RISK, POLICY RULES, AND NOISE: RETHINKING DEVIATIONS FROM UNCOVERED INTEREST PARITY

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Abstract

This paper investigates why the forward premium predicts the future depreciation with the 'wrong' sign and why the unobserved deviation from rational uncovered interest parity is negatively correlated with and is more volatile than the rationally expected depreciation. We examine the ability of three models to account for the data. They are, (i) the standard representative-agent asset pricing model, (ii) a model of monetary-policy with exchange-rate feedback, and (iii) a model of noise trading. Although the noise-trader model is highly stylized, calibrating the model to estimates from the literature analyzing survey expectations produces fragmentary evidence in favor of this approach.

Keywords: Risk premia, foreign exchange, policy rules, noise trading

JEL Classification
F31, F47

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Introduction

In this paper, we study possible causes of an asset pricing anomaly in international finance known as the forward premium bias.[1] The anomalous result is that the forward premium helps to predict the future percentage rate of currency depreciation, but with the wrong (negative) sign. Fama (1984) demonstrated that a corollary to the negative forward premium bias is that the deviation from rational uncovered interest parity, $p_t \equiv f_t - E_t s_{t+1}$, is negatively correlated with and is more volatile than the rationally expected rate of depreciation, $E_t(\Delta s_{t+1})$, where f_t and s_t are the logarithms of the forward and spot exchange rates, respectively. These facts have long posed a challenge to international economic theory. In this paper, we explore three approaches to explain these puzzles. They are: i) the standard representative-agent asset pricing model, ii) a monetary-policy rule model with exchange-rate feedback, and iii) a model of noise trading.

We begin by presenting the stylized facts that characterize the problem using quarterly data for the US, Britain, Germany, and Japan from 1976.1 to 1994.1. Our analysis here is organized around a vector error correction model (VECM) for the logarithms of spot and forward exchange rates which we employ to generate implied values of p_t and $E_t(\Delta s_{t+1})$. We establish the plausibility of our estimates by showing that they closely match a number of key sample moments and then ask if the estimated values of p_t behave like risk premia implied by the standard representative agent asset pricing model. While the extant literature has recognized that the standard model has difficulty in generating sufficiently volatile risk premia, our results suggest that the model breaks down at a deeper level than an inability to match unconditional second moments of the data.[2] Specifically, we find little evidence that the model even predicts p_t with the correct sign. We devote special attention to the implication that the sign of the risk premium is determined by the sign of the conditional covariance between the intertemporal marginal rate of substitution of money and the payoff from forward currency speculation. We find that the theoretically implied sign changes are largely absent from the data.

Next, we re-examine a recent contribution by McCallum (1994), who developed a non-risk interpretation of the p_t. In his model, monetary policy involves setting the interest differential according to a rule that smoothes interest rate fluctuations and offsets contemporaneous depreciations of the domestic currency. The essential element in explaining the

[1] See Hodrick (1987), Engel (1996), and Lewis (1995) for surveys of this literature.

[2] See Bekaert (1994), Backus *et. al.* (1993), and Cecchetti *et. al.* (1994), who show that the model generates insufficient volatility in the intertemporal marginal rate of substitution to account for the data.

data is the feedback of the contemporaneous depreciation to the interest differential which induces a perfect negative correlation between the p_t and the $E_t(\Delta s_{t+1})$. While McCallum and others report empirical support for the model, our inquiry into suggests two reasons to view his results with caution.[3] First, his theory requires the coefficient on the contemporaneous depreciation in the policy rule to be positive but when we estimate the policy rule, we obtain negative point estimates of this coefficient. Second, the results are not robust to a reasonable reformulation of the policy rule. The original formulation postulates the interest rate differential to depend on the contemporaneous rate of depreciation, which can be rationalized by a trading sequence in which the foreign exchange market closes before the monetary policy authorities determine the current period interest differential. A plausible alternative scenario, however, is that the interest differential is determined by the authorities prior to the opening of the foreign exchange market. Under this alternative trading sequence, the interest rate rule depends on the *lagged* depreciation and the forward premium bias vanishes.

Our third exploration examines the De Long *et. al.* (1990) model which combines rational investors with noise traders who hold distorted beliefs concerning future investment returns. Our treatment of noise-trader beliefs builds upon Froot and Frankel's (1989) finding that foreign exchange traders place excessive weight on the forward premium in forming their expectations of the future depreciation. Like McCallum's model, the p_t that emerges in this model has nothing to do with covariance risk. Instead, heterogeneity in beliefs among economic agents creates trading volume and induces systematic movements in p_t that are correlated with the forward premium. Drawing on empirical estimates from the literature analyzing survey exchange rate expectations, we find that plausible calibrations of the model are available. In addition to providing an explanation of the forward premium bias, this model provides an account for the apparent short-term overreaction of exchange rate changes and the gradual adjustment towards its fundamental value in the long run.[4]

The paper is organized as follows. Section 1 begins by presenting some stylized facts about the forward premium bias. Section 2 asks if the VECM-generated p_ts behave like the risk premia of the standard representative-agent asset pricing model. McCallum's policy rule

[3] See also, Zietz (1995) whose Monte Carlo simulations of McCallum's feedback rule yield a more accurate account of the data than several alternative models of p_t.

[4] Mark (1995), Chinn and Meese (1995), Mark and Choi (1996), Chen and Mark (1996), and Lothian and Taylor (1996) report empirical evidence of long-horizon reversion of exchange rates to their fundamental values. In related work on quasi-rational modeling of exchange rate determination, Goldberg and Frydman (1996) show that the exchange rate will overshoot and drift away from the fundamentals when agents hold heterogeneous beliefs and have imperfect knowledge of the economy.

theory is examined in section 3, the noise trader model is presented in section 4, and section 5 concludes.

1. Some Stylized Facts

To understand the behavior of p_t, we begin by organizing our discussion around Fama's (1984) decomposition of the forward premium,[5]

$$f_t - s_t = E_t(\Delta s_{t+1}) + p_t. \tag{1}$$

Using (1), the ex post depreciation can be expressed as $\Delta s_{t+1} = (f_t - s_t) + (v_{t+1} - p_t)$, where $v_{t+1} \equiv \Delta s_{t+1} - E_t(\Delta s_{t+1})$ is a rational forecast error. Since p_t is by construction, correlated with $f_t - s_t$, a regression of the ex post depreciation on the forward premium,

$$\Delta s_{t+1} = c + \beta(f_t - s_t) + \epsilon_{t+1}, \tag{2}$$

can be viewed as subject to an omitted variables bias which causes $\beta \neq 1$.[6] Our own estimates of eq.(2) from a quarterly sample of dollar rates of the pound (BP), the deutsche-mark (DM) and the yen (JY) are reported in table 1.[7] As can be seen, the estimated slope coefficients are all negative and significantly so at the five-percent level (under one-sided tests) for the BP and at the one-percent level for the yen.[8]

Taking the forward rate as an unbiased predictor of the future spot rate ($\beta = 1$) as a benchmark case, negative values of β imply that the forward premium (which by covered

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[5] We refrain from calling p_t a risk premium since we have not yet forked over a theory in which it is offered to investors as compensation for bearing risk. At this point, p_t is merely part of a statistical decomposition of the forward premium.

[6] Because s_t and f_t appear to be I(1), researchers such as Evans and Lewis (1993) and Elliott (1993) argue that the forward bias should be measured by the cointegrating regression $s_{t+1} = c + \beta f_t + v_{t+1}$ since under the alternative ($\beta \neq 1$), $E_t s_{t+1} = \beta f_t$ and the error term in (2) is $\epsilon_{t+1} = (\beta - 1)s_t + v_{t+1} \sim I(1)$. We study (2) because we are interested in studying the behavior of a stationary p_t and how its presence biases the slope coefficient away from 1. We take as a maintained hypothesis that the forward premium, and therefore the expected excess return p_t are I(0).

[7] The sample extends from 1976.1 to 1994.1. We follow Hansen and Hodrick (1983) by starting the sample in 1976.1 after the Rambouillet Conference. The sources for the exchange rates as well as the other data used in the paper are described in the appendix.

[8] Using monthly data and forward rates, McCallum's (1994) slope coefficient estimates are -4.74, -4.20, and -3.33 for the dollar/pound, dollar/D-mark, and dollar/yen rates over the period 1978–1990. The more negative estimates are a consequence of the particular sample period that he employs. We also note that Bekaert and Hodrick (1993) show that the forward premium bias is not caused by bid–ask spreads nor by failure to account for the two-day delivery lag on currency price quotations.

Table 1: Regressions of Future Depreciation on Forward Premium

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

	dollar/pound	dollar/D-mark	dollar/yen
$\hat{c}$	-0.013	0.006	0.033
(s.e.)	(0.009)	(0.009)	(0.010)
$\hat{\beta}$	-1.522	-0.136	-2.526
(s.e.)	(0.863)	(0.839)	(0.903)

interest parity is equivalent to the nominal interest rate differential) helps to predict the future depreciation but with the wrong sign. Fama demonstrates that the negative slope coefficients imply that the $p_t = i_t - i_t^* - E_t\Delta s_{t+1} = f_t - E_t s_{t+1}$, is both negatively correlated with and is more volatile than $E_t\Delta s_{t+1}$. That is, $\text{Cov}(p_t, E_t\Delta s_{t+1}) < 0$, and $\text{Var}(p_t) > \text{Var}(E_t\Delta s_{t+1})$. While Fama's analysis deduced the sign of the covariance, in the next two subsections we generate plausible estimates of p_t and $E_t\Delta s_{t+1}$ and the covariance between them.

