	–10.900
S_{13}–S_1	**–5.934**	**–5.815**	**–5.684**	**–5.646**	**–5.855**	**–5.659**	**–5.861**	**–5.857**	**–5.969**
S_{26}–S_1	**–4.115**	**–4.620**	**–4.200**	**–4.248**	**–4.208**	**–4.119**	**–4.240**	**–4.291**	**–4.437**
Forward Rate (90 days)	**–0.979**	**–3.693**	**–3.063**	**–3.412**	**–2.577**	**–2.583**	**–2.660**	**–2.469**	**–2.363**
(First Difference)	–12.988	–11.132	–11.218	–11.294	–11.319	–11.129	–11.258	–11.243	–10.890
FP (90 days)	**–20.792**	**–2.640**	**–3.324**	**–4.737**	**–1.853**	**–3.465**	**–1.603**	**–2.057**	**–1.078**
(First Difference)	–13.976	–12.348	–13.493	–11.543	–10.721	–13.097	–11.032	–10.782	–11.355
Forward Rate (180 days)	**–1.122**	**–3.760**	**–3.115**	**–3.512**	**–3.580**	**–2.643**	**–2.663**	**–2.446**	**–2.278**
(First Difference)	–13.095	–11.119	–11.307	–11.293	–11.300	–11.139	–11.254	–11.232	–10.871
FP (180 days)	**–2.532**	**–2.402**	**–2.619**	**–3.879**	**–1.308**	**–3.096**	**–1.348**	**–1.630**	**–0.587**
(First Difference)	–14.209	–12.424	–12.141	–14.259	–11.126	–13.030	–11.727	–11.095	–11.696
FE	**–5.607**	**–6.031**	**–5.872**	**–5.950**	**–5.958**	**–6.069**	**–5.970**	**–5.744**	**–5.834**
FR	**–5.654**	**–5.609**	**–5.641**	**–5.495**	**–5.830**	**–5.685**	**–5.828**	**–5.723**	**–5.781**

Note: ADF test is applied to all time series used in this paper. CAD is Canadian Dollar, GBP is British Pound, BEF is Belgium Franc, FRF is French Franc, DEM is German Mark, ITL is Italian Lira, NGL is Netherlands Guilder, CHF is Switzerland Franc, and JPY is Japanese Yen. S_{13}–S_1 is the change of spot rate in 90 days; S_{26}-S_1 is the change of spot rate in 180 days. *FP* is forward premium. *FE* is forecast error, and *FR* is forecast revision. The results report here are the statistics with 4 lags, and with both intercept and trend term. The 1% critical value is –3.9754, while the 5% and 10% critical values are–3.4182 and –3.1312 respectively. Wherever the level series (in bold) is not stationary, the same test is applied to the first difference of the level series. The results of unit root tests with trend only and with intercept only are not reported here as they do not change any of the conclusions.

isrespectively in the lower or upper quartile, and 0 otherwise. These two dummy variables are also included as interactive terms between Fe_{t-1} and $LoFE_{t-1}$ and $HiFE_{t-1}$. $DLFE_{t-1}$ equals $PSCH_{t-1}$ times $LoFE_{t-1}$, and $DHFE_{t-1}$ equals Fe_{t-1} times $HiFE_{t-1}$. If the foreign exchange markets under-react to information, the slope coefficients should be positive and negative if over-reaction holds. Finally, if traders are systematically optimistic, then $\beta_3 + \beta_4$ should be positive and $\beta_3 + \beta_5$ should be negative.

C. Data

The data cover the currencies of the ten major industrialized countries, United States, Canada, United Kingdom, Germany, France, Italy, Netherlands, Switzerland, Belgium, and Japan. Weekly spot and 180 and 90-day forward exchange rate data for 1981–1995 for the nine currencies against the U.S. dollar are obtained from the Harries Bank Weekly Review.[4] Table 1a reports the descriptive statistics for the data set. Three weekly closing exchange series are contained in the dataset, which are the spot rate, 90-day forward rate, and the 180-day forward rate.[5] All reported rates are in U.S.D. per foreign currency unit and the descriptive statistics are provided in table 1a. This data set contains 731 observations for each currency covering 14 years (1981–1994).

IV. Empirical Results

A. Preliminary Analysis

Table 2 reports the results of the tests for unit roots in each of the time series including the spot rate, forward rates for 90 and 180 days, forward premium for 90 and 180 days, changes in spot rates for 90 days and 180 days, and also the forecast error and forecast revision. From table 2, we can see that, with the only exception of 90-day forward rate of the French Franc, all spot rates, forward rates, and forward premiums have unit roots in the level series and become stationary for first differences. Similarly, changes in spot rates, forecast errors and forecast revisions are also stationary.

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4. As compiled by Professor Richard M. Levich of N Y U and provided to the authors.

5. The reported spot rate and forward rates in all tables for Italian Lira and Japanese Yen are the original value multiplied by one hundred.

Cointegration tests of the spot and 90-day forward rate, and the spot and 180-day forward rate for each currency are in table 3. Unlike Zivot (2000), we do not find the cointegrating vector [1,–1] for about half the currencies. This finding is not unusual. As summarized in Engel (1996), some studies find that the spot and the forward rate are cointegrated with the cointegrating factor [1,–1], other studies find they are cointegrated but the cointegrating vector is not [1,–1], and still others find they are not cointegrated.

