Federal Reserve Bank of Dallas
Globalization and Monetary Policy Institute
Working Paper No. 90
http://www.dallasfed.org/assets/documents/institute/wpapers/2011/0090.pdf

A Sentiment-Based Explanation of the Forward Premium Puzzle*

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September 2011

Abstract

This paper presents a sentiment-based explanation of the forward premium puzzle. Agents over- or underestimate the growth rate of the economy. All else equal, when perceived domestic growth is higher than perceived foreign growth, the domestic interest rate is higher than the foreign interest rate. At the same time, an econometrician would expect an increase in the home currency value. Together, the model with investor misperception can account for the forward premium puzzle. In addition, it helps explain the low correlation of consumption growth differentials and exchange rate growth and the high stock market correlation across countries, despite a low correlation of fundamentals. Finally, this paper provides direct empirical evidence supporting the mechanism in the sentiment-based explanation.

JEL codes: G12, F31, G14, G15

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1. Introduction

Uncovered interest rate parity (UIP) implies that the expected change in exchange rates (foreign price of domestic currency) should equal the interest rate differential between the foreign and domestic countries. Therefore, the regression coefficient of future changes in exchange rates on interest rate differentials should equal one. However, Fama (1984) and subsequent studies consistently find a negative coefficient in such regressions. That is, an increase in the foreign interest rate forecasts an appreciation of the foreign currency. The violation of UIP is often referred as the "forward premium puzzle" in the literature. This evidence also implies that there are predictable returns from investing in currency markets. The forward premium puzzle has inspired a vast theoretical work that arises to shed light on this puzzle.

In this paper, building on the concept of sentiment risk of Scheinkman and Xiong (2003) and Dumas, Kurshev, and Uppal (2009), we offer a sentiment-based explanation of the forward premium puzzle. In particular, we simply model a representative agent endowment economy for each country with complete home bias, and the agents in different countries share a common but subjective belief about future fundamentals. Agents can be optimistic (i.e., high sentiment) or pessimistic (i.e., low sentiment) about future endowment growth. When domestic sentiment is high, it means that both the home and foreign agents are optimistic about future U.S. endowment growth.[1] When agents are optimistic about the domestic economy, and all else is equal, the interest rate at home is higher than the foreign interest rate due to a strong desire to borrow to increase current consumption. Thus, the

[1]By modeling a representative agent in each country with homogeneous belief, we lose the interesting dynamics on the wealth distribution among the heterogeneous agents, as in Dumas, Kurshev, and Uppal (2009) and Xiong and Yan (2010). Thus, it is certainly interesting to consider heterogeneous beliefs. However, the purpose of the current paper is to illustrate that investor misperception can lead to the failure of UIP in the simplest possible model. We thus choose a simpler modeling approach.

key for our model to reproduce the failure of UIP is that high sentiment in one country can lead to an appreciation of this country's currency.

In a complete market, the (log) change in exchange rates, measured in units of the foreign goods per domestic goods, equals the difference between the (log) stochastic discount factors of the domestic and foreign countries. Hence, with recursive preferences, the exchange rate has to adjust to reflect differences in both current and future relative consumption across countries. When domestic sentiment is high today, high future growth at home is anticipated. Hence, from the economic agents' point of view, the home currency is expected to depreciate to reflect the anticipated difference in consumption across two countries in the future. The magnitude of this anticipated depreciation depends on the intertemporal elasticity of substitution (IES). However, an econometrician anticipates that the economic agent at home will receive a lower-than-expected endowment tomorrow, raising the marginal utility of consumption next period, and hence the home currency appreciates. The magnitude of this appreciation depends on the home agent's risk aversion since risk aversion determines the reduction in the marginal utility. Therefore, the econometrician is likely to observe a smaller depreciation or even an appreciation of home currency in the data. In particular, we show that when risk aversion is greater than the inverse of IES, the second effect dominates and high domestic sentiment predicts an appreciation of home currency from the econometrician's point of view. All together, when domestic sentiment is relatively high, the home interest rate is pushed up, and at the same time an appreciation of the domestic currency is expected. This can qualitatively account for the violation of the UIP condition in the data.

We further explore the model's ability to account for other stylized facts in the international markets. It is well documented that consumption growth is smooth and poorly correlated across countries, whereas the asset market returns are volatile and highly correlated across countries. It is also well known that the consumption growth differentials and exchange rate growth are poorly correlated in the data. Our simple model can help account for these patterns. The mechanism is very simple and similar in spirit to Colacito and Croce (2011). As long as the sentiment is highly correlated across countries, the pricing kernels are highly correlated. However, the realized consumption growth does not need to be highly correlated across countries. Due to the high correlation between pricing kernels, the asset returns are highly correlated, despite the lack of correlation of fundamentals. Moreover, since exchange rates are driven by both fundamentals and investor sentiment, the correlation between consumption growth differentials and exchange rate growth is also weakened, compared with traditional rational models (e.g., Backus and Smith (1993)). Lastly, the high correlation of pricing kernels and the low correlation of fundamentals also help address the exchange rate volatility puzzle raised by Brandt, Cochrane, and Santa-Clara (2006).

Using a data set with bilateral exchange rates between 19 industrial countries and the United States, we test the key refutable predictions for our model. For example, our model predicts that high sentiment in one country forecasts an appreciation of the country's currency, and high domestic sentiment predicts a low return on foreign exchange. Using investor sentiment data from Baker and Wurgler (2006), we indeed find that investor sentiment has significant power to forecast changes in exchange rates (relative to the U.S. dollar) and returns on foreign exchange with a correct sign as predicted by our model, with the same sign as predicted by the model. The results are strikingly consistent across all 19 industrial countries in the post-Bretton Woods period.

We also explore the predictive power of the "true" expected growth rate and the "misperceived" growth rate (i.e., sentiment) in the currency market, and we find that in predicting changes in exchange rates, both variables have significant power, but with an opposite sign. Whereas high sentiment predicts a higher future spot rate, high true expected growth rates predict a lower spot rate in the future. This evidence highlights the distinct role of sentiment and its special ability to account for a negative UIP coefficient. In a standard rational model, a high expected home-country growth rate predicts depreciation of the home-country currency. Our evidence actually supports this prediction. However, high expected home-country growth also implies a high domestic interest rate, hence leading to a positive UIP coefficient. On the other hand, a high misperceived domestic growth rate is associated with a high domestic interest rate, but predicts an appreciation of the home currency. Therefore, the misperception is crucial in generating a negative UIP coefficient.

It is well known that the forward premium (i.e., the interest rate differential between foreign and domestic countries) strongly predicts returns on foreign exchange. This paper further documents that investor sentiment has significant additional power in forecasting returns on foreign exchange. For many currencies, the R^2 of a regression in which both the forward premium and investor sentiment are included is more than double the R^2 of a regression in which the forward premium is the only predictor. Therefore, investor sentiment contains information that is not captured by the forward premium.

Considerable prior work on the forward premium puzzle has been done. A number of earlier studies have provided insightful analysis on the role of investor irrationality in foreign exchange markets.[2] Frankel and Froot (1987, 1990a) provide an early application of irrationality to currency markets. Mark and Wu (1998) develop a model in the noise trading setting of De Long, Shleifer, Summers, and Waldmann (1990), in which traders overweigh the forward premium when predicting future changes in the exchange rate. Gourinchas and

[2] There are numerous other studies attempt to explain this puzzle under rational expectations. Notable recent papers include Alvarez, Atkeson, and Kehoe (2009) who examine a segmented market, Bacchetta and Van Wincoop (2009) who use a rational inattention framework, Burnside, Eichenbaum, and Rebelo (2007) who include microstructure frictions, Farhi and Gabaix (2008) who employ a Rietz (1988) rare disaster framework, and Lustig and Verdelhan (2007) and Lustig, Roussanov, and Verdelhan (2009) who perform a cross-sectional analysis of foreign exchange portfolios. Earlier equilibrium models that attempt to explain the forward premium puzzle include Backus, Gregory, and Telmer (1993) and Bekaert (1996).

Tornell (2004) provide an explanation based upon a distortion in investors' beliefs about the interest rate process. Finally, in a closely related study, Burnside, Han, Hirshleifer, and Wang (2011) offer an explanation based on investor overconfidence on inflation.

This paper adds to the previous literature by showing that investors' misperception on the real growth rate can potentially induce a negative UIP coefficient. Investors' misperception could be derived endogenously from investor overconfidence. For example, when investors have a *constant* overconfidence bias about their signal on the growth rate, a *time-varying* misperception process can be generated endogenously in the framework of Scheinkman and Xiong (2003), Dumas, Kurshev, and Uppal (2009), and Xiong and Yan (2010). Thus, our approach allows us to use investor sentiment data to test the mechanisms inside our model directly. Indeed, our empirical evidence lends direct support for a sentiment-based explanation. More important, the same mechanism appears to help account for many salient features in international markets simultaneously. In particular, investor sentiment generates substantial long-run risk under recursive preferences, which helps account for many asset pricing moments in the international data.

The rest of the paper is organized as follows. Section 2 presents the sentiment-based exchange rate model and discusses its implications on the forward premium puzzle and several other puzzles in the international markets. Section 3 presents empirical evidence on the role of investor sentiment in the foreign exchange market. Finally, Section 4 concludes.

2. An Illustrative Example

In this section, we provide a simple example to convey the main idea of the paper. To make the presentation transparent, we assume complete home biases and complete markets. Two countries are symmetric and representative investors in both countries have power preferences and maximize their life-time utility: $\sum_{t=1}^{\infty} \delta^t \frac{c_t^{1-\gamma}}{1-\gamma}$.

Below we only consider domestic variables, and the corresponding foreign variables are denoted with a superscript "*". Assume that the data generating process for consumption growth is i.i.d. normal: $g_{t+1} = \mu_g + \sigma_g \epsilon_{g,t+1}$. However, all investors (homogeneously) believe that they can forecast consumption growth according to $g_{t+1} = \mu_g + s_t + \sigma_g \hat{\epsilon}_{g,t+1}$, where $\hat{\epsilon}_t$ is i.i.d. standard normal under investors' perception. Here, s_t can be interpreted as investor sentiment. It is worth emphasizing that we use the term "sentiment" in a very broad sense. It simply represents the difference between economic agents' (i.e., investors) belief and econometricians' belief. This difference in beliefs could be due to either *rational or irrational* learning. Moreover, we do not impose any structure on the dynamics of the sentiment process in this example. According to investors' belief, risk-free rates are:

$$r_{f,t} = -\log \delta + \gamma \mu_g + \gamma s_t - \frac{\gamma^2}{2} \sigma_g^2. \tag{1}$$

Thus, the risk-free rate differentials are:

$$r_{f,t}^* - r_{f,t} = \gamma \left(s_t^* - s_t \right). \tag{2}$$

Under a frictionless complete market, the (log) exchange rate e_t is linked to domestic and foreign discount factors m_t and m_t^* by the following equation:[3]

$$e_{t+1} - e_t = m_{t+1} - m_{t+1}^* = \gamma \left(g_{t+1} - g_{t+1}^* \right), \tag{3}$$

[3]See Backus, Foresi, and Telmer (2001) for a rigorous argument. Among others, Backus, Foresi, and Telmer (2001), Brandt, Cochrane and Santa-Clara (2006), and Colacito and Croce (2011) exploit this equation to relate the dynamics of the exchange rate to the dynamics of the domestic and foreign discount factors.

where the (log) exchange rate is defined as the foreign price per home consumption unit. Under investors' perception

$$\hat{\mathbf{E}}_t\left(e_{t+1}-e_t\right)=\gamma\left(s_t^*-s_t\right), \tag{4}$$

where $\hat{\mathbf{E}}_t(\cdot)$ is the expectation under economic agents' subjective belief conditional on information available up to time t. By looking at equation (2) and (4), it is clear that UIP holds ex ante under investors' perception. However, ex-post exchange rates evolve according to the actual data generating porcess, which is i.i.d. according to equation (3). Hence, an econometrician regressing equation (3) on equation (2) would estimate a coefficient zero. Thus, the UIP condition fails in this simple example.