1.1. A VECM for Log Spot and Forward Exchange Rates

Let $x_t' = (f_t, s_t), \varepsilon_t' = (\varepsilon_{f,t}, \varepsilon_{s,t})$, $z_t = f_t - s_t$ be the forward premium, and write the k-th order VECM in deviations from the mean form as

$$\Delta x_{t+1} = A(L)\Delta x_t + \delta z_t + \varepsilon_{t+1} \tag{3}$$

where $A(L)$ is a 2×2 k-th order matrix polynomial in the lag operator L, and $\delta' = (\delta_1, \delta_2)$. We fix the cointegration vector to be $e_0 = (1, -1)$.[9] Since $z_t = e_0 x_t$, premultiplying (3) by e_0 yields

$$z_{t+1} = e_0 A(L)\Delta x_t + (1 + \delta_1 - \delta_2) z_t + e_0 \varepsilon_{t+1}. \tag{4}$$

The system (3) and (4) can be stacked together as

$$\begin{pmatrix} \Delta x_{t+1} \\ z_{t+1} \end{pmatrix} = \begin{pmatrix} A(L) & \delta \\ e_0 A(L) & 1 + \delta_1 - \delta_2 \end{pmatrix} \begin{pmatrix} \Delta x_t \\ z_t \end{pmatrix} + \begin{pmatrix} \varepsilon_{t+1} \\ \varepsilon_{f,t+1} - \varepsilon_{s,t+1} \end{pmatrix} \tag{5}$$

[9] Baillie and Bollerslev (1989), Clarida and Taylor (1993), and Hai, Mark, and Wu (1996) find that log spot and log forward exchange rates are cointegrated with a cointegration slope coefficient equal to 1.

and conveniently expressed in the first-order *companion form*,

$$y_t = By_{t-1} + u_t = \sum_{j=0}^{\infty} B^j u_{t-j} \tag{6}$$

where $u_t = (\varepsilon_{f,t}, 0, \ldots, 0, \varepsilon_{s,t}, 0, \ldots, 0, \varepsilon_{f,t} - \varepsilon_{s,t})$ and B is structured to conform to $y_t' = (\Delta f_t, \ldots, \Delta f_{t-k+1}, \Delta s_t, \ldots, \Delta s_{t-k+1}, z_t)$. Let $V = E(u_t u_t')$, $C_0 = E(\tilde{y}_t \tilde{y}_t') = \sum_0^\infty (B^j) V (B^j)'$, and $C_k = E(\tilde{y}_t \tilde{y}_{t-k}') = B^k C_0$, where $\tilde{y}_t \equiv y_t - Ey_t$.[10] Let $e_1 = (1, 0, \ldots, 0)$ be a $2k+1$ dimensional row vector with 1 as the first element and zeros elsewhere to select out $\Delta f_t = e_1 y_t$ from the VECM. Define e_2 and e_3 analogously such that $\Delta s_t = e_2 y_t$, and $z_t = e_3 y_t$. These selection vectors allow us to efficiently express $E_t(\Delta s_{t+1})$ and p_t respectively as,[11]

$$E_t \Delta s_{t+1} = e_2 B y_t, \tag{7}$$

$$p_t = f_t - E_t s_{t+1} = (e_3 - e_2 B) y_t. \tag{8}$$

We emphasize eight moments of the joint distribution of f_t and s_t. Their formulae under the VECM are,

$$\text{Cov}[\Delta s_{t+1}, z_t] = e_2 C_1 e_3' \tag{9}$$

$$\text{Var}(z_t) = e_3 C_0 e_3' \tag{10}$$

$$\text{Cov}[z_t, z_{t-1}] = e_3 C_1 e_3' \tag{11}$$

$$\text{Var}(E_t \Delta s_{t+1}) = e_2 B C_0 B' e_2' \tag{12}$$

$$\text{Var}(p_t) = (e_3 - e_2 B) C_0 (e_3' - B' e_2') \tag{13}$$

$$\text{Cov}(p_t, p_{t-1}) = [e_3 - e_2 B] C_1 [e_3' - B' e_2'] \tag{14}$$

$$\text{Cov}(E_t \Delta s_{t+1}, p_t) = e_2 B C_0 [e_3' - B' e_2'] \tag{15}$$

$$\text{Cov}(E_t \Delta s_{t+1}, E_{t-1} \Delta s_t) = e_2 B C_1 B' e_2' \tag{16}$$

The ratio of (9) to (10) is the implied slope coefficient in the regression eq.(2) of the future depreciation on the forward premium. The ratio of (11) to (10) is the first-order auto-

[10] See Canova and Ito (1991), Bekaert and Hodrick (1992) and Bekaert (1995) for parallel analyses with vector autoregressions.

[11] The theory of the next section assumes that economic agents condition on an information set containing current and past values of the nominal interest rate, the price level and consumption in addition to current and past values of spot and forward exchange rates. We will show that the simple bi-variate system provides a plausible empirical model of spot and forward exchange rates. To be entirely consistent with the theory, the VECM could be expanded to account for these variables but doing so is not likely to alter our conclusions.

correlation coefficient of the forward premium, the ratio of (14) to (13) is the first-order autocorrelation coefficient of p_t, and (15) is the covariance between $E_t(\Delta s_{t+1})$ and p_t.

To calculate standard errors of the estimates and of the implied moments, let $\Sigma = E(\varepsilon_t \varepsilon_t')$ be the error covariance matrix and $\eta = [\text{vec}(B), \text{vech}(\Sigma)]$ be the the complete coefficient vector with true value η_0, and $h(\eta_T)$ be a vector of the implied moments of interest.[12] If η_T is our estimator, then $\sqrt{T}(\eta_T - \eta_0) \xrightarrow{D} N(0, -)$ and a mean-value expansion implies, $\sqrt{T}[h(\eta_T) - h(\eta_0)] \xrightarrow{D} N\left(0, \left(\frac{\partial h(\eta_0)}{\partial \eta}\right) - \left(\frac{\partial h(\eta_0)}{\partial \eta}\right)'\right)$.

1.2. Credible Estimates of p_t and $E_t(\Delta s_{t+1})$

Using the Schwarz (1978) information criterion, we determined that a lag length of 1 was appropriate for the VECMs of each currency.[13] The VECM–implied moments of interest and corresponding sample moments (where available) are displayed in Table 2. As can be seen in the first 4 rows of the table, the implied slope coeffcient from the regression of the future depreciation on the forward premium and the implied variance and first-order autocorrelation of the forward premium match up well with their sample counterparts.

[12] vech(Σ) vectorizes the distinct elements of the covariance matrix Σ.

[13] In preliminary data analysis, we found that the VECM with the known cointegrating coefficient of 1 is an appropriate representation for each of the three currencies since we found that the spot and forward rates are cointegrated and were unable to reject the hypothesis that the cointegrating vector is equal to 1 at standard significance levels. In determining the appropriate lag length of the VECM, we calculated Schwarz's (1978) Bayesian information criterion (SBC) and Akaike's (1974) information criterion (AIC). The AIC selects 2 lags for the BP and DM and 1 lag for the yen. On the other hand, the SBC selects 1 lag for all three currencies. We estimate the VECM with 1 lag for each currency for the obvious reason of parameter parsimony. We have conducted the Ljung and Box (1978) Q-test for the residuals and found no significant evidence of misspecification for each currency. We suppress reporting these results so as to use less space and will make them available upon request.

Table 2: Sample and Implied Moments from the Estimated VECM's

	BP		DM		Yen	
	Sample	Implied	Sample	Implied	Sample	Implied
$\frac{\text{Cov}[\Delta s_{t+1}, z_t]}{\text{Var}(z_t)}$	-1.522	-1.597	-0.136	-0.172	-2.526	-2.585
	(0.863)	(0.932)	(0.839)	(0.958)	(0.903)	(0.944)
$\text{Cov}(\Delta s_{t+1}, z_t)$	-0.968	-0.933	-0.111	-0.159	-1.569	-1.539
	(0.545)	(0.652)	(0.722)	(0.908)	(0.523)	(0.849)
$\text{Var}(z_t)$	0.636	0.584	0.815	0.927	0.621	0.595
	(0.112)	(0.212)	(0.131)	(0.684)	(0.101)	(0.259)
$\rho(z_t, z_{t-1})$	0.769	0.756	0.859	0.868	0.793	0.789
	(0.076)	(0.069)	(0.063)	(0.087)	(0.071)	(0.067)
$\text{Var}(E_t(\Delta s_{t+1}))$	n.a.	1.969	n.a.	0.818	n.a.	4.107
	n.a.	(2.122)	n.a.	(1.463)	n.a.	(3.349)
$\text{Var}(p_t)$	n.a.	4.420	n.a.	2.062	n.a.	7.780
	n.a.	(3.413)	n.a.	(2.913)	n.a.	(5.119)
$\text{Var}(p_t) - \text{Var}(E_t(\Delta s_{t+1}))$	n.a.	2.451	n.a.	1.244	n.a.	3.673
	n.a.	(1.433)	n.a.	(2.084)	n.a.	(1.900)
$\rho(p_t, p_{t-1})$	n.a.	0.737	n.a.	0.721	n.a.	0.778
	n.a.	(0.245)	n.a.	(0.418)	n.a.	(0.071)
$\text{Cov}(E_t(\Delta s_{t+1}), p_t)$	n.a.	-2.903	n.a.	-0.977	n.a.	-5.646
	n.a.	(2.708)	n.a.	(1.957)	n.a.	(4.149)

Note: Asymptotic standard errors in parentheses.

