The Forward Premium Puzzle Revisited

by

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Dedication

To my wife, Row, for your unending supply of love and support this year. Thank you for everything.

> "For the Lord gives wisdom, and from his mouth come knowledge and understanding."
>
> —Proverbs 2:6

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1 Introduction

The market for foreign exchange is the most active of any financial market in the world. According to the *Bank for International Settlements* Triennial Survey (2007), the global average daily trading volume in foreign exchange was estimated to be $3.2 trillion U.S. dollars in 2007 — more than six times larger than trading in U.S. Treasuries and 30 times larger than trading on the New York Stock Exchange — and is expected to reach over $5 trillion U.S. dollars in 2010. By comparison, daily U.S. GDP equals about $39 billion. Because foreign exchange trading is so much larger in volume than trade in goods and services, it seems reasonable to think that unbiasedness and liquidity will be of the highest order in the foreign exchange market. A large literature has examined whether the foreign exchange market is indeed as unbiased as one expects. Although there are a number of ways to examine unbiasedness in the foreign exchange market, one test in particular has generated a great deal of interest and debate: the test for the forward discount bias.

There are a number of discrepancies between the theory of international macroeconomics and the empirical evidence upholding it. One of the most striking examples results from this test for the forward discount bias, and is commonly termed the 'forward premium puzzle'. According to many economic models, when domestic nominal interest rates exceed foreign interest rates, the domestic currency will be expected to depreciate. This results from Fisher's (1930) interest parity condition, wherein the expected returns in one country should be equalized to the returns in a different country once converted to the same currency through speculation. As a result, the expected home currency returns on foreign bonds in excess of domestic bonds should equal zero. However, a large body of work has shown this prediction to be untrue during the floating rate period. In fact, future exchange rate changes and current interest rate differentials are negatively

correlated. In other words, relatively high domestic nominal interest rates lead to an appreciation of the domestic currency. This result, presented by Hansen and Hodrick (1983), Hsieh (1984), Fama (1984), Hodrick (1987), and more recently by Engel (1996), Bansal (1997, 2000), Backus et al. (2001), and Sarno (2005), is known as the forward premium puzzle.

The implications of the forward premium puzzle are troubling. The fundamental theoretical hypothesis of interest parity underpins the vast majority of models of international finance, and yet the forward premium puzzle suggests interest parity does not hold empirically. Rather, high interest rate currencies seem to appreciate relative to low interest rate currencies.

In this essay, I use Fama's classic regression test to measure the forward discount bias and report results over a large sample of countries. I show that the finding of forward discount bias is sensitive to (a) the time period being studied and (b) the base currency against which the exchange rate is evaluated. For instance, tests for bias on exchange rates against the British pound exhibit a tendency to move from the standard, forward premium anomaly result to unbiasedness over time. Tests over the last decade reveal little to no forward discount bias and movement toward interest parity for a number of currencies against the pound, euro and U.S. dollar. This finding is striking because up to this point, almost all empirical studies have shown a significant negative relationship between the interest rate differential and changes in the exchange rate. While this was the case through much of the 1970s, 80s and into the 90s, the nature of the relationship has recently moved closer toward that predicted by theory.

What might be the cause of the forward discount bias and the witnessed decline over the last decade? There are two explanations for the forward premium puzzle in the literature. Some argue that the negative correlation between the interest rate differential and future exchange rate changes is evidence of a time-varying risk premium on foreign exchange. The idea here is that when domestic

interest rates rise, investments in the assets of that country become riskier. This line of thought assumes risk aversion drives the forward discount bias. On the other hand, some assume that investors are risk neutral or that foreign exchange risk is completely diversifiable. These assumptions lead to the conclusion that expectational errors are the cause of any bias. This is interpreted as evidence of a failure of rational expectations.

While a wealth of research has attempted to establish the cause of the forward premium puzzle, the explanation of time-varying risk-premia seems to have less support empirically than the alternative. For instance, Froot and Frankel (1987, 1989) demonstrate that most of the puzzle can be explained by expectational errors. In other words, foreign exchange market participants forecast future exchange rates poorly, resulting in the anomalous negative relationship between interest differentials and depreciation. Although their work was rigorous and settled the argument at the time, they were only able to analyse the time-varying risk premium vs. expectational errors debate over a short horizon in the early- to mid-1980s due to data availability.

Does this result hold over a more recent time horizon as the bias has been disappearing for certain currencies? I examine this question using survey data on exchange rate expectations over a sample of sixteen currencies across an eighteen year span beginning in July 1990. Taken as a whole, the results confirm that the systematic portion of forward discount prediction errors are not capturing a time-varying risk premium. Rather, the assumption of rational expectations is rejected, leaving expectational errors as the primary explanation of the forward premium puzzle. Overall, the results of the unbiasedness regressions using the survey data suggest that uncovered interest parity holds for about half of the sample countries against the pound and euro, and the majority of the sample countries against the U.S. dollar.

The essay is organised as follows. The theoretical setup is derived in Section

2. The results for the test of the forward discount bias are provided in Section 3. Section 4 describes the survey data and decomposes the risk premium and the expectational errors. Section 5 tests for the existence of rational expectations. Tests of the forward discount bias without the assumption of rational expectations are conducted in Section 6, and Section 7 concludes.

2 Theoretical setup

2.1 Interest parity and unbiasedness

This section provides a brief overview of the theory behind the test for forward discount bias. I begin with covered interest parity (CIP). CIP is defined as the following:

$$(1 + i_t) = (1 + i_t^*)(\frac{F_t}{S_t}) \tag{1}$$

where i_t and i_t^* are interest rates on domestic and foreign deposits, respectively, S_t is the spot exchange rate, measured in units of domestic currency per foreign currency unit, and F_t is the the forward rate. The assumption of CIP is warranted, given the extensive empirical evidence that suggests it holds (Sarno and Taylor (Ch.2, 2003)). If it did not, arbitrage opportunities would arise.

I take the logarithm of this expression and use the approximation that $log(1 + i_t) \approx i_t$ to give:

$$i_t - i_t^* = f_t - s_t \tag{2}$$

where i_t and i_t^* are the interest rates on domestic and foreign deposits, respectively, s_t is the logarithm of the spot exchange rate, and f_t is the logarithm of the forward rate.

Uncovered interest parity (UIP) is defined as the following:

$$E_t[s_{t+j} - s_t] = i_t - i_t^* \tag{3}$$

where E_t is the expectation based on information at time t, and s_{t+j} is the j-period ahead spot exchange rate.

CIP and UIP together imply

$$E_t[s_{t+j} - s_t] = f_t - s_t,$$

giving us

$$E_t[s_{t+j}] = f_t$$

so that the forward is an unbiased forecast of the future spot exchange rate.

Now take

$$s_{t+j} = E_t[s_{t+j}] + u_{t+j}$$

where u_{t+j} is a purely random error term. This results from the assumption of rational expectations, where u_{t+j} has mean zero and is uncorrelated with the forward discount $(f_t - s_t)$ at time t.

This leads to the following regression equation that provides a test of the forward discount bias. The change in the exchange rate is regressed on the forward premium:

$$\Delta s_{t+j} = \alpha + \beta(f_t - s_t) + u_{t+j} \tag{4}$$

where Δ is the difference operator. If the UIP hypothesis holds, then $E_t[s_{t+j}] = f_t$ and consequently $\hat{\beta} = 1$.

2.2 Fama's Regression Test

Fama's influential 1984 paper on forward and spot exchange rates utilised this simple regression test (4) of the degree of predictable excess return variability. It provides the benchmark result in the forward premium literature.

Fama showed that $\hat{\beta} < 1$. In fact, $\hat{\beta}$ was significantly less than zero for all countries in his sample. Other authors obtained similar results throughout the 1980s and into the 90s. According to Froot (1990), the average coefficient across 75 published estimates was -0.88. Although some are positive, none is greater than or equal to the null hypothesis of $\hat{\beta} = 1$ in Froot's sample. More recently,

Bansal and Dahlquist (2000) find that $\hat{\beta}$ is negative for developed economies, but often positive for emerging market economies. They use cross-sectional methods to show that $\hat{\beta}$ is increasing in GNP per capita and decreasing in average inflation rate. Both point to a higher slope coefficient for developing economies. Despite this, it is more or less a stylized fact that the results of the unbiasedness test, using exchange rates against the U.S. dollar, reject the hypotheses of UIP and unbiasedness (Sarno (2005)).

2.3 The nature of β: economic implications

What is the slope coefficient in the Fama regression truly capturing? In order to give the reader a better understanding of the test for unbiasedness, I decompose the regression coefficient in this section. Taking the probability limit of β from equation (4) yields the following:

$$\beta = \frac{Cov(E_t \Delta s_{t+j}, f_t - s_t) + Cov(u_{t+j}, f_t - s_t)}{Var(f_t - s_t)} \tag{5}$$

where u_{t+j} is the expectational error of agents, while $E_t \Delta s_{t+j}$ is the actual expectation of market participants. The risk premium is defined as follows:

$$rp_t = (f_t - s_t) - E_t \Delta s_{t+j}. \tag{6}$$

Table 1 below shows the implications of different values of β. A negative slope-coefficient gives rise to the forward premium puzzle which implies that the risk premium is more volatile than the expected depreciation. A slope-coefficient greater than one implies the opposite. If $\beta = 1/2$, the variance of the risk premium equals the variance of the linear prediction of the exchange rate change.

Table 1: Economic interpretation of β

Case	β	$Var(rp_t)$ and $Var(E_t\Delta s_{t+j})$	$Cov(rp_t, E_t\Delta s_{t+j})$
I UIP holds	=1	$Var(E_t\Delta s_{t+j}) > Var(rp_t)$	=0
II Forward premium puzzle	<0	$Var(rp_t) > \lvert Cov(rp_t, E_t\Delta s_{t+j})\rvert > Var(E_t\Delta s_{t+j})$	<0
III	>1	$Var(E_t\Delta s_{t+j}) > \lvert Cov(rp_t, E_t\Delta s_{t+j})\rvert > Var(rp_t)$	<0
IV	=0.5	$Var(E_t\Delta s_{t+j}) = Var(rp_t)$	undetermined

As mentioned in Section 2.1, under the assumption of rational expectations the prediction error, u_{t+j}, is uncorrelated with the forward discount. Thus,

$$Cov(u_{t+j}, f_t - s_t) = 0$$

and (5) becomes

$$\beta = \frac{Cov(E_t\Delta s_{t+j}, f_t - s_t)}{Var(f_t - s_t)}.$$

Now, as long as the estimated slope-coefficient in the unbiasedness regression is less than half, $Var(rp_t) > Var(E_t\Delta s_{t+j})$. Much previous research has assumed rational expectations and thus claimed that the expected depreciation was less variable than the risk premium based on negative estimates of $\hat{\beta}$. I test the existence of rational expectations later in the essay using survey data on exchange rate forecasts.