However, in this simple example, the correlation between consumption growth differentials and exchange rate growth is one (see equation (3)), whereas this correlaiton is very low in the data (e.g., Backus and Smith (1993)). In the next section, we show that under recursive preferences, the UIP coefficient can be negative and the correlation between consumption growth differentials and exchange rate growth can also be substantially reduced.

3. An Exchange Rate Model with Investor Sentiment

In this section, we present a simple model of exchange rates with investor sentiment. To highlight the effect of investor sentiment on the forward premium puzzle, the model abstracts from money, and irrational belief is the only deviation from a standard two-country model. Hollifield and Yaron (2003) find that inflation risk is virtually unrelated to currency returns, and they conclude that currency models should focus on real risk. We therefore abstract our analysis from inflation and focus on the real side of the economy. A few recent studies on currency markets (e.g., Verdelhan (2010), Colacito and Croce (2011), and Engel (2011)) also shift the focus to real variables. In particular, Engel (2011) shows that Fama's (1984) results also hold in real terms.

3.1. Consumption Dynamics and Preferences

We analyze an economy with two countries that are denoted as domestic and foreign. To simplify the setup, we follow Colacito and Croce (2011) by specifying a separate pure exchange economy for each country. Consumption in the two countries is exogenously given and there is a complete home bias, meaning that the representative agent in each country only consumes the good with which he is endowed. Asset markets are complete. This setup allows us to analyze the asset prices in each country separately. Due to complete markets, we can then obtain the exchange rate dynamics by linking the pricing kernels in two countries. For convenience, we characterize endowments, preferences, and prices only for the domestic country. Identical expressions indexed by a "*" apply to the foreign country.

We consider a discrete-time economy with infinite horizons. To highlight the role in sentiment, we first assume that the true data-generating process for the consumption growth rate, $g_t \equiv \log(C_t) - \log(C_{t-1})$, is an i.i.d. process in this subsection.[4] The representative agent in the domestic economy (and the foreign economy) is sentimental and has a subjective belief that is different from the data-generating process observed by an econometrician. Under economic agents' subjective belief, the mean growth rate of the economy, s_t, is time-

[4]This assumption is innocuous and is relaxed in Section 3.4.

varying and the dynamics of consumption growth are as follows:

$$g_{t+1} = \mu_g + s_t + \sigma_g \hat{\epsilon}_{g,t+1} \tag{5}$$

$$s_{t+1} = \rho_s s_t + \sigma_s \epsilon_{s,t+1}, \tag{6}$$

where $\hat{\epsilon}_{g,t}$ and $\epsilon_{s,t}$ are i.i.d. standard joint normal under the economic agent's belief. A nonzero correlation between $\hat{\epsilon}_{g,t}$ and $\epsilon_{s,t}$ is allowed, and joint normality of the shocks are assumed throughout the paper. Since consumption is truly drawn from a distribution with a constant mean, we can interpret s_t as investor sentiment. When s_t is positive (negative), the agent is optimistic (pessimistic).

Formally, we assume that under the econometrician's view (i.e, the objective belief or the data-generating process), the dynamics for (g_t, s_t) are given by

$$g_{t+1} = \mu_g + \sigma_g \epsilon_{g,t+1} \tag{7}$$

$$s_{t+1} = \rho_s s_t + \sigma_s \epsilon_{s,t+1}, \tag{8}$$

where $\epsilon_{g,t}$ and $\epsilon_{s,t}$ are i.i.d. standard normal under the data-generating process.[5] Although consumption growth is i.i.d. under the data-generating process, sentiment still affects asset prices since equilibrium is determined by investors' beliefs. That is, the equilibrium prices are determined by the consumption dynamics given by equations (5) and (6). On the other hand, empirical tests depend on the true data-generating process. The difference between the subjective belief and the data-generating process is the key for the econometrician to obtain a negative UIP coefficient when analyzing the data. In a model with endogenous

[5]Strictly speaking, we need to show that there exist objective and subjective probability beliefs such that the dynamics of consumption follow those given here under these two probability measures. These are purely technical requirements, and the proof is just a simple application of the Girsanov theorem. The learning model in the appendix provides such an example.

investor sentiment (e.g., the model in the appendix), sentiment is likely to increase when the realized endowment is high. To capture this effect, we allow a nonzero correlation between $\epsilon_{g,t}$ and $\epsilon_{s,t}$, denoted as ρ_{gs}.

The above specification on consumption and sentiment represents the main departure from rational expectation models and hence deserves further discussion. Time-varying misperception on the growth rate (i.e., sentiment) could be derived from a learning model with overconfidence. Scheinkman and Xiong (2003), Dumas, Kurshev, and Uppal (2009), and Xiong and Yan (2010) elegantly provide such models. More importantly, in the appendix we provide an exchange rate model based on learning with overconfidence, and we show that such a mean-reverting sentiment process can be generated endogenously.[6] Nonetheless, we specify an exogenous sentiment process in our main text because modeling the origin of sentiment does not add economic insights for the purpose of this study, while it does complicate the analysis. Our overall approach is to keep the model as simple as possible while retaining the key ingredients needed to generate the failure of the UIP condition. Moreover, we show in the appendix that all the results remain when the sentiment process is modeled endogenously. We therefore believe that a model with exogenous sentiment is more effective in highlighting the role of sentiment in currency markets.

To complete the model, we follow Bansal and Yaron (2004) by specifying the investors' preferences over uncertain consumption stream C_t as the Epstein-Zin recursive utility function (e.g., Epstein and Zin (1989))

$$U_t = \left[(1-\delta) C_t^{\frac{1-\gamma}{\theta}} + \delta \left(\hat{\mathbf{E}}_t U_{t+1}^{1-\gamma} \right)^{\frac{1}{\theta}} \right]^{\frac{\theta}{1-\gamma}}, \tag{9}$$

where $\hat{\mathbf{E}}_t(\cdot)$ is the expectation under economic agents' subjective belief conditional on

[6] Empirically, the sentiment data from Baker and Wurgler (2006) also suggest that the sentiment process is mean-reverting. Thus, we specify the sentiment process as an AR(1) in equation (6).

information available up to time t, the parameter $0 < \delta < 1$ is the time discount factor, $\gamma \geq 0$ is the risk-aversion parameter, $\psi \geq 0$ is the intertemporal elasticity of substitution (IES) parameter, and $\theta = \frac{1-\gamma}{1-\frac{1}{\psi}}$. When risk aversion is larger than the reciprocal of IES, agents prefer early resolution of uncertainty of the consumption path (e.g., Kocherlakota (1990)). Hence, these preferences allow for agents' preference for the timing of the resolution of uncertainty. To generate a negative UIP coefficient, we need a preference for early resolution of uncertainty. However, unlike long-run risk models, we do not impose IES $\psi > 1$. Whether IES is below or above one has been the subject of a long-lasting debate in the literature. However, it is more conventional to assume a preference for early resolution of uncertainty.

3.2. The Stochastic Discount Factor

As shown in Epstein and Zin (1989), the logarithm of the intertemporal marginal rate of substitution (IMRS) is given by

$$m_{t+1} \equiv \log\left(M_{t+1}\right) = \theta \log \delta - \frac{\theta}{\psi} g_{t+1} + (\theta - 1)\, r_{a,t+1}, \tag{10}$$

where $r_{a,t+1}$ is the logarithm of the gross return on an asset that delivers aggregate consumption as its dividends each period. For any continuous return $r_{t+1} = \log\left(R_{t+1}\right)$, including the one on the consumption claim,

$$\hat{\mathbf{E}}_t \left[\exp\left(m_{t+1} + r_{t+1}\right)\right] = 1. \tag{11}$$

As we show below, with log-linear approximation, the return on wealth can be solved explicitly, and hence the IMRS can be obtained explicitly as well.

3.3. The Foreign Exchange Market

A foreign country is introduced into the model. The setup is similar to that used in Colacito and Croce (2011). For tractability, complete symmetry is imposed, and all the model parameters are identical across countries. Furthermore, we assume that the agents at home and abroad share the same belief, although their beliefs could be wrong. Thus, when domestic sentiment is high, it means that all the representative agents are homogeneously optimistic about the U.S. economy.

Again, under a frictionless complete market, the (log) exchange rate e_t is linked to domestic and foreign discount factors m_t and m_t^* by the following equation:

$$e_{t+1} - e_t = m_{t+1} - m^*_{t+1}. \tag{12}$$

Therefore, to solve for the exchange rate, we follow the standard argument in the long-run risk literature (e.g, Bansal and Yaron (2004) and Colacito and Croce (2011)), and we first compute the return on wealth, $r_{a,t+1}$, in the pricing kernel equation (10). It follows from Campbell-Shiller log-linear approximation that

$$r_{a,t+1} \approx \kappa_0 + \kappa_1 z_{t+1} - z_t + g_{t+1}. \tag{13}$$

We further approximate the price consumption ratio as a linear function of the state variable s_t. That is,

$$z_t \approx A_0 + A_1 s_t, \tag{14}$$

where A_0 and A_1 are constants. Substituting equations (13) and (14) back into Euler equation (11), we can solve for constants A_0 and A_1. In particular, $A_1 = \frac{1-\frac{1}{\psi}}{1-\kappa_1\rho_s}$.

Furthermore, substituting equations (13) and (14) back into equation (10) gives the equilibrium solution to the IMRS,

$$m_{t+1} = -\gamma g_{t+1} + \left(\gamma - \frac{1}{\psi}\right) s_t + \kappa_1 (\theta - 1) A_1 \sigma_s \epsilon_{s,t+1} + C_0, \tag{15}$$

where C_0 is a constant. Given the above expression for the pricing kernel, we can calculate the risk-free rate, which is determined by the agent's subjective belief and is given by

$$r_{f,t} = -\log\left(\hat{\mathbf{E}}_t \exp(m_{t+1})\right) = \frac{1}{\psi} s_t + C_1, \tag{16}$$

where C_1 is a constant. Thus, the real interest rate differential between foreign and domestic currency is

$$r^*_{f,t} - r_{f,t} = -\frac{1}{\psi}(s_t - s^*_t). \tag{17}$$

Here, we have imposed complete symmetry across countries. If we relax this assumption, $r^*_{f,t} - r_{f,t} = \frac{1}{\psi_2} s^*_t - \frac{1}{\psi_1} s_t$, where ψ_1 and ψ_2 are the IES for the domestic and foreign agent, respectively. Thus, we obtain the first testable prediction from our model.

Prediction 1 *Interest rate differentials are negatively associated with domestic investor sentiment s_t and positively associated with foreign investor sentiment s^*_t.*

Furthermore, it follows from equations (12) and (15) that the solution to changes in exchange rates is given by

$$e_{t+1} - e_t = \gamma g^*_{t+1} - \gamma g_{t+1} + \left(\gamma - \frac{1}{\psi}\right)(s_t - s^*_t) + (\theta - 1) A_1 \kappa_1 \sigma_s \left(\epsilon_{s,t+1} - \epsilon^*_{s,t+1}\right). \tag{18}$$

Notice that under the data-generating process, both ε_{t+1}, and ε^*_{t+1} have mean zero, and $\mathbf{E}_t\left(g^*_{t+1}\right) = \mathbf{E}_t(g_{t+1}) = \mu_g$. Here, $\mathbf{E}_t(\cdot)$ is the expectation under the econometrician's view (i.e., the objective belief). Therefore, taking the conditional expectation under the data-generating process yields

$$\mathbf{E}_t\left(e_{t+1}-e_t\right)=\left(\gamma-\frac{1}{\psi}\right)\cdot\left(s_t-s_t^*\right). \tag{19}$$

When investors prefer earlier resolution of consumption uncertainty (i.e., $\gamma-\frac{1}{\psi}>0$), the econometrician detects a positive relation between domestic investor sentiment and the expected changes in exchange rates. This leads to our second testable prediction from the model.