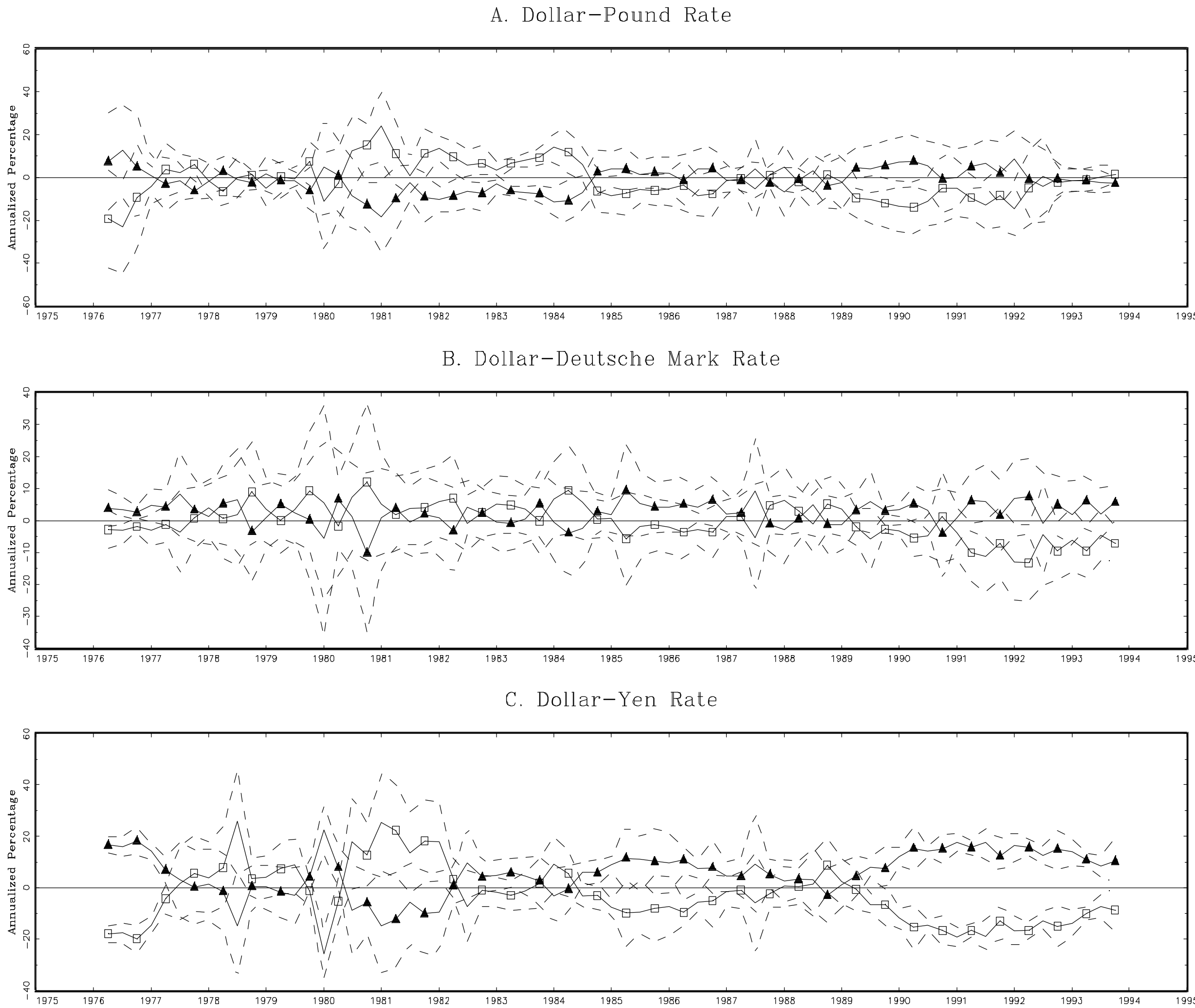


Figure 1: Estimated p_t (boxes) and $E_t(\Delta s_{t+1})$ (triangles) with 2-standard-error bands.

These results suggest that the VECM provides a reasonbaly accurate model of log spot and forward exchange rate, p_t, and $E_t(\Delta s_{t+1})$ behavior.[14] The estimated $\text{Var}(E_t\Delta s_{t+1})$ is significant for the BP and JY whereas the estimated $\text{Var}(p_t)$ is significant for all three currencies. Consistent with Fama's (1984) findings, the implied values of p_t are more volatile than the implied values of $E_t(\Delta s_{t+1})$. One-sided tests of the hypothesis, $\text{Var}(p_t) - \text{Var}(E_t\Delta s_{t+1}) = 0$, can be rejected at marginal significance levels of 0.04, 0.28, and 0.03 for the BP, DM, and JY respectively. The large first–order autocorrelation coefficients indicate that the implied

[14] Much research has been devoted to estimating p_ts. See Cumby (1988), who employs a projection procedure, Cheung (1993), Wolff (1987), and Hai, Mark, and Wu (1996) who utilize Kalman filtering techniques, and Bekaert and Hodrick (1992) and Canova and Ito (1991) who exploit VAR methods.

p_t is quite persistent in each case. The estimated correlations between p_t and $E_t(\Delta s_{t+1})$ implied by the values in rows 5, 6, and 9 are -0.99, -0.75, and -1.00 for the BP, DM, and JY respectively.

To see what the estimates $\hat{p}_t$ and $\hat{E}_t(\Delta s_{t+1})$ look like, we plot them along with their 2-standard-error bands in figures 1a–1c. The estimated series are seen to be persistent, especially for the BP and JY. Both series alternate between positive and negative values and change sign infrequently. Significantly positive and negative values can be observed in each of the series. We note further that, a number of common movements seem to be present across currencies. Each of the series contain spikes in early 1980 and 1981. The $\hat{p}_t$s are generally positive during the period of dollar strength from mid-1980 to 1985 and are generally negative from 1990 to late 1993. Finally, the large negative covariance between p_t and $E_t(\Delta s_{t+1})$ is plainly visible. Having obtained credible estimates of p_t, we now ask if it behaves like risk premia.

2. Does p_t Behave Like a Risk Premium?

Implications from Euler Equations

Let β be the subjective discount factor, R be the gross nominal return on a domestic currency denominated one-period discount bond, F be the one-period forward exchange rate, S be the spot exchange rate, C be consumption of the representative agent, and π be the purchasing power of the domestic money (the reciprocal of the price level). Then under constant relative risk aversion utility with coefficient γ, the respective Euler equations for pricing the forward exchange risk premium and the domestic currency bond in the standard representative-agent asset pricing model are,

$$0 = E_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\left(\frac{F_t - S_{t+1}}{S_t}\right)\left(\frac{\pi_{t+1}}{\pi_t}\right)\right], \tag{17}$$

$$\frac{1}{R_t} = E_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\frac{\pi_{t+1}}{\pi_t}\right]. \tag{18}$$

To economize on notation, let $\tilde{s}_{t+1} \equiv \frac{F_t - S_{t+1}}{S_t}$ denote the speculative profit and $m_{t+1}(\gamma) \equiv \left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\frac{\pi_{t+1}}{\pi_t}$ be the intertemporal marginal rate of substitution scaled by the discount factor β. Eqs. (17) and (18) together imply

$$E_t(\tilde{s}_{t+1}) = -(1 + i_t)\text{Cov}_t[m_{t+1}(\gamma), \tilde{s}_t], \tag{19}$$

where $E_t(\tilde{s}_{t+1})$ is, up to a Jensen's inequality term, p_t studied in section 1. We will ignore the effects of Jensen's inequality since the weight of the available evidence suggests that it is empirically unimportant.[15] Thus, according to the theory p_t is a risk premium which is determined by the right side of eq.(19). The dollar is seen to be risky when $\text{Cov}[m_{t+1}(\gamma), \tilde{s}_{t+1}]$ is negative because its value is low when consumption is low and therefore serves as a poor hedge against bad states of nature.

One of the sharpest implications of the model is that the sign of p_t is opposite the sign of $\text{Cov}_t[m_{t+1}(\gamma), \tilde{s}_{t+1}]$. From the perspective of the representative U.S. consumer, $m_{t+1}(\gamma)$ and $\tilde{s}_{t+1}$ should be negatively correlated whenever it is preceded by positive values of p_t, while from the perspective of the representative foreign consumer, $m^*_{t+1}(\gamma)$ and $\tilde{s}^*_{t+1}$ should be positively correlated whenever preceded by positive values of p_t (and vice-versa). To test these sign restrictions, we sort paired observations of $[m_{t+1}(\gamma), \tilde{s}_{t+1}]$ and $[m^*_{t+1}(\gamma), \tilde{s}^*_{t+1}]$ according to whether they were preceded by positive or negative values of $\hat{p}_t$ estimated in section 1. from the perspective of the US representative consumer who speculates against the BP, DM, and yen and from the perspective of British, German, and Japanese representative

[15] Engel (1984) and Cumby (1988) find little difference in the behavior of nominal deviations from uncovered interest parity and real deviations, suggesting that the Jensen's inequality problem is empirically unimportant. This appears to be the case here as well. In unreported results, we show that our main conclusions are unchanged under the assumption that the observations $(\frac{C_{t+1}}{C_t}, \frac{\pi_t}{\pi_{t+1}}, \frac{S_{t+1}}{S_t})$ are, conditional on date-t information, jointly log-normally distributed.

investors who speculate against the dollar.