2.4 Contributions and extensions

Fama and many others explored the relation between expected exchange rate changes and interest differentials using U.S. dollar exchange rates. Might the forward premium puzzle disappear if other currencies are used as the base currency? The forward discount test is not transitive across different exchange rates against the same base currency. *i.e.* Tests of the forward discount bias for two currencies against the U.S. dollar do not imply a result between the two currencies. For instance, Bossaerts and Hillion (1991) find positive estimates of $\hat{\beta}$ for most currencies against the French franc, while Flood and Rose (1996) find a higher slope-coefficient for economies within the Euro area versus the deutschemark than for economies versus the U.S. dollar.

Section 3 tests the unbiasedness hypothesis using as a base currency the British pound over a sample dating back to 1976 and the euro extending back to 1999. In addition, I update Fama's original regression test (4) for U.S. dollar exchange rates. I show that the forward premium puzzle is (a) unique to certain currency pairs and (b) unique to the time period during which the issue gained prominence in the international finance literature (the mid-70s to the mid-90s).

3 Tests of the forward discount bias

3.1 Data description

I collect weekly data from *Datastream* and the *Bank for International Settlements (BIS)* on spot exchange rates and forward rates. As the forward and spot rates are in logs and the differences are multiplied by 100, the variables are on a percent per month basis. The sample period is 1976 to 2009 for the pound cross-rates, 1977 to 2009 for the U.S. dollar rates, and 1999 to 2009 for the euro cross-rates. All datapoints are end-of-week. I am unable to collect data for all countries over the entire sample. Data extends back the furthest for the euro area countries, Canada, Japan, the U.K., and the U.S. Many of the developing countries have much shorter samples. The sample specific to each country is shown in Table 2. There are 36 countries in the sample, and over 40,000 observations in total.

Table 2: Sample countries

Country	Country code	British pound	Euro	U.S. dollar
Australia	AUD	01/1997-06/2009	01/1999-06/2009	07/1992-06/2009
Austria	AUT	01/1976-12/1998		12/1978-12/1998
Belgium	BLG	01/1976-12/1998		09/1977-12/1998
Canada	CAD	01/1976-06/2009	01/1999-06/2009	09/1977-06/2009
Switzerland	CHF	01/1976-06/2009	01/1999-06/2009	09/1977-06/2009
Czech Republic	CZK	01/1997-06/2009	01/1999-06/2009	12/1996-06/2009
Germany	DEU	01/1976-12/1998		09/1977-12/1998
Denmark	DNK	01/1976-06/2009	01/1999-06/2009	09/1977-06/2009
Spain	ESP	01/1976-12/1998		09/1977-12/1998
Euro area	EUR			01/1999-06/2009
Finland	FIN		01/1999-06/2009	01/1997-06/2009
France	FRA	01/1976-12/1998		09/1977-12/1998
Hong Kong	HKD	01/1997-06/2009	01/1999-06/2009	
Hungary	HUF	01/1997-06/2009	01/1999-06/2009	10/1997-06/2009
India	IND	10/1997-06/2009	01/1999-06/2009	01/1997-06/2009
Indonesia	INR	01/1997-06/2009		
Ireland	IRE	01/1976-12/1998		02/1992-12/1998
Italy	ITA	01/1976-12/1998		09/1977-12/1998
Japan	JPY	01/1976-06/2009	01/1999-06/2009	09/1977-06/2009
South Korea	KOR		02/2002-06/2009	02/2002-06/2009
Malaysia	MLY	01/1997-06/2009		01/1997-06/2009
Mexico	MXP	01/1997-06/2009		01/1997-06/2009
Netherlands	NLD	01/1976-12/1998		09/1977-12/1998
Norway	NOK	01/1976-06/2009	01/1999-06/2009	09/1977-06/2009
New Zealand	NZD	01/1997-06/2009	01/1999-06/2009	07/1992-06/2009
Philippines	PHP	01/1997-06/2009	01/1999-06/2009	
Portugal	POR	01/1976-12/1998		09/1977-06/2009
Saudi Arabia	SAU	01/1997-06/2009	01/1999-06/2009	06/1990-06/2009
South Africa	ZAR	01/1997-06/2009	01/1999-06/2009	
Sweden	SEK	01/1976-06/2009	01/1999-06/2009	09/1977-06/2009
Singapore	SGD	01/1997-06/2009	01/1999-06/2009	06/1990-06/2009
Taiwan	TWD	01/1997-06/2009	01/1999-06/2009	
Thailand	THB	01/1997-06/2009	01/1999-06/2009	01/1997-06/2009
Turkey	TUR	01/1997-06/2009	01/1999-06/2009	01/1997-06/2009
United Kingdom	UK	01/1976-06/2009	01/1999-06/2009	09/1977-06/2009
United States	USD	01/1976-06/2009	01/1999-06/2009	

In examining the forward premium puzzle, I look at 1- and 3-month forward rates. I follow the standard method and perform OLS. Weekly observations on 1-month rates imply an MA(3) due to the overlapping observation problem. To deal with this, covariance matrices are robust to heteroskedasticity (White (1980)) and serial correlation (Newey and West (1987)). The empirical results from using 1- or

3-month forward contracts are similar, and in the interest of saving space, I follow Fama (1984) and report only the evidence for 1-month forwards. Recent work by Chinn and Meredith (2004) has demonstrated that the forward bias is robust when using short-horizon data but fades in long-horizon UIP regressions. However, the difference between results at the 1- and 3-month horizons is sufficiently small to warrant exclusion.

3.2 British pound results

Tables 3 and 4 contain the results of the forward premium regressions (equation (4)) with the British pound as the base currency. Table 3 shows the results for countries with data available from 1976-1998, while Table 4 displays results for countries with data available from 1999-2009.

The results are consistent with the large body of work undertaken during the 1980s and 90s which showed that $\hat{\beta}$ was significantly negative and less than one. Although different currencies are included in each sample, it is clear that in each successive time period examined, the slope-coefficient rises across most currencies. The average value of $\hat{\beta}$ rises from -1.111 (1976-1985), to -0.260 (1986-1998), to 0.647 (1999-2003), to 1.890 (2004-2009). Not only has the forward discount bias disappeared over the course of the sample, but the average slope-coefficient is greater than one over the last five years.

Table 3: Forward discount bias against the British pound, 1976-1998

$$\Delta s_{t+1} = \alpha + \beta(f_t - s_t) + u_{t+1}$$

	Full Sample			1976-1985			1986-1998		
S_t	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\hat{\alpha}$	$\hat{\beta}$	R^2
AUT	-0.254**	-0.128	0.000	-0.395***	-0.211	0.001	-0.186	-0.160	0.000
BLG	-0.232***	-1.201***	0.023	-0.059	-1.722***	0.060	-0.197*	-0.309	0.001
CAD	-0.290***	-2.672***	0.027	-0.219*	-3.121***	0.088	-0.170	-2.149**	0.007
CHF	-0.294***	-0.113	0.000	-1.042***	-1.038***	0.032	-0.071	0.028	0.000
DEU	0.220***	1.085***	0.205	0.237**	1.036***	0.182	0.204***	1.155***	0.233
DNK	-0.089	-0.570**	0.006	0.260**	-1.228***	0.029	-0.059	-0.230	0.001
ESP	0.011	0.575*	0.014	0.112	0.525	0.012	-0.024	0.407	0.002
FRA	-0.015	-0.573*	0.007	0.198**	-0.865**	0.023	-0.122	-0.239	0.001
IRE	0.030	0.485**	0.006	0.159*	-0.401	0.001	0.028	0.685***	0.017
ITA	0.411***	-0.661***	0.013	1.199***	-1.517***	0.078	0.069	0.062	0.000
JPY	-1.361***	-2.562***	0.014	-2.890***	-5.234***	0.114	-1.652***	-2.959***	0.014
NLD	-0.672***	-1.583***	0.020	-1.412***	-3.226***	0.074	-0.221*	-0.289	0.001
NOK	-0.019	-0.030	0.000	-0.033	0.046	0.000	0.104*	-0.108	0.000
POR	0.246**	0.446***	0.030	0.713***	0.303**	0.016	0.085	0.177	0.001
SEK	0.086*	0.624**	0.005	0.059	0.894**	0.018	0.126*	-0.230	0.000
USD	-0.274***	-1.295***	0.010	-0.565***	-1.999***	0.045	0.071	-0.006	0.000
Average	-0.156	-0.511	0.024	-0.230	-1.110	0.048	-0.126	-0.260	0.017

*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

Table 4: Forward discount bias against the British pound, 1999-2009

$$\Delta s_{t+1} = \alpha + \beta(f_t - s_t) + u_{t+1}$$

	Full Sample			1999-2003			2004-2009		
S_t	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\hat{\alpha}$	$\hat{\beta}$	R^2
AUD	0.051	-2.706**	0.009	-0.174	-0.256	0.000	-0.306	0.836	0.000
CAD	-0.290***	-2.672***	0.027	0.148	4.223***	0.010	0.509	7.405***	0.027
CHF	-0.294***	-0.113	0.000	0.026	0.966***	0.025	-0.028	1.441***	0.052
CZK	-0.281***	1.183***	0.022	-0.070	2.990***	0.020	-0.158	2.497	0.007
DNK	-0.089*	-0.570***	0.006	-0.466**	-2.943	0.014	-0.645*	-2.681**	0.013
HKD	0.053	0.701*	0.002	0.029	0.318	0.000	0.331	2.924**	0.014
HUF	-0.367	0.774**	0.005	-0.318	0.617	0.002	0.074	-0.926	0.003
IND	0.440***	-1.638***	0.022	0.370**	-1.667***	0.020	0.133	-2.146***	0.025
INR	0.808**	0.290**	0.007	0.157	0.330***	0.036	0.235	-1.393	0.019
JPY	-1.361***	-2.562***	0.014	2.397***	6.649***	0.028	2.724**	8.262***	0.044
MLY	0.203	0.705	0.002	-0.159	2.392*	0.006	0.491	5.372***	0.040
MXP	0.408*	-0.178	0.002	0.299	-0.278	0.003	-0.001	0.533	0.011
NOK	-0.019	-0.030	0.000	-0.132	-0.061	0.000	-0.168	0.838	0.001
NZD	0.079	-0.271	0.000	-0.215	0.570	0.000	-2.010**	9.186**	0.027
PHP	-0.264	1.799***	0.024	-0.104	0.942	0.004	-0.861***	3.389**	0.020
SAU	-0.036	-0.232	0.000	0.043	0.664	0.001	0.261	3.771***	0.023
SEK	0.086	0.624	0.005	-0.166	-1.100	0.002	0.238	1.881	0.003
SGD	0.163	0.810	0.004	0.708**	3.585***	0.019	0.464	4.015***	0.034
THB	-0.044	1.545***	0.047	-0.064	-0.242	0.001	-0.369**	-0.906	0.008
TUR	1.612***	0.002	0.000	1.115***	-0.010	0.001	2.444**	-2.246**	0.019
TWD	0.167	0.485	0.003	0.082	0.445	0.003	0.018	0.717	0.004
USD	-0.274***	-1.295***	0.010	0.003	0.172	0.000	0.275	4.350***	0.024
ZAR	1.247***	-1.737**	0.009	1.808***	-3.416***	0.023	1.428**	-3.658**	0.023
Average	0.087	-0.221	0.010	0.231	0.647	0.010	0.221	1.890	0.019

*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

3.3 Euro results

Table 5 presents time-series evidence from the forward premium regression with the euro as the base currency. The average slope-coefficient over the entire sample (1999-2009) is -0.763. This does not match up with the British pound results, where $\hat{\beta}$ was positive on average over the last decade. However, when the sample is split into two, I find that $\hat{\beta}$ is negative on average (-1.878) over 1999-2003 but greater than one (1.814) from 2004-2009.