Prediction 2 *If $\gamma>\frac{1}{\psi}$, domestic investor sentiment s_t is positively associated with the changes in the exchange rate, $e_{t+1}-e_t$. That is, in the data, high domestic sentiment forecasts an appreciation of the domestic currency.*

It is worthy of note that under economic agents' belief, we have

$$\hat{\mathbf{E}}_t\left(e_{t+1}-e_t\right)=-\frac{1}{\psi}\cdot\left(s_t-s_t^*\right)=r_{f,t}^*-r_{f,t}. \tag{20}$$

Hence, when the sentiment about the domestic growth rate is high and all else equal, economic agents expect an appreciation of the foreign currency. Further, economic agents expect a UIP coefficient of one. This result is the same with traditional asset pricing models. The exchange rate has to reflect the differences in growth rates between two countries. If agents in the model expect a high growth rate in the future, they also anticipate the home currency to depreciate to reflect the differences in growth rates between two countries. Nonetheless, when confronted with the historical data, the econometrician detects a positive relation between sentiment and changes in exchange rates. More important, equation (20) is consistent with the findings in Frankel and Froot (1987, 1990b) that when ex-ante measures of expected exchange rate changes (based on survey data) instead of the ex post realizations are used as the dependent variable in UIP regression, the UIP coefficient is estimated to lie in the vicinity of one.

Finally, combining equations (17) and (19), we obtain our key result for the UIP regression:

$$\mathbf{E}_t\left(e_{t+1} - e_t\right) = \left(1 - \psi\gamma\right) \cdot \left(r^*_{f,t} - r_{f,t}\right). \tag{21}$$

We restate the result as the following key proposition.

Proposition 1 *The UIP coefficient is* $1 - \psi\gamma$*, which is always less than one and is negative as long as investors prefers early resolution of uncertainty.*

Proposition 1 is consistent with the empirical findings of Fama (1984) and Engel (2011). Therefore, this simple exchange rate model can reproduce the forward premium puzzle. We explain the model intuition below. Due to a complete market, the exchange rate (the foreign price of each home consumption unit) equalizes the marginal utility of consumption of the home and foreign agents, and hence it is positively related to the home agent's marginal utility of consumption. Under recursive preferences, the real exchange rate therefore has to adjust to reflect differences in both current and future relative consumption across countries. As we argued in the introduction, when domestic sentiment is high today, a high domestic growth rate is anticipated by economic agents. Hence, from economic agents' point of view, the home currency is expected to depreciate in the future to reflect the difference in consumption across two countries (e.g., equation (20)). Moreover, equation (20) implies that the magnitude of this anticipated depreciation depends on the intertemporal elasticity of substitution (IES). The easier it is to substitute consumption intertemporally, the less the anticipated depreciation.

However, to an econometrician who analyzes the historical data, there is another counter effect. The econometrician anticipates that the economic agent at home will receive a lower-than-expected endowment tomorrow, thus raising the marginal utility of consumption next period. Through this effect, the econometrician expects the home currency to appreciate. The magnitude of this appreciation depends on the agent's risk aversion since risk aversion determines the reduction in the marginal utility due to the lower-than-expected realized consumption endowment (e.g., equation (15)). Consequently, the econometrician is likely to observe a smaller depreciation or even an appreciation of home currency in the future. In particular, when risk aversion is greater than the inverse of IES, the second effect dominates and high domestic sentiment predicts an appreciation of home currency from the econometrician's point of view. At the same time, when domestic sentiment is high, the domestic interest is also high, due to the home agent's incentive to borrow to reduce the discrepancy between consumption today and in the future. Taken together, high interest currency is expected to appreciate in the econometrician's view. These effects together result in a negative coefficient in UIP regressions.

It is worth emphasizing that the difference of equation (20) and (21) implies that investors' prediction error on exchange rate growth is positively correlated with the forward premium (i.e. the interest rate differential). This is consistent with the findings in Froot and Frankel (1989) and Frankel and Chinn (1993). For example, Froot and Frankel (1989) examine the regression of expectation errors (based on survey data) on the forward premium. The authors find that the coefficient on the forward premium is significantly greater than zero, and this finding is robust.

The failure of the UIP condition also implies predictable returns in currency markets. We now turn to the effect of sentiment on the predictability of returns on foreign exchange. The return on foreign exchange is defined as the excess return of a domestic investor who borrows at the domestic risk-free rate (in logs), $r_{f,t}$, converts the funds into foreign currency, lends at the foreign risk-free rate (in logs), $r^*_{f,t}$, and then converts his earnings back to domestic currency. That is, the return on foreign exchange is just the return on a carry trade strategy. Hence, in logs, the return on foreign exchange, r_t^{FX}, is given by

$$r_{t+1}^{FX} = r^*_{f,t} - r_{f,t} + e_t - e_{t+1}. \tag{22}$$

Taking equations (17), (19), and (22) together, we have that under the econometrician's view, the expected returns on foreign exchange are given by[7]

$$\mathbf{E}_t\left(r_{t+1}^{FX}\right) = -\gamma \cdot (s_t - s_t^*). \tag{23}$$

The above argument leads to the third testable prediction from our model.

Prediction 3 *Returns on foreign exchange are negatively associated with domestic investor sentiment s_t, and positively associated with foreign investor sentiment s_t^*.*

Moreover, combining equations (17) and (23), we have the following result on return on foreign exchange:

$$\mathbf{E}_t\left(r_{t+1}^{FX}\right) = \gamma\psi \cdot \left(r^*_{f,t} - r_{f,t}\right). \tag{24}$$

To highlight its importance, we state it as another proposition below, which is consistent with the empirical evidence in Fama (1984).

Proposition 2 *The regression coefficient of returns on foreign exchanges on interest rate*

[7] Notice that from the economic agents' perspective, the expected return on foreign exchange is a constant (zero) and independent of s_t. This follows from equation (20) and the definition of the return of foreign exchange.

differentials is given by $\gamma\psi > 0$.

Finally, the model also has implications for the role of investor sentiment for bond yields and for returns on the consumption claim. Recall that the risk-free rate is given by $r_{f,t} = C_1 + \frac{1}{\psi} s_t$[8]. As a result, the following key implication for the predictive ability of investor sentiment for bond yield changes is obtained:

$$\mathbf{E}_t \left(r_{f,t+1} - r_{f,t} \right) = \frac{1}{\psi} \left(\rho_s - 1 \right) s_t. \tag{25}$$

Furthermore, the expected excess return on the unobservable consumption claim is given by

$$\mathbf{E}_t \left(r_{a,t+1} \right) - r_{f,t} = C_2 - s_t, \tag{26}$$

where C_2 is an appropriate constant. This leads to the following prediction of the model.

Prediction 4 *There is a negative relation between investor sentiment and future changes in bond yields. Sentiment negatively predicts returns on the consumption claim.*

In summary, our simple model can reproduce the forward premium puzzle. However, to test whether our proposed mechanism is in the data, we need to test the refutable Predictions 1-4. In Section 4., we provide evidence in support of Predictions 1-4. As a final note, we want to emphasize again that one does not necessarily need to interpret our key variable, s_t, as a investor sentiment bias. It simply represents the deviation of the economic agents' perception from the econometrican's perception. For example, s_t could be a result of agents'

[8]This equation implies a positive relation between the real interest rate and investor sentiment. In the data, the correlation between the realized real interest rate and investor sentiment is about 27%. Here, the realized interest rate is defined as the difference between the nominal interest rate and inflation.

rational learning on news shocks to technology or production, which is not observed by the econometrician.

3.4. An Extension of the Model

To highlight the importance of investor sentiment, so far we have assumed that the expected consumption growth rate is a constant under the objective measure, and hence sentiment fluctuations account for most of the movements for financial variables. We by no means think that sentiment alone can account for a large set of moments of international financial and macroeconomic variables. Other economic forces must also be at play. For example, Colacito and Croce (2011) consider a version of international long-run risk model and show that the model can help account for a large set of international asset-pricing puzzles. However, due to the constant risk premium, their model cannot address the failure of UIP. In this section, we extend the model in the previous section by introducing time-varying consumption growth under the objective measure, as in Colacito and Croce (2011). We then use the sentiment-augmented model to study the failure of UIP, which is the focus of our paper.

Under investors' belief, the domestic consumption growth dynamics can be assumed to be given by

$$
\begin{aligned}
g_{t+1} &= \mu_g + x_t + s_t + \sigma_g \hat{\epsilon}_{g,t+1} \\
x_{t+1} &= \rho_x x_t + \sigma_x \epsilon_{x,t+1} \\
s_{t+1} &= \rho_s s_t + \sigma_s \epsilon_{s,t+1},
\end{aligned}
$$

where $(\epsilon_{g,t}, \epsilon_{x,t}, \epsilon_{s,t})$ is i.i.d. joint normal (under the agent's subjective belief) with mean zero and variance one, and cross-correlations are allowed. Under the econometrician's view (i.e., the data-generating processes), however, the dynamics of consumption and sentiment are given by

$$
\begin{aligned}
g_{t+1} &= \mu_g + x_t + \sigma_g \epsilon_{g,t+1} \\
x_{t+1} &= \rho_x x_t + \sigma_x \epsilon_{x,t+1} \\
s_{t+1} &= \rho_s s_t + \sigma_s \epsilon_{s,t+1}.
\end{aligned}
$$

All the shocks are i.i.d. standard normal over time, but cross-correlations are allowed. Similar dynamics are assumed for foreign consumption. In this more general case, using a similar argument as in previous subsection, it can be shown that the expected change in exchange rates is given by

$$
\mathbf{E}_t \left(e_{t+1} - e_t\right) = -\frac{1}{\psi}\left(x_t - x_t^*\right) + \left(\gamma - \frac{1}{\psi}\right)\left(s_t - s_t^*\right), \tag{27}
$$

and the interest rate differential (i.e., the one-period forward premium) is

$$
r_{t,f}^* - r_{t,f} = \frac{1}{\psi}\left(x_t^* - x_t + s_t^* - s_t\right). \tag{28}
$$

Therefore, the true expected consumption growth and the misperceived growth have opposite predictive power for the change in the exchange rate. This prediction nicely highlights the distinct role of the misperception in consumption growth and the true expected consumption growth. We provide empirical support for this novel prediction in the next section. For simplicity, assuming independence between x_t and s_t under the objective belief, the regression coefficients of n-period changes in the exchange rate on the n-period forward premium (i.e., the long-horizon UIP coefficients) are given by

$$\beta_n = \frac{\left(\frac{1-\rho_x^n}{1-\rho_x}\right)^2 \frac{var(x_t^*-x_t)}{var(s_t-s_t^*)} - (\psi\gamma - 1)\left(\frac{1-\rho_s^n}{1-\rho_s}\right)^2}{\left(\frac{1-\rho_x^n}{1-\rho_x}\right)^2 \frac{var(x_t^*-x_t)}{var(s_t^*-s_t)} + \left(\frac{1-\rho_s^n}{1-\rho_s}\right)^2}. \tag{29}$$

With straightforward algebra, one can show the following proposition.

Proposition 3 *The coefficient β_n is increasing in horizon n, as long as $\rho_x > \rho_s > 0$. Further, if $\frac{var(x_t^*-x_t)}{var(s_t-s_t^*)} < \gamma\psi - 1$, the one-period UIP coefficient β_1 is negative.*

In the appendix, we show that through learning with overconfidence, $\rho_x > \rho_s > 0$ holds for the endogenous sentiment process.[9] As an illustrative example,[10] we simply set $\gamma = 10, \psi = 1.5,$, and $\rho_x = 0.979$ (from Bansal and Yaron (2004)) and let $\rho_s = 0.9 < \rho_x$, and $\frac{var(x_t^*-x_t)}{var(s_t-s_t^*)} = \frac{1}{2}(\gamma\psi - 1) < \gamma\psi - 1$. Then the conditions in the above proposition are satisfied, and the long-horizon UIP coefficients β_n are given by

Horizon (months)	1	3	12	24	48	60	120
UIP coefficient	-0.86	-0.63	0.09	0.51	0.77	0.82	0.89

Hence, the UIP condition holds better at longer horizons, which is consistent with the empirical findings in Gourinchas and Tornell (2004) and Meredith and Chinn (2004). In particular, at longer horizons of five and ten years, Chinn and Meredith (2004) find much less negative forward premium bias.

[9] This result is intuitive. Misperception is the difference between the true expected growth rate and the perceived expected growth rate. Hence, the persistence of the difference process should be smaller than that of the original processes.

[10] We perform a more serious calibration exercise in the Section 3.5..

3.5. Additional Implications for Correlations and Volatilities

Although the main purpose of this paper is to provide a simple sentiment-based explanation for the forward premium puzzle, we also want to explore the model's ability to account for other major puzzles in international markets. Since the model is originally proposed to account for the failure of UIP, this serves as a natural "out-of-sample" test of the model.

