Overconfidence in Foreign Exchange Markets

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Abstract

Overconfidence in Foreign Exchange Markets

This paper examines if overconfidence can be an explanation to the forward premium puzzle in foreign exchange markets. We investigate overconfidence by analysing traders' over-precision toward noisy signals. We find some evidence that traders' overconfidence about their signals for spot and forward rates contributes to the forward premium puzzle. Among the four signals we use, i.e., money supply, inflation, nominal interest rates, and economic growth, traders show overconfidence about money supply in JPY and EUR, inflation in CHF and GBP, and short-term interest rates in CAD.

Keywords : Overconfidence, Uncovered Interest Parity, Forward Premium Puzzle, Behavioural Finance, Foreign Exchange Markets

1. Introduction

The forward premium anomaly resulted from the failing Uncovered Interest Parity (UIP) hypothesis in financial markets has been one of the most puzzling economic phenomena. Academic attempts with a number of different approaches to provide possible explanations to the puzzle have been made but without decisive solution yet[1]. Among them, we investigate investors' psychological biases in foreign exchange market as one important reason to the anomaly. With the rise of behavioural finance, psychological approaches have gained popularity[2]. In this branch of studies, investors are assumed to be irrational rather than rational, and their behavioural biases cause various anomalies that are not well explained with rational framework. Our focus in this study lies in behavioural biases, overconfidence in particular, of traders in the foreign exchange market. Overconfidence is assumed to greatly affect one's judgement in decision making, resulting in mispricing.

Overconfidence is defined in several different ways in the psychology or science literature[3]. Under the assumption that markets are efficient, any information should be fully and instantaneously reflected in prices (Fama et al., 1969). This process of pricing can be modelled in the Bayesian framework where traders form a posterior expectation at the arrival of new information. On the other hand, when investors are overconfident about the signals they receive, they over-react to the signals and thus the posterior expectation is biased(DeLong et al. (1988), Griffin and Tversky (1992), Odean (1998), Daniel, Hirshleifer, and Subrahmanyam (1998, 2001), Gervais and Odean (2001), Deaves et al. (2010), and Lambert et al. (2012)).

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1 See Malkiel and Fama (1970) and Froot and Frankel (1989).

2 See Fama (1998), Barberis et al. (1998), Benos (1998), Hong and Stein (1999), Shleifer (2000), Hirshleifer and Luo (2001), Barberis and Thaler (2003), Oberlechner and Osler (2008), Hwang and Rubesam (2013), Alti and Tetlock (2014), Baker and Ricciardi (2014), Barberis et al. (2015), and Huang et al. (2015).

3 Some researches on the psychology of overconfidence include Moore and Healy (2008), Johnson and Fowler (2011), Ifcher and Zarghamee (2014), Ehrlinger et al. (2016), and Balzan (2016).

In our model, we observe investors' overconfidence in the following two ways. First, overconfident (under-confident) investors may underestimate (overestimate) the variance of noisy signals. They will evaluate differently how much precise the information they receive, or how big the noises are. Then they will construct biased beliefs according to their evaluations. We calculate the overconfidence coefficients and explore their trends in the last three decades. When the coefficients are greater than 1, we decide that the investors are overconfident about their information set, and coefficients between 0 and 1 reveal under-confidence of investors. The negative coefficients may represent contrarian investment strategies but we can still judge by their absolute values. Second, considering that experts are likely to be overconfident in making investments in forward markets[4], we compare overconfidence coefficients in spot markets and forward markets of major currencies of five countries, CAD of Canada, JPY of Japan, CHF of Switzerland, EUR of the European Union (EU), and GBP of the United Kingdom (UK). If overconfidence in the forward market is greater than its counterpart in the spot market, then we can consider that overconfidence is dominant in the market at certain corresponding time periods.

One of the aims of this study is to examine if overconfidence can be an explanation to the forward premium puzzle in the foreign exchange market. We first calculate overconfidence coefficients using the aggregate signals in spot and forward markets, respectively. Then we construct beta coefficients and compare their signs to those of the estimation outcomes of the forward premium equations. Taking a psychological approach, we assume that the anomaly is caused by the price distortion due to overconfidence biases the investors have. If our assumption is correct, the beta estimates calculated by overconfidence coefficients in spot and forward markets must be able to replicate the signs of the regression outcomes. We observe that overconfidence explains the failure of the UIP hypothesis. In other words, we observe the

[4] See DeLong et al. (1988), Griffin and Tversky (1992), and Odean (1998).

presence of overconfidence in the markets for CAD and JPY and the identical signs of the beta coefficients for those two currency markets out of five. Therefore, it seems probable to conclude that the failing UIP and the Forward Premium Puzzle are attributable to the psychological biases the investors have towards market signals as long as overconfidence is present in the market. The other markets for CHF, EUR, and GBP do not show mean overconfidence greater than 1. Therefore, different signs of beta coefficients indicate that the anomaly in those markets can be due to factors other than overconfidence.

Next, we investigate if investors show different level of overconfidence towards each signal. As investors observe multiple signals in the market, they receive and update them with uneven degrees of severity and respond to differently. That is, in addition to how overconfidence changes over time, we are also interested in how differently the investors react to each macroeconomic signal: money supply, inflation, nominal short-term interest rates, and economic growth. In the empirical work, we estimate the signal-wise overconfidence. Literature on overconfidence and its impacts on financial market mostly focus on heterogeneity in information processing among investors, but they do not show towards which signals traders are more likely to be overconfident. The purpose of this study is to fill the gap in the literature by answering this question. To put the results briefly, investors' reactions are not consistent over the entire markets. They show different levels of overconfidence toward different macroeconomic signals in each currency market. Investors in the markets for JPY and EUR mostly over-react to money supply (M2), those in the markets for CHF and GBP over-react to inflation (PPI), and those in the market for CAD over-react to short-term interest rates (STIR). See Section 4 for more detailed explanations.

This paper is organized as follows. First, the literature review in Section 2 provides the background and motivation of this research. Section 3 provides the model to construct the noisy signals and estimate overconfidence coefficients toward each signal. Then, we repeat the same steps with the newly constructed aggregate signals and estimate the overall overconfidence in each market. Section 4 delivers the empirical test results on the presence of overconfidence. It reports the comparison of beta coefficients and explains how overconfidence can be an explanation to the forward premium puzzle. It also explains about toward which signals the investors respond most sensitively. Finally, Section 5 provides the conclusion.

2. Literature review

According to the UIP hypothesis, the expected return on domestic asset must be equivalent to the expected return on its foreign counterpart by exchange rate adjustment. The UIP predicts that higher domestic nominal interest rates lead to currency depreciation and thus to increase in the ratio of foreign currency to domestic currency, yielding forward premium or profits in carry trades. The vis-a-vis relation between expected changes in exchange rates and nominal interest rate differentials, however, has few supporting empirical findings. For example, Fama (1984), Froot and Thaler (1990) and Sarno (2005) find results that contradict what the UIP predicts: currencies with higher interest rates tend to appreciate rather than depreciate. Fama (1984), particularly, shows that regressions of changes in spot exchange rate on forward premium (forward less spot) yield negative slope coefficients, indicating the failure of the UIP and the occurrence of forward premium puzzle as a result.

A large volume of studies explores the puzzle from various perspectives. For instance, Verdelhan (2010) and De Paoli and Sondergaard (2017) suggest persistent consumption habits as a vehicle to explain the anomaly, whose models are based on Campbell and Cochrane's (1999) habit-based preferences. Rietz (1988), Barro (2006) and Farhi and Gabaix (2015) consider rare disasters and their impacts on the changes in exchange rates. Gourinchas and Rey (2007) and

Alquist and Chinn (2008) explain that forward premium anomaly occurs due to financial adjustments in each country, where future excess returns on net foreign portfolio and trade surpluses are expected to offset the loss from the external accounts. Bacchetta and van Wincoop (2010) and Gabaix and Maggiori (2015) take behavioural approaches to explore the puzzle. The former focuses on infrequent portfolio decisions of investors while the latter examines how financiers' behaviours could have explanatory power to the anomaly. There have been other works focusing on structural factors such as trade openness (Bodart et al., 2015), and heterogeneity in information among investors (Bacchetta and van Wincoop, 2006; Beckmann and Stix, 2015).