Table 5: Forward discount bias against the euro, 1999-2009

$$\Delta s_{t+1} = \alpha + \beta(f_t - s_t) + u_{t+1}$$

	Full Sample			1999-2003			2004-2009		
S_t	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\hat{\alpha}$	$\hat{\beta}$	R^2
AUD	-0.100	0.307	0.000	-0.138	0.220	0.000	0.504	-1.688	0.000
CAD	0.057	-4.552***	0.017	0.142	-6.551***	0.046	-0.107	1.615	0.001
CHF	-0.432*	-2.722	0.007	-0.893***	-5.708***	0.060	0.000	0.510	0.000
CZK	-0.237**	0.835	0.004	-0.280**	0.904	0.006	-0.250**	0.986	0.001
DNK	0.008*	-0.399**	0.016	0.028***	-1.379***	0.065	0.001	-0.068	0.001
HKD	0.130	-2.282**	0.012	0.130	-4.189***	0.054	0.196	1.885	0.006
IND	1.174***	-3.093***	0.052	1.049***	-2.696***	0.052	0.822***	-2.461***	0.027
JPY	1.134**	4.441**	0.011	-0.280	-1.213	0.001	3.138***	14.005***	0.076
KOR	0.503**	-1.026	0.003	-0.178	4.275***	0.015	0.268	-2.200	0.016
MXP	1.817***	-2.293***	0.078	2.397***	-2.655***	0.130	1.242**	-1.894	0.009
NOK	0.044	-0.205	0.000	0.197	-1.392	0.011	-0.293**	8.737***	0.060
NZD	-0.952***	3.637***	0.016	-0.571	1.870	0.002	-2.589**	8.006**	0.024
PHP	0.567	-0.686	0.002	2.038***	-2.839**	0.031	0.162	-0.797	0.001
SAU	0.229*	-2.119***	0.010	0.360**	-4.958***	0.064	0.069	2.621**	0.011
SEK	0.125*	-2.219*	0.005	0.102	-5.974***	0.052	0.433***	11.003***	0.046
SGD	-0.035	-0.674	0.001	-0.160	-2.170	0.004	-0.020	0.785	0.002
THB	0.077	0.084	0.000	0.177	0.457	0.001	-0.022	-0.197	0.000
TUR	1.279***	-0.006	0.000	2.002***	0.003	0.000	3.574***	-2.660***	0.033
TWD	0.142	-0.075	0.000	0.136	-0.259	0.001	0.218	0.682	0.004
USD	0.215	-2.449**	0.011	0.199	-4.920***	0.058	0.052	2.337	0.007
ZAR	0.657	-0.525**	0.002	0.312	-0.256	0.001	1.969	-3.109	0.008
Average	0.305	-0.763	0.012	0.322	-1.878	0.031	0.446	1.814	0.016

*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

3.4 U.S. dollar results

Table 6 presents results of the forward premium regression with the U.S. dollar serving as the base currency over the pre-euro period. Table 7 reports the post-euro results. Note that the two tables contain different sets of currencies. Over the full sample, the slope-coefficient is negative on average. Again, when the sample is split, the average value of $\hat{\beta}$ moves from -1.647 (1977-1985) to 0.134 (1986-1998). However, the upward trend in the slope-coefficient seen in the pound regressions is not replicated over the 1999 to 2009 period as the average of $\hat{\beta}$ across the sample countries is -0.541 (see Table 7). Like the pound and euro results, the average value of $\hat{\beta}$ exceeds one (2.410) over the 2004-2009 horizon.

Table 6: Forward discount bias against the U.S. dollar, 1977-1998

$$\Delta s_{t+1} = \alpha + \beta(f_t - s_t) + u_{t+1}$$

	Full Sample			1977-1985			1986-1998		
S_t	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\hat{\alpha}$	$\hat{\beta}$	R^2
AUT	-0.146	-0.721*	0.004	-0.232	-1.474	0.008	-0.230**	0.083	0.000
BLG	0.015	-0.423	0.002	0.332	-0.246	0.001	-0.181*	-0.759	0.004
CAD	0.061	-0.814***	0.005	0.336***	-1.752***	0.038	0.106*	-0.796***	0.012
CHF	-0.484***	-1.092***	0.009	-2.277***	-3.539***	0.048	-0.290*	-1.008*	0.006
DEU	-0.158	-0.769**	0.005	-0.743*	-2.705**	0.021	-0.225*	0.250	0.000
DNK	0.071	-0.884***	0.007	0.752***	-1.735***	0.041	-0.037	-0.578	0.003
ESP	-0.141	2.012***	0.058				-0.141	2.012***	0.058
FRA	0.002	0.294	0.002	0.320*	0.366	0.004	-0.151	-0.232	0.000
ITA	0.031	0.447	0.002	0.943***	-0.648**	0.008	-0.601**	1.604*	0.017
JPY	-0.875***	-2.137***	0.024	-1.491***	-2.928***	0.063	-0.849***	-2.098***	0.016
NLD	-0.264**	-1.348***	0.013	-1.111***	-4.133***	0.068	-0.234**	-0.142	0.000
NOK	0.055	-0.100	0.000	0.401***	-0.678**	0.012	-0.077	0.405	0.003
POR	0.006	0.895***	0.028				0.006	0.895***	0.028
SEK	0.113	-0.015	0.000	0.586***	-1.291***	0.020	-0.107	0.701*	0.007
UK	0.301***	-1.834***	0.017	0.451***	-4.053***	0.112	-0.077	0.023	0.000
Average	-0.103	-0.578	0.012	-0.133	-1.909	0.034	-0.193	0.023	0.010

*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

Table 7: Forward discount bias against the U.S. dollar, 1999-2009

$$\Delta s_{t+1} = \alpha + \beta(f_t - s_t) + u_{t+1}$$

	Full Sample			1999-2003			2004-2009		
S_t	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\hat{\alpha}$	$\hat{\beta}$	R^2
AUD	0.215	-1.836**	0.006	-0.011	-1.021	0.002	-1.251***	5.616***	0.028
CAD	0.061	-0.814***	0.005	-0.229**	-0.831	0.001	-0.145	4.196**	0.010
CHF	-0.484***	-1.092***	0.009	-0.696***	-2.935***	0.015	-0.013	1.020	0.001
CZK	-0.352***	0.982***	0.009	-0.351**	1.324	0.003	-0.289	2.128	0.006
DNK	0.071	-0.884***	0.007	-0.168	-2.689***	0.016	-0.124	1.098	0.002
EUR				-0.199	-1.732**	0.009	-0.046	2.945*	0.012
FIN	-0.230	-2.765***	0.016	-0.220	-2.587***	0.013	-0.039	2.959*	0.012
HUF	0.179	-0.260	0.001	0.248	-0.532	0.003	0.250	-0.664	0.005
IND	0.504***	-0.884***	0.022	0.308**	-0.580	0.010	0.399**	-0.829**	0.018
JPY	-0.875***	-2.137***	0.024	-0.335	-0.758	0.002	0.153	1.099	0.003
KUW	-0.124***	1.393***	0.096	-0.153***	2.787***	0.274	-0.130***	3.071***	0.367
MLY	0.222**	-0.007*	0.000	-0.063	0.003*	0.000	0.020	2.521**	0.032
MXP	0.668***	-0.429***	0.013	0.649***	-0.696***	0.023	0.472	-0.501	0.004
NOK	0.055	-0.100	0.000	-0.086	-0.331	0.000	-0.081	3.350**	0.025
NZD	0.036	-0.450	0.000	-0.033	-0.383	0.000	-3.883***	12.461***	0.089
PHP	0.097	0.561***	0.013	0.026	0.311	0.002	-0.539**	0.810	0.014
POL	-0.379	0.777***	0.011	-0.372	0.694*	0.005	-0.575**	2.688**	0.012
SAU	0.003	-0.218	0.025	0.003	-0.308	0.035	-0.006	-0.456	0.050
SEK	0.113	-0.015	0.000	-0.068	-1.568**	0.007	0.338	4.412***	0.032
SGD	-0.142	-0.445	0.002	-0.285**	-1.355**	0.009	-0.143	0.736	0.001
THB	-0.055	0.268**	0.022	-0.086	0.048	0.003	-0.307**	0.080	0.010
UK	0.301	-1.834	0.017	-0.002	0.174	0.000	-0.298	4.270	0.025
Average	-0.014	-0.542	0.014	-0.087	-0.511	0.019	-0.284	2.410	0.034

*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

3.5 Changes in $\hat{\beta}$ over time

Although no formal tests are conducted, the slope-coefficient does seem to be increasing across time for most countries in the sample against all three base currencies. Certainly this case can be made for the pound exchange rates. The evidence is not as clear for the euro and U.S. dollar. However, over the last five years, the average of the value of the slope coefficient across all sample currencies is 1.890 (pound exchange rates), 1.814 (euro exchange rates), and 2.410 (U.S. dollar exchange rates). Granted, different countries are included in the samples depending on data availability and the introduction of the euro. But overall, the results suggest that the variance of the expected depreciation is greater than the

variance of the risk premium, the opposite outcome of the forward bias puzzle. I will examine this possibility more formally later in the essay.

The key message from these regression results is that tests of the forward discount bias are highly sensitive to (a) the base currency and (b) the time period over which the tests are conducted. This contrasts with research conducted in the 1980s and 90s that found a significant forward discount bias for the vast majority of currencies studied - regardless of the time horizon in question or the base currency (Froot (1990)).

4 Explanations: risk premia or expectational errors

Although there is some evidence of unbiasedness in the last decade, over the full sample there is a consistent forward discount bias across most currencies. I now examine the cause of the forward discount bias using survey data on exchange rate expectations. The forecast data from the survey allows us to separate the effects of risk premia and expectational errors without assuming rational expectations hold. This section describes the survey data and provides theoretical grounding for the subsequent tests, Section 5 presents results of tests of the existence of rational expectations, Section 6 presents results of tests for the forward discount bias using the survey data, and Section 7 concludes.