Specifically, we consider three stylized facts here. First, it is well documented that consumption growth is smooth and poorly correlated across countries, whereas asset market returns are volatile and highly correlated across countries. Second, it is also well known that consumption growth differentials and the exchange rate changes are poorly correlated (e.g., the Backus-Smith (1993) puzzle). Third, more recently, Brandt et al. (2006) argue that high equity premia imply highly volatile pricing kernels (about 50%). In addition, consumption growth is poorly correlated across countries. Within a power utility setting, this would suggest a low correlation between pricing kernels across countries. Together, it implies that the volatility of exchange rates should be much larger than the $10 \sim 15\%$ value observed in the data (see equation (12)). In other words, pricing kernels should be much more correlated than that suggested by consumption data, and hence quantities and prices have dramatically different implications for the correlations between the pricing kernels.[11]

In an intriguing paper, Colacito and Croce (2011) cleverly break the link between the correlation of consumption growth and the correlation of the pricing kernel by introducing highly correlated long-run consumption. In their model, pricing kernels are mostly driven by the small but persistent long-run consumption components, which are highly correlated across countries. Thus, a high correlation between pricing kernels can be reconciled with a

[11] For our model with investor misperception, the exact Hansen-Jagannathan bound actually does not apply. Hence, in theory the pricing kernels in our model do not need to be as volatile as the maximum observed Sharpe ratio. Thus, the price-implied international correlation between the pricing kernels does not need to be as high as in Brandt et al. (2006). This already makes the issue less puzzling.

low consumption correlation. Their model can also reproduce many other stylized facts in both macroeconomic and financial variables, including the low cash flow correlations, but high asset return correlations. Below we show that our simple sentiment-based model can also help generate these patterns in the data. Thus, our model provides an alternative, yet not necessarily mutually exclusive, explanation for the patterns observed in the data. One advantage of our model is that the same mechanism can help reproduce the forward premium puzzle and the low correlation between consumption growth differentials and exchange rate changes.

The mechanism of our model is very simple and similar in spirit to Colacito and Croce (2011). Even if the realized consumption growth rates are only weakly correlated across countries, the pricing kernels can still be highly correlated (see equation (15)), as long as investor sentiment is highly correlated across countries. The high correlation between pricing kernels also helps generate high asset return correlations across countries, despite low cash flow correlations. Moreover, since both sentiment and consumption affect the movements in exchange rates, the model can produce a low correlation between the observed consumption growth differentials and the exchange rate growth. In this sense, our model helps resolve the Backus-Smith puzzle. Differing with Colacito and Croce (2011), even if the sentiment process is volatile and persistent, the observed consumption growth still behaves like an i.i.d. process. Although it is hard to identify the slow-moving predictable consumption component from the consumption data, survey data do show that there is significant variation on perceived growth rates. For example, the Survey of Professional Forecasters data show that the perceived GDP growth is almost as volatile as the realized GDP itself. Thus, the volatile perceived growth rate can produce large long-run risk in the model, rasing the model's ability to match asset pricing models.

In Table 1, we briefly calibrate our model. Column 1 reports the results for a model with i.i.d. consumption growth and without investor sentiment (i.e., $\sigma_x = \sigma_s = 0$). The stock market's dividend is a levered claim on consumption with leverage $\phi = 2$. In this case, the pricing kernel is poorly correlated; the correlations between the stock market returns across countries are very low; and the consumption growth differentials and exchange rate growth are perfectly correlated. Since the risk aversion is low, the equity premium is low, as is stock market volatility. All of these results are well known. In column 2, we introduce investor misperception into the calibration. We set the international correlation of sentiment to be 93%. A few important changes are noticed. First, since misperception is persistent, the equity premium is now much larger and stock returns are also volatile due to the perceived long-run risk. Second, the stock market correlation across countries is as high as 73.3%, despite a negative dividend growth correlation. This is, of course, due to the high correlation between the resulting pricing kernels, which is now about 91% . Third, the correlation between consumption growth differentials and exchange rate growth is no longer perfect. Instead, it is only 52.2%. Here, the model is simulated at a monthly frequency. If we time aggregate the observations to an annual frequency, this correlation is even lower, closer to the counterpart in the data. Fourth, despite a large equity premium and a low consumption correlation, the model does not produce excessive volatility in foreign exchange. This is due to the large correlation of pricing kernels that resulted from the highly correlated sentiment.

In column 3, we shut down the investor sentiment channel and introduce a highly correlated long-run risk component as in Colacito and Croce (2011). We also raise the risk aversion and leverage to obtain a reasonable equity premium. Confirming their results, we also find that the model can successfully reproduce many stylized facts in the international macro and financial variables. However, there is one side effect of the highly correlated long-run risk. The correlation between consumption growth differentials and exchange rate growth is excessively high. With almost perfect correlation between long-run consumption components across countries, virtually all of the exchange rate movements come from the short-run consumption shocks. Moreover, most of the consumption movements are due to short-run shocks since consumption growth is almost an i.i.d. process. Taken together, it implies a very high correlation between consumption growth differentials and exchange rate growth. In our calibration, this correlation is almost perfect, and it is still more than 80% after time aggregation to an annual frequency. Colacito and Croce (2008) show that by relaxing the assumption of the complete home bias, this correlation can be reduced. Instead, we show that introducing investor sentiment is an alternative mechanism for reducing this correlation.

For completeness, we incorporate both "objective" long-run risk and misperception into the model in the last column. As we can see, the sentiment-augmented model helps reduce the correlation between foreign exchange growth and consumption growth differentials. In our calibration, the variation of sentiment is about $66 - 70\%$ of the variation of the realized consumption growth. This value seems a bit large, but it is consistent with the Survey of Professional Forecasters and Livingston Forecast data, both available from the Philadelphia FED. For example, the ratio of the forecasted growth volatility and realized growth volatility ranges from 46% to 88%, depending on the survey data and the forecast horizons. Reducing the volatility of sentiment and increasing risk aversion would increase the correlation of foreign exchange growth and consumption growth differentials, but would leave the rest of the results almost intact. Finally, since $\gamma\psi > 1$ and $\sigma(x_t - x_t^*)/\sigma(s_t - s_t^*) < \gamma\psi - 1$ in our calibrations with misperception, the UIP coefficients in those scenarios are negative.

Due to the short sample periods of the available data, it is very hard to identify long-run consumption components using consumption data alone. Previous studies (e.g., Bansal et al. (2009) and Colacito and Croce (2011)) therefore use financial variables to help estimate the long-run consumption component. Asset prices reflect the misperceived consumption growth, whereas the realized consumption growth does not. Our model provides another justification for looking at the financial data to identify the long-run risk. More specifically, with investor misperception, we should not just use realized consumption growth to identify perceived consumption growth. Instead, the price dividend ratio and the interest rate should contain a direct measure of the perceived long-run risk. Thus, our model provides a natural account for why estimation based on the prices and interest rates tends to support the long-run risk model more strongly. In this sense, we view our model as an alternative interpretation of the long-run risk model from a different angle, and hence our analysis complements that of Colacito and Croce (2011). Alternatively, misperception provides a natural way to generate long-run risk. Since the perceived growth rate can be substantially more volatile than the true expected growth rate, our misperception-based model can produce large asset price volatility with a low risk aversion coefficient.

Of course, we do not claim that this simple model can quantitatively account for all of the patterns observed in the data. Nonetheless, it is comforting to know that the same mechanism in the model can help reproduce many stylized facts in the international markets simultaneously. The next subsection further discusses the implication on carry trade. We then proceed to the empirical test of the key predictions (Predictions 1-4) of the model.

3.6. The Carry Trade

So far, our discussion focuses mainly on the time-series implications of the two-country model. We further discuss the cross-sectional dimension of the model in this subsection. Formally, we would need extend the two-country model to an n-country model to discuss the cross-sectional implications, which is beyond the scope of this study (see, e.g., Bakshi, Carr, and Wu (2008)). Instead, we just treat the two countries in our model as a pair of countries in a potential n-country model, as in a majority of the current literature.

Proposition 2 predicts that an investor could earn abnormal excess returns by holding the short term debt of countries with high short rates and shorting the short term bond of countries with low short rates (i.e., the carry trade). However, it is worth noting that the model implies that profits are available by trading based on *transitory* interest rate differentials, not by holding the short-term bond of a country that persistently has a higher average interest rate. To see this, suppose that the average endowment growth rates, μ_g and μ_g^* are different in domestic and foreign countries but the all other shocks are i.i.d., it follows from a reformulation of equation (18) that the country with persistently low interest rates (i.e., low average endowment growth rates) will on average appreciate. Thus, carry trading is less profitable. This is consistent with the empirical findings that countries with steadily higher interest rates have had steady currency depreciations (see, e.g., Table 2 below or Cochrane (1999)). Therefore, to make carry trading more profitable, one should focus on the transitory interest rate differentials. This implication is the same with the overconfidence model of Burnside et al. (2011).

The model implies that rational investors could earn profits through carry trade. Since we have assumed that all investors are identically biased, similar to Burnside et at. (2011), they do not engage in the carry trade to exploit the failure of UIP in equilibrium. If we were to introduce rational investors into the model, we conjecture that the effect of misperception on UIP would be reduced but not eliminated. This is because sentiment uncertainty represents a systematic risk. Even if prices reflect incorrect expectations, there is no risk-free arbitrage opportunity for rational investors (see, e.g., De Long et al. (1990)). Thus, the risk inherent in carry trades limits the arbitrage activities by risk averse rational investors. Indeed, in many behavioral models, asset prices reflect the beliefs of both rational and irrational investors, with weights depending on the risk bearing capacities of the different group (see, e.g., De

Long et al. (1990), Daniel, Hirshleifer, and Subrahmanyam (2001), and Dumas, Kurshev, and Uppal (2009)). In this sense, our representative agent model can be viewed as a reduced-form of the heterogeneous agent model.

4. Empirical Tests

In this section, we first introduce notation for the predictive variables.We then discuss the empirical design and data used in the analysis and present summary statistics. Empirical results follow. The majority of our analysis is under real terms. However, our results also hold if nominal exchange rates are used. Those results are omitted for brevity.

4.1. Definition of Variables

First, define changes in spot rates as

$$\Delta e_t = e_t - e_{t-1}. \tag{30}$$

In the empirical test that follows, we follow Engel and West (2005) and choose a 3-month forward rate. It is one of the most popular and easily available forward rates for all of the industrial countries during the period 1973-2009. The 3-month forward exchange rate F_t is observed at the end of month t for a delivery at the end of month $t+3$. Let $f_t = log(F_t)$. The 3-month forward premium is defined as

$$fp_t = f_t - e_t. \tag{31}$$

By covered interest parity, fp_t equals the difference between the 3-month risk-free rate (from the end of month t to the end of month $t+3$) in the foreign country at the end of month t and the 3-month domestic risk-free rate the end of month t. The return on foreign exchange is therefore given by

$$r_{t+3}^{FX} = f_t - e_{t+3}. \tag{32}$$

Finally, sentiment s_t is defined as the sentiment measure by Baker and Wurgler (2006). We also measure the true expected growth rate, x_t, as the trailing average of the past 3-year consumption growth rates as in Bansal, Dittmar, and Lundblad (2005).

4.2. Empirical Design

The empirical specifications are standard long-horizon predictive regressions (e.g., Fama and French (1988) and Hodrick (1992)). All variables are observed monthly. The future changes in spot rates and returns on foreign exchange rates are regressed onto investor sentiment, s_t. Therefore, the dependent variable is either the log change in foreign exchange rate, $e_{t+h} - e_t$, with different horizons or the 3-month log return on foreign exchange, r_{t+3}^{FX}. The independent variables are investor sentiment, s_t, or other predictive variables.

For example, to examine the ability of investor sentiment to predict changes in spot rates, the main regression is

$$e_{t+h} - e_t = \alpha_h + \beta_s s_t + \epsilon_{t,t+h}. \tag{33}$$

The error term $\epsilon_{t,t+h}$ is an element of the time $t+h$, and is autocorrelated due to overlapping observations when the forecast horizon, h, is greater than one. Newey-West (1987) standard errors are used to adjust for this autocorrelation and potential heteroscedasticity. The t-statistics resulting from the adjustment test the null hypothesis that a given slope coefficient equals zero.