To obtain a preliminary assessment of the relationship between the forecast error and the forecast revision, this paper examines subgroups when observations are grouped according to the signs of the forecast revisions and the signs of the forecast errors. Table 4 presents these results and reports the number of observations in each group and the percentage of each group in the total observations (707) for each currency. The over- and under- reaction columns reflect respectively the sums of the columns with different signs for *FR* and *FE* (*FR*<0 with *FE*>0 and *FR*>0 with *FE*<0) and the same signs for *FR* and *FE* (*FR*<0 with *FE*<0 and *FR*>0 with *FE*>0).

As seen in table 4, the patterns observed for the totals are also reflected in the case of each currency. The totals for positive *FE*s (optimism) are lower (46% versus 54%) and on average these foreign exchange markets exhibit pessimism. The totals for the over- and under-reaction columns (42% versus 58%) seem to suggest that foreign exchange investors and markets tend on average to under- react to new information. Overall, these preliminary results indicate that participants in the foreign exchange markets tend to be somewhat pessimistic and generally under-react to new information.

B. Under- versus Over-Reaction

This section reports table 5, 6 and 7 results of the more formal tests designed to assess over- versus under-reaction in foreign exchange markets. Table 5 reports the results of estimating equation (6). The coefficients of $PSCH_t$ for all currencies are statistically significantly positive. Using the unexpected prior period change in exchange rates as the independent variable gives similar results also with significant positive slope coefficients. The positive slope coefficients in these regressions indicate that the forward rates do not reflect all of the expected changes, that is they under-react to information in prior changes in the spot rate.

TABLE 3. Co-integration between Spot Rate and Forward Rate

		Eigenvalue	Likelihood Ratio	5% Critical Value	1% Critical Value	Hypothesized No. of CE(s)
CAD	S vs. f90	0.030844	23.24911	15.41	20.04	None **
		0.000694	0.504052	3.76	6.65	At most 1
	S vs.f180	0.024754	18.70013	15.41	20.04	None *
		0.000692	0.502440	3.76	6.65	At most 1
GBP	S vs. f90	0.033512	30.35030	15.41	20.04	None **
		0.007688	5.603409	3.76	6.65	At most 1*
	S vs.f180	0.032407	29.51635	15.41	20.04	None **
		0.007683	5.599362	3.76	6.65	At most 1*
BEF	S vs. f90	0.023705	18.69838	15.41	20.04	None *
		0.001693	1.233661	3.76	6.65	At most 1
	S vs.f180	0.016192	13.18614	15.41	20.04	None
		0.001787	1.302079	3.76	6.65	At most 1
FRF	S vs. f90	0.043735	36.18691	15.41	20.04	None **
		0.004975	3.630633	3.76	6.65	At most 1
	S vs.f180	0.028233	24.40814	15.41	20.04	None **
		0.004877	3.558852	3.76	6.65	At most 1
DEM	S vs. f90	0.010478	8.557530	15.41	20.04	None
		0.001221	0.889631	3.76	6.65	At most 1
	S vs.f180	0.007322	6.470196	15.41	20.04	None
		0.001537	1.120135	3.76	6.65	At most 1

(*Continued*)

TABLE 3. (Continued)

		Eigenvalue	Likelihood Ratio	5%Critical Value	1%Critical Value	Hypothesized No. of CE(s)
ITL	S vs. f90	0.033154	32.58888	25.32	30.45	None **
		0.010988	8.043314	12.25	16.26	At most 1
	S vs.f180	0.027320	28.12882	25.32	30.45	None *
		0.010879	7.963481	12.25	16.26	At most 1
NGL	S vs. f90	0.012555	10.68117	15.41	20.04	None
		0.002036	1.483452	3.76	6.65	At most 1
	S vs.f180	0.009035	8.414563	15.41	20.04	None
		0.002479	1.807200	3.76	6.65	At most 1
CHF	S vs. f90	0.008969	9.375983	15.41	20.04	None
		0.003897	2.834758	3.76	6.65	At most 1
	S vs.f180	0.007875	9.431598	15.41	20.04	None
		0.005072	3.691414	3.76	6.65	At most 1
JPY	S vs. f90	0.013154	12.92129	15.41	20.04	None
		0.004498	3.281708	3.76	6.65	At most 1
	S vs.f180	0.013836	14.17339	15.41	20.04	None
		0.005521	4.030340	3.76	6.65	At most 1 *

Note: Johansen co-integration test is applied to each currency between the spot rate and the 90-day forward rate, and between the spot rate and the 180-day forward rate. * (**) denotes rejection of the hypothesis at 5% (1%) significance level. L.R. test indicates 1 cointegrating equation (CE) at 5% significance level. CAD is Canadian Dollar, GBP is British Pound, BEF is Belgium Franc, FRF is French Franc, DEM is German Mark, ITL is Italian Lira, NGL is Netherlands Guilder, CHF is Switzerland Franc, and JPY is Japanese Yen.