In particular, in foreign exchange market, Burnside, Han, Hirshleifer, and Wang (BHHW) (2011) investigate that trader overconfidence could be an explanation for the forward premium puzzle. They find that investors who are overconfident in their information about future inflation cause a greater overshooting in the forward rate and carry trade profits. Using purchasing power parity as the benchmark model, they show that their model can explain the forward premium bias and other stylized facts in foreign exchange markets. Chuang and Lee (2006) is another work to document the presence of overconfidence in financial markets by characterising four hypotheses on overconfidence. Behavioural approaches mostly focus on disparate information processing of agents in the market, with a given set of informative signals and biases. To answer one of our research inquiries: towards which signals the investors show overconfidence, we assume that investors receive signals of macroeconomic variables and evaluate them with different weights.

Through an extensive literature survey, we first decide the information traders use to predict exchange rates. Four informative variables were selected: differentials in money supply, inflation, nominal interest rates, and economic growth between two countries following the traditional monetary model in Frankel (1979). Empirical validity in Bilson (1978) and many other advocates are referred to below. Traders in the foreign exchange markets observe those macroeconomic variables and extract certain signals on which they put more or less weights than they should. Morris and Shin (2002), Baeriswyl and Cornand (2014), and Naini and Naderian (2016) suggest possible reasons to such unequal weighting. First, it can be due to incomplete common knowledge available. Economic agents have information on only relevant to their own activities but are incompletely informed about the impacts on the aggregate level. In other words, if agents put a large weight on certain signals, then there is a possibility of over-reaction to them. Another reason to over-reaction is inaccuracies contained in the signals received. This contradicts to the traditional assumption of complete information and homogeneous reactions of agents. Our model considers both sides, that is, the information the investors receive contains noises in itself and is responded to differently.

Nominal policy rate differentials are commonly used in exchange rate determination, as it was originally considered in the UIP hypothesis model. Fama (1975) and Frankel (1979) explain that changes in nominal interest rate also reflect changes in expected inflation rate in line with Fisher's equation. When the expectation on the domestic inflation level changes, traders would adjust their expectations for the value of domestic currency and future exchange rates. Bilson (1978) provide empirical validity of nominal interest rates along with real income and money supply. Other examples are Kirikos (2002) and De Bock and Filho (2015). Nominal interest rates are usually concerned along with the intervention of monetary policy authorities in their exchange rate determination[5]. Similarly, monetary expansions by the central banks are of typical use and have well-documented effects on exchange rates as in Dornbusch (1976), Engel and Frankel (1982, 1984) and Cornell (1982). Also, a greater supply of domestic money in foreign exchange market than others will decrease its value relative to other currencies. Money supply differentials between two countries are employed in our regression because they are important

[5] See McCallum (1994) and Anker (1999).

signals from which traders receive information on changes in exchange rates. Bilson (1978) reports that M2 and M3 are more suitable in this type of analysis than using M1, so we choose M2 particularly due to its data availability. The third variable we include is real income growth. While the effects of exchange rates on economic growth have been extensively explored[6], the opposite direction has gained relatively less attention. The monetary model in Bilson (1978) includes real income as an indicator of domestic purchasing power and consequential demand for money. In our study, Industrial Production Index (IPI) is used instead of Gross Domestic Production (GDP) because IPI is available in monthly frequency while the latter is not. Finally, the relation between inflation rates and exchange rates has been explored in a large body of literature (Kamin (1996)[7], Choudhri and Hakura (2006), and Gali and Monacelli (2005)). As explained in Frankel (1979), the monetary model of exchange rate determination is to capture the changes in demand for money as a result of movements toward money market equilibrium. In other words, inflation leads to a higher demand for money and depreciation in the value of domestic currency. We use Producer Price Index (PPI) instead of widely used Consumer Price Index (CPI) due to data availability.

3. Model setup

We first propose a model that can be used for the estimation of overconfidence using Bayesian framework as in Odean (1999), Daniel, Hirshleifer, and Subrahmanyam (DHS) (1998,

[6] See Aghion et al. (2009), Rodrik (2008) and Eichengreen (2007).

[7] Kamin (1996) examines the inertial impacts of past inflation on the real exchange rate adding reliability to the theory.

2001), and Epstein and Schneider (2008). Following these studies, we define overconfidence as over-precision in signals.[8]

3.1 Price perceived by overconfident traders

Suppose that the log-price of a currency follows a random walk:

$$p_t = p_{t-1} + \epsilon_t, \tag{1}$$

where a shock is $\epsilon_t \sim N(0, \sigma_{\epsilon t}^2)$. At time *t*, traders receive signals to predict ϵ_{t+1} in a similar way to those of DHS (1998) and Epstein and Schneider (2008). The signal for the log-price consists of a shock on the future payoff at time *t* + 1 and noise at time *t*:

$$s_t = \epsilon_{t+1}(1 + \varepsilon_t),$$

where $\varepsilon_t \sim N(0, \sigma_{\varepsilon t}^2)$ represents noise, $\mathrm{cov}(\epsilon_{t+1}, \varepsilon_t) = 0$, and $\mathrm{var}(s_t) = \sigma_{\epsilon t+1}^2(1 + \sigma_{\varepsilon t}^2)$. For traders, the state of the world is represented by p_t and s_t, and traders' expectation is decided by their posterior about ϵ_t given s_t whose variances are unknown to them.

Upon receiving the signal, traders apply Bayes' rule to update their prior beliefs about the price. During the updating process, overconfident traders believe that their information about the future price is more precise than it actually is, as in Odean (1998), DHS (1998, 2001), Gervais and Odean (2001), and Epstein and Schneider (2008). Suppose that the parameter γ_t represents this overprecision: overconfident traders undervalue the variance of noise, i.e., $\frac{1+\sigma_{\varepsilon t}^2}{\gamma_t}$, and thus γ_t is larger than 1, whereas γ_t would appear to be between 0 and 1 for traders who are not confident about their information. Then, upon receiving s_t, traders' posterior mean is

$$E_t^b(p_{t+1}|s_t) = p_t + \gamma_t w_t s_t, \tag{2}$$

$$var_t^b(p_{t+1} - p_t|s_t) = \gamma_t^2 var_t(w_t s_t) \tag{3}$$

[8] Overconfidence appears in the forms of over-precision, over-placement, and overestimation. A typical type of overconfidence discussed in the finance and economics literature is over-precision about the signal.

where $w_t = \frac{1}{1+\sigma_{\varepsilon t}^2}$, the super-scripts b reflect the bias due to their behavoiral biases, i.e., overconfidence. The effects of overconfidence on traders' posterior mean and variance are proportional to the overconfidence level γ_t and γ_t^2, respectively.

Overconfident traders are more likely to trade derivatives such as options or futures than underlying assets, because they can take advantege of the high leverage in derivatives. Moreover, derivatives have relative merits with respect to their liquidity, transaction costs, and easiness of shorting. Because of these speculators' preference for derivatives, empirical studies find that derivatives indeed lead their underlying prices.[9] An implicit assumption in this setting is that the overconfident traders are risk-neutral and the profit maximization is the only goal. For these traders derivaties may be regarded as an easy trading space to achieve their goal. On the other hand, other uninformed investors who do not receive the signal are assumed to be risk averse. Then, the overconfident traders push prices away from fully rational values as described below. See DHS (1998) for detailed explanation.