4.3. Data

To test our model predictions, we need a proxy for investor misperception (i.e., sentiment). The misperception proxy is usually hard to obtain since it typically requires measures of ”true” expected growth and ”perceived” growth, both of which are difficult to estimate. We find that Baker and Wurgler’s (2006) sentiment index serves as a good proxy for misperception since it is orthogonalized against a set of fundamental variables. The monthly sentiment index spans over 42 years, from July 1965 to December 2007. Baker and Wurgler (2006) form their composite sentiment index by taking the first principal component of six measures of investor sentiment. The principal component analysis filters out idiosyncratic noise in the six measures and captures their common component. The six measures are the closed-end fund discount, the number and the first-day returns of IPOs, NYSE turnover, the equity share in total new issues, and the dividend premium. The individual measures are orthogonalized against industrial production, consumption growth, and NBER recession indicators before the principal component analysis is performed.

The data set on foreign exchange includes monthly spot and 3-month forward exchange rates between the U.S. dollar and currencies in 19 industrial countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, and the U.K. The data sample is between 1973m1 and 2008m12 for most countries and may vary in some countries due to data availability. Legacy exchange rates derived by Haver Analytics are used for currencies of Euro-area member countries after they switched to the euro. Again, we choose the 3-month forward rate because it is one of the most popular rates used in the literature (e.g., Engel and West (2005)) and is easily available for all the industrial countries during the period 1973-2009.

Monthly CPI data for these 19 countries and the United States over 1973m1 to 2008m12 are obtained from the IMF. Annual real consumption per capita from 1970 to 2007 is obtained from the OECD. Quarterly real U.S. consumption per capita comes from the BEA. Finally, some argue that the nature of the flexible exchange rate system during our sample period is not well understood by market participants in the early 1970s (see, e.g., Hansen and Hodrick (1980)). We therefore discard the first two years of data and start our sample from 1975m1. Nonetheless, our results are virtually the same even if we include the first two years of early data.

Spot exchange rates come from the Federal Reserve, and 3-month forward exchange rates come from the International Financial Statistics (IFS). The spot and forward exchange rates are used to calculate interest rate differentials between the U.S. dollar and other currencies. For several countries, some of the forward exchange rates are missing in the IFS. In these cases, the forward rate is obtained from Bloomberg or is calculated from the 3-month interest rate obtained from the G-10 data set. The choice of data source is dictated by data availability. Finally, we obtain monthly prices for 1- to 5-year zero-coupon bonds from June 1952 to December 2008 from CRSP.

4.4. Summary Statistics

Because the absolute magnitude of the Baker and Wurgler sentiment index has no particular meaning, we standardize the index to mean zero and unit standard deviation. The monthly sentiment series is quite persistent with annualized autocorrelation of 78%, whereas the autocorrelation calculated from Baker and Wurgler (2006) annual sentiment series is 68%.

The sentiment index is plotted in Figure 1. It appears to capture most anecdotal accounts of fluctuations in sentiment. Immediately after the 1961 crash of growth stocks, investor sentiment was low but rose to a subsequent peak in the 1968 and 1969 "electronics bubble." Sentiment fell again by the mid-1970s, but it picked up and reached a peak in the "biotech bubble" of the early 1980s. In the late 1980s, sentiment dropped but rose again in the early 1990s, reaching its most recent peak during the "internet bubble."

To facilitate comparison with prior literature, we report summary statistics for exchange rates in nominal terms. Table 2 reports the summary statistics for the monthly change in spot rate (Δe_t). The means and standard deviations of variables are given in percentages. The volatility of the monthly change in spot rate is about 3% for most of the sample countries, which is consistent with previous studies. The autocorrelation of the change in spot rate is very low, which suggests that spot rates behave like a random walk.

Table 2 shows that the currencies of Japan, Switzerland, Austria, Denmark, Germany, and the Netherlands appreciate the most against the U.S. dollar from 1973m1 to 2007m12. Precisely these countries (except Denmark) have lower interest rates than the United States during this period (or equivalently, a negative forward premium). This implies that the expectation hypothesis in currency markets seems to hold on average or in the long run. On the other hand, Table 2 also indicates that the countries with a high average interest rate also yield a slightly higher return on foreign exchange. This suggests that sorting on the interest rate differential could yield a significant spread (e.g., Lustig and Verdelhan (2007)). The volatility of returns on foreign exchange is much more volatile than the forward premium, consistent with the finding in Fama (1984).

4.5. Main Empirical Evidence

In the model, all the results pertain to real exchange rates and real interest rates. However, a majority of prior empirical studies use nominal rates. In the empirical tests below, we focus on real terms using nominal exchange rates as robustness checks. We want to emphasize that all of our empirical results are robust to both real and nominal exchange rates. Finally, because a majority of foreign exchange transactions involve U.S. dollars (about 86%), the U.S. dollar is used as the domestic currency throughout the paper.

As noted in Section 3., the real interest rate differential (i.e. the forward premium) is positively related to domestic consumption volatility, negatively related to the domestic surplus ratio, and negatively related to domestic sentiment. Since we do not have a long sample of the real interest rate, we cannot test Prediction 1 directly. Nonetheless, we use nominal rates to provide some suggestive evidence. The last column of Table 2 shows support for this prediction. The correlation between the nominal forward premium and domestic sentiment is negative for all of the 19 industrial countries, consistent with Prediction 1 in Section 3..

According to Prediction 2, changes in real exchange rates are positively related to domestic sentiment. The evidence in Table 3 is consistent with this prediction. Note that, to match the 3-month forward rate, here we focus on 3-month changes in exchange rates rather than 1-month changes. In untabulated results, we show that the results are very similar when we use one-month changes or 1-year changes in exchange rates, although the R^2 is bigger in longer horizon regressions. The results also remain similar if we use nominal exchange rates. These results, omitted for brevity, are available upon request. Finally, according to Prediction 3, returns on foreign exchange are negatively related to domestic sentiment. The results from Table 3 confirm this prediction as well. The coefficients for all the 19 countries have the correct sign, and more than two thirds of them are statistically significant.

Because sentiment data are not available for all 19 industrial countries, the analysis so far is based on U.S. investor sentiment only. This does not pose much of an issue for the sentiment-based explanation since adding foreign investor sentiment to the right-hand side of the above regressions is likely to strengthen the results. The reason for this is the following. Given a likely positive correlation of investor sentiment across countries, a standard result from the omitted variable regression suggests that the regression coefficient of exchange rate changes on domestic sentiment will increase if foreign investor sentiment is included in the regression. Thus, including foreign sentiment is likely to strengthen our empirical results. Indeed, controlling for Baker, Wurgler, and Yuan's (2009) sentiment for Canada, France, Germany, Japan, and UK,[12] we still find that the t-statistics for sentiment in regressions of returns on foreign exchange on sentiment are -2.285, -2.208, -2.986, -0.268 and -0.306 for Canada, France, Germany, Japan, and UK, respectively. The negative sign is consistent with our Prediction 3.

Previous studies have proposed alternative models to reproduce the failure of UIP. Typically, these explanations work in the following manner. The interest rate differential is approximately a linear function of some state variable (e.g., investor sentiment in our model or surplus ratios in habit models), and the expected change in exchange rates and the expected return on foreign exchange are also approximately a linear function of the same state variable. If the coefficients on the interest rate differential and on the expected change in exchange rates are opposite, then the model yields a negative coefficient in the UIP regression. However, these models operate through different mechanisms and constitute

[12]Sentiment data for Canada, France, Germany, Japan, and UK are available from Baker, Wurgler, and Yuan (2009). However, there are only 16 annual observations from 1980-2005. Moreover, not all the original six individual components in Baker and Wurgler (2006) sentiment index are available for these countries to construct the principal component.

fundamentally different views of the sources and the pricing of risk. Thus, it is particularly important to test the underlying model-implied relations between the state variables in the model and the exchange rate growth or returns on foreign exchange. The supportive evidence for Prediction 1-3 indicates that the misperception is an empirically relevant channel in explaining the forward premium puzzle. In untabulated analysis, we first construct measures of the surplus ratio and consumption volatility. We then empirically compare our misperception-based explanation with the explanations based on habit-formation (e.g., Verdelhan (2010)) and long-run risk (e.g., Bansal and Shaliastovich (2009)). The results, omitted for brevity and available upon request, seem to suggest that the misperception channel is at least as empirically relevant as the habit channel in the habit-formation model and the stochastic consumption volatility channel in the long-run risk model.

4.6. The Distinct Role of x_t and s_t

The evidence in the previous subsection provides support for the key channels in the sentiment-based explanation. In this subsection, we want to highlight the distinct role of the the objective growth rate (i.e., x_t) and the "misperceived" growth rate (i.e., sentiment) on exchange rate dynamics. The extended model in Section 3.4. shows that although both x_t and s_t are positively related to the interest rate, they have opposite power in predicting subsequent exchange rate changes.

To test this prediction, we first construct the true expected growth rate, x_t, as the trailing average of past 3-year consumption growth rates as in Bansal, Dittmar, and Lundblad (2005). Then we regress changes in exchange rates onto both investor sentiment (i.e., s_t) and expected consumption growth (i.e., x_t). Consistent with this prediction, Table 4 shows that indeed sentiment is positively related to changes in exchange rates, whereas the true expected growth rate is negatively related to changes in exchange rates. These results thus highlight the role of misperception in accounting for the negative UIP coefficient. The true expected growth rate goes the wrong way by producing a positive UIP coefficient. Since both predictors s_t and x_t are persistent, like the regression of returns on the price dividend ratio, it might be easier to identify their predictive power at long horizons. We therefore report regression results for 1-month, 3-month, and 1-year changes in exchange rates. The results are usually slightly more significant, and the R^2s are larger for long horizon regressions, consistent with the traditional regression of returns on the dividend yield. Finally, all the results are similar if we use nominal exchange rates instead.

In untabulated analysis, we find that in a regression in which the true expected growth rate, x_t, is the only predictor, only two out of the 19 regressions have a significantly negative sign for x_t. Thus, controlling for the misperceived growth, s_t, substantially improves the predictive power of x_t. In sum, this subsection documents the robust empirical fact that investor sentiment positively predicts changes in future spot rates, whereas the opposite holds for the true expected growth rate. The predictive power of investor sentiment is very robust across the 19 industrial countries.

4.7. Forecasting Returns on Foreign Exchange by Sentiment

The forward premium predicts future returns on foreign exchange (e.g., Fama (1984), Hansen and Hodrick (1980)). The popular carry trade in practice is based on this idea as well. Prediction 3 states that investor sentiment serves as a contrarian predictor of returns on foreign exchange.[13] This subsection empirically examines whether investor sentiment can predict returns on foreign exchange by controlling for the forward premium, the most well-

[13] Our model is written in real terms. But the expected returns on foreign exchange are equivalent when defined in terms of real or nominal terms (see, e.g., equation (1) and (2) in Engel (2011)).

known predictor for returns on foreign exchange.

In Table 5, returns on foreign exchange are first regressed on the 3-month forward premium. This table confirms the finding from previous studies on the predictive ability of the forward premium. The high values of Newey-West t-statistics indicate that the forward premium is indeed a significant predictor of returns on foreign exchange. In the second predictive regression, investor sentiment, s_t, is also included in the regression. The results show that investor sentiment is a statistically significant predictor of returns on foreign exchange. Further, the economic significance of the predictability is rather large. A one-standard-deviation increase in investor sentiment is associated with a decrease in annualized future returns on foreign exchange of about 6% on average.

In addition, the interaction between the forward premium and investor sentiment is generally positive and significant for 8 out of 19 countries. This indicates that the forward premium has stronger predictive power for returns on foreign exchange when sentiment is high. This is probably because when sentiment is high, sentiment traders exert greater influence. Karlsson, Loewenstein, and Seppi (2009) document that individual investors, the primary candidates for sentiment traders, check their portfolios more frequently and trade their stocks more aggressively during market run-ups. When sentiment is low, however, more rational investors occupy the market because, as Barber and Odean (2008) show, pessimistic investors stay out of market due to their reluctance to take short positions. Hence, the forward rate is closer to being an unbiased predictor for the future spot rate. Out of the 19 industrial countries, the adjusted R^2 more than doubles for 11 countries. For example, the forward premium only has weak power to predict returns on the Sweden krona with an R^2 of 2%. However, when investor sentiment and other predictors are included in the regression, the R^2 increases to 11% and the Newey-West adjusted t-statistic for investor sentiment is -4.97.