Figure 2a. US Consumption, Pound Speculation
Standardized Observations Preceeded by $\hat{p}_t>0$

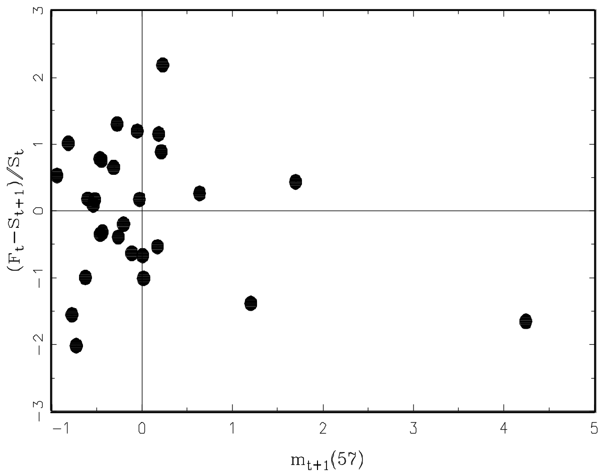


Figure 2b. US Consumption, Pound Speculation
Standardized Observations Preceeded by $\hat{p}_t<0$

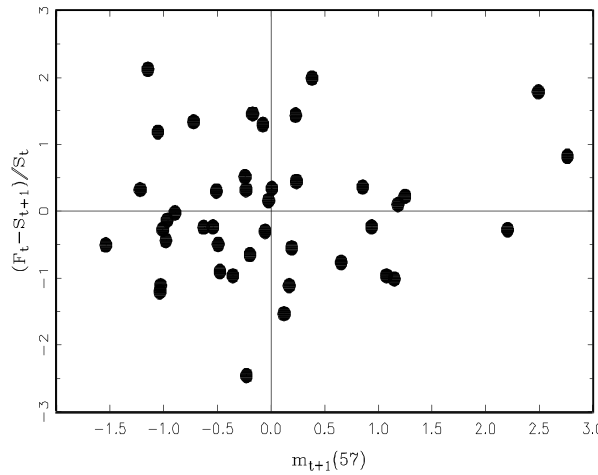


Figure 2c. UK Consumption, Dollar Speculation
Standardized Observations Preceeded by $\hat{p}_t<0$

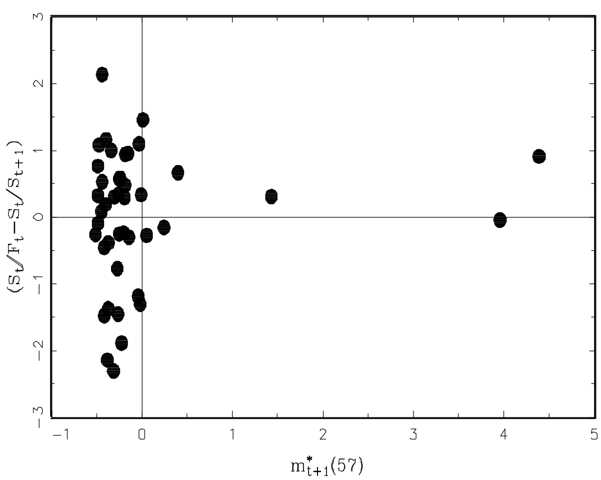
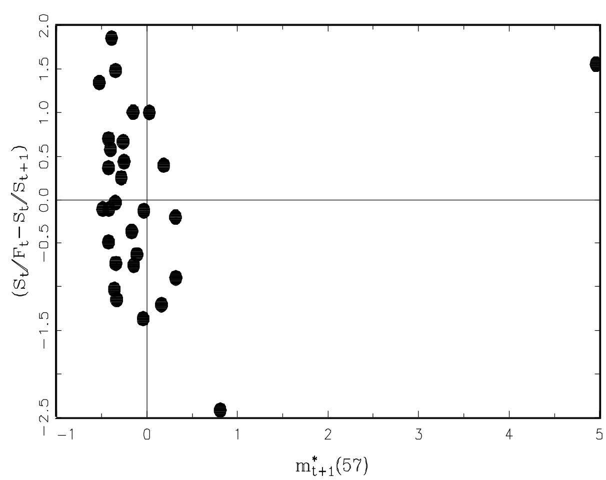


Figure 2d. UK Consumption, Dollar Speculation
Standardized Observations Preceeded by $\hat{p}_t>0$



In making these calculations, we need to choose a value for γ. Previous research suggests that values of γ in excess of 50 are required to match the unconditional first and second moments of financial data.[16] Accordingly, we set $\gamma = 57$ to bias the results in favor of the model and display standardized values of the sorted observations in figures 2–4. According to the theory, the figures on the left (2a, 2c, 3a, 3c, 4a, and 4c) should contain negatively correlated observations while the figures on the right should contain positively correlated

[16]Kandel and Stambaugh (1990) show that the equity premium puzzle and mean reversion in equity prices can be explained with $\gamma = 57$, while Bekaert (1994) finds that with $\gamma > 50$, the volatility of the intertemporal marginal rates of substitution satisfies the Hansen-Jagannathan (1991) volatility bounds implied by spot and forward exchange rate data.

pairs, but as can be seen, the data in all of the figures appear largely to be random.[17]

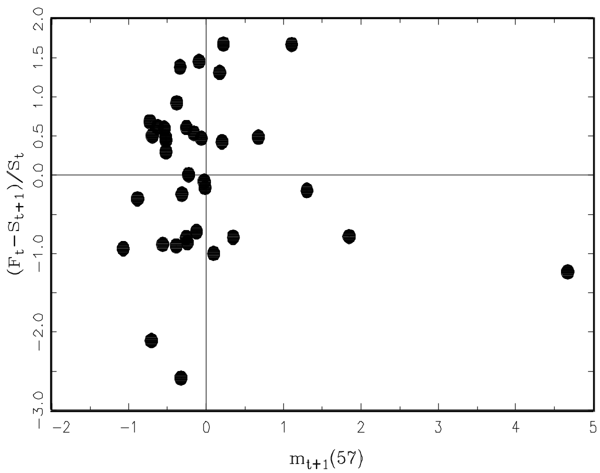


Figure 3a. US Consumption, DM Speculation
Standardized Observations Preceeded by $\hat{p}_t>0$

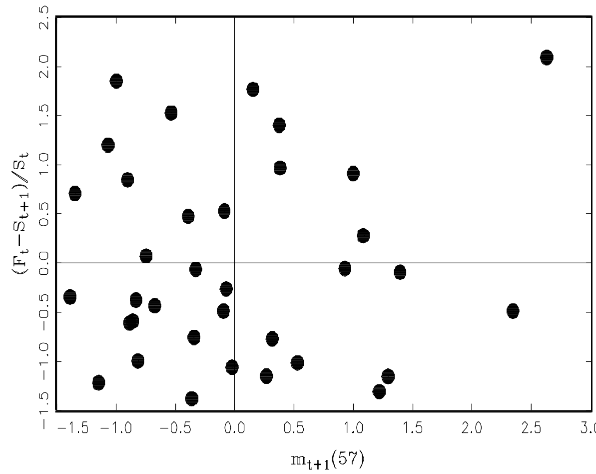


Figure 3b. US Consumption, DM Speculation
Standardized Observations Preceeded by $\hat{p}_t<0$

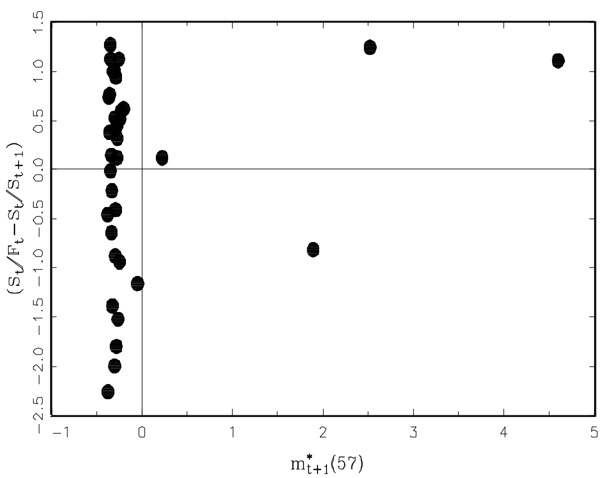


Figure 3c. German Consumption, Dollar Speculatior
Standardized Observations Preceeded by $\hat{p}_t<0$