4.1 Survey data description

3-month ahead exchange rate predictions are obtained from *Consensus Economics* surveys dating back to July 1990. While Froot and Frankel (1989) had only five currencies in their sample over very short horizons (two to four years), the *Consensus* data provide forecasts for sixteen currencies over an eighteen year period. The reported exchange rate forecasts are a simple arithmetic average of all of the individual predictions obtained by *Consensus*. Although surveys are not a perfect measure of expectations, they have been used in a wide range of economic studies. The case for using survey data on exchange rate expectations is sound,

as respondents are directly involved in the spot and forward markets for foreign exchange. *Consensus* foreign exchange survey respondents include large international banks, financial institutions such as pension funds and mutual funds, economic consultancies, and academic institutions. The *Consensus* surveys are conducted on a monthly basis. Currencies included in the survey are shown in Table 8, along with descriptive statistics for exchange rates against the U.S. dollar. The survey data is available for sixteen countries in total. Because the data are 3-month ahead expectations, I use the 3-month forward rates in the analysis that follows.

Table 8: *Consensus Economics* exchange rate expecations survey data

Percent per annum

s_t	Sample	Mean forward rate error $f_t - s_{t+j}$	Mean risk premium $f_t - E_t[s_{t+j}]$	Mean survey prediction error $E_t[s_{t+j}] - s_{t+j}$
AUT	07/1990-12/1998	0.013	-3.760	4.024
BLG	07/1990-12/1998	0.202	-4.490	5.117
CAD	07/1990-06/2009	0.361	2.370	-2.010
CHF	07/1990-06/2009	-0.567	-1.494	3.489
DEU	07/1990-12/1998	-0.030	-3.207	0.449
DNK	07/1990-06/2009	1.329	0.880	3.948
ESP	07/1990-12/1998	-2.853	-3.108	-6.379
EUR	01/1999-06/2009	1.782	4.576	-0.930
FRA	07/1990-12/1998	0.826	-2.747	2.368
ITA	07/1990-12/1998	0.144	1.322	4.364
JPY	07/1990-06/2009	-0.936	-3.304	-2.512
NLD	07/1990-12/1998	-0.101	-4.056	6.353
NOK	07/1990-06/2009	1.163	3.676	2.357
SEK	07/1990-06/2009	-0.654	3.253	-2.964
UK	07/1990-06/2009	-0.797	0.162	0.927
US	07/1990-06/2009			

Note: All descriptive statistics above are for exchange rates against the U.S. dollar and are percent per annum.

4.2 Variability of the risk premium and exchange rate expectations

The survey data shed light on the relative volatility of the risk premium and expected depreciation. As mentioned earlier, Fama (1984) and Hodrick and Srivastava (1986) argue that the variance of expected depreciation is smaller than that of the risk premium. Table 9 details the variance of the forward rate error ($Var(f_t - s_{t+j})$), expected changes in the spot rate ($Var(E_t \Delta s_{t+j})$), and the risk

premium ($Var(rp_t)$). Although the magnitude of the variance of expected depreciation is comparable to that of the risk premium, the former is larger than the latter in all but one case. I will test the hypothesis that the variance of the risk premium is greater than the variance of expected depreciation in Section 5.

Table 9: *Consensus Economics* exchange rate expecations survey data

Comparison of variances, percent per annum

s_t	Sample	Var($f_t - s_{t+j}$)	Var(rp_t)	Var($E_t \Delta s_{t+j}$)	Var(rp_t) > $Var(E_t \Delta s_{t+j})$
AUT	07/1990-12/1998	125.670	55.173	55.768	No
BLG	07/1990-12/1998	124.619	52.704	55.005	No
CAD	07/1990-06/2009	58.252	16.716	17.348	No
CHF	07/1990-06/2009	129.685	54.879	57.609	No
DEU	07/1990-12/1998	125.112	41.242	41.864	No
DNK	07/1990-06/2009	120.707	47.819	52.927	No
ESP	07/1990-12/1998	110.226	38.558	50.432	No
EUR	01/1999-06/2009	120.802	46.901	49.473	No
FRA	07/1990-12/1998	111.891	39.630	40.726	No
ITA	07/1990-12/1998	140.555	39.996	39.420	Yes
JPY	07/1990-06/2009	140.505	42.427	42.819	No
NLD	07/1990-12/1998	125.781	47.550	50.166	No
NOK	07/1990-06/2009	141.412	49.347	51.425	No
SEK	07/1990-06/2009	134.224	43.936	45.287	No
UK	07/1990-06/2009	105.090	28.353	28.529	No

Note: All descriptive statistics above are for exchange rates against the U.S. dollar and are percent per annum.

4.3 Risk premia vs. expectational errors

What explains the existence of the forward discount bias? There are two explanations provided in the literature. To aid in understanding, it is helpful to reexamine the Fama regression coefficient. Recall that the probability limit of the coefficient β from equation (4) is

$$\frac{Cov(E_t \Delta s_{t+j}, f_t - s_t) + Cov(u_{t+j}, f_t - s_t)}{Var(f_t - s_t)}$$

and that the risk premium is defined as the following:

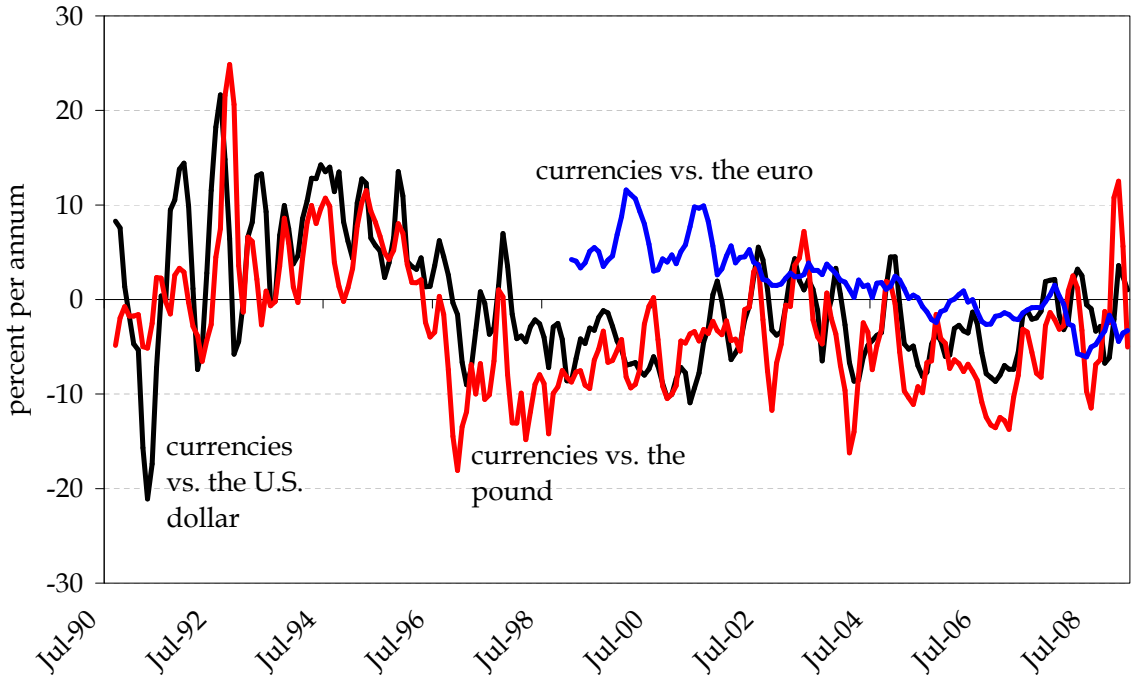
$$rp_t = (f_t - s_t) - E_t \Delta s_{t+j}.$$

With no information on agents' expected future spot rate, $E_t[s_{t+j}]$, previous research has assumed one of two things: (a) either the risk premium is zero,

in which case equation (4) can be interpreted as a test of market efficiency, or (b) expected depreciation equals zero ($E_t \Delta s_{t+j} = 0$) so that all of the forward discount is attributed to the risk premium. *i.e.* $rp_t = f_t - s_t$. If exchange rates are best captured by a random walk, meaning the current spot rate is the best forecast of the future value of the exchange rate, this latter assumption may be reasonable.

But is this assumption valid? Figure 1 plots a moving average of the mean expected depreciation across all of the currencies included in the *Consensus Economics* survey against the pound (red line), euro (blue line), and U.S. dollar (black line), respectively. From the figure, it is obvious that the expected depreciation does not equal zero, but is highly variable and may be positive or negative. For individual country exchange rates, the expected changes are even more variable than in the aggregate. It looks as though the assumption of random walk expectations is faulty.

Figure 1: Mean expected depreciation



Source: Author's calculations using exchange rate data

The most effective way to drop this assumption is to obtain actual data on exchange rate expecations. The *Consensus* survey data on exchange rate expectations provide a direct estimate of $E_t \Delta s_{t+j}$. This allows me to examine the existence of a risk premium without assuming that investors' expect the change in the spot rate to equal zero. Sections 5 and 6 include a number of formal tests to examine the impact of time-varying risk premia and expectational errors on the forward discount, utilising the expectations data from the survey to do so.

5 Do expectational errors explain any of the forward premium puzzle?

In this section I will formally test the hypothesis that expectational errors explain the premium puzzle. These tests also allow us to determine the existence of rational expectations.

5.1 A test of rational expectations

Over the years, there have been a number of attempts to pin down the relationship between movements in exchange rates and fundamentals. Beginning with the classic work of Meese and Rogoff (1983), in which a random walk outperforms a number of alternative specifications, the random walk has generally been accepted as the benchmark model of exchange rate behaviour. Although there have been countless attempts to overturn the Meese-Rogoff finding, only a few authors have been successful (MacDonald and Taylor (1993), Chinn and Meese (1995), Mark (1995), MacDonald and Marsh (1997), Mark and Sul (2001)). Even in the cases of success, the ability of alternative models to outperform a random walk often depends on the particular currency pair in question and the horizon being examined.