Taken together, the empirical evidence indicates that investor sentiment contains information about foreign exchange rates that is not captured by the forward premium.

4.8. Additional Evidence from Bond Markets

This section presents empirical evidence on the predictive ability of investor sentiment on bond yield changes (i.e., Prediction 4). It serves as an additional robustness check on the model's prediction.

Fama and Bliss (1987) run the following regression to test the expectation hypothesis:

$$r_{f,t+n-1} - r_{f,t} = \alpha + \beta(f_t^{(n)} - r_{f,t}) + e_{t+n-1},$$

where $r_{f,t}$ is the 1-period bond yield (in logs) from time t to t+1 and $f_t^{(n)}$ is the time t log forward rate between periods t+n-1 and t+n. The expectation hypothesis implies that $\beta = 1$. That is, future yields move one-for-one with forward-spot spreads. The forward-spot spread is also referred to as the Fama-Bliss factor or FB factor. Fama and Bliss (1987) regress each excess return against the same-maturity forward-spot spread and provide classic evidence against the expectation hypothesis in long-term bonds.

Panel A of Table 6 reports summary statistics for a zero-coupon bond at different maturities. On average, the yield is upward sloping, and the volatility of the long-term yield is slightly lower. The yields for all maturities are so persistent that they almost appear as a random walk. Panel B of Table 6 repeats the classical Fama-Bliss regression with updated data. As in Fama and Bliss (1987), Panel B confirms that the forward-spot spread predicts excess bond returns.

Panel C of Table 6 shows that investor sentiment significantly predicts yield changes. In particular, sentiment triples the R^2 for all maturities compared with the case in which the forward-spot rate is the only predictor. This is consistent with Prediction 4. For the 5-year yield change, the R^2 reaches as high as 41%. In addition, the interaction between sentiment and the forward-spot spread is significant in the long run and the coefficient is negative. This indicates that the forward-spot spread predicts a higher (and closer to one-to-one) change in future yields when sentiment is lower. Nonetheless, our current model can not account for the failure of the expectation hypothesis. It might be fruitful in future research to further explore the role of investor sentiment on the failure of the expectation hypothesis. Finally, Yuan (2008) shows that the Baker and Wurgler (2006) sentiment index has strong negative power in predicting future excess market returns, consistent with Prediction 4.

In sum, our results suggest that investor sentiment plays an important role not only in the stock market but also in two other major markets, the bond market and the foreign exchange market.

5. Conclusion

This paper presents a sentiment-based model that can account for the forward premium puzzle. In addition, the model also helps reproduce many observed patterns in the international markets, such as the low correlation between consumption growth differentials and exchange rate changes. We show that sentiment induced long-run risk is particularly useful in reproducing many key asset pricing moments. This observation could be applied to resolve other puzzles in asset markets in future research. Moreover, we also provide evidence in support of the key mechanism in the model. Our empirical evidence suggests that investor sentiment has substantial predictive power for both the currency and the bond markets. Thus, this study indicates that investor sentiment seems to be a pervasive predictor in various asset markets and provides out-of-sample support for the important role of investor sentiment in the stock market noted by previous studies (e.g., Baker and Wurgler (2006)).

The evidence of expectation-driven fluctuations in the currency market has policy implications. Exchange rate movements can change the relative prices of imports and exports when prices are fixed in the exporter's currency in the short run. A major benefit of exchange rate flexibility is that it facilitates adjustment of the relative price in response to a country-specific real shock. However, as argued by Devereux and Engel (2007), if exchange rate movements are mainly driven by changes in expectations rather than by current demand and supply conditions in the goods market, exchange rate fluctuations may cause price distortions in the goods market rather than facilitate price adjustments. This is especially true if exchange rates are driven by irrational changes in expectations as documented in this paper.

Appendix

The purpose of this appendix is to show that a model in the spirit of Scheinkman and Xiong (2003), Dumas, Kurshev, and Uppal (2009), and Xiong and Yan (2010) can generate endogenously a sentiment process that is similar to the one we specified exogenously in Section 2. Due to our assumption of the complete home bias and complete markets, we can analyze each country separately, then determine the exchange rate by linking the two pricing kernels. We therefore only consider the home country below.

In the home country, we assume that the true data-generating process for the endowment is as follows:

$$\begin{aligned} g_{t+1} &= x_t + \sigma_g \epsilon_{g,t+1} \\ x_t &= \rho_x x_{t-1} + \sigma_x \epsilon_{x,t}. \end{aligned}$$

Because the agent does not observe the true expected growth rate x_t, he has to estimate it from the historical data. In addition to consumption growth g_t, the agent observes a public signal

$$\zeta_t = \sigma_\zeta \epsilon_{\zeta,t}.$$

We assume that $(\epsilon_{g,t}, \epsilon_{x,t}, \epsilon_{\zeta,t})$ are i.i.d. standard normal and mutually independent. However, due to overconfidence, the representative agent believes that $\epsilon_{\zeta,t}$ is correlated to $\epsilon_{x,t}$ and believes that ζ_t has the following dynamics, with $\phi \in (0,1)$ as the correlation parameter measuring overconfidence:

$$\zeta_t = \sigma_\zeta \phi \epsilon_{x,t} + \sqrt{1-\phi^2}\sigma_\zeta \epsilon_{\zeta,t}.$$

Let us define $a_t \equiv \hat{\mathbf{E}}_t(x_t)$, and $P_t = \hat{\mathbf{Var}}_t(x_t)$, where $\hat{\mathbf{E}}_t(\cdot)$ and $\hat{\mathbf{Var}}_t(x_t)$ denote the mean and variance operators under the agent's information set up to time t, respectively. Then, we can define s_t as

$$s_t \equiv a_t - x_t, \tag{34}$$

which can be interpreted as investor sentiment as before since s_t measures the optimism (pessimism) on the growth rate of the endowment. By a standard application of the Kalman filter, one can show that

$$P_t = \frac{P_{t-1}\rho_x^2 \sigma_g^2}{P_{t-1} + \sigma_g^2} + \sigma_x^2\left(1-\phi^2\right).$$

At the steady state, we have

$$P_t = P \equiv \sigma_g^2 \frac{\sqrt{\left((1-\rho_x^2) - \frac{\sigma_x^2(1-\phi^2)}{\sigma_g^2}\right)^2 + 4\frac{\sigma_x^2(1-\phi^2)}{\sigma_g^2}} - \left((1-\rho_x^2) - \frac{\sigma_x^2\left(1-\phi^2\right)}{\sigma_g^2}\right)}{2} \equiv \sigma_g^2 \hat{P} \quad (35)$$

The Kalman filter also implies that the dynamics for a_t are given by

$$a_t = \rho_x a_{t-1} + K_1 \left(g_t - \mu_g - a_{t-1}\right) + K_2 \zeta_t,$$

where

$$K_1 = \frac{\rho_x \hat{P}}{\hat{P}+1} \quad \text{and} \quad K_2 = \frac{\sigma_x \phi}{\sigma_\zeta}.$$

Hence, for the the agent, the dynamics of consumption are

$$\begin{aligned} g_{t+1} &= \mu_g + a_t + \left(g_{t+1} - \mu_g - a_t\right) \\ a_t &= \rho_x a_{t-1} + K_1 \left(g_t - \mu_g - a_{t-1}\right) + K_2 \zeta_t \end{aligned}$$

The sentiment (misperception) process s_t has the following mean-reverting feature:

$$s_t = a_t - x_t = \rho_s s_{t-1} + K_1 \sigma_g \epsilon_{g,t} + K_2 \zeta_t - \sigma_x \epsilon_{x,t}, \quad (36)$$

where the persistence parameter is $\rho_s \equiv \rho_x - K_1 < \rho_x$. Hence, the endogenous sentiment is less persistent than the true expected growth rate. Again, assume that the agent has a recursive utility:

$$U_t = \left[\left(1-\delta\right) C_t^{\frac{1-\gamma}{\theta}} + \delta \left(\hat{\mathbf{E}}_t U_{t+1}^{1-\gamma}\right)^{\frac{1}{\theta}}\right]^{\frac{\theta}{1-\gamma}}, \quad (37)$$

where the parameter $\theta \equiv \frac{1-\gamma}{1-\frac{1}{\psi}}$. Now we can solve the model the same way as before by using a_t as the state variable. The logarithm of the intertemporal marginal rate of substitution (IMRS) is given by

$$m_{t+1} \equiv \log\left(M_{t+1}\right) = \theta \log \delta - \frac{\theta}{\psi} g_{t+1} + \left(\theta - 1\right) r_{a,t+1}, \quad (38)$$

where $r_{a,t+1}$ is the logarithm of the gross return on an asset that delivers aggregate consumption as its dividends each period. For any continuous return $r_{t+1} = \log\left(R_{t+1}\right)$, including the one on the consumption claim,

$$\hat{\mathbf{E}}_t \left[\exp\left(m_{t+1} + r_{t+1}\right)\right] = 1. \tag{39}$$

Plugging in the Campbell-Shiller log-linear approximation, $r_{a,t+1} \approx \kappa_0 + \kappa_1 z_{t+1} - z_t + g_{t+1}$, and the log-linear approximation on the price dividend ratio, $z_t \approx A_0 + A_1 a_t$, into the above Euler equation, we can solve for constants A_0 and A_1. In particular, we have $A_1 = \frac{1-1/\psi}{1-\kappa_1 \rho_x}$, the same as before. Furthermore, substituting the Campbell-Shiller log-linear approximation back into equation (38) gives the equilibrium solution to the IMRS,

$$m_{t+1} = -\gamma g_{t+1} + \left(\gamma - \frac{1}{\psi}\right) a_t + \kappa_1 \left(\theta - 1\right) A_1 \left[K_1 \left(g_{t+1} - \mu_g - a_t\right) + K_2 \zeta_{t+1}\right] + C_m, \tag{40}$$

where the constant C_m is a properly defined constant.

Given the pricing kernel, the risk-free rate is determined by the agent's subjective belief and is given by

$$r_{f,t} = -\log\left(\hat{\mathbf{E}}_t \exp\left(m_{t+1}\right)\right) = \frac{1}{\psi} a_t + C_1, \tag{41}$$

where C_1 is a proper constant. Thus, the interest rate differential between domestic and foreign currency is

$$r^*_{f,t} - r_{f,t} = -\frac{1}{\psi}\left(a_t - a^*_t\right) \tag{42}$$

Following from equation (40), we can write down the solution to the changes in exchange rates as follows (due to complete markets):

$$\begin{aligned} e_{t+1} - e_t &= m_{t+1} - m^*_{t+1} \\ &= \gamma g^*_{t+1} - \gamma g_{t+1} + \left(\gamma - \frac{1}{\psi}\right)\left(a_t - a^*_t\right) + \left(\theta - 1\right) A_1 \kappa_1 \\ &\quad \times \left(K_1 \left(g_{t+1} - \mu_g - a_t\right) + K_2 \zeta_{t+1} - K_1 \left(g^*_{t+1} - \mu_g - a^*_t\right) - K_2 \zeta^*_{t+1}\right). \end{aligned}$$

Let $\mathbf{E}_t(\cdot)$ be the expectation under the econometrician's view (i.e., the objective belief). Notice that under the data-generating process, both ζ_{t+1}, and ζ^*_{t+1} have mean zero, and $\mathbf{E}_t\left(g^*_{t+1}\right) = \mathbf{E}_t\left(g_{t+1}\right) = x_t$. Therefore, taking the conditional expectation under the data-generating process yields

$$\mathbf{E}_t\left(e_{t+1} - e_t\right) = -\frac{1}{\psi}\left(x_t - x^*_t\right) + \left(\gamma - \frac{1}{\psi} - \left(\theta - 1\right) A_1 \kappa_1 K_1\right)\left(s_t - s^*_t\right). \tag{43}$$