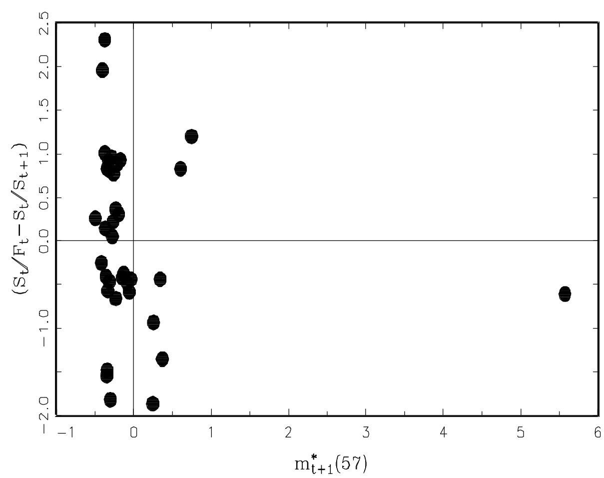


Figure 3d. German Consumption, Dollar Speculatior
Standardized Observations Preceeded by $\hat{p}_t>0$

These results can be quantified by fitting regression lines through the scatter plots which are reported in table 3. It can be seen that the estimated slope coefficients typically have the wrong sign. The slope coefficients in regressions with US data have the correct sign for the BP and DM but are not statistically significant. The corresponding slope coefficients for the JY have the wrong sign. In regressions using the foreign country data for observations preceeded by $p_t < 0$, none of the estimated slope coefficients have the predicted sign. For

[17]We experimented with several alternative specifications and found the results to be robust. In results not reported, we made these calculations assuming $\gamma = 4$. We also investigated the sensitivity of the calculations to Jensen's inequality by making the calculations under the assumption that the consumption growth and foreign exchange returns are log-normally distributed.

Table 3: Regressions of speculative profits on the intertemporal marginal rate of substitution of money sorted according to whether observations are preceded by $\hat{p}_t > 0$ or $\hat{p}_t < 0$. $\tilde{s}_{t+1} \equiv \frac{F_t - S_{t+1}}{S_t}$, $\tilde{s}^*_{t+1} \equiv \frac{S_t}{F_t} - \frac{S_t}{S_{t+1}}$, $m_{t+1}(\gamma) \equiv \left(\frac{C_{t+1}}{C_t}\right)^{-\gamma} \frac{\pi_{t+1}}{\pi_t}$, $m^*_{t+1}(\gamma) \equiv \left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\gamma} \frac{\pi^*_{t+1}}{\pi^*_t}$.

A. US Perspective: $\tilde{s}_{t+1} = \beta_0 + \beta_1 m_{t+1}(57) + \epsilon_{t+1}$						
	$\hat{\beta}_0$	$\hat{\beta}_1$	R^2	$\hat{\beta}_0$	$\hat{\beta}_1$	R^2
	$p_t > 0$			$p_t < 0$		
BP	0.040	-0.021	0.047	-0.045	0.026	0.014
	(0.020)	(0.018)		(0.030)	(0.035)	
DM	0.020	-0.012	0.009	-0.023	0.011	0.002
	(0.022)	(0.021)		(0.034)	(0.042)	
Yen	-0.037	0.067	0.131	-0.007	-0.027	0.044
	(0.037)	(0.036)		(0.018)	(0.019)	
B. Foreign Perspective: $\tilde{s}^*_{t+1} = \beta^*_0 + \beta^*_1 m^*_{t+1}(57) + \epsilon^*_{t+1}$						
	$\hat{\beta}^*_0$	$\hat{\beta}^*_1$	R^2	$\hat{\beta}^*_0$	$\hat{\beta}^*_1$	R^2
	$p_t < 0$			$p_t > 0$		
BP	0.016	0.003	0.014	-0.028	0.004	0.019
	(0.010)	(0.004)		(0.013)	(0.006)	
DM	0.005	0.002	0.043	-0.008	-0.003	0.020
	(0.012)	(0.002)		(0.012)	(0.004)	
Yen	0.010	0.019	0.015	-0.008	-0.029	0.066
	(0.020)	(0.023)		(0.022)	(0.023)	

Note: Standard errors in parentheses.

observations preceeded by $p_t > 0$, we obtain the correct positive sign only for the BP, but this estimate also is not statistically significant.

Figure 4a. US Consumption, Yen Speculation
Standardized Observations Preceeded by $\hat{p}_t>0$

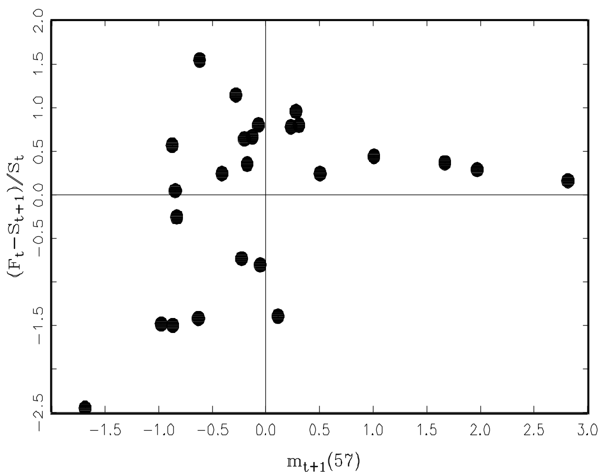


Figure 4b. US Consumption, Yen Speculation
Standardized Observations Preceeded by $\hat{p}_t<0$

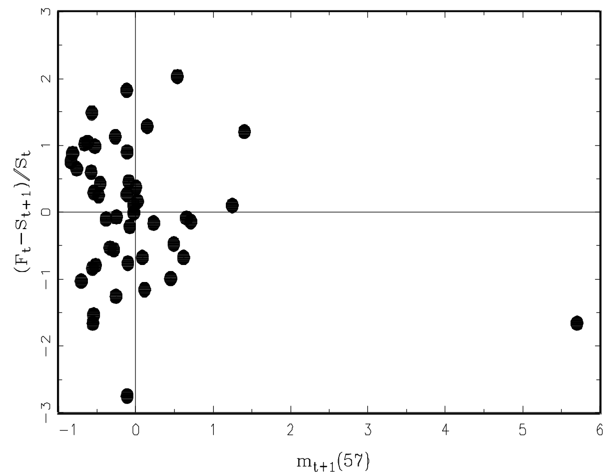


Figure 4c. Japanese Consumption, Dollar Speculatio
Standardized Observations Preceeded by $\hat{p}_t<0$

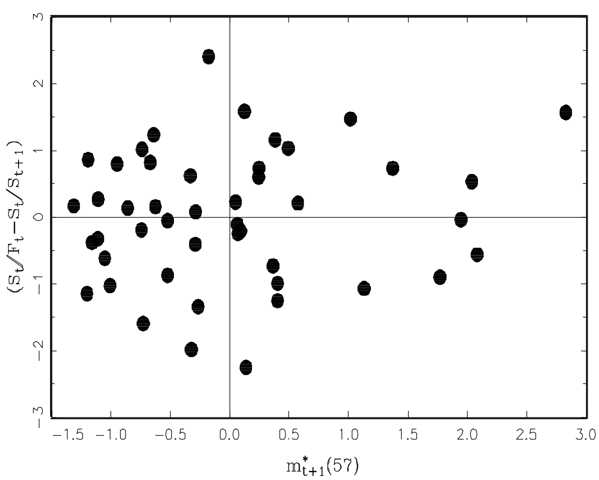
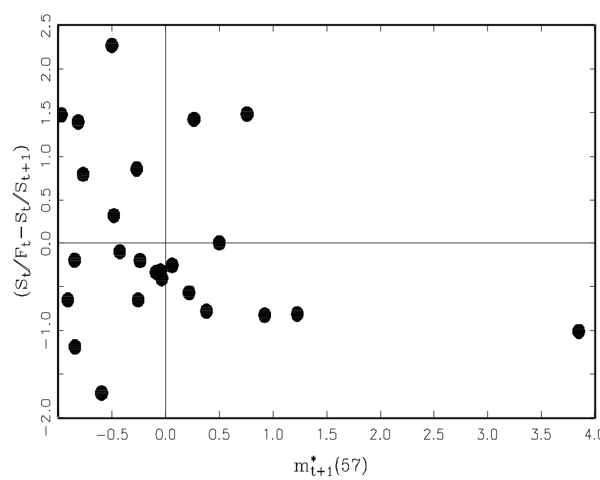


Figure 4d. Japanese Consumption, Dollar Speculatio
Standardized Observations Preceeded by $\hat{p}_t>0$



The inability of the standard model to produce a risk premium with the correct sign suggests that the model breaks down at a more fundamental level than the difficulty in producing sufficiently volatile intertemporal marginal rates of substitution. Indeed, we employed parameter values under which the model has been shown to match unconditional second moments of foreign exchange and equity returns data. So if the implied values of p_t do not have the properties consistent with compensation for risk, what can explain their behavior? We turn to two non (covariance) risk theories of the determination of p_t.

3. Rethinking Policy Rules

In a recent contribution, McCallum (1994) develops a theory in which p_t is not compensation for bearing economic risk but is perfectly correlated with the forward premium because of the dependence of the monetary policy rule depends on the rate of currency depreciation. After first reviewing McCallum's model, we show that the empirical evidence in support for his theory is weak and, that the model's conclusions are not robust to a reasonable respecification of the policy rule.