If the random walk outperforms any alternative, why don't agents simply use the contemporaneous spot rate as their forecast? As Figure 1 demonstrated, the measured expected depreciation from the survey was highly variable and did not equal zero. This question leads to one of the most powerful tests of rational expectations in the foreign exchange market. The forecast error is regressed on expected depreciation:

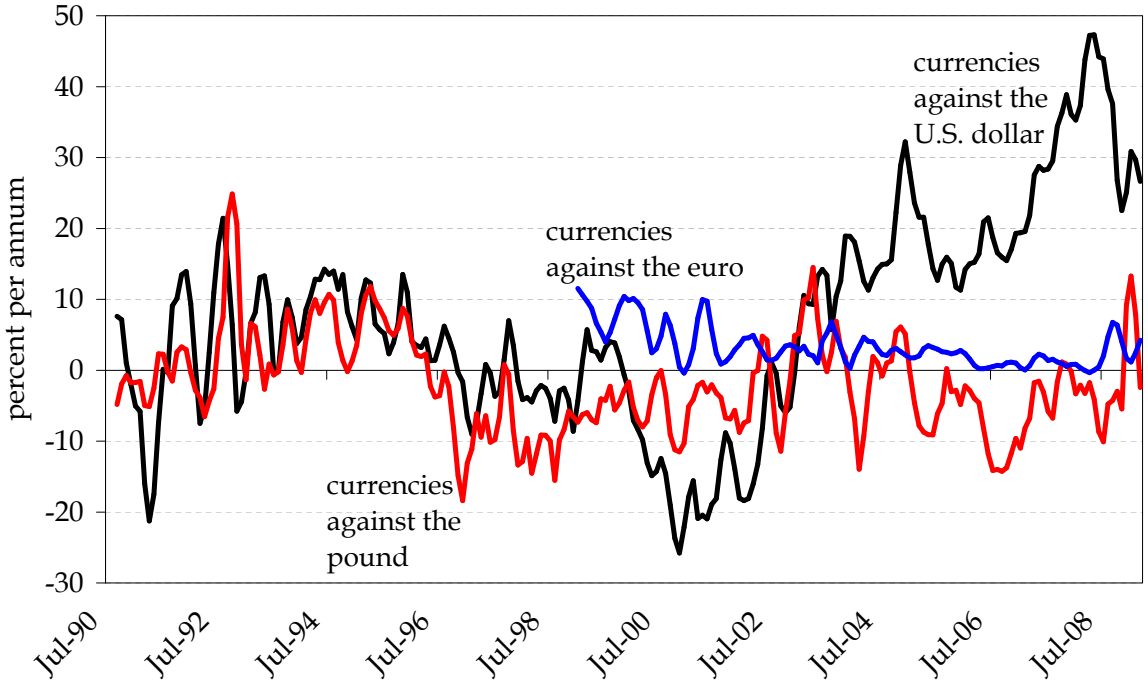
$$E_t\Delta\hat{s}_{t+j} - \Delta s_{t+j} = \delta_1 + \gamma_1(E_t\Delta\hat{s}_{t+j}) + v_{t+j} \tag{7}$$

where the null hypothesis is $\delta_1 = \gamma_1 = 0$. The error term captures the survey measurement error minus the unexpected change in the spot rate, $v_{t+j} = \epsilon_t - u_{t+j}$. The left-hand-side of (7) is the forecast error (for the rate of depreciation) while the right-hand-side is the forecast itself. This allows for a test of rational

expectations. Under the null hypothesis, the forecast error should be uncorrelated with anything at time t, including the forecast itself.

Figure 2 plots moving average mean survey forecast errors $(E_t[s_{t+j}] - s_{t+j})$ across all sample currencies against the pound (red line), euro (blue line) and U.S. dollar (black line). Although aggregated across currencies, the forecast errors are quite large.

Figure 2: Mean forecast error

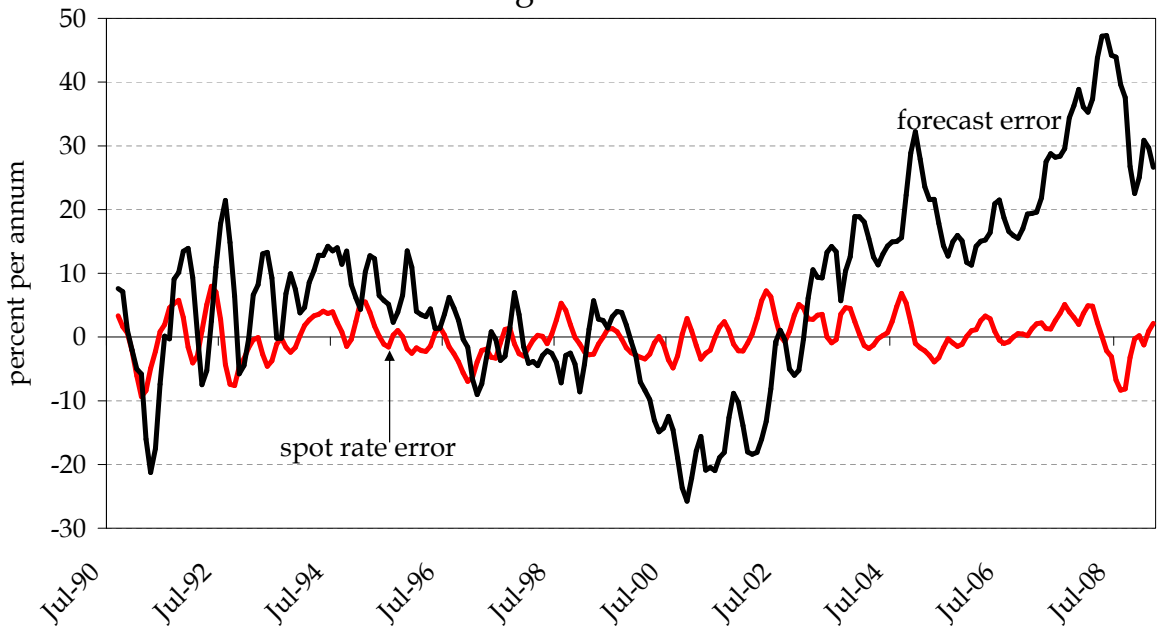


Source: Author's calculations using survey data and exchange rate data

Figure 3 plots the moving average mean forecast error $(E_t[s_{t+j}] - s_{t+j})$ — the black line — and the moving average mean spot rate prediction error $(s_t - s_{t+j})$ — the red line — for currencies against the U.S. dollar. The figure shows that investors would be better off on average using the current spot rate as their forecast. The formal test of this hypothesis is as follows: if $\gamma_1 = 1$, investors would

be better off placing more weight on the current spot price in their forecasts.

Figure 3: Mean spot rate error vs. mean forecast error
Currencies against the U.S. dollar



Source: Author's calculations using survey data and exchange rate data

5.1.1 British pound results

The results from regression (7) are found in Table 10. In all cases, the test of $\gamma_1 = 0$ is resoundingly rejected. On the other hand, the test of $\gamma_1 = 1$ cannot be rejected for thirteen of the sample countries. The exceptions are Belgium, the Netherlands and Norway. For all other countries, investors would fare much better on average by giving more weight to the contemporaneous spot rate in their forecasts. The joint hypothesis that there are no expectational errors, *i.e.* that $\delta_1 = \gamma_1 = 0$, is rejected for all countries at the one percent level. Overall, these results suggest a forceful rejection of rational expectations from the *Consensus* surveys for forecasts

of exchange rates against the pound.

Table 10: Tests of rational expectations, British pound exchange rates

$$E_t\Delta\hat{s}_{t+j} - \Delta s_{t+j} = \delta_1 + \gamma_1(E_t\Delta\hat{s}_{t+j}) + v_{t+j}$$

s_t	$\hat{\delta_1}$	$\hat{\gamma_1}$	p-value: $\hat{\gamma_1} = 0$	p-value: $\hat{\gamma_1} = 1$	R^2	DF	DW	F test: $\hat{\delta_1} = 0, \hat{\gamma_1} = 0$	p-value
AUT	0.098	1.196	0.000	0.114	0.436	(1, 100)	0.601	49.719	0.000
BLG	0.038	1.293	0.000	0.028	0.478	(1, 100)	0.621	48.715	0.000
CAD	0.310	1.071	0.000	0.530	0.321	(1, 223)	0.730	49.677	0.000
CHF	0.490	1.046	0.000	0.663	0.326	(1, 223)	0.627	51.048	0.000
DEU	0.131	1.195	0.000	0.223	0.342	(1, 100)	0.580	29.682	0.000
DNK	0.062	1.229	0.000	0.113	0.440	(1, 100)	0.627	37.979	0.000
ESP	-0.790	0.852	0.000	0.404	0.268	(1, 100)	0.595	12.807	0.000
FRA	0.108	1.192	0.000	0.171	0.368	(1, 100)	0.620	36.996	0.000
IRE	-0.214	1.114	0.000	0.470	0.385	(1, 100)	0.507	25.893	0.000
ITA	-0.805	0.927	0.000	0.670	0.265	(1, 100)	0.628	20.109	0.000
JPY	0.815	1.152	0.000	0.234	0.274	(1, 223)	0.558	40.973	0.000
NLD	0.098	1.252	0.000	0.081	0.449	(1, 100)	0.630	40.785	0.000
NOK	-0.027	0.820	0.000	0.060	0.272	(1, 223)	0.685	45.464	0.000
POR	-0.415	1.077	0.000	0.489	0.390	(1, 100)	0.656	50.362	0.000
SEK	-0.434	0.860	0.000	0.257	0.302	(1, 223)	0.646	71.454	0.000
ZAR	-1.488	1.074	0.000	0.500	0.355	(1, 188)	0.773	47.712	0.000

5.1.2 Euro results

Regression (7) results for currencies against the euro are found in Table 11. The test of $\gamma_1 = 0$ is rejected for all sample countries except Sweden. The test of $\gamma_1 = 1$ cannot be rejected for five of the eight sample countries: Canada, Denmark, Japan, South Africa and the U.K. Investors would fare much better on average by giving more weight to the contemporaneous spot rate in their forecasts. The joint hypothesis that there are no expectational errors, *i.e.* that $\delta_1 = \gamma_1 = 0$, cannot be rejected for Switzerland, but is rejected for all other countries at the five percent level. As with the pound results, I reject the hypothesis of rational expectations in euro exchange rate forecasts from the *Consensus* surveys.

Table 11: Tests of rational expectations, euro exchange rates

$$E_t\Delta\hat{s}_{t+j} - \Delta s_{t+j} = \delta_1 + \gamma_1(E_t\Delta\hat{s}_{t+j}) + v_{t+j}$$

s_t	$\hat{\delta_1}$	$\hat{\gamma_1}$	p-value: $\hat{\gamma_1} = 0$	p-value: $\hat{\gamma_1} = 1$	R^2	DF	DW	F test: $\hat{\delta_1} = 0, \hat{\gamma_1} = 0$	p-value
CAD	0.393	0.745	0.004	0.316	0.065	(1, 121)	0.665	5.361	0.006
CHF	0.077	0.453	0.063	0.025	0.060	(1, 121)	0.661	2.197	0.116
DNK	0.009	0.818	0.000	0.104	0.413	(1, 121)	0.933	35.512	0.000
JPY	-0.011	1.000	0.000	1.000	0.215	(1, 121)	0.521	18.548	0.000
NOK	-0.280	0.440	0.029	0.006	0.037	(1, 121)	0.569	3.085	0.049
SEK	-1.522	0.249	0.305	0.002	0.009	(1, 121)	0.513	30.526	0.000
UK	-0.449	0.864	0.000	0.596	0.093	(1, 121)	0.658	6.525	0.002
ZAR	-1.180	0.954	0.000	0.817	0.112	(1, 121)	0.678	15.199	0.000

5.1.3 U.S. dollar results

Regression (7) results for currencies against the U.S. dollar are found in Table 12. The test of $\gamma_1 = 0$ is rejected for all sample countries at the one percent significance level. The test of $\gamma_1 = 1$ cannot be rejected for all sample countries but South Africa. The joint hypothesis that there are no expectational errors, *i.e.* that $\delta_1 = \gamma_1 = 0$, is rejected for all countries at the one percent level. These results suggest a forceful rejection of rational expectations of currency movements against the U.S. dollar from the surveys.