Therefore, when traders trade currencies following their posterior expectation, the effects of overconfidence on the derivatives are larger than those on the underlying currencies. For given p_t, when the posterior expectation of forwards by traders who receive signal s_t is instantaneously reflected in forwards, the forwards rate is

$$f_t^b = E_t^b(f_{t+1}|s_t) = p_t + \gamma_t^f w_t s_t, \tag{4a}$$

where γ_t^f represents trader confidence level in the derivatives (forward) market. When $\gamma_t^f > 1$, overconfidence arises whereas underconfidence arises when $1 > \gamma_t^f > 0$. Likewise, when traders' posterior expectation of the spot rate is instantaneously reflected in the spot rate, the spot rate at time *t* appears

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[9] Many previous studies show empirical evidence that derivatives indeed lead their underlying prices (Hansen and Hodrick (1980), Amin and Lee, 1997; Cao, Chen, and Griffin, 2005; Chakravarty, Gulen, and Mayhew, 2004; Chan, Chung, and Fong, 2002; Chan, Kot, and Ni, 2011; Manaster and Rendleman, 1982; Pan and Poteshman, 2006)

$$p_t^b = E_t^b(p_{t+1}|s_t) = p_t + \gamma_t^s w_t s_t, \tag{5a}$$

where γ_t^s represents trader confidence level in the spot rate. When there is no over- or under-confidence, $\gamma_t^f = \gamma_t^s = 1$, the forward and spot rates are

$$f_t = E_t^b(f_{t+1}|s_t) = p_t + w_t s_t, \tag{4b}$$

$$p_t^* = E_t^b(p_{t+1}|s_t) = p_t + w_t s_t, \tag{5b}$$

respectively, and the biases are $(\gamma_t^f - 1)w_t s_t$ and $(\gamma_t^s - 1)w_t s_t$, respectively.

Finally, at time $t+1$ when full information ϵ_{t+1} is released without noise, the underlying price appears as

$$p_{t+1} = p_t + \epsilon_{t+1} = p_t^b - \gamma_t^s w_t s_t + \epsilon_{t+1}. \tag{6}$$

Traders repeat the prediction at time $t+1$ with noisy signal s_{t+1} as follows

$$f_{t+1}^b = E_{t+1}^b(f_{t+2}|s_{t+1}) = p_{t+1} + \gamma_{t+1}^f w_{t+1} s_{t+1}, \tag{7}$$

$$p_{t+1}^b = E_{t+1}^b(p_{t+2}|s_{t+1}) = p_{t+1} + \gamma_{t+1}^s w_{t+1} s_{t+1}. \tag{8}$$

Note that p_t is not directly observed. Traders only observe f_t^b and p_t^b, the outcome of their trading. To examine the relation between overconfidence and forward premium puzzle, we run the regressions below.

Proposition The regression equations are

$$p_{t+1}^b - f_t^b = \alpha + \beta^f\left(f_t^b - p_t^b\right) + \delta_t, \tag{9}$$

where $\beta^f = \frac{1-\gamma_t^f}{\left(\gamma_t^f - \gamma_t^s\right)}$, and

$$p_{t+1}^b - p_t^b = \alpha + \beta^p\left(f_t^b - p_t^b\right) + \delta_t, \tag{10}$$[10]

where $\beta^p = \frac{1-\gamma_t^s}{\left(\gamma_t^f - \gamma_t^s\right)}$.

Proof (See the Appendix.)

[10] While the UIP hypothesis suggests that changes in interest rates lead to changes in the evaluation s of domestic currency, our study investigates the beta coefficients from the forward premium regressions.

The proposition explains the forward premium puzzle with traders' overconfidence, i.e., negative coefficients on $f_t^b - p_t^b$ in (10). First, we consider traders who normally react to the signal they receive, i.e. $\gamma_t^f > 0$ and $\gamma_t^s > 0$. When traders are overconfident about their signal and they trade futures rather than spots, we would expect that the effects of overconfidence on the forward reates are larger than those on the spot rates. Thus we expect $\gamma_t^f > \gamma_t^s > 1$. In this case, the proposition shows the subsequent reversals, i.e., $\beta^f < 0$ and $\beta^p < 0$. Traders over-react to signals in both spot and forward markets, but forwards are affected more than spots because they trade forwards rather than spots. On the other hand, when traders are underconfident in signals and trade spots rather than forwards, i.e, $1 > \gamma_t^s > \gamma_t^f$, negative β^f and β^p are observed.

Second, we can think of investors who have a contrarian investing style towards the signal. In this case, overconfidence coefficients are negative. When investors are overconfident in the contrarian way, we would observe $-1 > \gamma_t^s > \gamma_t^f$, which will result in $\beta^f < 0$ and $\beta^p < 0$. On the other hand, a contrarian underconfidence will be the case such that $0 > \gamma_t^f > \gamma_t^s > -1$. In this case we would observe $\beta^f > 0$ and $\beta^p > 0$. Other cases are also interesting. For example, when traders in the underlying market are underconfident ($1 > \gamma_t^s$) but those in the forwards are overconfident ($\gamma_t^f > 1$), the subsequent reversals arises in $p_{t+1}^b - f_t^b$, i.e., $\beta^f < 0$, but the price difference between forwards and the spot rate increases $p_{t+1}^b - p_t^b$ because of a positive β^p. We revisit this in Section 4.2.2 when interpreting the outcomes.

Summarising, the negative coefficients β^f and β^p indicate that traders are either overconfident or underconfident about signals and they trade forwards when overconfident and spots when underconfident. One exception is the case where positive betas reveal that investors are contrarian and underconfident towards the market signals they receive. Contrarian investment is a prevailing strategy in the financial markets. Investors who take this measure would buy poorly performing currencies and sell them at higher rates. As explained above, a positive β^p for forward premium is a driving force of deppreciation of domestic currency relative to its foreign counterpart.

3.2 Procedure for empirical analysis

We need the signal $s_{kt} = \epsilon_{t+1}(1 + \varepsilon_{kt})$ to test the hypotheses. At time t, traders cannot *ex ante* identify the shock (ϵ_{t+1}) included in the signal. Once price is updated with the signal, then traders realise the contribution of the signal on the spot and forward rates *ex post*. Therefore, we estimate the signal that traders use to update the spot and forward rates under the assumption that traders have perfect foresight. Construction of the noisy signal s_t is as follows. From equation (5a), we have

$$p_{t-1}^b = p_{t-1} + \gamma_{t-1}^s w_{t-1} s_{t-1},$$

$$p_t^b = p_t + \gamma_t^s w_t s_t,$$

$$p_{t+1}^b = p_{t+1} + \gamma_{t+1}^s w_{t+1} s_{t+1}.$$

Let

$$\begin{aligned}\nabla p_{t+1}^b &= p_{t+1}^b - p_{t-1}^b \\ &= p_{t+1} - p_{t-1} + \gamma_{t+1}^s w_{t+1} s_{t+1} - \gamma_{t-1}^s w_{t-1} s_{t-1} \\ &= \epsilon_{t+1} + \epsilon_t + \gamma_{t+1}^s w_{t+1} s_{t+1} - \gamma_{t-1}^s w_{t-1} s_{t-1},\end{aligned}$$

where p_t^b is the realized log price we can observe and ∇p_{t+1}^b is the log-difference with two lags. For forward markets, we apply γ_{t+1}^f and γ_{t-1}^s instead. If the foreign exchange markets instantaneously respond to the market signals, only unexpected news (random-walk residuals) affects exchange rates. Under the assumption of perfect foresight, we construct the signal *k* ($s_{kt} = \epsilon_{t+1}(1 + \varepsilon_{kt})$) and then the signal ($s_t = \epsilon_{t+1}(1 + \varepsilon_t)$) using the following four steps:

1st step: $s_{kt}=\alpha_k+\beta_k\nabla p_{t+1}^b+\nu_{kt}$ where $\beta_k=\frac{cov(\nabla p_{t+1}^b,s_{kt})}{var(\nabla p_{t+1}^b)}=\frac{cov(\epsilon_{t+1},s_{kt})}{var(\nabla p_{t+1}^b)}=\frac{var(\epsilon_{t+1})}{var(\nabla p_{t+1}^b)}$.