3.1. McCallum's Model

McCallum's model is given by the two equations,

$$p_t = x_t - E_t(\Delta s_{t+1}), \tag{20}$$

$$x_t = \lambda \Delta s_t + \sigma x_{t-1} + \zeta_t, \tag{21}$$

where $x_t \equiv R_t - R_t^*$ is the nominal interest differential and $\{\zeta_t\}$ and $\{p_t\}$ are *i.i.d.* shocks. McCallum also considers the case where $\{p_t\}$ follows an AR(1) process, but the basic insight can be obtained under the simple case of independence. Market participants have rational expectations but hold distorted views on uncovered interest parity which, as postulated in eq.(20), holds with error. Eq.(21) is the monetary policy rule pursued by the authorities where $0 < \lambda$ and $0 < \sigma \leq 1$. The authorities are assumed to set the interest differential to smooth out exchange rate and interest rate fluctuations.

The model can be solved by the method of undetermined coefficients. The vector of time t information determining Δs_t is (x_{t-1}, ζ_t, p_t), so an appropriate guess solution is

$$\Delta s_t = \phi_1 x_{t-1} + \phi_2 \zeta_t + \phi_3 p_t. \tag{22}$$

Eqs.(22) and (20) imply $p_t = (1 - \phi_1) x_t$. We substitute this expression with eq.(22) into eq.(21) to obtain

$$x_t = \lambda \phi_3 (1 - \phi_1) x_t + (\lambda \phi_2 + 1) \zeta_t + (\lambda \phi_1 + \sigma) x_{t-1}. \tag{23}$$

Equating coefficients in eq.(23) yields $\phi_1 = -\sigma/\lambda, \phi_2 = -1/\lambda, \phi_3 = 1/(\lambda + \sigma)$. The solution for the exchange rate is therefore,

$$\Delta s_{t+1} = -\frac{\sigma}{\lambda} x_t - \frac{1}{\lambda} \zeta_{t+1} + \frac{1}{\lambda + \sigma} p_{t+1}. \tag{24}$$

Table 4: 2SLS Estimates of Quarterly Monetary Policy Rule: $x_t = c + \lambda\Delta s_t + \sigma x_{t-1} + \zeta_t$. Instruments for Δs_t are $(1, \Delta s_{t-1}, \Delta s_{t-2}, x_{t-1}, x_{t-2})$.

	$\hat{c}$	$\hat{\lambda}$	$\hat{\sigma}$	R^2
BP	-0.141	0.001	0.720	0.583
	(0.089)	(0.037)	(0.100)	
DM	0.092	-0.041	0.854	0.704
	(0.074)	(0.043)	(0.066)	
JY	0.342	-0.050	0.653	0.511
	(0.241)	(0.066)	(0.190)	

Note: Standard errors in parentheses.

That the model explains the forward premium bias can be seen by observing that the coefficient on the interest differential, $-\sigma/\lambda$, is negative. This point can also be seen by noting that the omitted variable from the forward premium regression eq.(2) is

$$p_t = \left(1 + \frac{\sigma}{\lambda}\right) x_t. \tag{25}$$

The policy rule thus induces p_t to be perfectly correlated with the independent variable in the regression. Taking expectations on both sides of eq.(24) yields

$$p_t = -\left(1 + \frac{\lambda}{\sigma}\right) E_t \Delta s_{t+1}. \tag{26}$$

p_t is thus seen to be perfectly negatively correlated with and more volatile than $E_t(\Delta s_{t+1})$.

3.2. Empirical Estimates of the Policy Rule

We estimate the policy rule (21) by 2SLS and report our results in table 4. Using the instrument set $(1, \Delta s_{t-1}, \Delta s_{t-2}, x_{t-1}, x_{t-2})$, the point estimates for λ are negative (but insignificant) for the DM and JY. While we find a positive point estimate of λ for the BP, it is not significant. The empirical support for the policy rule (21) appears tenuous.

3.3. An Alternative Policy Rule

We next investigate the issue of the sequence of trading implied by the discrete-time policy rule. Under eq.(21), foreign exchange trading is completed before agents are able to observe x_t but the monetary authorities observe Δs_t prior to setting period t's interest differential. Suppose instead, that the sequence of within period trading is reversed so that after observing Δs_{t-1} and x_{t-1} from the previous period the authorities set x_t at the beginning of period t . After x_t is revealed, foreign exchange trading takes place thus determining Δs_t. Under this alternative trading sequence, the policy rule becomes

$$x_t = \lambda \Delta s_{t-1} + \sigma x_{t-1} + \zeta_t. \tag{27}$$

Since x_t is determined when the foreign exchange market opens, we conjecture the solution

$$\Delta s_t = \phi_1 x_t + \phi_2 p_t. \tag{28}$$

which with (20) implies $p_t = x_t - \phi_1 E_t x_{t+1}$. Substituting this expression into (27) generates the restrictions $\lambda \phi_1^2 + \sigma \phi_1 - 1 = 0$ and $\lambda \phi_1 \phi_2 = -1$. We take the positive root $\phi_1(\lambda, \sigma) = \frac{-\sigma + \sqrt{\sigma^2 + 4\lambda}}{2\lambda}$ and discard the unstable negative root which exceeds 1 in absolute value when λ and σ are close to 1. This implies that $\phi_2(\lambda, \sigma) = -1/(\lambda \phi_1(\lambda, \sigma))$ and a solution,

$$\Delta s_t = \phi_1(\lambda, \sigma) x_t - \frac{1}{\lambda \phi_1(\lambda, \sigma)} p_t = x_{t-1} - p_{t-1} - \frac{1}{\lambda \phi_1(\lambda, \sigma)} p_t + \phi_1(\lambda, \sigma) \zeta_t \tag{29}$$

The significance of this solution is that the policy rule induces no dependence between p_t and x_t or $E_t \Delta s_{t+1}$ beyond what is originally assumed in eq.(20). The forward premium bias induced by the actions of the authorities vanishes. The covariance between the DRUIP and the RED is $\text{Cov}(p_t, E_t \Delta s_{t+1}) = -\text{Var}(p_t)$, but this follows directly from (20) and the stochastic independence between x_t and p_t and is not behavior induced by the monetary policy rule.

4. Thinking About Noise

In this section, we apply the overlapping-generations noise trader model of De Long *et. al.* (1990) to the pricing of foreign currencies. Here, heterogeneous beliefs across agents generate trading volume and excess currency returns. Black (1986) suggests that the complexity of the real world environment prevents noise traders from distinguishing pseudo-signals from news. Because these individuals think that the pseudo-signals contain information about economic fundamentals their beliefs regarding prospective investment returns appear distorted by waves of excessive optimism and pessimism.[18] The resulting trading dynamics produce transitory deviations of the exchange rate from its fundamental value. Because noise-traders may push the price even farther away from the fundamanental value in the next period, short-horizon rational investors face the risk that they may be forced to sell while the price lies below its fundamental value.

4.1. A Noise-Trader Model for Foreign Exchange

Consider a two-country constant population partial equilibrium model with the following features.

- People are born with a full stomach but no assets and live for 2 periods. The young do not consume but make portfolio decisions to maximize expected utility of second period wealth, which is entirely consumed when old.

- The home country currency unit is called the 'dollar' and the foreign country currency unit is called the 'pound.' In each country, there is a one-period asset that is safe in terms of the local currency. Both assets are available in perfectly elastic supply so that in period t, people can borrow or lend any amount at the gross dollar rate of interest, R_t or at the gross pound rate of interest, R_t^*. The nominal interest differential–and hence by covered interest parity, the forward premium–is assumed to be exogenous. This assumption reflects the idea that interest rates reflect national economic conditions which are largely separate from currency movements. The forward rate is set simply to prevent covered interest arbitrage profits.

- There are legal restrictions on currency use. In order for financial wealth to have value, it must be denominated in the currency of the country that the individual resides. Thus in the second period, the domestic agent converts wealth to dollars and the foreign agent converts wealth to pounds.

Domestic Agents: The domestic young decide whether to borrow dollars and lend pounds or vice versa. Let λ_t be the portfolio position taken with long pound positions represented by

[18] Frankel and Froot (1989), Elliott and Ito (1995) and others have found that survey expectations of exchange rate changes are not rational, that survey forecast errors are systematic and that the survey risk premium is essentially zero. Debondt and Thaler (1986) report evidence of investor and financial analyst overreaction to news, while LeBaron (1992) and Taylor (1992) show that technical trading rules are at least as good as ARIMA models in predicting exchange rates.