Table 12: Tests of rational expectations, U.S. dollar exchange rates

$$E_t\Delta\hat{s}_{t+j} - \Delta s_{t+j} = \delta_1 + \gamma_1(E_t\Delta\hat{s}_{t+j}) + v_{t+j}$$

s_t	$\hat{\delta_1}$	$\hat{\gamma_1}$	p-value: $\hat{\gamma_1} = 0$	p-value: $\hat{\gamma_1} = 1$	R^2	DF	DW	F test: $\hat{\delta_1} = 0, \hat{\gamma_1} = 0$	p-value
AUT	-0.295	1.090	0.000	0.564	0.349	(1, 98)	0.641	25.530	0.000
BLG	-0.375	1.129	0.000	0.411	0.364	(1, 97)	0.651	27.577	0.000
CAD	0.917	-0.047	0.000	0.497	0.001	(1, 223)	0.775	44.510	0.000
CHF	-0.003	0.172	0.000	0.854	0.017	(1, 223)	0.715	50.589	0.000
DEU	-0.287	1.093	0.000	0.619	0.286	(1, 98)	0.641	17.696	0.000
DNK	0.015	0.673	0.000	0.611	0.370	(1, 223)	0.844	52.299	0.000
ESP	-0.832	0.824	0.000	0.404	0.193	(1, 97)	0.564	7.723	0.001
EUR	0.676	1.109	0.000	0.441	0.342	(1, 121)	0.669	32.002	0.000
FRA	-0.368	1.163	0.000	0.372	0.331	(1, 97)	0.670	21.691	0.000
IRE	0.345	0.969	0.000	0.878	0.278	(1, 97)	0.585	14.628	0.000
ITA	-1.038	0.978	0.001	0.937	0.197	(1, 97)	0.573	6.357	0.003
JPY	0.397	0.350	0.000	0.019	0.060	(1, 223)	0.505	80.401	0.000
NLD	-0.309	1.103	0.000	0.556	0.330	(1, 97)	0.643	20.831	0.000
NOK	-0.477	-0.051	0.000	0.919	0.001	(1, 223)	0.682	40.876	0.000
POR	-0.883	1.114	0.000	0.501	0.347	(1, 97)	0.607	23.041	0.000
SEK	-1.998	-0.171	0.000	0.721	0.013	(1, 223)	0.781	35.323	0.000
UK	0.931	-0.042	0.000	0.900	0.001	(1, 223)	0.765	16.127	0.000
ZAR	1.602	0.067	0.020	0.055	0.001	(2, 146)	0.662	0.000	0.000

The results of (7) across the sample reject the assumption of rational expectations strongly. There is also some evidence that investors would do well to place more weight on the current spot price in their forecasts. There is one problem with (7) however: the surveys appear on the right-hand side as well as the left-hand-side. This introduces the possibility of measurement error.

5.2 An alternative test of rational expectations

To get rid of the problem of measurement error, I perform a different test of rational expectations, replacing $E_t\Delta\hat{s}_{t+j}$ on the right-hand side of (7) with the forward discount, resulting in:

$$E_t\Delta\hat{s}_{t+j} - \Delta s_{t+j} = \delta_2 + \gamma_2(f_t - s_t) + v_{t+j} \tag{8}$$

Why switch out the expected depreciation ($E_t\Delta\hat{s}_{t+j}$) for the forward discount ($f_t - s_t$)? First of all, the results of Section 5.1 demonstrate that the forward discount is highly correlated with the expected depreciation. As $(f_t - s_t)$ is free of

measurement error and the data is readily available to investors in real-time, the forward discount serves as an excellent instrumental variable. If $\beta_1 > 0$, speculation could have yielded profits if an investor had "bet against the market". As Froot and Frankel point out, betting against the market is much more practical if expressed as "bet against the (observable) forward discount" than as "do the opposite of whatever you were going to do".

5.2.1 British pound results

Table 13 reports OLS regressions of (8). The data again reject the hypothesis of rational expecations ($\delta_2 = \gamma_2 = 0$) for all countries but Spain, Ireland, Japan and Portugal. The test of $\gamma_2 = 0$ is rejected in favour of excessive speculation for all countries but Canada, Spain, Ireland, Italy, Japan and Portugal.

Table 13: Tests of rational expectations, British pound exchange rates

$$E_t \Delta \hat{s}_{t+j} - \Delta s_{t+j} = \delta_2 + \gamma_2 (f_t - s_t) + v_{t+j}$$

s_t	$\hat{\delta_2}$	$\hat{\gamma_2}$	p-value: $\hat{\gamma_2} = 0$	R^2	DF	DW	F test: $\hat{\delta_2} = \hat{\gamma_2} = 0$	p-value
AUT	1.922	4.322	0.000	0.112	(2, 100)	0.326	8.049	0.001
BLG	1.824	3.859	0.000	0.117	(2, 100)	0.331	8.384	0.000
CAD	-0.714	0.245	0.885	0.000	(2, 223)	0.392	2.350	0.098
CHF	2.143	2.878	0.000	0.065	(2, 223)	0.460	7.914	0.001
DEU	1.414	3.398	0.001	0.097	(2, 100)	0.338	6.932	0.002
DNK	0.837	3.245	0.000	0.150	(2, 100)	0.343	7.804	0.001
ESP	-0.862	0.919	0.289	0.019	(2, 100)	0.376	1.650	0.197
FRA	0.822	3.292	0.000	0.147	(2, 100)	0.336	7.374	0.001
IRE	0.537	0.187	0.801	0.001	(2, 100)	0.375	0.571	0.567
ITA	-1.607	0.663	0.288	0.011	(2, 100)	0.430	7.871	0.001
JPY	1.225	0.770	0.720	0.001	(2, 223)	0.329	0.214	0.808
NLD	2.478	4.950	0.000	0.162	(2, 100)	0.369	10.919	0.000
NOK	-0.759	1.740	0.004	0.044	(2, 223)	0.499	9.218	0.000
POR	-0.219	1.114	0.102	0.036	(2, 100)	0.353	1.523	0.223
SEK	-1.840	1.389	0.065	0.022	(2, 223)	0.452	30.458	0.000
ZAR	-4.559	2.727	0.020	0.038	(2, 146)	0.376	2.968	0.055

5.2.2 Euro results

Table 14 reports OLS regressions of (8) for currencies against the euro. The data reject the hypothesis of rational expectations ($\delta_2 = \gamma_2 = 0$) for all countries but

Switzerland. The test of $\gamma_2 = 0$ is rejected in favour of excessive speculation for half of the sample countries: Canada, Japan, South Africa, and the U.K.

Table 14: Tests of rational expectations, euro exchange rates

$$E_t \Delta \hat{s}_{t+j} - \Delta s_{t+j} = \delta_2 + \gamma_2 (f_t - s_t) + v_{t+j}$$

s_t	$\hat{\delta_2}$	$\hat{\gamma_2}$	p-value: $\hat{\gamma_2} = 0$	R^2	DF	DW	F test: $\hat{\delta_2} = \hat{\gamma_2} = 0$	p-value
CAD	0.206	7.495	0.000	0.116	(2, 121)	0.667	10.634	0.000
CHF	0.205	0.451	0.836	0.000	(2, 121)	0.508	0.031	0.970
DNK	0.050	-0.080	0.783	0.001	(2, 121)	1.037	4.783	0.010
JPY	-6.891	-9.804	0.004	0.077	(2, 121)	0.402	4.461	0.014
NOK	-0.922	1.110	0.230	0.015	(2, 121)	0.538	2.970	0.055
SEK	-1.895	0.354	0.852	0.000	(2, 121)	0.491	34.206	0.000
UK	-1.703*	6.163	0.001	0.090	(2, 121)	0.577	9.797	0.000
ZAR	-9.232	6.086	0.000	0.143	(2, 121)	0.527	16.576	0.000

5.2.3 U.S. dollar results

U.S. dollar results for OLS regressions of (8) are reported in Table 15. The data reject the hypothesis of rational expecations ($\delta_2 = \gamma_2 = 0$) for all countries but Austria, Belgium, Spain, France, the Netherlands, Norway, and the U.K. The test of $\gamma_2 = 0$ is rejected in favour of excessive speculation for just over half of the sample countries.

Table 15: Tests of rational expectations, U.S. dollar exchange rates

$$E_t \Delta \hat{s}_{t+j} - \Delta s_{t+j} = \delta_2 + \gamma_2 (f_t - s_t) + v_{t+j}$$

s_t	$\hat{\delta_2}$	$\hat{\gamma_2}$	p-value: $\hat{\gamma_2} = 0$	R^2	DF	DW	F test: $\hat{\delta_2} = \hat{\gamma_2} = 0$	p-value
AUT	0.889	0.675	0.447	0.005	(2, 98)	0.389	1.117	0.332
BLG	1.031	1.048	0.187	0.014	(2, 97)	0.397	1.988	0.142
CAD	-0.614	1.091	0.037	0.010	(2, 223)	0.364	3.077	0.048
CHF	1.087	2.281	0.011	0.039	(2, 223)	0.444	3.321	0.038
DEU	0.738	0.742	0.001	0.007	(2, 100)	0.410	6.932	0.002
DNK	-0.223	1.676	0.003	0.035	(2, 223)	0.422	4.756	0.010
ESP	1.463	-1.480	0.045	0.062	(2, 73)	0.448	2.366	0.101
EUR	-0.247	4.716***	0.003	0.076	(2, 121)	0.467	6.409	0.002
FRA	0.807	0.468	0.514	0.004	(2, 97)	0.387	1.188	0.309
IRE	-2.090	-0.937	0.027	0.033	(2, 73)	0.717	6.707	0.002
ITA	2.466	-2.470	0.033	0.078	(2, 97)	0.437	2.631	0.077
JPY	2.505	2.524	0.001	0.042	(2, 223)	0.365	7.520	0.001
NLD	0.906	1.213	0.157	0.018	(2, 97)	0.416	1.722	0.184
NOK	-0.791	0.436	0.547	0.002	(2, 223)	0.382	1.642	0.196
POR	1.720	-0.660	0.217	0.023	(2, 73)	0.359	2.429	0.095
SEK	-1.897	0.621	0.535	0.005	(2, 223)	0.367	8.432	0.000
UK	-0.873	-1.429	0.271	0.013	(2, 223)	0.406	1.558	0.213

Section 5 shows that agents would be better off using the current spot price as their forecast. More importantly, the assumption of rational expectations is strongly rejected by the data. Both Fama (1984), and Hodrick and Srivistava (1986) assume rational expectations hold in their analysis of the forward discount bias and tests for the existence of a risk premium. More recent work has also assumed the existence of rational expectations (Engel (1996), Backus *et al.* (2001), Sarno (2005)). Future research should avoid this assumption if at all possible, as the data strongly rejects it.