TABLE 4. Forecast Revision and Over/Under-Reaction in Forward Rate Forecasts

	Optimism ($FE > 0$)			Pessimism ($FE < 0$)					
	$FR < 0$	$FR > 0$	Subtotal	$FR < 0$	$FR > 0$	Subtotal	Over-reaction	Under-reaction	Total
CAD	**166**	**143**	**309**	**150**	**248**	**398**	**293**	**414**	**707**
	23	20	44	21	35	56	41	59	
GBP	**204**	**146**	**350**	**157**	**200**	**357**	**303**	**404**	**707**
	29	21	50	22	28	50	43	57	
BEF	**179**	**136**	**315**	**151**	**241**	**392**	**287**	**420**	**707**
	25	19	45	21	34	55	41	59	
FRF	**170**	**139**	**309**	**157**	**241**	**398**	**296**	**411**	**707**
	24	20	44	22	34	56	42	59	
DEM	**183**	**149**	**332**	**160**	**215**	**375**	**309**	**398**	**707**
	26	21	47	23	30	53	44	56	

(*Continued*)

TABLE 4. (Continued)

	Optimism ($FE > 0$)			Pessimism ($FE < 0$)					
	$FR < 0$	$FR > 0$	Subtotal	$FR < 0$	$FR > 0$	Subtotal	Over-reaction	Under-reaction	Total
ITL	**169**	**145**	**314**	**150**	**243**	**393**	**295**	**412**	**707**
	24	21	44	21	34	56	42	58	
NGL	**191**	**144**	**335**	**153**	**219**	**372**	**297**	**410**	**707**
	27	20	47	22	31	53	42	58	
CHF	**207**	**142**	**349**	**149**	**209**	**358**	**291**	**416**	**707**
	29	20	49	21	30	51	41	59	
JPY	**185**	**153**	**338**	**159**	**210**	**369**	**312**	**395**	**707**
	26	22	48	22	30	52	44	56	
Total	**1654**	**1297**	**2951**	**1386**	**2026**	**3412**	**2683**	**3680**	**6363**
	26	20	46	22	32	54	42	58	

Note: This table reports the forecast revisions and errors for each currency. The numbers of observations are in bold letters and the percentage of each part of the total number of observations for each currency is below. Overreaction is the sum of the observations with different signs of *FR* and *FE* (*FR* < 0 with *FE* > 0, and *FR*>0 with *FE* < 0), while under reaction is the sum of observations with the same sign of *FR* and *FE* (*FR* > 0 with *FE* > 0, and *FR* < 0 with *FE* < 0). CAD is Canadian Dollar, GBP is British Pound, BEF is Belgium Franc, FRF is French Franc, DEM is German Mark, ITL is Italian Lira, NGL is Netherlands Guilder, CHF is Switzerland Franc, and JPY is Japanese Yen.

TABLE 5. Prior Spot Rate Change as Determinants of the Forecast Error

	FE and *PSCH* Equation			*FE* and *UPCH* Equation		
Country	intercept	*PSCH*	R^2	intercept	*UPCH*	R^2
Canada	–0.0032	0.9425	0.6624	–0.0034	0.9659	0.6038
	–9.06**	37.05**		–8.368**	32.65**	
U.K.	–0.0110	1.0542	0.7465	–0.0118	1.1026	0.6939
	–5.23**	45.38**		–5.10**	39.82**	
Belgium	–0.0001	1.0803	0.7464	–0.0001	0.0302	0.6941
	–2.37*	45.37**		–2.16*	39.84**	
France	–0.0010	1.0699	0.7285	–0.0010	0.0061	0.6748
	–4.79**	43.32**		–4.50**	38.10**	
Germany	0.0013	1.0505	0.7278	0.0014	1.0948	0.6743
	1.93	43.24**		1.95	38.05**	

(*Continued*)

TABLE 5. (Continued)

Country	*FE* and *PSCH* Equation intercept	*PSCH*	R^2	*FE* and *UPCH* Equation intercept	*UPCH*	R^2
Italy	–0.0000	1.1149	0.7491	–0.0000	1.1688	0.6969
	–9.03**	45.70**		–8.58**	40.10**	
Netherlands	0.0009	1.0553	0.7357	0.0010	1.1020	0.6829
	1.51	44.12**		1.55	38.81**	
Switzerland	0.0030	1.0416	0.7333	0.0032	1.0864	0.6804
	3.59**	43.85**		3.50**	38.59**	
Japan	0.0000	1.0184	0.7266	0.0000	1.0611	0.6738
	6.58**	43.12**		6.62**	38.01**	

Note: This table reports regression results for the current forecast error as a function of the prior spot rate change, $FE_t = \alpha_0 + \alpha_1 PSCH_{t-1} + e_t$ where FE_t is the time t forecast error and $PSCH_t$ is the prior spot rate change ($S_{t-1} - S_{t-2}$). The second regression is $FE_t = \alpha_0 + \alpha_1 USCH_{t-1} + e_t$. $USCH_{t-1}$ is $PSCH_{t-1}$ minus the average change of the prior 3-month spot rate. Coefficients of independent variables are reported with t-statistics in the line below. ** indicates the significant level at 1% and * indicates the significant level at 5%.