In this decomposition, s_{kt} is divided into two components, $\beta_k\nabla p_{t+1}^b$ that contributes to ∇p_{t+1}^b (or ϵ_{t+1}) and $\alpha_k+\nu_{kt}$ which can be interpreted as noise.

2nd step: $s_{kt}=\sqrt{\beta_k}\nabla p_{t+1}^b(\sqrt{\beta_k}+\frac{\alpha_k+\nu_{kt}}{\sqrt{\beta_k}\nabla p_{t+1}^b})=\epsilon_{t+1}(1+\varepsilon_{kt})$,

where $\varepsilon_{kt}=\frac{\alpha_k+\nu_{kt}}{\sqrt{\beta_k}\nabla p_{t+1}^b}+\sqrt{\beta_k}-1$.

From the 2nd step, we can estimate ϵ_{t+1} and ε_{kt}. Since ϵ_{t+1} is one-month-ahead error term in the price, it is not a signal-specific term. Note that the variance of $\sqrt{\beta_k}\nabla p_{t+1}^b$ in the 2nd step is equivalent to $var_t(\epsilon_{t+1})$, because $var_t\left(\sqrt{\beta_k}\nabla p_{t+1}^b\right)=\beta_k var_t\left(\nabla p_{t+1}^b\right)$

$$=\frac{var_t(\epsilon_{t+1})}{var_t(\nabla p_{t+1}^b)}var_t\left(\nabla p_{t+1}^b\right)=var_t(\epsilon_{t+1}).$$

If β_k is negative, we can apply $\sqrt{|\beta_k|}\nabla p_{t+1}^b$ instead. We use conditional variance, which can be estimated with the GARCH(1,1) model. Assume that $\epsilon_t=\sigma_{\epsilon_t}\zeta_t$ and $\varepsilon_{kt}=\sigma_{\varepsilon_{kt}}\xi_t$ where $\zeta_t\sim t(v_1)$ and $\xi_t\sim t(v_1)$, respectively. If $\sigma_{\epsilon_t}^2$ and $\sigma_{\varepsilon_{kt}}^2$ follow GARCH(1,1) processes and ζ_t and ξ_t are independent, then we have $var_t(s_{kt})=E_t((\epsilon_{t+1}(1+\varepsilon_{kt}))^2)=E_t(\epsilon_{t+1}^2(1+\varepsilon_{kt})^2)=E_t\left(\sigma_{\epsilon_t}^2\right)E_t(\zeta_t^2)\left(1+E_t(\sigma_{\varepsilon_{kt}}^2)E_t(\xi_t^2)\right)=\frac{var_t(s_{kt})}{E_t\left(\sigma_{\epsilon_t}^2\right)}=1+E_t(\sigma_{\varepsilon_{kt}}^2)$. Therefore, we can estimate $\sigma_{\epsilon_{t+1}}^2$ and $\sigma_{\varepsilon_{kt}}^2$ from the 2nd step. Now estimate b^{p^*} and b^{f^*} from equation (11).

$$p_{t+1}^b-p_{t-1}^b=a^p+b_k^{p*}s_{kt}+e_{pt}$$

$$p_{t+1}^b-p_{t-1}^b=a^f+b_k^{f*}s_{kt}+e_{ft} \tag{11}$$

where $b_k^{p*}=\frac{cov(p_{t+1}^b-p_{t-1}^b,s_{kt})}{var(s_{kt})}=\frac{cov(\epsilon_{t+1},s_{kt})}{var(s_{kt})}=\frac{var(\epsilon_{t+1})}{var(s_{kt})}=\frac{1}{1+\sigma_{\varepsilon k}^2}=w_{pk}$, and $b_k^{f*}=w_{fk}$.

Also, we can construct equation (12),

$$p_t^b-p_{t-1}^b=\alpha^p+b_k^{p\prime*}s_{kt}+\xi_{pt}$$

$$p_t^b-p_{t-1}^b=\alpha^f+b_k^{f\prime*}s_{kt}+\xi_{ft} \tag{12}$$

where $b_k^{p\prime*} = \frac{cov(s_{kt}, p_t^b - p_{t-1}^b)}{var(s_{kt})} = \frac{cov(s_{kt}, \epsilon_t + \gamma_{kt}^s w_{kt} s_{kt} - \gamma_{kt-1}^s w_{kt-1} s_{kt-1})}{var(s_{kt})}$

$$= \frac{\gamma_{kt}^s w_{pkt} var(s_{kt})}{var(s_{kt})} = \gamma_k^s w_{pk},$$

and likewise, $b_k^{f\prime*} = \frac{\gamma_{kt}^f w_{fkt} var(s_{kt})}{var(s_{kt})} = \gamma_k^f w_{fk}$.

Then, overconfidence coefficients in spot and forward markets can be obtained as following: $\gamma_k^s = b_k^{p\prime*}/b_k^{p*}$ and $\gamma_k^f = b_k^{f\prime*}/b_k^{k*}$, representing overconfidence toward signal k in spot and forward markets, respectively. The first two steps can be repeated to decompose ϵ_{t+1} and ε_{kt} for each s_{kt}. Once each of the signal is decomposed, then the aggregate signal traders use to predict exchange rates, s_t, can be obtained by weighting these individual signals as follows.

3rd step: $\nabla p_{t+1}^b = \mu + \sum_{k=1}^K \pi_k s_{kt} + \nu_{t+1}$ to obtain $w_k^* = \frac{\pi_k}{\sum_{k=1}^K \pi_k}$.

Note that the sum of w_k^* is one and thus w_k^* is the weight on signal k.

4th step: $s_t = \sum_{k=1}^K w_k^* s_{kt} = \epsilon_{t+1}(1 + \varepsilon_t)$, where $\varepsilon_t = \sum_{k=1}^K w_k^* \frac{\alpha_k + \nu_{kt}}{\sqrt{\beta_k} \nabla p_{t+1}^b}$,

where ϵ_{t+1} and ε_t are the aggregated fundamental shock and noise from all K signals, respectively. Also, applying the same weights, we can get the γ_t^s, γ_t^f, and w_t using a similar method.

4. Empirical Analysis

4.1 Data description

The effects of trader overconfidence on exchange rates are investigated for the five major currencies: Canadian Dollar (CAD), Japanese Yen (JPY), Switzerland Franc (CHF), European

Euro (EUR), and British Pound (GBP), against U.S. Dollar (USD). Monthly spot and forward exchange rates from January 1985 to December 2016 are obtained from Thomson Reuter's Datastream, and taken natural log differentials in order to calculate monthly changes in the rates.

Various variables have been proposed to explain exchange rates in the literature. Among these, we select four macroeconomic variables as our signal: money supply (m_t), output growth (y_t), short-term nominal interest rates (i_t), and inflation rates (π_t). These variables are those used in the classical monetary model in Frankel (1979)[11] and Engel (2011, 2013) who explain the changes in spot exchange rates of domestic currencies against its foreign partner in the form of domestic less foreign (the U.S.). We take the U.S. as the foreign country whose macroeconomic variables are presented with a superscript with an asterisk, because our exchange rates are released using direct quotation. We conduct our study using these conventional variables as a fundamental analysis before considering more variables.

For the short-term interested rates, we use three-month Treasury Bill (TB) rates. For the Euro, our analysis is restricted by the shorter time series of short-term interest rate which is available since January 1990. The interest rates (i_t) are calculated with respect to the U.S. TB rate (i_t^*): $i_t - i_t^*$. For money supply, after considering various concepts of money as suggested in Bilson (1978), we use M2 of each country in local currencies. Producer Price Index (PPI) is used as proxy for inflation, and Industrial Production Index (IPI) is used in lieu of national output because of its monthly releases.[12] These three indices are taken log-differences between the five countries and the U.S.: $m_t - m_t^*$, $y_t - y_t^*$, and $\pi_t - \pi_t^*$, respectively, where m_t, y_t, and π_t represent the logarithms of M2, PPI, and IPI, respectively.