6 Tests of the forward discount bias using the survey data

The results in Section 3 demonstrated the failure of the joint hypothesis of UIP and rational expectations over most of the sample currencies across various horizons. Section 5 showed that the rational expectations assumption built into the classic tests of unbiasedness does not hold because the forecast errors can be predicted, either by the forecast itself or by the forward discount, both of which are known at time t. Does the failure of rational expectations explain the rejection of the joint hypothesis of UIP and rational expectations? Might UIP hold given the expected depreciation rather than the actual?

Tests of the forward discount bias without the assumption of rational expectations are conducted below. The test is as follows:

$$E_t \Delta \hat{s}_{t+j} = \alpha_1 + \beta_1 (f_t - s_t) + \epsilon_t. \tag{9}$$

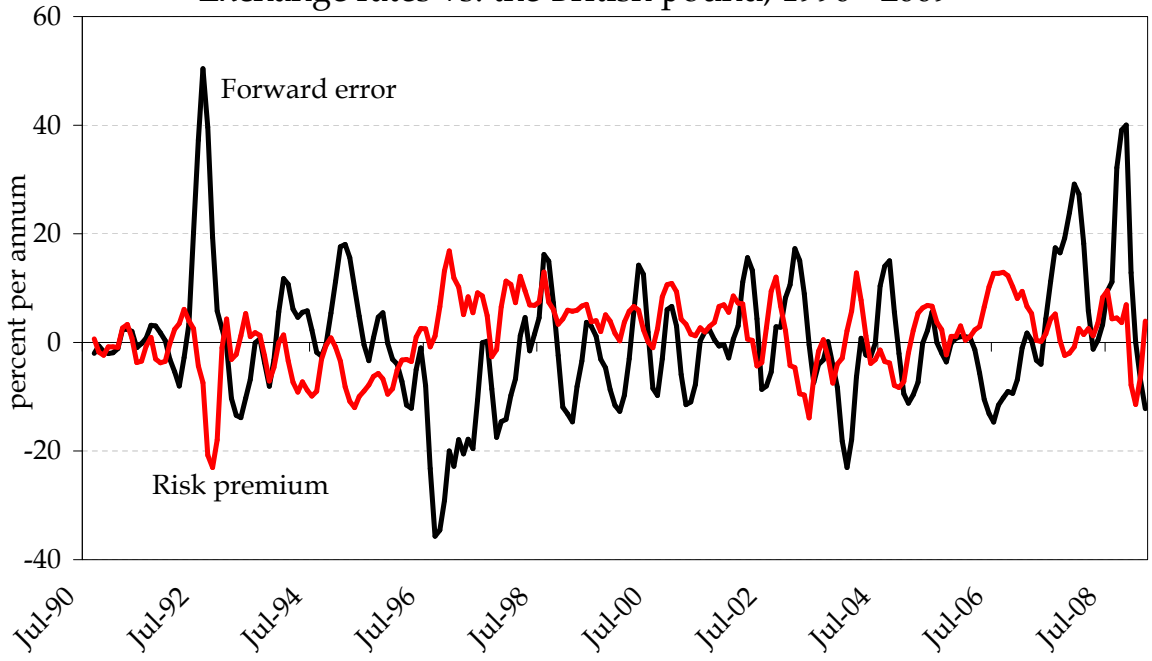
This is identical to Fama's regression test (4), except I regress the survey measure of expected depreciation against the forward discount instead of the actual depreciation against the forward discount. As in Section 3, the null hypothesis is that $\beta_1 = 1$ and UIP holds. ϵ_t, the regression error in (9), captures the random measurement error of the exchange rate expectations. In other words, $E_t \Delta \hat{s}_{t+j} = E_t \Delta s_{t+j} + \epsilon_t$, where $E_t \Delta s_{t+j}$ is the true unobservable market expected change in the spot rate. Because the surveys appear only on the left-hand side of

(9), the test statistics are robust to the presence of random measurement error in the survey data.

Equation (9) can also be viewed as a test of the correlation of the forward discount with the risk premium. If the correlation is zero, $\beta_1 = 1$, and there is no time-varying risk premium. Figures 4, 5 and 6 plot the mean of the risk premium ($rp_t = f_t - E_t[s_{t+j}]$) — the red line — and the mean of the forward discount prediction errors ($f_t - s_{t+j}$) — the black line. The plots are 3-month moving averages of the risk premia and forward rate errors aggregated across all sample countries with survey data available. The risk premia and forward rate errors look uncorrelated at best, or even negatively correlated, suggesting no time-varying risk premium, or a risk premium acting against the forward discount bias.

Figure 4: Risk premium and forward error

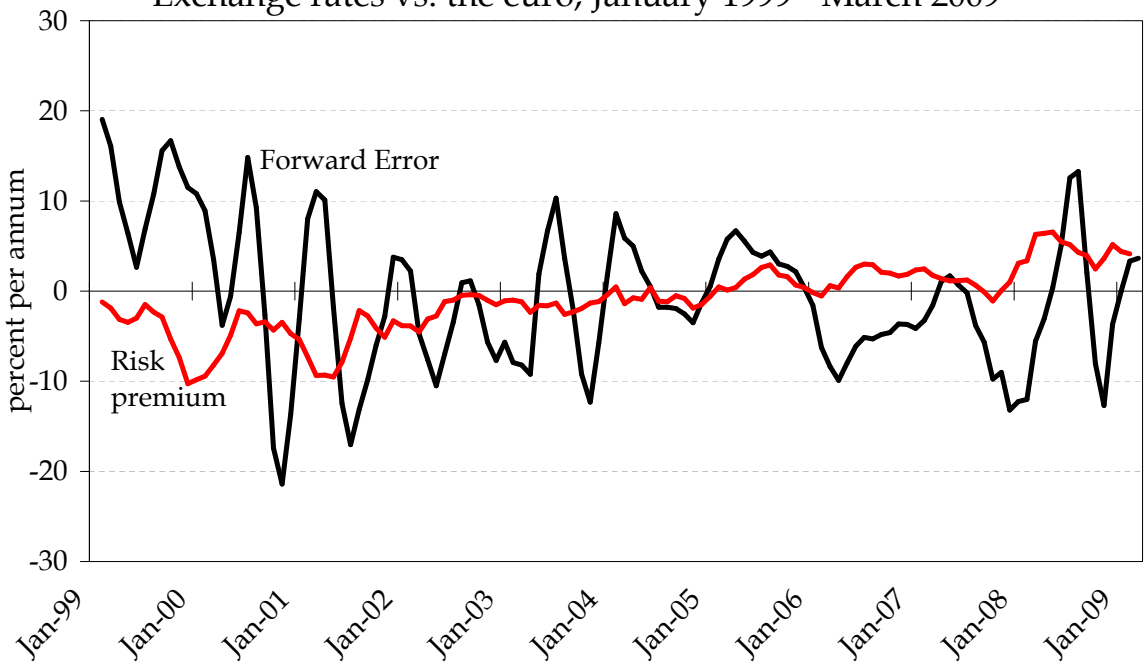
Exchange rates vs. the British pound, 1990 - 2009



Source: Author's calculations using survey data and exchange rate data

Figure 5: Risk premium and forward error

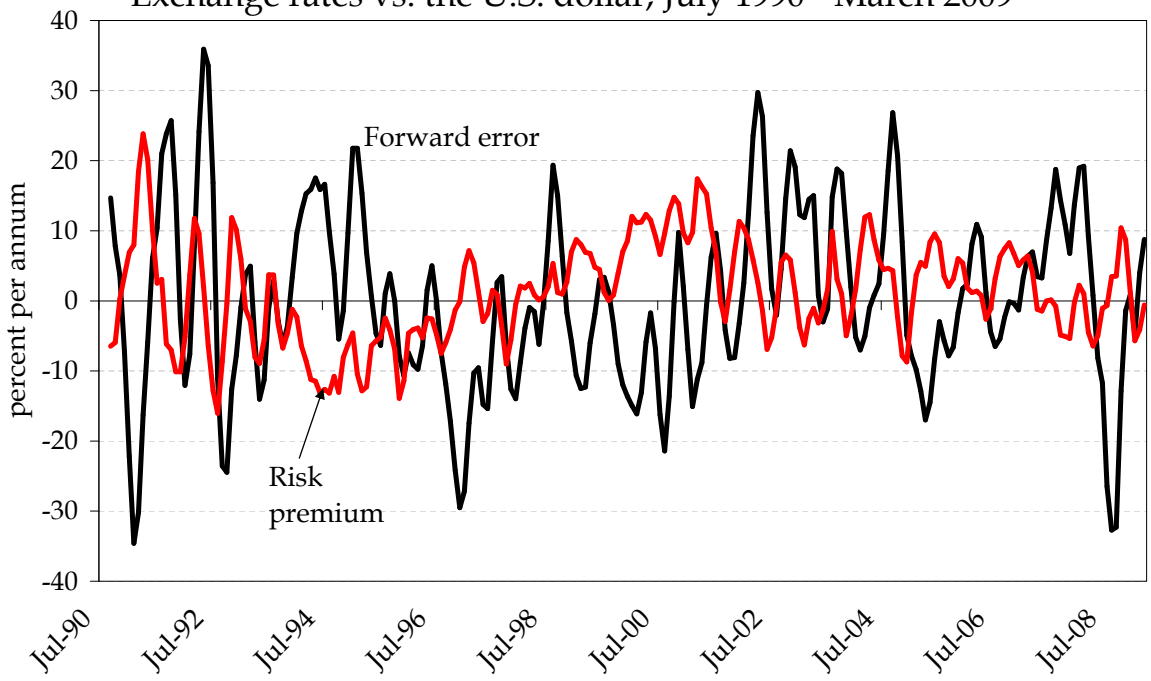
Exchange rates vs. the euro, January 1999 - March 2009



Source: Author's calculations using survey data and exchange rate data

Figure 6: Risk premium and forward error

Exchange rates vs. the U.S. dollar, July 1990 - March 2009



Source: Author's calculations using survey data and exchange rate data

Equation (9) also allows a test of the hypothesis of a mean-zero risk premium: $\alpha_1 = 0$. Combining the test for no time-varying risk premium with the test for a mean-zero risk premium yields the hypothesis of a risk premium equal to zero, in which case the forward discount bias is explained entirely by forecast error: $E_t \Delta \hat{s}_{t+j} = (f_t - s_t)$. The plots of the aggregated risk premia in Figures 4, 5, and 6 do not seem to be mean-zero. Although eyeball econometrics are sometimes useful, a formal analysis is conducted below.

6.1 British pound results

Table 15 reports the OLS regressions of (9) for currencies against the pound. The data provide some evidence in favour of the null hypothesis of no time-varying

risk premium. $\hat{\beta_1}$ is statistically indistinguishable from one for six of the sixteen countries in the sample: Canada, Ireland, Italy, Japan, Norway and South Africa. For the other countries, the hypothesis that the risk premium is correlated with the forward discount cannot be rejected. Notice, however, that $\hat{\beta_1}$ is statistically significant and greater than one for the other ten countries. This implies that the variance of expected depreciation is greater than that of the risk premium, matching up with the descriptive statistics found in Table 9. *i.e.* $Var(rp_t) < Var(E_t[s_{t+j}])$.