TABLE 6. Determinants of the Predicted Change in Exchange Rates

Country	intercept α_0	*LoPSCH* α_1	*HiPSCH* α_2	*PSCH* α_3	*DLPSCH* α_4	*DHPSCH* α_5	R^2
Canada	0.0023	–0.0012	0.0007	0.0550	–0.1160	–0.0541	0.0476
	23.56**	–3.26**	1.85	2.30*	–4.01**	–1.70	
U.K.	0.0067	–0.0033	0.0051	0.0413	–0.0404	–0.0467	0.12
	15.32**	–2.48*	2.75**	3.29**	–2.61**	–2.25*	
Belgium	0.0001	–0.0000	–0.0001	0.0094	–0.0303	0.0840	0.0198
	10.96**	–1.93	–1.83	0.86	–2.09*	1.81	
France	0.0008	–0.0002	–0.0002	–0.0078	–0.0159	0.0478	0.0109
	17.15**	–1.51	–0.98	–0.60	–0.88	1.9	
Germany	–0.0011	–0.0017	–0.0010	0.0488	–0.1216	0.0074	0.0686
	–6.77**	–3.15**	–1.26	3.30**	–5.98**	0.29	

(*Continued*)

TABLE 6. (Continued)

Country	intercept α_0	*LoPSCH* α_1	*HiPSCH* α_2	*PSCH* α_3	*DLPSCH* α_4	*DHPSCH* α_5	R^2
Italy	0.0000	–0.0000	–0.0000	–0.0052	–0.0251	0.0835	0.0673
	29.76**	–0.10	–1.93	–0.41	–1.55	3.50**	
Netherlands	–0.0008	–0.0016	–0.0006	0.0517	–0.1169	–0.0003	0.0748
	–5.51**	–3.59**	–0.95	3.73**	–6.13**	–0.01	
Switzerland	–0.0027	–0.0026	0.0012	0.0926	–0.1775	–0.0802	0.1441
	–15.40**	–4.33**	1.51	7.31**	–9.70**	–4.03**	
Japan	–0.0000	–0.0000	0.0000	0.0096	–0.0373	0.0000	0.0579
	–17.15**	–3.68**	0	2.32*	–2.37*	0	

Note: This table reports the regression results of equation (7) where the predicted change of exchange rate *PredCh* is the dependent variable. $PSCH_{t-1}$ is the prior spot rate change (S_{t-1}–S_{t-2}). $LoPSCH_{t-1}$ and $HiPSCH_{t-1}$ equal one if $PSCH_{t-1}$ is in the lower or upper quartile for t–2, and 0 otherwise. Two dummy variables are the interactive term between $PSCH_{t-1}$ and $LoPSCH_{t-1}$ and $HiPSCH_{t-1}$. $DLPSCH_{t-1}$ equals $PSCH_{t-1}$ times $LoPSCH_{t-1}$, and $DHPSCH_{t-1}$ equals $PSCH_{t-1}$ times $HiPSCH_{t-1}$. Results are reported in Panel A. Panel B reports the regression of *PredCh* against $UPCH_{t-1}$, which is $PSCH_{t-1}$ minus the average change of the prior 3-month spot rate. Same dummy variables are also included. Coefficients of independent variables are reported with t-statistics. ** indicates the significant level at 1% and * indicates the significant level at 5%.

TABLE 7. Determinants of the Forecast Revision

Country	intercept α_0	$LoFE_{t-1}$ α_1	$HiFE_{t-1}$ α_2	FE_{t-1} α_3	$DLFE_{t-1}$ α_4	$DH\,FE_{t-1}$ α_5	R^2
Canada	–0.0034	–0.0076	–0.0034	1.306	–0.563	–0.1722	0.477
	–3.05**	–1.97*	–1.25	6.9**	–2.42*	–0.73	
U.K.	–0.0001	0.0305	–282	1.1336	0.2182	–0.1521	0.5401
	–0.02	1.59	–1.14	7.46**	1.2	–0.61	
Belgium	0	–0.0003	0.0017	1.4811	–0.4679	–1.2607	0.5705
	0.92	–1.01	3.74**	11.47**	–2.61**	–5.19**	
France	–0.0002	–0.0012	0.006	1.3859	–0.3028	–0.8428	0.5688
	–0.3	–0.52	2.15*	10.70**	–1.59	–3.27**	
Germany	0.0034	0.0065	0.038	1.351	–0.2078	–1.1704	0.5272
	1.85	1.14	4.03**	10.17**	–1.15	–4.91**	

(*Continued*)

TABLE 7. (Continued)

Country	intercept α_0	$LoFE_{t-1}$ α_1	$HiFE_{t-1}$ α_2	FE_{t-1} α_3	$DLFE_{t-1}$ α_4	$DH\ FE_{t-1}$ α_5	R^2
Italy	0	0	0	1.5449	–0.0189	–1.7659	0.6216
	–0.91	2.50*	4.30**	12.22**	–0.12	–6.89**	
Netherlands	0.0038	0.0001	0.0331	1.2597	–0.2103	–1.0892	0.526
	2.37*	0.03	4.00**	9.40**	–1.14	–4.57**	
Switzerland	0.0079	0.0093	0.0428	1.4331	–0.1661	–1.2372	0.525
	3.33**	1.23	3.87**	10.96**	–0.88	–5.68**	
Japan	0.0001	–0.0002	0.0002	1.0861	–0.7076	–0.3383	0.5141
	4.04**	–2.08*	2.36*	8.55**	–2.86**	–1.76	

Note: This table reports the result of equation (10). The dependent variable is the forecast revision (*FR*). Independent variables include FE_{t-1}, the prior period forecast error, $LoFE_{t-1}$ and $HiFE_{t-1}$, both equal one if C is in the lower or upper quartile, and 0 otherwise, and two dummy variables which are the interactive term between FE_{t-1} and $LoFE_{t-1}$ and $HiFE_{t-1}$. $DLFE_{t-1}$ equals $PSCH_{t-1}$ times $LoFE_{t-1}$, and $DHFE_{t-1}$ equals FE_{t-1} times $HiFE_{t-1}$. Coefficients of independent variables are reported with *t*-statistics in the line below. ** indicates the significant level at 1% and * indicates the significant level at 5%.