All the logarithms of macroeconomic variables were taken on the residuals produced after

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[11] $\Delta e_{t+1} = \beta_0 + \beta_1(m_t - m_t^*) + \beta_2(y_t - y_t^*) + \beta_3(i_t - i_t^*) + \beta_4(\pi_t - \pi_t^*) + \varepsilon_t$, where e_t stand for log of spot exchange rate as the amount of domestic currency equivalent to 1 USD, and Δe_{t+1} is its monthly change $\Delta e_{t+1} = (e_{t+1} - e_t)$.

[12] For the economic growth in Switzerland, we implement interpolation since its IPI is only published in the quarterly frequency.

applying Autoregressive (AR) processes for each variable. If the foreign exchange market is efficient, then exchange rates fully reflect all past information and should follow Markov processes. The lags in the AR processes depend on the residual autocorrelation of variables and thus are not necessarily the same. In fact, these variables are highly persistent, but only unexpected signals matter.

4.2 Empirical results

4.2.1 Estimation of overconfidence coefficients

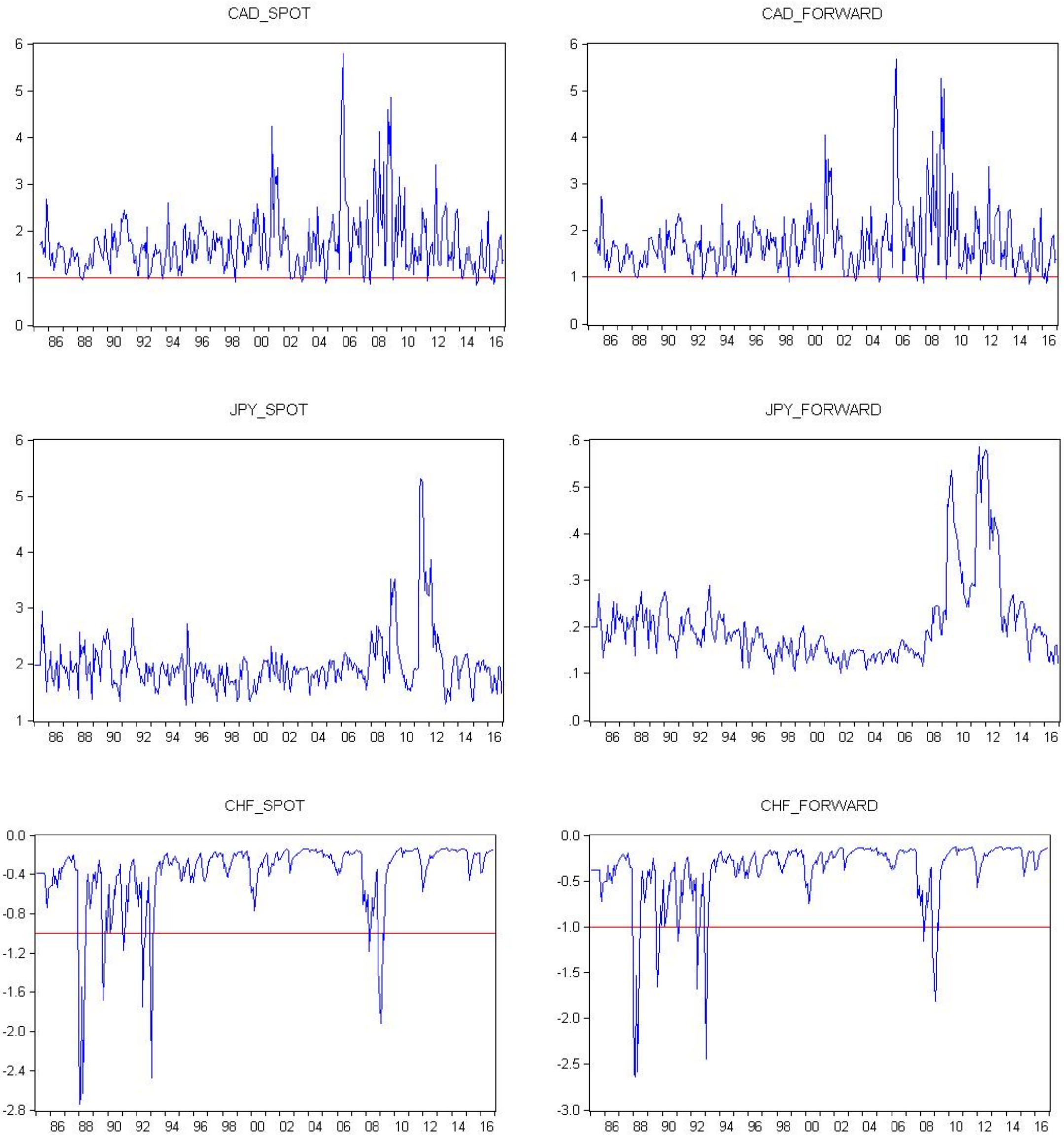
The overconfidence coefficient in each market is estimated following the steps explained in the previous subsection. Each macroeconomic signal is calculated as described in Step 1 and Step 2. The aggregate signal $s_t = \sum_{k=1}^{K} w_k^* s_{kt}$ is constructed through Step 3 and Step 4. Then the overconfidence for the individual signal (γ_{kt}^s and γ_{kt}^f) and that for the aggregated signal (γ_t^s and γ_t^f) are calculated using equations (11) and (12). Table 1 and Figure 1 show the results.

Table 1 Summary of overconfidence in spot and forward markets

	Spot					Forward				
	CAD	JPY	CHF	EUR	GBP	CAD	JPY	CHF	EUR	GBP
Mean	1.72	1.98	-0.39	-0.43	0.35	1.73	0.20	-0.38	0.98	0.48
Median	1.60	1.91	-0.27	-0.38	0.33	1.62	0.18	-0.26	0.82	0.45
Max	5.8	5.31	-0.13	-0.21	1.25	5.68	0.59	-0.12	3.12	1.79
Min	0.86	1.26	-2.74	-1.22	0.16	0.85	0.10	-2.64	0.40	0.20
Std. Dev	0.65	0.49	0.38	0.16	0.13	0.66	0.09	0.36	0.51	0.19

Figure 1   Overconfidence in spot and forward markets

Figure 1 illustrates the features of overconfidence in the market for each currency, CAD, JPY, CHF, EUR, and GBP. As mentioned in the model setting, the gamma coefficients whose absolute values are greater than 1 reveal overconfidence, and those between 0 and 1 reveal under-confidence. The horizontal straight line represents $\gamma = 1$, the threshold for overconfidence. Negative coefficients represent reversed reactions toward signals, i.e. contrarian investing strategy. Regardless of the sign, we decide that there is overconfidence when the absolute value of gamma is greater than 1. The overall sign of gamma coefficient is determined by the impact each macroeconomic variable has on the return.