From equation (42) and (43), we can solve for the UIP coefficient, and it is given by

$$\beta_{UIP} = 1 - \left[(\psi\gamma - 1) \left(1 + \frac{\kappa_1 \rho_x}{1 - \kappa_1 \rho_x} \frac{\hat{P}}{\hat{P} + 1} \right) + 1 \right] \left[1 - \frac{cov\left(\left(x_t - x_t^* \right), \left(a_t - a_t^* \right) \right)}{var\left(a_t - a_t^* \right)} \right] \tag{44}$$

At steady state, one can show that

$$\begin{aligned} var\left(a_t\right) &= \frac{\sigma_x^2 \rho_x^2}{1 - \rho_x^2} \frac{\hat{P}}{\left(\hat{P} + 1 - \rho_x^2\right)} \left\{ 1 - \frac{\left(\hat{P} + 1\right)\left(1 - \rho_x^2\right)}{\left(\hat{P} + 1\right)^2 - \rho_x^4} \right\} + \sigma_x^2 \phi^2 \frac{\left(\hat{P} + 1\right)^2}{\left(\hat{P} + 1\right)^2 - \rho_x^2} \\ cov\left(x_t, a_t\right) &\approx \frac{\sigma_x^2 \rho_x^2}{1 - \rho_x^2} \frac{\hat{P}}{\hat{P} + 1 - \rho_x^2} \end{aligned}$$

When $\phi = 1$ (i.e., completely overconfident), we have $\hat{P} = 0$. Then we have

$$\beta_{UIP} = 1 - \psi\gamma, \tag{45}$$

which is the same as before, and the UIP coefficient is negative as long as the agent prefers an early resolution of uncertainty. When the international correlation is zero, we have

$$\begin{aligned} \beta_{UIP} &= 1 - \left[(\psi\gamma - 1) \left(1 + \frac{\kappa_1 \rho_x}{1 - \kappa_1 \rho_x} \frac{\hat{P}_{11}}{\hat{P}_{11} + 1} \right) + 1 \right] \times \\ &\times \left[\frac{ -\frac{\rho_x^2}{1-\rho_x^2} \frac{\hat{P}_{11}}{\left(\hat{P}_{11}+1-\rho_x^2\right)} \frac{\left(\hat{P}_{11}+1\right)\left(1-\rho_x^2\right)}{\left(\hat{P}_{11}+1\right)^2-\rho_x^4} + \phi^2 \frac{\left(\hat{P}_{11}+1\right)^2}{\left(\hat{P}_{11}+1\right)^2-\rho_x^2} }{ \frac{\rho_x^2}{1-\rho_x^2} \frac{\hat{P}_{11}}{\left(\hat{P}_{11}+1-\rho_x^2\right)} \left\{ 1 - \frac{\left(\hat{P}_{11}+1\right)\left(1-\rho_x^2\right)}{\left(\hat{P}_{11}+1\right)^2-\rho_x^4} \right\} + \phi^2 \frac{\left(\hat{P}_{11}+1\right)^2}{\left(\hat{P}_{11}+1\right)^2-\rho_x^2} } \right] \end{aligned} \tag{46}$$

We can show that β_{UIP} is decreasing in overconfidence parameter ϕ. In typical numerical examples, we find that as long as ϕ is larger than 0.3, β_{UIP} is small or negative (results available upon request). The above results suggest that when the overconfidence bias is not too small, an econometrician tends to find a UIP coefficient less than one or even negative in the data. Hence, in this appendix, we provide a simple model with endogenous sentiment, and we show that the results are similar in the model with exogenous sentiment. However, the intuition in the model with exogenous sentiment is more straightforward.

Figure 1: U.S. Investor Sentiment Index

The investor sentiment index is from 1965:07 to 2007:12. The sentiment index is the first principal component of six measures. The six measures are the closed-end fund discount, the NYSE share turnover, the number of and average of first-day returns on initial public offerings (IPOs), the equity share in new issues, and the dividend premium. To control for macro conditions, the six raw sentiment measures are regressed on the growth of industrial production, the growth of durable consumption, the growth of nondurable consumption, the growth of service consumption, the growth of employment, and a dummy variable for National Bureau of Economic Research (NBER) recessions.

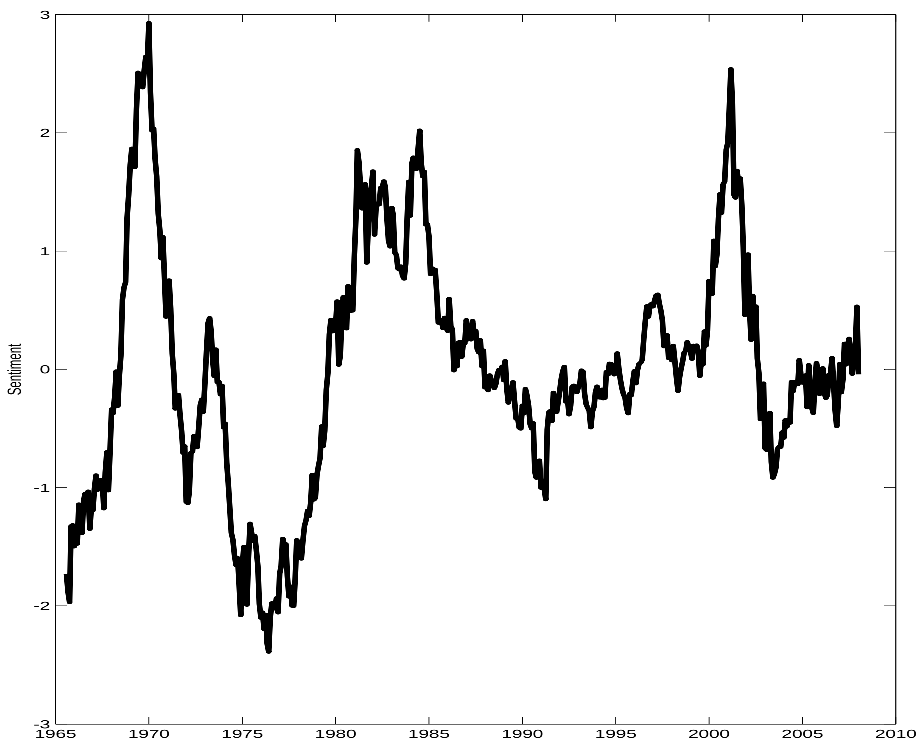

Table 1: Calibration

This table reports the key moments of international markets for our symmetric calibration. The model is calibrated at a monthly frequency. The dividend growth is specified as $g_{d,t+1} = \mu_d + \phi(x_t + s_t) + \sigma_d \hat{\epsilon}_{d,t+1}$ under agents' perception and $\hat{\epsilon}_{d,t}$ is i.i.d. normal under agents' perception. However, under the data-generating process, $g_{d,t+1} = \mu_d + \phi x_t + \sigma_d \epsilon_{d,t+1}$, where the data-generating process for $\epsilon_{d,t}$ is i.i.d. normal. The following parameters are fixed through all calibrations: $\mu_g = 0.0015$, $\mu_d = 0.0007$, $\sigma_g = 0.006$, $\sigma_d = 0.027$, $\rho_x = 0.987$, $\rho_s = 0.965$, $\delta = 0.998$, $\rho(\epsilon_s, \epsilon_s^*) = 0.930$, $\rho(\epsilon_x, \epsilon_x^*) = 0.999$, $\rho(\epsilon_g, \epsilon_g^*) = 0.3$, $\rho(\epsilon_d, \epsilon_d^*) = -0.1$, and all the unspecified correlations are set to zero.

Risk aversion γ	2.750	2.750	5.750	2.750
IES ψ	2.500	2.500	2.500	2.500
σ_s	0.000	0.132	0.000	0.132
σ_x	0.000	0.000	0.030	0.024
Leverage (ϕ)	2.000	2.000	3.000	2.000
Correlation b/t log pricing kernel: $\rho(m_t, m_t^*)$	0.301	0.907	0.936	0.922
Volatility of FX growth $\sigma(\Delta e_{t+1})$	0.068	0.129	0.141	0.129
AC(1) of FX growth $\rho(\Delta e_{t+1}, \Delta e_t)$	-0.001	-0.012	-0.001	-0.012
$\rho(g_{t+1}^* - g_{t+1}, \Delta e_{t+1})$	1.000	0.522	0.999	0.523
Average price-dividend ratio	4.033	3.118	2.903	3.020
Volatility of price-dividend ratio (%)	0.000	20.876	27.755	25.034
Mean excess stock return (%)	-0.455	3.372	4.429	4.135
Volatility of excess stock return (%)	9.358	21.383	18.259	22.663
Sharpe ratio of the stock market	-0.049	0.158	0.243	0.182
Average interest rate $E(r_f)$ (%)	3.048	1.962	2.172	1.761
Volatility of interest rate $\sigma(r_f)$ (%)	0.000	0.697	0.259	0.727
Interest rate correlation $\rho(r_f, r_f^*)$	1.000	0.929	1.000	0.935
Correlation b/t excess market returns	-0.099	0.733	0.711	0.763
Correlation b/t consumption growth $\rho(g, g^*)$	0.301	0.301	0.363	0.342
Volatility of consumption growth (%)	2.079	2.079	2.177	2.142
Correlation b/t dividend growth $\rho(g_d, g_d^*)$	-0.099	-0.099	-0.054	-0.086
Volatility of dividend growth (%)	9.358	9.358	9.555	9.414
Volatility of pricing kernel	0.057	0.300	0.396	0.327
Ratio of var(s)/var(g)	0.000	0.702	0.000	0.661
Ratio of var(x)/var(g)	0.000	0.000	0.088	0.058

Table 2: Summary Statistics

This table reports mean ($E(\cdot)$), standard deviation (σ), and autocorrelation (ρ) for monthly changes in exchange rates (Δe_t), the 3-month forward premium (fp_t) (e.g., the difference between the foreign interest rate and the U.S. rate), and 3-month (overlapping) returns on foreign exchange (r_t^{FX}) (e.g., borrow from the U.S. dollar and invest in the foreign bond). All variables are observed at a monthly frequency. The last column reports the contemporaneous correlation between sentiment and the forward premium. The sample is observed monthly from 1973m1 to 2007m12 during which both exchange rate data and sentiment data are available. The means and standard deviations are on a percentage basis.

Country	$E(\Delta e_t)$	$\sigma(\Delta e_t)$	$\rho(\Delta e_t)$	$E(fp_t)$	$\sigma(fp_t)$	$\rho(fp_t)$	$E(r_t^{FX})$	$\sigma(r_t^{FX})$	$\rho(r_t^{FX})$	$corr(fp_t, s_t)$
Australia	0.09	2.95	-0.00	0.90	1.04	0.69	0.52	5.29	0.69	-0.21
Canada	-0.00	1.56	0.02	0.19	1.50	0.91	0.20	3.13	0.73	-0.17
Denmark	-0.07	3.12	0.03	0.44	0.90	0.79	0.61	5.72	0.71	-0.41
Japan	-0.24	3.31	0.04	-0.72	1.06	0.80	-0.07	6.17	0.72	-0.39
New Zealand	0.11	3.23	0.05	1.03	0.99	0.96	0.58	5.99	0.75	-0.02
Norway	-0.04	2.91	0.02	0.60	1.48	0.34	0.69	5.34	0.67	-0.15
Sweden	0.08	3.07	0.09	0.44	1.15	0.64	0.20	5.69	0.72	-0.25
Swiss	-0.28	3.52	0.05	-0.82	0.87	0.81	-0.05	6.54	0.71	-0.24
U.K.	0.04	2.95	0.07	0.55	0.78	0.75	0.42	5.50	0.70	-0.48
Austria	-0.21	3.19	0.04	-0.26	0.84	0.85	0.32	6.17	0.71	-0.48
Belgium	-0.11	3.19	0.05	0.19	0.74	0.80	0.36	6.17	0.71	-0.16
Finland	-0.01	2.95	0.05	0.90	1.34	0.89	0.67	5.57	0.71	-0.57
France	-0.03	3.10	0.03	0.24	0.69	0.80	0.07	5.86	0.71	-0.21
Germany	-0.20	3.23	0.05	-0.49	0.76	0.93	0.06	6.20	0.70	-0.26
Ireland	0.06	2.99	0.04	0.41	0.93	0.82	0.92	5.49	0.71	-0.11
Italy	0.20	3.00	0.09	1.47	1.36	0.51	0.74	5.81	0.74	-0.11
Netherlands	-0.18	3.20	0.03	-0.25	0.96	0.49	0.09	6.11	0.69	-0.30
Portugal	0.39	3.15	0.08	1.67	1.02	0.99	1.50	5.76	0.72	-0.38
Spain	0.14	3.03	0.10	1.29	1.92	0.25	0.42	6.17	0.79	-0.21
Expected Sign										-

Table 3: Forecasting Exchange Rate Changes and Returns on Foreign Exchange by Sentiment

This table reports results from the monthly overlapping predictive regression of 3-month changes in real exchange rates and 3-month returns on foreign exchange on investor sentiment, s_t, respectively. The sample is monthly from 1973m1 to 2007m12 during which investor sentiment data are available. β is the coefficient of the corresponding regression. Similarly, t is the t-statistic, and R^2 is the adjusted r-squared for the predictive regression. The Newey-West standard error is used to adjust for heteroscedasticity and autocorrelation in error terms. The coefficient β for sentiment is in percentage.