TABLE 8. Forecast Error and Forecast Revision Regressions- Pooled Set

	Pooled Dataset	Over-reaction	Under-reaction
Intercept	**–0.002**	**–0.001**	**–0.003**
	–3.443**	–2.049*	–5.108**
FR	**–0.122**	**0.646**	**–0.643**
	–10.02**	42.280**	–56.439**
Adjusted R^2	**0.015**	**0.400**	**0.464**
Observations	**6363**	**2684**	**3679**

Note: This table reports regression results for $FE_t = \alpha + \beta FR_t + \mu_t$ for the pooled dataset. *FE* is forecast error and *FR* is forecast revision. The null hypothesis of rationality requires $\alpha = \beta = 0$. Coefficients (in bold) and *t*-statistics (below them) are reported, as well as the adjusted *R* squares and number of observations (both are in bold). The pooled dataset is further divided into subgroups of over and under reaction. Overreaction is the sum of the observations with different sign of *FR* and *FE* (*FR* < 0 with *FE* > 0, and *FR* > 0 with *FE* < 0); under reaction is the sum of observations with the same sign of *FR* and *FE* (*FR*>0 with *FE* > 0, and *FR* < 0 with *FE* <0).

Table 6 reports the results of the regressions for equation 7 for the impact of prior period changes on predicted exchange rate changes for all nine countries. These regressions evaluate the impact of prior changes in the extreme quartiles as well as for the two middle quartiles. As the results presented in the middle section of this table indicate, for the middle two quartiles, six of the prior change coefficients are significantly positive (the other three are not significant) indicating under-reaction and confirming the results presented in the prior table. In examining the first three columns of results in this table for the lower quartile, except for the U.K., the composite coefficients for the lower quartile are all negative (over-reaction) while the composite coefficients for the upper quartile are mostly positive (under-reaction). This combination of coefficients indicates systematic pessimism in the reaction of the forward rate to new information for seven of the nine exchange rates examined (the signs of the coefficients only for the U.K. pound indicate optimism but they are not significant).[6]

Table 7 reports results for the regressions for equation 8 that examine forecast revisions as reflected in changes in forward rates. As may be expected, last period forecast error seems to have a large and

6. Regressions using the unexpected prior period changes show similar results and are not presented here for brevity but are available from the authors.

significant impact on the forecast revision since all of the coefficients are significantly positive and the R^2s are generally high. Consistent with results in table 3, the coefficient of Fe_{t-1} are all positive for all nine currencies, indicating that the forward exchange rate systematically under-reacts to information.[7]

C. Pessimism versus Optimism

This section, and tables 8 and 9 report on the results of the more formal tests designed to assess pessimism versus optimism in foreign exchange markets. Table 8 reports the result of regressions of the pooled dataset and of the two subgroups, over-reactions and under- reactions. The null hypothesis of rationality requires both intercept and coefficient of *FR* be zero in the regression, while positive α implies optimism, negative α implies pessimism, positive β implies over-reaction, and negative β implies under- reaction to new information. The regression results of pooled dataset indicate that rationality is clearly rejected.[8] We find significant negative coefficients of both the intercept and *FR*, indicating non-rationality, pessimism, and under-reaction to new information.

Table 8 also presents the results for the two subgroups, over-reaction and under-reaction.[9] Both the intercept terms are negative indicating pessimism in each case. As expected, the β coefficient is positive for the over-reaction group and negative for the under-reaction group. As expected, the regression *R*-squares are much higher for the split samples.

Table 9 panel A reports the overall and subgroup (over- and under-reaction) regression results for each currency. The results indicate that under-reaction with pessimism is a consistent pattern for all currencies and rationality is definitely rejected for all these currencies. As expected, for each currency, the coefficients for the over-reaction groups are positive while they are negative for the under-reaction groups. The intercept coefficient for each currency's under-reaction group is negative indicating pessimism uniformly. The intercept

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7. The signs of the coefficients for the lower and upper quartiles do not indicate systematic pessimism or optimism in this case.

8. Since the pooled data set contains data for nine currencies and for 14 years, we may have a problem with time series cross-sectional cross-correlation in error terms, so we also estimate the regressions using the seemingly unrelated regression (*SUR*) procedure to supplement our *OLS* results. The two sets of results are very similar and give similar results.

9. When a dummy for over- and under-reaction is introduced in the pooled regression, it is highly significant and the other coefficients remain significant.