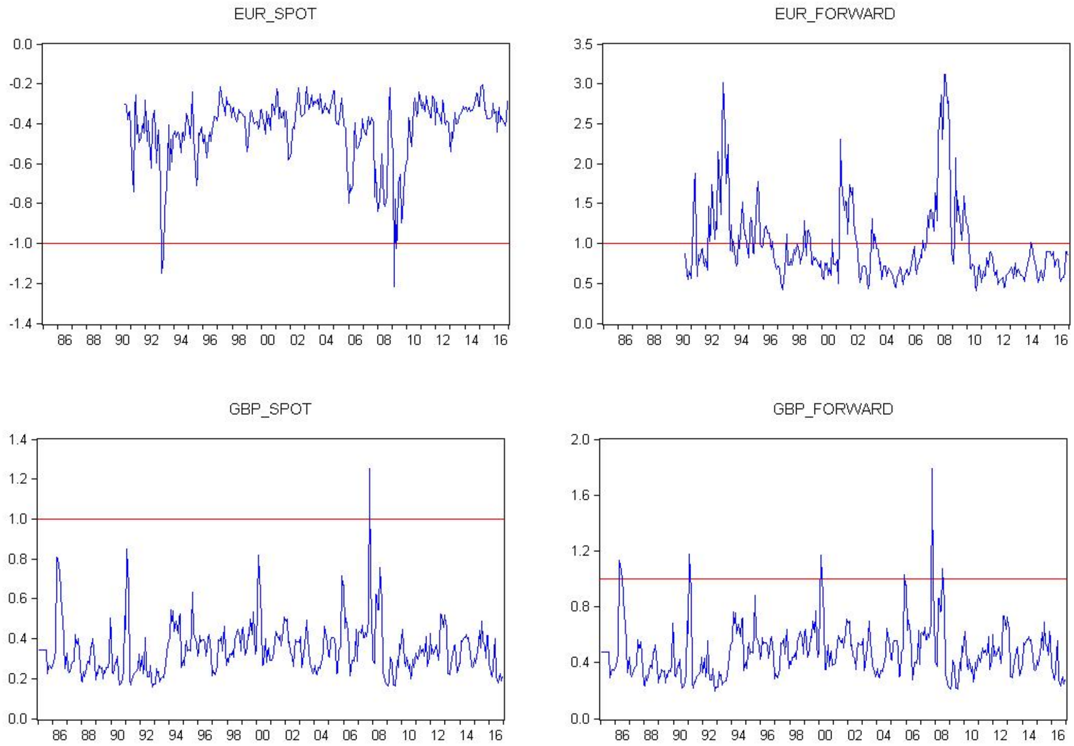


Table 1 and Figure 1 present some interesting results. The overconfidence levels in spot and forward markets for each currency mostly have similar ups and downs with some minor discrepancies. The markets for CAD and GBP show the similar features of confidence level in spot and forward markets, showing slightly stronger beliefs in the forward markets. Investors are mostly overconfident toward CAD and under-confident toward GBP. For CHF, its markets show very similar confidence level in making contrarian investment decisions, except that investors are a little more confident in spot market. The markets for the euro show an opposite sign in the overconfidence in forward market and the spot market. The euro traders are more confident in forward market than they are in spot market. Greater confidence in forward market is relevant to the contrarian strategy they take in spot market. They tend to be reluctant in believing the market signals in spot market but take the opposite attitudes toward their future gains. For example, if they strongly believe that the signals they observe in spot market suggest a negative impact on the value of the currency, they invest more and expect to gain profit in its forward market. Another interesting feature appears in the markets for JPY. It is the only currency whose markets have consistent confidence level of investors in both spot and forward markets. Investors are either overconfident in spot market or under-confident in forward market but show stronger confidence in spot market. A possible explanation to the consistent responses is that JPY is relatively riskless than other currencies in our sample, that is, investors rarely expect big changes in the evaluation of JPY. The under-confidence in forward market can be due to the same reason. Investors are not speculating much in JPY market because they do not expect big changes and thus high returns from the currency itself.

The trends of overconfidence are closely related to economic events in each country. Most of the markets experience sudden drops in investor confidence when the 2008 global recession occurs, right after experiencing a peak beforehand. Investors in JPY markets respond to the quantitative easing from 2010 to 2013 as a part of Abenomics, while they were not affected much by the Asian financial crisis in 1997. Traders in the markets for CHF, EUR, and GBP experience a large drop in the degree of their confidence in 2009 and a recovery soon, but experience another drop as precursory movements before the debt crisis in the five European countries (PIIGS)[13] occurs.

Table 1 above reports the presence of overconfidence and under-confidence in each market in terms of the magnitude. According to the third row in Table 1, the average overconfidence coefficients in forward markets are greater than those in spot markets, except for CHF with a minor difference and for JPY. This also illustrates that investors are not much confident about their chances to gain high returns in forward market for JPY. The following Table 2 provides the

[13] The five EU member countries that were considered weaker economically following the 2008 financial crisis: Portugal, Italy, Ireland, Greece and Spain

portions of overconfidence and under-confidence in each market for the entire sample period. The markets for CHF, EUR and GBP show an obvious tendency for under-confidence, while those for CAD show a prevailing tendency for overconfidence and those for JPY belong to neither.

Table 2 Ratio of overconfidence levels in each currency market

We use the absolute values of gamma coefficients, either greater than 1 or less than 1, when deciding whether a coefficient represents overconfidence or under-confidence. We simply count the number of gammas in each category and their ratio out of the whole sample period, regardless of their signs in order to represent the pure intense of confidence.

(Unit : %)

	$0 < \|\gamma_t\| < 1$ Under-confidence		$1 < \|\gamma_t\|$ Overconfidence	
	Spot	Forward	Spot	Forward
CAD	5.3	4.2	94.7	95.8
JPY	0.0	100.0	100.0	0.0
CHF	94.7	94.7	5.3	5.3
EUR	98.4	67.5	1.6	32.5
GBP	99.7	97.6	0.3	2.4

Table 2 suggests that the investors of confidence is extremely divided into either overconfident or under-confident, except for the markets for JPY. The traders of JPY are extremely overconfident in spot market and extremely under-confident in forward market, while the other four currencies belong to one category. Overall, it is obvious that investors do not judge the preciseness of the information they observe in the markets with perfect rationality but rather have biased beliefs toward it.

4.2.2 Overconfidence and forward premium puzzle

In this subsection, we investigate if overconfidence can be an explanation to the forward premium puzzle in foreign exchange markets. For this analysis, we take the forward premium regression (9) and (10) presented in Section 3. The estimated slope coefficients have been known to be negative in the previous literature, as solid evidence to the failure of the UIP hypothesis. If the market is efficient, the investors have a perfect foresight because they possess complete information sets and update them instantaneously as new signals come in. In other words, if the UIP hypothesis is correct, then we should observe a one-to-one relation between the forward premium and the return, represented by the betas of positive one. However, this may fail due to biases the investors have in decision makings, and will end up with deviations from zero alphas and betas equal to one. The real markets contain inefficiency and experience price distortions due to investors' irrational expectations which we attribute to investors' psychological biases, i.e. overconfidence and under-confidence. This leads to negative slope coefficients estimated through regression (9) and (10). Table 3 provides the sets of betas $\widehat{\beta^p}$ and $\widehat{\beta^f}$ overconfidence coefficients in spot and forward markets, γ^s and γ^f. The beta coefficients are calculated as $=\beta_\gamma^f=\frac{1-\gamma_t^f}{\left(\gamma_t^f-\gamma_t^s\right)}$, and $\beta_\gamma^p=\frac{1-\gamma_t^s}{\left(\gamma_t^f-\gamma_t^s\right)}$, respectively. The time underscript is meaningless in this calculation becaue beta is not time-varying. For each γ_t^f and γ_t^s, we use the averages reported in Table 1.

Table 3 Estimates for slope coefficients of (9) and (10)

The first two columns are beta estimates from the two regressions using the observed spot and forward exchange rates. The third and fourth columns are mean overconfidence coefficients reported in Table 1. The last two columns are betas calculated with γ^s and γ^f, the average level of overconfidence or under-confidence in each market.