What about the null hypothesis of a mean-zero risk premium? The hypothesis cannot be rejected for Canada, Portugal and South Africa. For the other thirteen sample countries, there is strong evidence of a constant term in the risk premium. Notice that the constant term in the risk premium can be significantly positive or negative, depending on the country in question.

In addition, the F-tests shown in Table 15 reject the joint hypothesis that $\alpha_1 = 0$ and $\beta_1 = 1$ at the ten percent significance level for all countries, at the five percent level for thirteen of the countries, and at the one percent level for eleven of the countries. Thus, the hypothesis that $E_t\Delta\hat{s}_{t+j} = (f_t - s_t)$ is rejected.

Table 15: Forward discount bias using the survey data, British pound exchange rates

$$E_t\Delta\hat{s}_{t+j} = \alpha_1 + \beta_1(f_t - s_t) + \epsilon_t$$

s_t	$\hat{\alpha_1}$	$\hat{\beta_1}$	p-value: $\hat{\beta_1} = 1$	R^2	DF	DW	F test: $\hat{\alpha_1} = 0, \hat{\beta_1} = 1$	p-value
AUT	1.381***	3.286***	0.001	0.205	(2, 100)	1.060	6.584	0.002
BLG	1.400***	3.029***	0.000	0.244	(2, 100)	1.026	7.606	0.001
CAD	-0.336	2.093***	0.112	0.034	(2, 223)	1.263	6.320	0.002
CHF	0.889**	1.808***	0.054	0.082	(2, 223)	1.150	2.511	0.084
DEU	0.820**	2.288***	0.014	0.176	(2, 100)	1.160	3.258	0.043
DNK	0.649**	2.745***	0.002	0.362	(2, 100)	1.316	5.278	0.007
ESP	-0.629**	2.384***	0.002	0.331	(2, 100)	1.266	6.044	0.003
FRA	0.574*	2.665***	0.003	0.366	(2, 100)	1.266	4.826	0.010
IRE	0.736***	0.548	0.414	0.018	(2, 100)	0.880	4.516	0.013
ITA	-1.113***	1.286***	0.467	0.124	(2, 100)	1.504	14.776	0.000
JPY	2.044*	2.074**	0.276	0.022	(2, 223)	1.062	4.858	0.009
NLD	1.711***	3.567***	0.000	0.287	(2, 100)	1.221	8.494	0.000
NOK	-0.956***	1.151**	0.760	0.043	(2, 223)	1.137	14.474	0.000
POR	-0.270	1.720***	0.039	0.248	(2, 100)	1.438	2.422	0.094
SEK	-1.504***	2.383***	0.005	0.154	(2, 223)	1.359	59.725	0.000
ZAR	1.046	-0.239	0.114	-0.006	(2, 146)	1.150	2.436	0.091

*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

6.2 Euro results

The results of regression (9) for exchange rates against the euro are shown in Table 16. The data provide some evidence in favour of the null hypothesis of no time-varying risk premium. $\hat{\beta_1}$ is statistically indistinguishable from one for four of the eight countries in the sample: Norway, South Africa, Switzerland, and the U.K.

As with the pound results, there is strong support for a constant term in the risk premium. F-tests also reject the joint hypothesis that $\alpha_1 = 0$ and $\beta_1 = 1$ soundly. Thus, the hypothesis that $E_t\Delta\hat{s}_{t+j} = (f_t - s_t)$ cannot be supported.

Table 16: Forward discount bias using the survey data, euro exchange rates

$E_t\Delta\hat{s}_{t+j} = \alpha_1 + \beta_1(f_t - s_t) + \epsilon_t$

s_t	$\hat{\alpha_1}$	$\hat{\beta_1}$	p-value: $\hat{\beta_1} = 1$	R^2	DF	DW	F test: $\hat{\alpha_1} = 0, \hat{\beta_1} = 1$	p-value
CAD	0.571***	2.296***	0.068	0.086	(2, 121)	1.170	13.027	0.000
CHF	-0.025	0.257	0.576	-0.008	(2, 121)	0.652	4.452	0.014
DNK	0.068***	-0.416	0.000	0.029	(2, 121)	1.276	15.617	0.000
JPY	-4.258***	-6.381***	0.000	0.145	(2, 121)	0.455	22.096	0.000
NOK	-1.009***	1.415***	0.202	0.117	(2, 121)	1.004	23.209	0.000
SEK	-1.469***	-1.341**	0.000	0.029	(2, 121)	1.088	152.834	0.000
UK	0.856*	1.231	0.827	0.029	(2, 121)	1.298	32.916	0.000
ZAR	1.250	0.856	0.740	0.015	(2, 121)	0.920	7.184	0.001

*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

6.3 U.S. dollar results

The results of regression (9) for U.S. dollar exchange rates are found in Table 17. The data provide very strong evidence in favour of the null hypothesis of no time-varying risk premium, as $\hat{\beta_1}$ is statistically indistinguishable from one for all currencies in the sample except the deutchsemark and the euro. Estimates include 0.990 for the Belgian franc, 1.028 for the Canadian dollar, 1.189 for the Spanish pesata, 1.085 for the Netherlands guilder, 1.006 for the Norwegian Krone, and 0.759 for the Portugese escudo. The euro estimate is 2.623, implying $var(rp_t) < var(E_t\Delta s_{t+j})$.

F-tests of the joint hypothesis that $\alpha_1 = 0$ and $\beta_1 = 1$ are rejected in all cases but for the Swiss franc, Italian lira, and British pound. As a result, $E_t\Delta\hat{s}_{t+j} =$

$(f_t - s_t)$ for these countries, meaning the hypothesis that the risk premium equals zero cannot be rejected. For the remaining countries, there is strong evidence of a constant term in the risk premium. Indeed, $\hat{\alpha_1}$ is large and statistically significant for most countries in the sample.

Table 17: Forward discount bias using the survey data, U.S. dollar exchange rates

$$E_t \Delta \hat{s}_{t+j} = \alpha_1 + \beta_1 (f_t - s_t) + \epsilon_t$$

s_t	$\hat{\alpha_1}$	$\hat{\beta_1}$	p-value: $\hat{\beta_1} = 1$	R^2	DF	DW	F test: $\hat{\alpha_1} = 0, \hat{\beta_1} = 1$	p-value
AUT	0.998***	0.642	0.472	0.006	(2, 100)	1.014	4.960	0.009
BLG	1.125***	0.990**	0.982	0.032	(2, 100)	1.019	5.932	0.004
CAD	-0.596***	1.028***	0.925	0.032	(2, 223)	1.252	9.682	0.000
CHF	0.556	1.486***	0.317	0.049	(2, 223)	1.021	1.336	0.265
DEU	0.820**	2.288***	0.014	0.176	(2, 100)	1.160	3.258	0.043
DNK	-0.352	1.661***	0.030	0.111	(2, 223)	1.040	3.624	0.028
ESP	0.624*	1.189**	0.713	0.113	(2, 76)	1.377	2.933	0.059
EUR	-0.999***	2.623***	0.028	0.084	(2, 121)	1.170	11.594	0.000
FRA	0.793***	0.706*	0.412	0.023	(2, 100)	1.143	4.017	0.021
IRE	-1.670***	1.375***	0.432	0.159	(2, 76)	1.374	21.125	0.000
ITA	0.311	0.389	0.331	0.000	(2, 100)	1.414	0.684	0.507
JPY	0.561*	0.651*	0.333	0.008	(2, 223)	0.950	7.388	0.001
NLD	1.002***	1.085**	0.861	0.043	(2, 100)	1.081	5.218	0.007
NOK	-0.921***	1.006***	0.986	0.036	(2, 223)	0.936	8.220	0.000
POR	1.206**	0.759	0.600	0.083	(2, 76)	1.285	5.186	0.008
SEK	-1.766***	1.612***	0.105	0.112	(2, 223)	1.124	28.521	0.000
UK	-0.218	0.600	0.472	0.007	(2, 223)	1.435	0.477	0.622
ZAR	1.046	-0.239	0.114	-0.006	(2, 146)	1.150	2.436	0.091

*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

Overall, the results of the unbiasedness regressions using the survey data suggest that UIP holds for about half of the sample countries against the pound and euro, and the majority of the sample countries against the U.S. dollar. This is in stark contrast with the results of Section 3, where there is a strong forward discount bias for the majority of countries against all three base currencies. Dropping the faulty assumption of rational expectations gives much stronger evidence for UIP.

This section also provided a formal test of the hypothesis that time-varying risk premia explain the forward premium puzzle. Again, in about half of the sample exchange rates against the euro and pound, the existence of a time-varying risk premium was rejected. In all but two cases against the U.S. dollar, the hy-

pothesis was rejected. For most of the remaining countries, the slope coefficient $\hat{\beta_1}$ was greater than one, meaning a time-varying risk premium exists but acts against the forward discount bias. Taken as a whole, this provides fairly strong evidence against the hypothesis that time-varying risk premia can account for the forward discount bias.

7 Conclusion

A common result in the international finance literature is that the forward discount is biased and negatively related to the change in the exchange rate. In the first part of this essay, I find that the forward discount bias does not necessarily hold across all currencies or time periods. Rather, for pound and euro cross-exchange rates, the forward premium puzzle disappears over time. For U.S. dollar exchange rates, the evidence is not as clear, but there is a general trend toward a decline in the discount bias over time. Notably, over the last five years, the results suggest a complete reversal of the historical anomaly across all three base currencies, with a strong movement toward unbiasedness and UIP. The reasons for this are unclear. Future work should address this result, particularly if the overturning of the forward discount bias is maintained over a longer time period.

The second half of the essay examines two different hypotheses offered to explain the forward premium puzzle. The first is that there is a time-varying risk premium in the foreign exchange market. The second is that expectational errors are the cause of any forward discount bias. I use survey data on exchange rate expectations to analyse the presence of a time-varying risk premium, expectational errors or a combination of the two from July 1990 to June 2009. Five main results can be taken from this analysis.

1. The data provide strong evidence that expected changes in the exchange rate are not mean zero or constant, but are highly variable and differ significantly from the current spot price, undermining the common assumption in the literature of random walk expectations.

2. The hypothesis that the variance of the risk premium is greater than the variance of expected depreciation is strongly rejected.

3. The hypothesis of rational expectations is also rejected over the majority of currencies against the pound, euro, and U.S. dollar.

4. Using the survey data, I test for unbiasedness in the foreign exchange market without the rational expectations assumption and find that UIP holds for about half of the euro and pound sample exchange rates and all but two of the sample exchange rates against the U.S. dollar. In other words, the data rejects the existence of a time-varying risk premium for half of the currencies against the euro and pound, and the majority of currencies against the U.S. dollar.

5. When there is evidence that a time-varying risk premium exists, it is by and large acting in the opposite direction of the forward discount bias.

In summary, the body of evidence points to systematic expectational errors as the more likely cause of the forward discount bias rather than time-varying risk premia.

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