TABLE 9. Relation between Forecast Error and Forecast Revision for Each Currency

Panel A

	All Observations	Over-reaction	Under-reaction	All Observations	Over-reaction	Under-reaction	All Observations	Over-reaction	Under-reaction
	Canadian Dollar			British Pound			Belgium Franc		
Intercept	**–0.002**	**0.000**	**–0.001**	**–0.002**	**–0.005**	**–0.006**	**0.000**	**0.000**	**0.000**
	–2.90**	–0.379	–0.757	–0.467	–1.027	–1.525	–2.79**	0.262	–3.5**
FR	**–0.037**	**0.532**	**–0.700**	**–0.140**	**0.653**	**–0.644**	**–0.119**	**0.603**	**–0.608**
	–0.995	14.02**	–15.9**	–3.86**	13.8**	–19.6**	–3.24**	12.9**	–16.6**
Adjusted R^2	**0.000**	**0.401**	**0.379**	**0.019**	**0.385**	**0.487**	**0.013**	**0.365**	**0.396**
Observations	**707**	**293**	**414**	**707**	**303**	**404**	**707**	**287**	**420**
	French Franc			German Mark			Italian Lira		
Intercept	**–0.001**	**0.000**	**–0.001**	**–0.002**	**0.000**	**–0.004**	**–0.001**	**0.000**	**–0.001**
	–3.25**	–0.818	–3.2**	–1.977*	0.294	–3.07**	–3.20**	–0.637	–4.45**
FR	**–0.111**	**0.595**	**–0.621**	**–0.055**	**0.598**	**–0.607**	**–0.092**	**0.676**	**–0.628**
	–3.11**	14.47**	–16.6**	–1.493	13.53**	–15.6**	–2.546*	15.20**	–19.2**
Adjusted R^2	**0.012**	**0.414**	**0.400**	**0.002**	**0.372**	**0.379**	**0.008**	**0.439**	**0.473**
Observations	**707**	**296**	**411**	**707**	**309**	**398**	**707**	**295**	**412**

(*Continued*)

TABLE 9. (Continued)

	All Observations	Over-reaction	Under-reaction	All Observations	Over-reaction	Under-reaction	All Observations	Over-reaction	Under-reaction
	Netherlands Guilder			Switzerland Franc			Japanese Yen		
Intercept	**–0.002**	**0.000**	**–0.006**	**–0.002**	**–0.004**	**–0.002**	**–0.005**	**–0.003**	**–0.006**
	–2.139*	0.013	–3.9**	–1.072	–2.129*	–1.409	–3.77**	–2.137*	–3.9**
FR	**–0.075**	**0.605**	**–0.671**	**–0.077**	**0.675**	**–0.651**	**–0.103**	**0.658**	**–0.671**
	–2.018*	13.33**	–17.8**	–2.076*	16.17**	–17.3**	–2.78**	17.01**	–17.8**
Adjusted R^2	**0.004**	**0.374**	**0.393**	**0.005**	**0.481**	**0.446**	**0.009**	**0.481**	**0.446**
Observations	**707**	**297**	**410**	**707**	**312**	**395**	**707**	**312**	**395**

Note: This table reports the regression results of $FE_t = \alpha + \beta FR_t + \mu_t$ for each currency. *FE* is forecast error and *FR* is forecast revision for each currency. The null hypothesis of rationality requires $\alpha = \beta = 0$. Coefficients (in bold) and *t*-statistics (below them) are reported, as well as the adjusted *R* squares and number of observations (both are in bold). Each currency is further divided into subgroups of over and under reaction. Overreaction is the sum of the observations with different sign of *FR* and *FE* (*FR* < 0 with *FE* > 0, and *FR*>0 with *FE* < 0); under reaction is the sum of observations with the same sign of *FR* and *FE* (*FR* > 0 with *FE* > 0, and *FR* < 0 with *FE* <0).

TABLE 9B. Estimated Tests of the Economic Significance of Alphas Estimated in Panel A

Panel B
(i) With the Average Forecast Revision for Each Currency

Currency	Avg. *FR*	Est. of Alpha	Est. of Beta	Est. of *FE*	*FE*–0 beta		*FE*–0 alpha	
					FE	Change	*FE*	Change
CAD	0.001	–0.002	–0.037	–0.002037	–0.002	2%	–0.000037	55x
GBP	–0.005	–0.002	–0.14	–0.001300	–0.002	35%	0.000700	3x
BEF	0.002	0.000	–0.119	–0.000238	0.000	100%	–0.000238	none
FRF	0.001	–0.001	–0.111	–0.001111	–0.001	11%	–0.000111	10x
DEM	0.001	–0.002	–0.055	–0.002055	–0.002	3%	–0.000055	37x
ITL	0.000	–0.001	–0.092	–0.001000	–0.001	none	0.000000	n/a
NGL	0.001	–0.002	–0.075	–0.002075	–0.002	4%	–0.000075	28x
CHF	0.001	–0.002	–0.077	–0.002077	–0.002	4%	–0.000077	27x
JPY	0.005	–0.005	–0.103	–0.005515	–0.005	10%	–0.000515	11x

(*Continued*)

TABLE 9B. (Continued)

(ii) With the Same Forecast Revision for Each Currency

Currency	Fixed *FR*	Est. of Alpha	Est. of Beta	Est. of *FE*	*FE*–0 beta		*FE*–0 alpha	
					FE	Change	*FE*	Change
CAD	0.001	–0.002	–0.037	–0.002037	–0.002	2%	–0.000037	55x
GBP	0.001	–0.002	–0.14	–0.002014	–0.002	1%	–0.000014	144x
BEF	0.001	0.000	–0.119	–0.000119	0.000	100%	–0.000119	none
FRF	0.001	–0.001	–0.111	–0.001111	–0.001	11%	–0.000111	10x
DEM	0.001	–0.002	–0.055	–0.002055	–0.002	3%	–0.000055	37x
ITL	0.001	–0.001	–0.092	–0.001092	–0.001	9%	–0.000092	12x
NGL	0.001	–0.002	–0.075	–0.002075	–0.002	4%	–0.000075	28x
CHF	0.001	–0.002	–0.077	–0.002077	–0.002	4%	–0.000077	27x
JPY	0.001	–0.005	–0.103	–0.005103	–0.005	2%	–0.000103	60x

Note: *FE* and *FR* are the mean of forecast error and forecast revision for each currency as reported in Table 1b. Estimates of alpha and beta are from the regression, $FE_t = \alpha + \beta FR_t + \mu$. The estimated *FE* is the *FE* calculated using *FR*, estimates of alpha, and estimates of beta. Simulated *FE* is calculated using *FR* and estimates of beta with alpha equals to zero. The last column reports the change of estimated actual *FE* as compared to the simulated *FE* with assumed alpha of zero.

coefficients for the over- reaction groups differ somewhat with six of them being negative (pessimism) and only three (Dutch Guilder, German Mark, and Belgian Franc) being positive (optimism). Overall, these results indicate general under-reaction and pessimism in revisions.