	$\widehat{\beta^f}$	$\widehat{\beta^p}$	γ^s	γ^f	β_γ^f	β_γ^p
CAD	-1.786	-0.786	1.72	1.73	-73	-72
JPY	-0.933	0.067	1.98	0.2	-0.45	0.55
CHF	-1.066	-0.066	-0.39	-0.38	138	139
EUR	-1.066	-0.066	-0.43	0.98	0.014	1.014
GBP	-2.277	-1.277	0.35	0.48	4	5

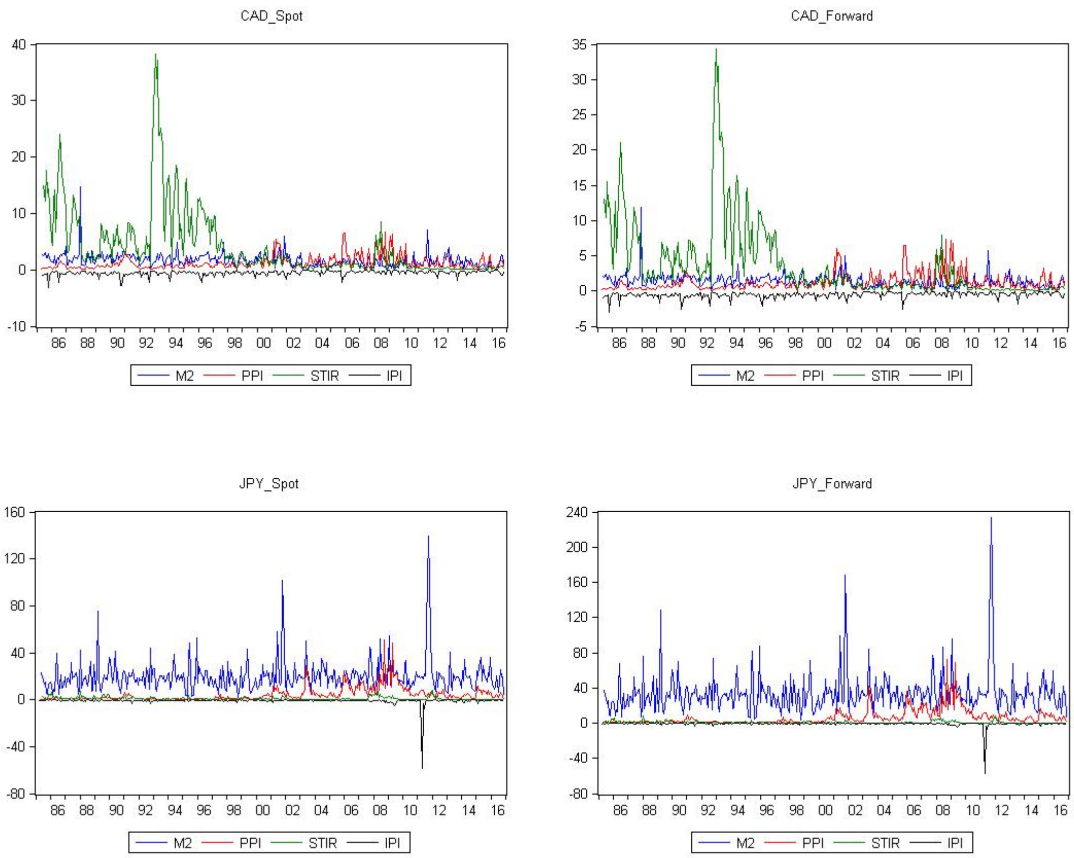
As previous researches have provided, $\beta^p < 0$ and $\beta^f < 0$ indicate that the UIP hypothesis does not hold in the real markets. As explained in Section 3, negative betas indicate either $\gamma^f > \gamma^s > 1$ or $1 > \gamma^s > \gamma^f$, where forward market experiences a stronger overconfidence than spot market. If the investors take contrarian strategies, or if we allow negative gammas, negative betas rather indicate either $-1 > \gamma^s > \gamma^f$ or $\gamma^f > \gamma^s > -1$. We observe that CAD is the only currency the investors show pure overconfidence toward the market signals they receive. Investors are under-confident toward signals in the markets for CHF, EUR and GBP with the absolute values of gamma less than one. CAD and JPY are two currencies whose betas have the same signs, out of our five samples. We observe that if overconfidence is dominant in at least one of spot and forward markets, then negative beta coefficient can be explained. Therefore, we can conclude that investors' overconfidence can help understand the negative signs of beta estimates yielded from the forward premium regressions.

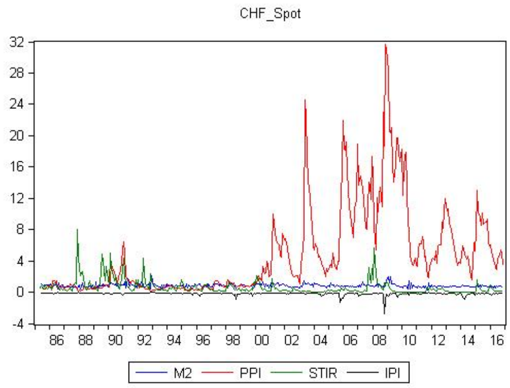
4.2.3 Overconfidence towards four signals

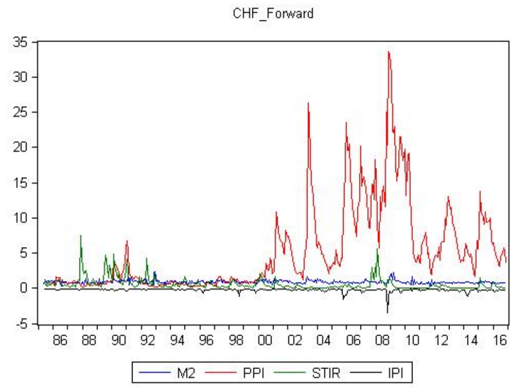
In this subsection, we investigate toward which signal the investors are more likely to become overconfident. Investors show different level of over-reaction toward the four signals, i.e., money supply (M2), inflation (PPI), short-term interest rates (STIR), and economic growth proxied by Industrial Production Index (IPI). Figure 2 shows their movements and features in spot markets and forward markets respectively.

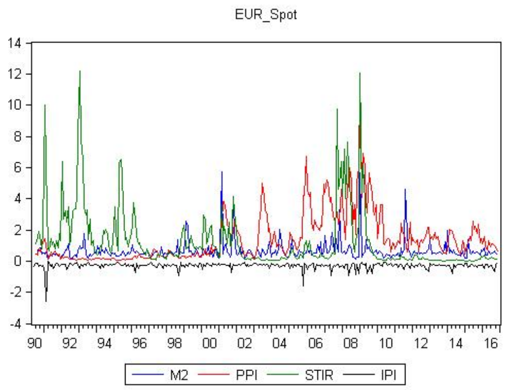
Figure 2 Overconfidence towards four signals in foreign exchange markets

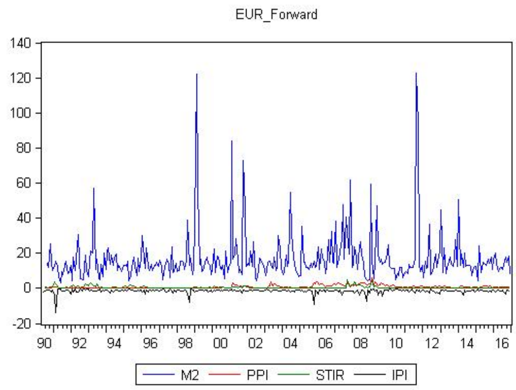
Figure 2 illustrates the overconfidence toward each signal in each currency market. We present the responses after adjusting their signs, following the theoretical monetary model in Frankel (1979) and the empirical results in Bilson (1978). Money supply, inflation, and nominal interest rates are expected to have positive impacts on exchange rates, while economic growth has a negative impact on exchange rates. The sign adjustment is used in constructing the aggregate signal but is not significant in this analysis, for we only care about their magnitudes to decide toward which signal the investors show overconfidence the most.