	$(e_{t+3} - e_t)$ on s_t			(r^{FX}_{t+3}) on s_t		
Country	$\beta(s_t)$	$t(s_t)$	R^2	$\beta(s_t)$	$t(s_t)$	R^2
Australia	0.75	2.41	0.02	-1.93	-3.98	0.07
Canada	0.10	0.48	-0.00	-0.42	-1.72	0.01
Denmark	1.02	2.36	0.03	-1.39	-3.14	0.05
Japan	1.02	2.33	0.02	-1.39	-3.14	0.04
New Zealand	0.85	1.87	0.02	-1.38	-2.27	0.04
Norway	0.67	1.67	0.01	-0.98	-2.32	0.03
Sweden	1.09	2.44	0.03	-1.40	-2.99	0.05
Swiss	1.28	2.01	0.02	-1.38	-2.45	0.04
U.K.	0.92	2.38	0.03	-0.91	-1.51	0.02
Austria	1.06	2.51	0.03	-1.47	-2.75	0.05
Belgium	1.28	2.75	0.04	-1.42	-2.64	0.05
Finland	0.61	1.56	0.01	-1.28	-2.96	0.04
France	1.01	2.07	0.03	-1.15	-1.95	0.03
Germany	1.44	2.49	0.03	-1.31	-2.51	0.04
Ireland	0.70	1.43	0.01	-1.09	-1.27	0.01
Italy	0.56	1.00	0.01	-1.55	-1.80	0.03
Netherlands	1.13	2.36	0.03	-1.48	-2.75	0.05
Portugal	0.59	0.98	0.01	-2.71	-0.91	0.02
Spain	0.73	1.30	0.01	-1.16	-1.57	0.03
Expected Sign	+	+		-	-	

Table 4: Forecasting Changes in Exchange Rates by Sentiment and True Expected Growth Rates

This table reports results from the monthly overlapping predictive regression of 1-, 3-, and 12-month changes in real exchange rates on investor sentiment, s_t, and the true expected growth rate x_t. The sample is monthly from 1973m1 to 2007m12 for regressions with investor sentiment. β is the coefficient of the corresponding regression. Similarly, t is the t-statistic, and R^2 is the adjusted r-squared for the predictive regression. The Newey-West standard error is used to adjust for heteroscedasticity and autocorrelation in error terms. The coefficient β for sentiment is in percentage.

	$e_{t+1} - e_t$ on s_t and x_t					$e_{t+3} - e_t$ on s_t and x_t					$e_{t+12} - e_t$ on s_t and x_t				
Country	$\beta(s_t)$	$t(s_t)$	$\beta(x_t)$	$t(x_t)$	R^2	$\beta(s_t)$	$t(s_t)$	$\beta(x_t)$	$t(x_t)$	R^2	$\beta(s_t)$	$t(s_t)$	$\beta(x_t)$	$t(x_t)$	R^2
Australia	0.29	2.38	-0.08	-0.11	0.00	0.78	2.51	-0.91	-0.49	0.02	2.56	2.10	-8.30	-1.40	0.07
Canada	0.02	0.28	0.65	1.67	0.00	0.07	0.35	1.03	1.00	0.00	0.06	0.06	-2.43	-0.68	0.00
Denmark	0.38	2.36	-1.24	-1.61	0.01	1.14	2.55	-4.18	-2.08	0.04	3.17	2.11	-18.78	-3.08	0.12
Japan	0.37	2.38	-0.27	-0.35	0.01	1.05	2.38	-1.04	-0.51	0.02	3.26	1.90	-7.96	-1.31	0.06
New Zealand	0.37	2.08	-1.20	-1.72	0.01	0.99	2.22	-4.57	-2.25	0.04	2.52	1.80	-16.45	-3.01	0.09
Norway	0.24	1.67	-0.92	-1.31	0.00	0.75	1.85	-2.84	-1.58	0.02	2.16	1.56	-11.73	-2.06	0.07
Sweden	0.37	2.40	-0.51	-0.68	0.01	1.16	2.46	-2.26	-1.09	0.03	3.43	1.91	-14.14	-2.05	0.09
Swiss	0.51	2.22	-1.96	-2.01	0.01	1.48	2.35	-6.73	-2.63	0.05	4.38	2.39	-28.01	-3.64	0.18
U.K.	0.35	2.75	-1.03	-1.39	0.01	1.03	2.91	-3.41	-1.81	0.04	3.38	3.02	-14.61	-2.89	0.15
Austria	0.39	2.44	-1.26	-1.66	0.01	1.19	2.78	-4.10	-2.13	0.04	3.68	2.86	-17.41	-3.23	0.13
Belgium	0.45	2.72	-1.24	-1.59	0.02	1.40	3.03	-4.18	-2.09	0.06	4.59	2.74	-18.05	-3.02	0.15
Finland	0.23	1.59	-1.10	-1.47	0.00	0.72	1.74	-3.82	-1.91	0.02	1.72	1.14	-15.56	-2.24	0.07
France	0.40	2.42	-1.45	-1.88	0.01	1.16	2.54	-4.89	-2.38	0.05	3.28	1.83	-19.05	-3.10	0.12
Germany	0.54	2.47	-1.80	-1.78	0.01	1.62	2.77	-5.88	-2.29	0.05	5.11	3.03	-25.12	-3.31	0.15
Ireland	0.21	1.53	-1.12	-1.64	0.00	0.65	1.96	-4.03	-2.34	0.03	1.61	1.54	-15.31	-3.26	0.10
Italy	0.25	1.34	-1.58	-1.83	0.01	0.72	1.41	-5.20	-2.36	0.03	1.72	0.86	-18.44	-2.93	0.08
Netherlands	0.43	2.41	-1.57	-1.97	0.01	1.28	2.65	-4.96	-2.42	0.05	3.79	2.61	-18.97	-3.11	0.13
Portugal	0.22	1.06	-0.32	-0.35	-0.00	0.64	1.05	-1.61	-0.65	0.01	1.71	0.57	-10.46	-1.18	0.03
Spain	0.25	1.18	-0.92	-0.96	0.00	0.82	1.40	-3.13	-1.19	0.02	2.58	1.09	-16.35	-2.13	0.07
Expected Sign	+	+	-	-		+	+	-	-		+	+	-	-	

Table 5: Forecast Returns on Foreign Exchange by Sentiment and the Forward Premium

This table reports results from two regressions. The first (on the left) is the monthly overlapping predictive regression of 3-month returns on foreign exchange (e.g., borrow at the U.S. risk-free rate and invest in the foreign 3-month risk-free bond, then convert back to dollar) onto the 3-month forward premium, fp_t. The second (on the right) is the monthly overlapping predictive regression of 3-month returns on the 3-month forward premium, fp_t, investor sentiment, s_t, and the interaction between s_t and fp_t. The sample period is from 1973m1 to 2007m12. The Newey-West standard errors are used to adjust for heteroscedasticity and autocorrelation in error terms. The coefficient β for sentiment is in percentage.

Country	fp_t	$t(fp)$	adj-R^2	fp_t	$t(fp)$	s_t	$t(s_t)$	$s_t fp_t$	$t(s_t fp_t)$	adj-R^2
Australia	1.41	4.51	0.08	1.27	3.63	-1.30	-3.08	-0.50	-0.97	0.12
Canada	1.06	11.40	0.26	0.97	8.07	-0.25	-1.01	0.48	1.60	0.27
Denmark	1.21	3.50	0.03	1.06	2.28	-1.39	-2.54	0.51	1.59	0.06
Japan	2.90	5.86	0.12	2.75	3.98	0.29	0.50	0.92	1.67	0.13
New Zealand	2.10	4.87	0.13	1.87	4.19	-1.50	-1.98	0.37	0.73	0.16
Norway	0.99	5.47	0.08	0.90	4.24	-1.09	-2.27	0.41	1.77	0.10
Sweden	0.66	1.32	0.02	0.62	1.33	-1.99	-4.97	1.71	4.04	0.11
Swiss	1.95	3.26	0.07	1.74	3.01	-0.61	-0.61	0.34	0.49	0.08
U.K.	1.83	2.84	0.06	2.16	2.92	-0.96	-1.75	1.65	2.51	0.13
Austria	1.78	3.01	0.06	1.32	2.06	-0.67	-1.09	0.56	0.90	0.08
Belgium	1.18	1.63	0.02	1.09	1.35	-1.51	-2.64	0.45	0.76	0.05
Finland	0.58	1.55	0.02	0.34	0.57	-1.84	-2.77	0.48	1.37	0.05
France	1.79	2.30	0.04	1.74	2.40	-1.50	-2.51	1.75	2.47	0.08
Germany	1.41	1.93	0.03	1.34	1.97	0.70	0.64	2.27	2.00	0.08
Ireland	0.72	0.95	0.01	0.90	1.81	-1.26	-1.61	4.59	2.83	0.08
Italy	0.57	1.04	0.01	-0.02	-0.03	-4.86	-3.26	2.06	2.18	0.08
Netherlands	1.58	3.57	0.06	1.24	2.91	-0.97	-1.61	0.24	0.56	0.08
Portugal	1.34	1.63	0.05	1.46	1.26	-7.39	-2.26	4.57	2.40	0.09
Spain	1.03	4.02	0.10	0.98	4.55	-1.62	-2.33	0.64	2.28	0.13

Table 6: Bond Yields and Investor Sentiment

Panel A reports summary statistics for bond yields at different maturities. $y_t^{(n)}$ is the yield at time t for a zero-coupon bond that expires in n years. Data are from 1965m1 to 2007m12. In Panel B, future yield changes are regressed on the forward-spot spread at corresponding maturity, i.e., the Fama-Bliss factor (FB). In Panel C, future yield changes are regressed on the current Fama-Bliss factor, sentiment, and their interaction.

Panel A: Summary Statistics for Yields at Different Maturities.

	$y_t^{(1)}$	$y_t^{(2)}$	$y_t^{(3)}$	$y_t^{(4)}$	$y_t^{(5)}$
mean	0.055	0.057	0.058	0.060	0.060
std	0.029	0.028	0.028	0.027	0.027
Skewness	0.888	0.861	0.855	0.847	0.855
Kurtosis	3.940	3.725	3.645	3.573	3.485
AC(1)	0.986	0.989	0.990	0.990	0.991

Panel B: Yield Change Regression

Maturity	$\beta(FB)$	$t(FB)$	$R^2(FB)$
2	0.152	0.710	0.004
3	0.412	1.388	0.032
4	0.620	2.832	0.078
5	0.840	3.671	0.128

Panel C: Yield Changes Regression With Sentiment:

Maturity	$\beta(FB)$	$t(FB)$	$\beta(S_t)$	$t(s_t)$	$\beta(s_t \cdot FB)$	$t(s_t \cdot FB)$	R^2
2	0.069	0.325	-0.004	-1.928	-0.075	-0.378	0.068
3	0.391	1.322	-0.011	-3.555	-0.170	-0.747	0.241
4	0.691	3.506	-0.011	-3.294	-0.430	-2.466	0.374
5	0.904	5.347	-0.010	-2.293	-0.506	-2.648	0.406

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