The results presented in table 9 panel A are economically very important. Table 9 panel B reports estimates of the economic significance of the estimated alpha and beta coefficients for each currency. This panel compares estimates of *FE* based on the equation estimated in panel A with the *FE* based on assuming an alpha of zero and separately assuming a beta of zero. The top part compares these two estimates of *FE* using the average *FR* for that currency while the bottom part of this panel compares the two estimates of *FE* using a standard *FR* that is the same for all currencies. The estimates of beta are economically important as using estimated betas make important differences in estimated *FE*s. However, as the last column indicates, the economic importance of alpha is many times greater. Using the estimated alpha results in an estimated *FE* that is many multiples of the *FE* estimated when assuming an alpha of zero. As the variables involved are all small numbers, as are the estimated alphas, clearly the estimated alphas are both statistically significant and economically important.

V. Conclusions

The relation between spot and forward rates in the currency markets is important for many economic decisions including investing, hedging, and economic policymaking. However, this relationship remains an empirical and theoretical puzzle and there is much debate about the extent to which the forward rate is an unbiased forecast of the future spot rate.

As in recent literature on over- and under-reaction in other asset (equity) markets and in the revision behavior of economic forecasters and financial analysts, this paper assesses pessimism/optimism and under/over-reaction in revisions of forward rates as forecasts of the future spot rate for the currencies of the nine major industrialized countries. It is documented that for forward rates as forecasts of future spot rates, the rationality hypothesis is firmly rejected and revisions in forward rates as forecasts of future spot rates reflect significant systematic pessimism and systematic under- reaction to new information. These results are robust to alternative research methodologies and hold both for the pooled data set and for the nine currencies examined.

In spite of the extraordinarily high trading volumes in currency

markets, these results documenting the non-rational behavior of changes in forward exchange rates are consistent with similar behavioral biases observed in other asset markets. The results presented here have important implications for policy-makers, currency overlay managers, and other investors. For example, the results documented here suggest investment strategies for extraordinary returns as investors who account for the behavioral biases reflected in forward rates can expect to achieve higher risk-adjusted returns.

References

Abel, A. B. 2002. An exploration of the effects of pessimism and doubt on asset returns. *Journal of Economic Dynamics and Control* 26(7–8): 1075–1092.

Aggarwal, R. 2004. Puzzles in international economics and finance: Central Bank of Ireland Edgeworth Lecture. *Economic and Social Review* 35(1): 241–250.

Aggarwal, R.; Mohanty, S.; and Song, F. 1995. Are survey forecasts of macroeconomic variables rational? *Journal of Business* 68 (1): 99–119.

Amir, E., and Ganzach, Y. 1998. Overreaction and under reaction in analyst's forecast. *Journal of Economic Behavior and Organization* 37(3): 333–347.

Ashiya, M., and Doi, T. 2001. Herd behavior of Japanese economists. *Journal of Economic Behavior & Organization* 46(3): 343-346.

Ashiya, M. 2002. Accuracy and rationality of Japanese institutional forecasters. *Japan and the World economy* 14 (2): 203–213.

Bacchetta, P., and Van Wincoop, E. 2005. Rational inattention: A solution to the forward discount puzzle? NBER Working Paper No. 11633, September.

Backus, D. K.; Gregory, A.; and Velmer, C. I. 1993. Accounting for forward rates in markets for foreign currency. *Journal of Finance* 48 (6): 1887–1908.

Baillie, R. T. 1988. Econometric tests of rationality and market efficiency. *Econometrics and Economic Theory*, Michigan State. Papers 8805.

Ball, L., and Croushore, D. 2001. Expectations and the Effects of monetary policy. Federal Reserve Bank of Philadelphia, Working Paper No. 01–12, August.

Bansal, R. A.; Gallant, R.; Hussey, R.; and Tauchen, G. 1995. Non-parametric Estimation of structural models for high frequency currency market data. *Journal of Econometrics* 66(2): 251–287.

Barberis, N.; Schleifer, A.; and Vishny, R. 1998. A model of investor sentiment. *Journal of Financial Economics* 49(3): 307–343.

Bekaert, G.; Hodrick, R.; and Marshall, D. 1997. The implications of first order risk aversion for asset market risk premiums. *Journal of Monetary Economics* 40(1): 3–39.

Bekaert, G., and Hodrick, R. 2001. Expectation hypotheses tests *Journal of*

Finance 56(4): 1357–1394.

Bonser-Neal, C. 1996. Does central bank intervention stabilize foreign exchange rates? *Federal Reserve Bank of Kansas City Economic Review* (No. 1, First Quarter), pp. 43–57.

Cavaglia, S; Verschoor, W. F. C.; and Wolff, C. C. P. 1994. On the biasedness of forward foreign exchange rates: Irrationality or risk premia? *Journal of Business* 67(3): 321–343.