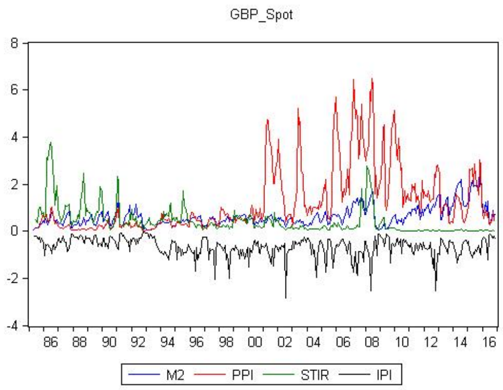


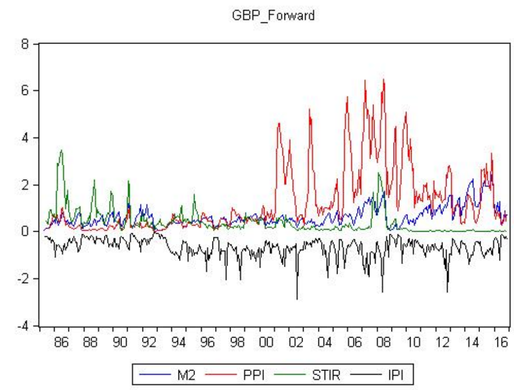












We observe that investors show different levels of confidence toward each signal. Some conspicuous cases include nominal interest rates in CAD markets, money supply in JPY markets and EUR spot market, and economic growth in CHF and GBP markets. Economic growth receives the least confidence among the signals. Table 4 below presents them more in a more precise way.

Table 4 Overconfidence towards each signal in spot and forward markets

Overconfidence toward each signal is estimated from the regressions (11) and (12) following Step 1 and Step 2. A greater magnitude means a greater overconfidence toward that signal.

	$\lvert\gamma_{kt}^{f}\rvert$				$\lvert\gamma_{kt}^{s}\rvert$			
	M2	PPI	STIR	IPI	M2	PPI	STIR	IPI
CAD	0.86	0.98	1.56	0.37	1.03	0.98	1.71	0.36
JPY	28.56	4.8	0.52	0.6	16.77	3.43	0.52	0.6
CHF	0.84	4.34	0.36	0.21	0.79	3.76	0.37	0.18
EUR	17.24	0.63	0.27	1.30	0.66	1.11	0.74	0.27
GBP	0.63	0.88	0.27	0.45	0.63	0.88	0.30	0.48

According to what Table 4 reports, it can be inferred toward which signal the investors overreact or under-react the most in each market. Traders appear to be overconfident about the signal of short-term interest rates in CAD markets, those of money supply in both JPY and EUR, and that of economic growth in CHF and GBP. On the other hand, the signal about economic growth is not really considered in CAD and CHF, and the signal about short-term interest rates is not considered in JPY EUR, and GBP.

5. Conclusion

In this study, we examine if investors' overconfidence biases toward market signals can be an explanation to the forward premium puzzle in foreign exchange markets. We identify overconfidence toward the four macroeconomic signals and their aggregate in spot and forward markets for the five major currencies: CAD, JPY, CHF, EUR and GBP. Comparing the signs of slope coefficients from the forward premium regressions with betas estimated from considering overconfidence in spot and forward markets, we find some evidence that the puzzle is attributable to overconfidence. If overconfidence is present in either spot or forward markets, then the negative sign of beta from the forward premium regressions is replicated by overconfidence coefficients. Our results imply that the anomaly in CAD and JPY markets are explained by the presence of overconfidence, while it is not explained for the other three currencies where under-confidence is dominant.

We have also investigated toward which signals the investors show overconfidence. Investors show different levels of overconfidence toward the signals in each currency. Investors for JPY and EUR mostly over-react to money supply, those for CHF and GBP over-react to inflation, and those for CAD over-react to short-term interest rates.

We suggest three directions for the future explorations. First, using more than our four signals will provide interesting results. The four signals come from the traditional monetary model, but there can be other factors in the exchange rate determination. The investors will show a wider range in overconfidence toward more signals, and this will bring significant changes to the estimation results. Second, sampling a different time span will change the mean overconfidence coefficients. In our estimation, CHF, EUR, and GBP show mean overconfidence coefficient less than one, showing under-confidence. We take average of overconfidence over the entire sample period to obtain mean overconfidence in spot and forward markets. However, if we narrow down the sample period, the results may be different depending on which window we are looking at. Third, using higher frequency data will yield more robust results, if available. Investors receive signals in the market and update their information sets much more frequently than a monthly basis.

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Appendix : Proof of Proposition

We have

$$p_{t+1}^b - p_t^b = \epsilon_{t+1} + \gamma_{t+1}^s w_{t+1} s_{t+1} - \gamma_t^s w_t s_t$$
$$p_{t+1}^b - f_t^b = \epsilon_{t+1} + \gamma_{t+1}^s w_{t+1} s_{t+1} - \gamma_t^f w_t s_t$$
$$f_t^b - p_t^b = (\gamma_t^f - \gamma_t^s) w_t s_t,$$

For the regression equation $p_{t+1}^b - f_t^b = \alpha + \beta\left(f_t^b - p_t^b\right) + \delta_t$, we have

$$\beta = \frac{cov\left(\epsilon_{t+1} + \gamma_{t+1}^s w_{t+1} s_{t+1} - \gamma_t^f w_t s_t, \left(\gamma_t^f - \gamma_t^s\right) w_t s_t\right)}{var\left(\left(\gamma_t^f - \gamma_t^s\right) w_t s_t\right)}$$
$$= \frac{\left(\gamma_t^f - \gamma_t^s\right) w_t \sigma_{\epsilon t+1}^2 - \gamma_t^f \left(\gamma_t^f - \gamma_t^s\right) w_t^2 \sigma_{\epsilon t+1}^2 (1 + \sigma_{\varepsilon t}^2)}{\left(\gamma_t^f - \gamma_t^s\right)^2 w_t^2 \sigma_{\epsilon t+1}^2 (1 + \sigma_{\varepsilon t}^2)}$$
$$= \frac{1 - \gamma_t^f}{\left(\gamma_t^f - \gamma_t^s\right)}$$

For the regression equation $p_{t+1}^b - p_t^b = \alpha + \beta\left(f_t^b - p_t^b\right) + \delta_t$, we have

$$\beta = \frac{cov\left(\epsilon_{t+1} + \gamma_{t+1}^s w_{t+1} s_{t+1} - \gamma_t^s w_t s_t, \left(\gamma_t^f - \gamma_t^s\right) w_t s_t\right)}{var\left(\left(\gamma_t^f - \gamma_t^s\right) w_t s_t\right)}$$
$$= \frac{\left(\gamma_t^f - \gamma_t^s\right) w_t \sigma_{\epsilon t+1}^2 - \gamma_t^s \left(\gamma_t^f - \gamma_t^s\right) w_t^2 \sigma_{\epsilon t+1}^2 (1 + \sigma_{\varepsilon t}^2)}{\left(\gamma_t^f - \gamma_t^s\right)^2 w_t^2 \sigma_{\epsilon t+1}^2 (1 + \sigma_{\varepsilon t}^2)}$$
$$= \frac{1 - \gamma_t^s}{\left(\gamma_t^f - \gamma_t^s\right)}.$$

QED

국문 초록

외환 시장의 과신

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경제학과

이영인

본 논문은 외환 시장의 과신이 선도 프리미엄 퍼즐에 대한 설명이 될 수 있는가에 대해 탐구하고자 한다. 본 연구에서는 투자자들이 노이즈를 포함한 시장 신호에 보이는 과대 확신을 이용하여 과신을 분석한다. 그 결과, 투자자들이 현물 환율과 선물 환율에 보이는 과신이 과신이 선도 프리미엄 퍼즐에 기여한다는 증거를 발견하였다. 또한 본 논문은 투자자들이 어떤 시장 신호에 대해 가장 큰 과신을 보이는지 연구하고자 한다. 시장 신호로 사용된 화폐 공급, 인플레이션, 단기 이자율, 경제성장 중에서, 투자자들은 엔과 유로 시장에서는 화폐 공급에, 스위스 프랑과 영국 파운드 시장에서는 인플레이션에, 그리고 캐나다 달러 시장에서는 단기 이자율에 가장 큰 과신을 보인다는 것을 알 수 있었다.

주제어 : 과신, 유위험 이자율 평가설 , 선도 프리미엄 퍼즐, 행동경제, 외환시장