positive values and long dollar positions given by negative values. To take a long pound position, the young trader borrows λ_t dollars at the gross interest rate R_t and invests λ_t/S_t pounds at the gross rate R_t^*. When old, the pound payoff $R_t^* \frac{\lambda_t}{S_t}$ is converted into $\frac{S_{t+1}}{S_t} R_t^* \lambda_t$ dollars. A long position in dollars is achieved by borrowing $-\frac{\lambda_t}{S_t}$ pounds and investing the proceeds in the dollar asset at R_t. In the second period, the domestic agent sells $-(S_{t+1}/S_t)R_t^* \lambda_t$ dollars in order to repay the pound debt $-R_t^* \frac{\lambda_t}{S_t}$. In either case, the net payoff is $\left(\frac{S_{t+1}}{S_t} R_t^* - R_t\right) \lambda_t$. We use the approximations $\frac{S_{t+1}}{S_t} \simeq (1 + \Delta s_{t+1})$ and $\frac{R_t}{R_t^*} = \frac{F_t}{S_t} \simeq 1 + x_t$ where $x \equiv (f - s)$ to express the net payoff as[19]

$$[\Delta s_{t+1} - x_t] R_t^* \lambda_t. \tag{30}$$

Foreign Agents: We denote the foreign agent's portfolio position by λ_{*t} with positive values indicating long pound positions. To take a long pound position, the foreign young borrows λ_{*t} dollars and invests $\frac{\lambda_{*t}}{S_t}$ pounds at the gross interest rate R_t^*. Next period's net pound payoff is $\left(R_t^* \frac{1}{S_t} - \frac{1}{S_{t+1}} R_t\right) \lambda_{*t}$. A long dollar position is achieved by borrowing $-\frac{\lambda_{*t}}{S_t}$ pounds and investing $-\lambda_{*t}$ dollars. The net pound payoff in the second period is $-\left(\frac{1}{S_{t+1}} R_t - \frac{1}{S_t} R_t^*\right) \lambda_{*t}$. Using the approximation $\frac{F_t S_t}{S_t S_{t+1}} \simeq 1 + x_t - \Delta s_{t+1}$, we express the net pound payoff as

$$[\Delta s_{t+1} - x_t] R_t^* \frac{\lambda_{*t}}{S_t} \tag{31}$$

Market Clearing: The foreign exchange market clears when net dollar sales of the current young equals net dollar purchases of the current old,

$$\lambda_t + \lambda_{*t} = \frac{S_t}{S_{t-1}} R_{t-1}^* \lambda_{t-1} + R_{t-1} \lambda_{*t-1} \tag{32}$$

4.1.1. Fundamental and Noise Traders

A fraction μ of domestic and foreign traders are fundamentalists who have rational expectations. The remaining fraction $1 - \mu$ are noise traders whose beliefs concerning future returns from their portfolio investments are distorted. Let the speculative positions of home fundamentalist and noise traders be given by λ_t^f and λ_t^n respectively. Similarly, let foreign fundamentalist and noise trader positions be λ_{*t}^f and λ_{*t}^n. The total portfolio position of domestic residents is $\lambda_t = \mu \lambda_t^f + (1 - \mu) \lambda_t^n$ and of foreign residents is $\lambda_{*t} = \mu \lambda_{*t}^f + (1 - \mu) \lambda_{*t}^n$.

To distinguish between the distorted beliefs of noise traders and the objective beliefs of the fundamentalists, let subjective expectations conditioned on date-t information be

[19] These approximations are necessary in order to avoid dealing with Jensen inequality terms when evaluating the foreign wealth position which render the model untractable.

denoted by $\mathcal{E}_t(\cdot)$. Fundamentalists are rational, so their subjective expectations coincide with the mathematical conditional expectation, $E_t(\cdot)$.

The Objective Function: Utility displays constant absolute risk aversion with coefficient γ. The young construct a portfolio to maximize the expected utility of next period wealth, W_{t+1},

$$\mathcal{E}_t\left(-e^{-\gamma W_{t+1}}\right). \tag{33}$$

Both fundamental and noise traders believe that conditional on time-t information, W_{t+1} is normally distributed. Note that (33) is the (negative of) the conditional moment generating function of W_{t+1}. Thus, maximizing the expression (33) conditional on time-t information is equivalent to maximizing

$$\mathcal{E}_t(W_{t+1}) - \frac{\gamma}{2}\mathcal{V}_t(W_{t+1}) \tag{34}$$

where $\mathcal{V}_t(W_{t+1})$ is the conditional subjective variance of next period wealth.

4.1.2. A Fundamentals ($\mu = 1$) Economy

We begin by assuming that everyone is rational ($\mu = 1$) so that $\mathcal{E}_t(\cdot) = E_t(\cdot)$ and $\mathcal{V}_t(\cdot) = V_t(\cdot)$. Total second period wealth of the fundamentalist domestic agent is the portfolio payoff plus c dollars of exogenous 'labor' income which is paid in the second period.[20] We simplify the exposition by assuming that R^* is fixed. The forward rate is set to eliminate covered interest arbitrage profits, which implies that the forward premium, $\frac{R_t}{R^*} = \frac{F_t}{S_t} \simeq 1 + x_t$ is exogenous and inherits its stochastic properties from R_t. Accordingly, we assume

$$x_t = \rho x_{t-1} + v_t \tag{35}$$

where $0 < \rho < 1$, and $v_t \sim i.i.d.$ with $E(v_t) = 0$ and $\text{Var}(v_t) = \sigma_v^2$. Second period wealth can now be written as

$$W_{t+1}^f = [\Delta s_{t+1} - x_t]R^*\lambda_t^f + c \tag{36}$$

They evaluate the conditional mean and variance of next period wealth as[21]

$$E_t(W_{t+1}^f) = [E_t(\Delta s_{t+1}) - x_t]R^*\lambda_t^f + c \tag{37}$$

[20] The exogenous income is introduced to lessen the likelihood of negative second period wealth realizations, but as in De Long *et. al.*, we cannot rule out such a possibility.

[21] Baillie and Bollerslev (1989b) find little evidence that percentage changes in nominal exchange rates are conditionally heteroskedastic beyond the 1-week horizon. Accordingly, we assume that $\{\Delta s_t\}$ is a conditionally homoskedastic process with mean zero and fixed variance σ_s^2.

$$V_t(W^f_{t+1}) = R^{*2}V_t(\Delta s_{t+1})(\lambda^f_t)^2 = R^{*2}\sigma^2_s(\lambda^f_t)^2 \tag{38}$$

The domestic fundamental trader's problem is to choose λ^f_t to maximize

$$[E_t(\Delta s_{t+1}) - x_t]R^*\lambda^f_t + c - \frac{\gamma}{2}R^{*2}(\lambda^f_t)^2\sigma^2_s. \tag{39}$$

which is attained by setting

$$\lambda^f_t = \frac{[E_t(\Delta s_{t+1}) - x_t]}{\gamma R^*\sigma^2_s} \tag{40}$$

The foreign fundamental trader faces an analogous problem. The second period pound-wealth of fundamentalist foreign agents is the payoff from portfolio investments plus an exogenous pound payment of 'labor' income c_*, $W^f_{*t+1} = [\Delta s_{t+1} - x_t]R^*\frac{\lambda^f_{*t}}{S_t} + c_*$. The solution is to choose $\lambda^f_{*t} = S_t\lambda^f_t$. These portfolios combined with the market clearing condition (32) imply the difference equation

$$E_t\Delta s_{t+1} - x_t = \Gamma_t(E_{t-1}\Delta s_t - x_{t-1}) \tag{41}$$

where $\Gamma_t \equiv \left(\frac{1}{1+S_t}\right)\left(\frac{S_t}{S_{t-1}}R^* + S_{t-1}R_{t-1}\right)$. The level of the exchange rate is indeterminate but it is easily seen that a solution for the rate of depreciation is

$$\Delta s_t = \frac{1}{\rho}x_t = x_{t-1} + \frac{1}{\rho}v_t. \tag{42}$$

Since v_t is independent of x_{t-1}, $E_t(\Delta s_{t+1}) = x_t$ and this fundamentals solution displays no forward premium bias. Note also, that the depreciation is more volatile than the forward premium ($\sigma_s = (1/\rho^2)\sigma_x$).

4.1.3. A Noise Trader ($\mu < 1$) Economy

The current young domestic noise trader holds beliefs for the conditional mean and variance of next period wealth W^n_{t+1} of

$$\mathcal{E}_t(W^n_{t+1}) = [E_t\Delta(s_{t+1}) - x_t]\,R^*\lambda^n_t + n_tR^*\lambda^n_t + c, \tag{43}$$

$$\mathcal{V}_t(W^n_{t+1}) = R^{*2}(\lambda^n_t)^2\sigma^2_s. \tag{44}$$

Noise trader beliefs about expected returns are distorted by the stochastic process $\{n_t\}$. They can compute $E_t(X_{t+1})$, but believe that factors in addition to news affect returns. They appear to over react to news and to be excessively optimistic or pessimistic. Noise traders display excess dollar pessimism when $n_t > 0$ for they believe the dollar will be weaker in the future than what is justified by the fundamentals. (Recall that a positive value of λ_t represents a long position in pounds and a negative value represents a long position in dollars.)

In their work with survey expectations, Froot and Frankel (1989) found that foreign exchange traders place excessive weight on the forward premium in forming their expectations of the future depreciation. We model noise trader beliefs by building in this idea of excessive importance of the forward premium and assume that the distortion in their beliefs evolve according to

$$n_t = kx_t + u_t, \tag{45}$$

where $k > 0, \{u_t\} \sim i.i.d.$ with $E(u_t) = 0$ and $\text{Var}(u_t) = \sigma_u^2$. The domestic noise trader's problem is to maximize

$$\lambda_t^n \left(E_t \Delta s_{t+1} - x_t + n_t\right) - \frac{\gamma}{2} R^* (\lambda_t^n)^2 \sigma_s^2, \tag{46}$$

and the solution is to choose

$$\lambda_t^n = \lambda_t^f + \frac{n_t}{\gamma R \sigma_s^2}. \tag{47}$$

The foreign noise trader holds similar beliefs, solves an analogous problem and chooses

$$\lambda_{*t}^n = S_t \lambda_t^n. \tag{48}$$

Substituting these optimal portfolio positions into the market clearing condition (32) yields the stochastic difference equation

$$[E_t \Delta s_{t+1} - x_t] + (1-\mu)n_t = \Gamma_t([E_{t-1}\Delta s_t - x_{t-1}] + (1-\mu)n_{t-1}), \tag{49}$$

where $\Gamma_t \equiv \frac{1}{1+S_t}\left(\frac{S_t}{S_{t-1}} R^* + R_{t-1} S_{t-1}\right)$. Using the method of undetermined coefficients, it can be verified that

$$\Delta s_t = \frac{1}{\rho} x_t - \frac{(1-\mu)}{\rho} n_t - (1-\mu) u_{t-1} \tag{50}$$

is a solution. This solution has a number of interesting properties.