Cecchetti, S. G.; Lam, P.-S.; and Mark, N. C. 2000. Asset pricing with distorted beliefs: Are equity returns too good to be true? *American Economic Review* 90(4): 787–805.

Chernenko, S.; Schwarz, K. B.; and Wright, J. H. 2004. The information content of forward and futures prices: Market expectations and the price of risk. FRB International Finance discussion paper no. 808.

Cumby, R. 1988. Is it Risk? Explaining deviations from uncovered interest rate parity *Journal of Monetary Economics* 22(2): 279–299.

Daniel, K. D.; Hirshleifer, D.; and Subrahmanyam, A. 1998. Investor psychology and security market under- and over-reactions. Journal of Finance 53: 1839–1886.

Daniel, K. D., and Titman, S. 1999. Market efficiency in an irrational world. *Financial Analysts Journal* 55(6): 28–40.

DeGrauwe, P.; Dieci, R.; and Grimaldi, M. 2005. Fundamental and non-fundamental equilibiria in the foreign exchange market: A behavioral finance framework. CESifo Working Paper No. 1431, March.

DeLong, J. Bradford; Shleifer, A.; Summers, L. H.; and Waldmann, R. J. 1990. Positive feedback investment strategies and destabilizing rational speculation. *Journal of Finance* 45(2): 887–908.

Easterwood, J., and Nut, S. 1999. Inefficiency in analysts' earnings forecasts: Systematic misreaction or systematic optimism? *Journal of Finance* 54 (5): 1777–1797.

Engel, C. 1996. The forward discount anomaly and the risk premium: A survey of recent evidence. *Journal of Empirical Finance* 3(3): 123–192.

Frankel, J. A., and Froot, K. A. 1986. Interpreting tests of forward discount bias using survey data on exchange rate expectations. NBER Working Paper No. 1963.

Frankel, J. A., and Froot, K. A. 1989. Forward discount bias: is it an exchange risk premium? *Quarterly Journal of Economics* 104(1): 139–161.

Frankel, J. A. and Froot, K. A. 1990. Chartists, Fundamentalists, and trading in the foreign exchange markets. *American Economic Review* 80(2): 181–185.

Frankel, J. A. and Rose, A. 1994. A Survey of empirical research on nominal exchange rates. National Bureau of Economic Research, Working Paper No. 4865.

Ghosh, S. 1997. United States trade balance announcements: The nature of its data revisions. *Oxford Bulletin of Economics and Statistics* 59(3): 371–383.

Hansen, L., and Hodrick, R. 1983. Risk averse speculation in the forward

foreign exchange market in Jeffrey A. Frankel, (Ed.), *Exchange Rates and International Macroeconomics*. University of Chicago Press, pp. 113–142

Hirshleifer, D. 2001. Investor psychology and asset pricing. *Journal of Finance* 56(4): 1533–1597.

Hollifield, B., and Uppal, R. 1997. An examination of uncovered interest rate parity in segmented international commodity markets. *Journal of Finance* 52(5): 2145–2170.

Humpage, O. 1987. Should we intervene in exchange markets? *Federal Reserve Bank of Cleveland Economic Commentary* (February 1), pp. 1–4.

Jackson, A., and Johnson, T. 2006. Unifying underreaction anomalies. *Journal of Business* 79(1): 75–114.

Karamanoiu, I., and Raedy, J. S. 2000. Financial analysts' forecasting revisions as evidence of the usefulness of form 20f reconciliation and disclosures. SSRN Working Paper.

Lakonishok, J.; Shleifer, A.; and Vishny, R. 1994. Contrarian investment, extrapolation, and risk. *Journal of Finance* 49(5):1541–1578.

La Porta, R. 1996. Expectations and the cross-section of stock returns. *Journal of Finance* 49(5): 1715–1742.

Levich, R. M. 1979 On the efficiency of markets fore foreign exchange in Dornbusch, R., Frankel, J. (Eds.), *International Economic Policy Theory and Evidence*. John Hopkins Press, pp. 246–267.

Lewis, K. K. 1989. Changing beliefs and systematic rational forecast errors with evidence from foreign exchange. *American Economic Review* 79(4): 621–636.

Lewis, K. K. 1995. Puzzles in international financial markets in G. Grossman and Kenneth Rogoff (Eds.), *Handbook of International Economics*. Elsevier Science, pp. 1913–1971.

MacDonald, R., and Taylor, M. F. 1992. Exchange rate economics: A survey. IMF Staff Papers 39(1): 1–57.

Nofsinger, J. R., and Sias, R.W. 1999. Herding and feedback trading by institutional and individual investors. *Journal of Finance* 54(6): 2263–2295.

Poteshman, A. M. 2001. Underreaction, overreaction, and increasing misreaction to information in the options market. *Journal of Finance* 56(3): 851–876.

Shiller, R. J. 2002. Bubbles, human judgment, and expert opinion. *Financial Analysts Journal* 58(3): 18–26.

Shleifer, A., and Vishny, R. W. 1997. The limits of arbitrage. *Journal of Finance* 52(1): 35–55.

Villanueva, O. M. 2005. FX Dynamics, limited participation, and the forward bias anomaly. *Financial Review* 40(1): 67–93.

Wermers, R. 1999. Mutual fund herding and the impact on stock prices. *Journal of Finance* 54(2): 581–622.

Zivot, E. 2000. Cointegration and forward and spot exchange rate regressions. *Journal of International Money and Finance* 19(6): 785–812.