1. Both fundamentalists and noise traders believe, ex ante, that they will earn positive profits from their portfolio investments and the differences in their beliefs lead them to take opposite sides of the transactions. When noise traders are excessively pessimistic and take short positions in the dollar, fundamentalists take the offsetting long position.

The expected fundamentalist payoff is $E_t\Delta s_{t+1} - x_t = -(1-\mu)n_t$ and the expected noise-trader payoff is $\mathcal{E}_t\Delta s_{t+1} - x_t = \mu n_t$. As the measure of noise traders approaches 0 ($\mu \to 1$), the fundamentals solution with no trading is restored. Foreign exchange risk, excess currency movements, and trading volume are induced entirely by noise traders. Neither type of trader is guaranteed to earn profits or losses, however. The ex post profit depends on the sign of

$$\Delta s_{t+1} - x_t = -(1-\mu)n_t + \frac{1}{\rho}[1-k(1-\mu)]v_{t+1} - \frac{1-\mu}{\rho}u_{t+1} \tag{51}$$

which can be positive or negative.

2. The model can generate a negative forward premium bias. Substituting expressions (45) and (35) into eq.(50) yields,

$$\Delta s_{t+1} = [1-k(1-\mu)]x_t + \xi_{t+1} \tag{52}$$

where $\xi_{t+1} \equiv (1/\rho)[1-k(1-\mu)]v_{t+1} - (1-\mu)/\rho u_{t+1} - (1-\mu)u_t$ is orthogonal to x_t. The implied slope coefficient in a regression of the future depreciation on the forward premium will be negative provided that $1-k(1-\mu) < 0$. If we assume it is, then we also have,

3. The DRUIP covaries negatively with and is more volatile than the RED. This can be seen from the implied second moments of the RED and the DRUIP which are,

$$\text{Cov}([x_t - E_t(\Delta s_{t+1})], E_t(\Delta s_{t+1})) = k(1-\mu)(1-k(1-\mu))\sigma_x^2 - (1-\mu)^2\sigma_u^2 \tag{53}$$

$$\text{Var}(x_t - E_t(\Delta s_{t+1})) = (1-\mu)^2[k^2\sigma_x^2 + \sigma_u^2] \tag{54}$$

$$\text{Var}(E_t(\Delta s_{t+1})) = \text{Var}(x_t - E_t(\Delta s_{t+1})) + [1-2k(1-\mu)]\sigma_x^2. \tag{55}$$

What evidence is there that the values of k and μ required for the model to explain the data are plausible? Research on the properties of survey exchange rate forecasts provides fragmentary evidence in support of the model. One estimate of μ comes directly from Frankel and Froot (1986). They note that $x_t = \mu E_t(\Delta s_{t+k}) + (1-\mu)\mathcal{E}_t(\Delta s_{t+k})$ where they attribute non-fundamentalist expectations $\mathcal{E}_t(\Delta s_{t+k})$ to 'chartists.' They assume that all of the survey respondents are fundumentalists and that chartists predict no change in the exchange rate. Using the average 6-month forecasts over five currencies from the Economist and AMEX surveys, they estimate $\mu = x_t/E_t(\Delta s_{t+k})$ to have been as high as 0.88 during the late 1970s

Table 5: Values of k and μ implied by survey forecasts

		Economist 3-month	Economist 6-month	Economist 12-month	AMEX 6-month	AMEX 12 month
	β	-1.209	-1.981	0.289	-2.418	-2.138
	β_2	2.513	2.987	0.517	3.635	3.108
m=0	k	2.513	2.987	0.517	3.635	3.108
	μ	0.121	0.002	-0.374	0.060	-0.010
m=0.3	k	3.590	4.267	0.739	5.192	4.440
	μ	0.385	0.301	0.038	0.342	0.293
m=0.6	k	6.282	7.466	1.293	9.086	7.770
	μ	0.648	0.601	0.450	0.624	0.596
m=0.9	k	25.127	29.866	5.174	36.350	31.081
	μ	0.912	0.900	0.863	0.906	0.899

Note: β and β_2 are from Frankel and Froot (1989). β is the slope coefficient from the regression of the depreciation on the forward premium over the survey period. β_2 is the slope coefficient from the regression of the survey forecast error on the forward premium. m is the fraction of the survey respondants assumed to be fundamentalists.

and as low as 0.11 in 1983. Using these implied values of μ to match $\beta = 1-k(1-\mu) = -1.39$ which is the average slope coefficient estimate from table 1 implies $2.69 < k < 19.92$.

An objection to Frankel and Froot's assumption that all of the survey respondents are fundamentalists can be raised because survey forecast errors typically display over-reaction to changes in the forward premium. For example, row 2 of table 5 displays the slope coefficients (β_2) that Frankel and Froot (1989) estimate by regressing the survey forecast error $\Delta s^e_{t+k} - \Delta s_{t+k}$ on the forward premium. So an alternative way to proceed might be to let $\Delta s^e_{t+k} = mE_t(\Delta s_{t+k}) + (1-m)\mathcal{E}_t(\Delta s_{t+k})$ be the average survey forecast of the k-period depreciation where m is the proportion of survey sample represented by fundamentalists.[22] Under the assumption that the noise-trader model is true, $\beta = 1-k(1-\mu)$, and $\beta_2 = k(1-m)$. Perhaps it would be reasonable to assume $m = \mu$ but unfortunately, μ and k cannot be determined in this case and some assumption about m must be made a priori. Thus for $m = 0.0, 0.3, 0.6, 0.9$, table 5 reports values of k and μ implied by Frankel and Froot's estimates of β and β_2.

Values of $m = 0$ or $m = 0.9$ generates evidence unfavorable to the model as the implied μ values for the 12-month forecasts are negative under $m = 0$ while the implied k values seem implasuibly high under $m = 0.9$. Taking $m = 0.3$ or $m = 0.6$, yields seemingly plausible

[22] Δs^e_{t+k} is the median survey forecast in the Frankel and Froot studies. Our calculations are based on the mean since with only 2 types of expectations, the median forecast is not unique.

values of μ and k.

5. Conclusion

Our re-examination of two rational theories–the standard representative-agent asset pricing model and McCallum's (1994) policy-rule model– suggests that they be applied with caution in interpreting the forward premium bias. The standard pricing model provides an intuitive and appealing theory of the forward foreign exchange risk premium but has little explanatory power. Our examination of one of the model's sharpest implications–that the sign of the deviation from rational uncovered interest parity is determined by the sign of the conditional covariance between the scaled intertemporal marginal rate of substitution of money and the payoff from forward exchange speculation–found little support from the data. Our results suggest that the problems with the model are more serious than the difficulty in producing sufficient unconditional volatility.[23] McCallum's model on the other hand, attempts to understand deviations from rational uncovered interest parity within a non-risk framework while preserving rationality of market participants. Evidently, these results are somewhat fragile and weak empirical support for the required behavior of the monetary authorities suggests that this model also be applied with some circumspection.

While the search for a rational theory of the forward premium bias has proved elusive, a potentially promising alternative approach is the quasi–rational noise–trader model of De Long*et. al.*. In addition to providing an account of the forward premium bias, the model provides an explanation for why observed foreign exchange trading volume vastly exceeds the amount necessary to finance international commerce, and the source of transient deviations of the exchange rate from its fundamental value.

[23] It is possible that the theory is true, but we've assumed and estimated the wrong data generating process. If the process produces occasional regime shifts, as described in Engel and Hamilton (1990), accounting for the peso-problem as in Evans and Lewis (1993), Backus *et. al.* (1994) and Bakaert and Hodrick (1993) would be necessary. A proper analysis of the peso problem is beyond the scope of the present paper.

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Appendix

Exchange rates: Spot and three-month forward exchange rates are taken from Harris Bank's *Weekly Review* and are drawn from those Fridays occurring nearest to the end of the calendar quarter.

Per capita consumption: for the Unites States, we use consumption expenditure on nondurables plus services divided by population. Both consumption and population data are from Citibank's *Citibase* data bank. For the other three countries, aggregate consumption expenditure and population data are taken from IMF's *International Financial Statistics* (*IFS*).

The remaining the data are from the *IFS*. Prices are measured by consumer price indices, interest rates are three-month Treasury bill rates for the United States and the United Kingdom, and call money rates for Germany and Japan (T-bill rates are not available for the latter two countries), Output, measured by industrial production, and the terms of trade, calculated as the ratio of the unit value index for exports to the unit value index for imports.